ESC2010 Sessions & Convenors

T: Tectonics **OS**: Outreach & Society & Cooperation **SD**: Seismology: Seismic Data Monitoring, Data Analysis and Products (see also ES)
ES: Seismology: Earthquake Sources **SW**: Seismology: Structures and Wave Propagation **SH**: Seismic hazard **TS**: Tsunami

T The birth and death of subduction zones: case studies from the Mediterranean. *J. Déverchère, M-A Gutscher, A. Billi*
T/SD1 Active deformation in Western Greece: linking rifting, strike-slip and subduction. *E. Sokos, J. Papoulia, H. Lyon-Caen, D. Slejko*
T/SD2 Earthquake and tectonics: from paleoseismicity to plate tectonics. *O. Bellier, E. Gràcia*
OS1 Earthquakes and society: Is the way seismologists communicate satisfactory? *S. Solarino, F. Haslinger*
OS2 Earthquake Education for Risk reduction: European and non-European Experiences. *V. Castelli, E. Baroux, R. Camassi*
OS3 Transnational research and infrastructure collaboration activities in Euro-Med. *C. Cornou, P. Charvis*
OS4 Seismology at school. *D. Hatzfeld, P. Denton, A. Sauron-Sornette* ***Session sponsored by the Fondation MAIF***
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SD2 Collecting the macroseismic data after damaging events using European macroseismic scale: a decade of field experience. *A. Tertulliani, I. Cecic, M. S. Barbano*
SD3 Real Time waveforms and shakemaps. *X. Goula, P. Dominique*
SD4 Compiling the earthquake history of the European Mediterranean area. *P. Albini, O. Scotti, J. Battló, A. Rovida*
SD5 Earthquake-induced landslides and application of seismic monitoring to characterise landslide dynamics. *O. Maquaire, J-P. Malet*
SD6 GPS, InSAR and Seismology. *A. Ganas, P. Briole*
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SD9 Transportable broadband arrays in southwest Europe: towards a homogeneous coverage of the European continent. *A. Villasenor*
SD10 Internet macroseismology. *R.M.W. Musson, R. Bossu, I. Cecic*
SD11 Scientific and technological advances in earthquake early warning and rapid response. *M. Picozzi, C. Zulfikar*
SD12 Information Technology Applications in Seismology. *L. Kamb, J-P. Vilotte*
SD13 Machine Learning in Seismology and Hazard Analysis. *M. Ohrnberger, P. Gaillard, F. Scherbaum*
SD14 Volcano seismology: new perspectives and research directions. *J. Virieux, A. Zollo*
ES1 Triggered and induced seismicity. *S. Lasocki, V. Rudajev, M. Nesterenko*
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ES4 Methods and data for the study of events recorded on pre-WWSSN historical seismograms. *G. Ferrari, J. Batlló*
ES5 Earthquake sources and source parameters. *P. Bormann, R. Madariaga, L. Rivera, A. Michelini*
ES6 Physics of seismicity: field, laboratory and theoretical studies. *T. Chelize, Y. Gueguen, V. Gitis, J. Schmittbuhl*
ES7 Seismic analyses of non earthquake related sources. *M. Dietrich, M. Kristekova*
ES8 New approaches to earthquake predictability and time-dependent seismic hazard and risk assessment at local and regional scales. *S. Wiemer, W. Marzocchi, G. Papadopoulos, M. Erdik*
ES9 Approaches to modelling seismic scenarios. *G. Zonno, A. Carvalho, R. Rotondi, M-J. Jimenez*
ES10 Applying Seismology to Monitoring for Nuclear Explosions. *J. Coyne, P. Grenard*
ES11 The State of European Statistical Seismology. *J. D. Zechar, D. Schorlemmer*
ES12 Natural and induced seismicity driven by fluids: observations and modelling. *T. Fischer, H. Fabriol, T. Kraft* ***Session sponsored by Magnitude***
ES13 Fundamentals of moderate to great earthquakes forecasts. *G. Purcaru, A. Zavyalov*
SW1 The centennial of the Mohorovicic discontinuity. *M. Herak, M. Grad, D. Herak*
SW2 Surface wave seismology with different wavelengths. *J. Badal, P. Malischewsky*
SW3 Finite frequency tomography - the first ten years. *G. Nolet, K. Sigloch, S. Chevrot*
SW4 Ambient vibration seismology. *P. Malischewsky, D. Albarello*
SW5 Random wavefields and coda: novel methods and applications. *N. Shapiro, M. Campillo, L. Margerin, O. Sebe*
SW6 Seismological and structural studies in the European Arctic. *M. Pirli, M. Grad, J. Schweitzer*
SH1 Geological input for seismic hazard assessment: A European perspective. *S. Baize, G. Valensise, T. Winter*
SH2 Magnitude scaling and regional variation of ground motion (Joint ESC-SSA session). *S. Akkar, F. Cotton, D. Wald* ***Session sponsored by the French Accelerometric Network / RAP***
SH3 Global, regional and local initiatives on seismic hazard assessment: Towards setting new standards. *J. Woessner, M. Sorensen, R. Pinho, D. Giardini*
SH4 Site effects and their effects on the uncertainties on ground motion prediction equations. *S. Parolai, V. Sokolov*
TS Tsunamis: new efforts in tsunamigenic earthquakes monitoring and establishment of warning systems in the Euro-Mediterranean region. *F. Schindelé, G. Selvaggi, S. Tinti*

THANKS TO ALL OUR CONVENORS!

ES10 - APPLYING SEISMOLOGY TO MONITORING FOR NUCLEAR EXPLOSIONS

Monday 6, 10h20-12h00

ES10/MO/O1 - PROGRESS AND ACHIEVEMENTS IN MONITORING COMPLIANCE WITH THE COMPREHENSIVE NUCLEAR TEST-BAN-TREATY (CTBT)

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Since the CTBT was opened for signature in 1996, the Preparatory Commission of the CTBTO has worked towards implementing the verification regime called for by the Treaty. The initial International Monitoring System (IMS) network consisted mostly of capable legacy stations (from an earlier prototype) for the seismic, hydro-acoustic, infrasound and radionuclide technologies. The IMS network has now been extended to the point where about 80% of the seismic networks (41 primary and 95 auxiliary stations) are now certified to IMS standards as well as 10 hydro-acoustic and 42 infrasound stations (90 and 70% complete); in addition 59 radionuclide particulate stations and ten laboratories are certified (74 and 60% complete) and 24 radionuclide noble gas stations are sending data to the International Data Centre (IDC.) Progress has been made in the network calibration for seismic location and magnitude, surface-wave processing, and analysis tools. In hydro-acoustics, the use of the hydrophone triads has been optimized. Infrasound processing has made considerable advances to the point where data from improved sensors are routinely automatically processed, reviewed and published. CTBT verification relies on fusion of the waveform data with that from the radionuclide network. Over the past 10 years, the measurement sensitivity has increased for both particulate and noble gas (Xenon) radionuclides. The noble gas systems were at the prototype stage in 2000 and have improved nearly ten-fold in detection capability. Finally, the interpretation of radionuclide and waveform data requires sophisticated atmospheric transport modelling to relate the observations to a common origin. The CTBT is ultimately verified by its Member States, and an important activity of the organization is to provide the data and tools to the States and to train their representatives to making informed decisions.

ES10/MO/O2 - SUPERVISED CLASSIFICATION METHODS FOR SEISMIC PHASE IDENTIFICATION

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The Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) is installing the International Monitoring System (IMS), which includes a global network of seismic, hydroacoustic, and infrasound sensors to monitor compliance with the CTBT. These data are processed by the International Data Centre to detect and locate events that may be related to a nuclear test. For all of the technologies, the data are first processed on a station-by-station basis to detect signals and extract features that identify the propagation phase (e.g. *P, S, Lg, …*). These discrete detections from the stations are processed at the network level to produce automatic event lists, which are subsequently reviewed by an analyst to produce a reviewed event bulletin. The station processing step identifies seismic and acoustic phases and network processing relies on this identification to associate observations from different stations with events. As a consequence, the accuracy and reliability of automatic and reviewed bulletins depend on the success of the station processing. Over the past ten years, a large database of analyst-reviewed detections is available to improve the current system by applying machine learning methods. During an initial study, several classification methods were compared: decision tree with bagging; logistic regression; neural networks trained with back-propagation; Bayesian networks as generative class models; naive Bayesian classification; support vector machines. An initial assessment shows that the phase identification process could be improved 61 to 84% accuracy over the current operational system using a decision tree with bagging algorithm. We present further results from a study using a much larger learning dataset and a prototype operational implementation.

ES10/MO/O3 - A REGIONAL SEISMIC TRAVEL TIME MODEL FOR NORTH AMERICA

S. Myers[1], *M. Begnaud*[2], *S. Ballard*[3], *A. Ramirez*[1], *S. Phillips*[2], *M. Pasyanos*[1], *H. Benz*[4], *R. Buland*[4]
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We extend the Regional Seismic Travel Time (RSTT) tomographic effort to North America. In previous work we developed a real-time method to capture the 1st-order effects of 3-dimensional crust and upper mantle structure on RSTTs. The model parameterization is a global tessellation of nodes with a velocity profile at each node. Interpolation of the velocity profiles generates a 3-dimensional crust and laterally variable upper mantle velocity. The upper-mantle velocity profile at each node is represented as a linear velocity gradient, which enables travel time computation in approximately 1 millisecond. Fast computation allows the model to be used in routine analyses and in operational monitoring systems. Model velocities are optimized for travel-time prediction using a tomographic formulation that adjusts the mantle velocity at the Moho, the mantle velocity gradient, and the average crustal velocity. After tomography across Eurasia, rigorous tests find that Pn travel time residuals are reduced from a standard deviation of approximately 1.75 seconds (ak135 model) to approximately 1.25 seconds. Further, location error is consistently reduced by approximately 45% for events located using the Pn phase. For North American tomography we begin by reconciling North American seismic bulletins. To these bulletins we add high-quality data sets that improve data coverage and data quality, including arrival times reported by the Array Network Facility for USArray stations. In the western United States, USArray provides unprecedented data coverage with station spacing of approximately 70 km. The National Earthquake Information Center (NEIC) researchers contribute unique ground-truth data sets that have been culled over decades. NEIC data is particularly helpful in eastern North America, where the seismicity rate is low. Arrival-time measurements from all sources are re-associated, and event locations that are best constrained by seismic data are relocated using all available arrivals. Events with known locations, e.g. explosions, are not relocated and these events help to establish absolute travel time accuracy. Seismic locations are evaluated against network coverage criteria to estimate hypocenter accuracy. The full error budget for each travel time – hypocenter uncertainty and arrival-time measurement uncertainty – is evaluated to provide a datum-specific uncertainty that establishes weighting in the tomographic inversion. Model validation includes prediction of travel times, as well as relocation of ground-truth events to measure location accuracy. Neither the travel time validation data nor the location validation data are used in the tomographic inversion.

ES10/MO/O4 - SEISMO-ACOUSTIC ENERGY GENERATION AND PARTITION FOR SURFACE EXPLOSIONS OF DIFFERENT DESIGN

Y. Gitterman[1], *R. Hofstetter*[1]
[1]*The Geophysical Institute of Israel*

Experimental surface explosions of broad yield range (0.5-82 ton) and various design were conducted by the Geophysical Institute of Israel in 2008-2009 at Sayarim Military Range (SMR), Negev desert, with the goal to establish a Ground Truth (GT0) infrasound dataset for Middle East/Mediterranean region. Small test explosions (0.5-1 ton) of different explosive type and detonation direction (upward and downward) showed diverse cratering effect indicating the seismic energy generation. The largest Calibration Explosion was successfully conducted on 26 August 2009. A charge of about 82 tons of HE explosives, assembled as a pyramid on the soft sediment surface, was detonated upwards. High-pressure values were measured in the range 200-600 m. Analysis showed higher peak pressures than predicted; this effect was found also at infrasound stations at local and regional distances, indicating a possible asymmetric energy radiation to the atmosphere. The resulting crater and seismic magnitude estimated by Israel Seismic Network were smaller than expected for this on-surface charge. Peak amplitudes of surface waves were found much higher than in P-wave group, as opposite to the case of explosions of outdated ammunition with downward detonation. These results confirmed that the charge design for the Calibration Explosion provided the necessary

explosion energy generation and partition: maximum of energy to the atmosphere and minimum to the ground. The high-pressure observations were utilized for estimation of TNT equivalent yield of ~0.1 kT (based on positive impulse in air-shock wave), considered as an important Ground Truth parameter. Thus the Sayarim Explosion provided the first full GT0 source dataset for on-surface large explosions, recorded by infrasound stations of International Monitoring System (IMS). Infrasound signals were well observed at distances up to 3,500 km, at numerous portable and permanent stations in Israel, Mediterranean-basin countries and central Europe. Far-regional portable stations were deployed westward, due to seasonal favorable conditions of infrasound propagation, caused by the westerly stratospheric winds. Obtained records were already used for analysis of infrasound signal propagation, source location and yield estimation.

ES10/MO/O5 **- INTERNATIONAL SEISMOLOGICAL CENTRE: PROVIDING DATA SETS FOR SCIENTIFIC RESEARCH**

I. Bondar[1], J. Harris[1], D. Storchak[1]
[1]International Seismological Centre

The International Seismological Centre (ISC) hosts and maintains high-quality data sets openly accessible to the scientific community. The groomed ISC bulletin (EHB; Engdahl et al., 1998) spans nearly 50 years (1960-2007) and contains some 138,000 events with more than 22 million arrival data. The events were relocated with the EHB location algorithm and were selected from the ISC bulletin using the criterion of having at least 10 teleseismic stations with secondary azimuthal gap less than 180°. The EHB catalogue is regularly updated by Bob Engdahl. The IASPEI Reference Event List consists of more than 7,300 globally distributed ground truth events (earthquakes and explosions) with a location accuracy of 0-5 km. The effort was coordinated by the CoSOI/IASPEI Working Group on Reference Events for Improved Locations co-chaired by Bob Engdahl and Paul Richards. The ISC, in cooperation with USGS NEIC, also maintains the International Seismographic Station Registry in order to facilitate international data exchange. The station registry contains information about more than 15,000 seismic stations worldwide.

ES4 - METHODS AND DATA FOR THE STUDY OF EVENTS RECORDED ON PRE-WWSSN HISTORICAL SEISMOGRAMS

Monday 6, 10h20-12h00

ES4/MO/O1 **- HISTORICAL SEISMOGRAPHS AND SEISMOGRAMS AT THE GEOPHYSICAL INSTITUTE OF THE UNIVERSITY OF COIMBRA. ITS IMPORTANCE FOR PRESENT RESEARCH.**

S. Custódio[1], J. Narciso[1], J. Batlló[2], F. Lopes[3], D. Martins[4], P. Ribeiro[1], C. Gomes[3]
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The Geophysical Institute of the University of Coimbra (IGUC) was founded in 1864 as the meteorological observatory. Seismic observations started regularly 43 years later, in 1907. IGUC was home to the first seismic instrument deployed in mainland Portugal. As early as 1891 IGUC acquired an Angot seismograph. However, no traces of it have been located. Ever since, different instruments have been operated at the observatory (Milne, Wiechert horizontal and vertical pendulums, Grenet, Geotech short and long period, and currently an STS-2). These instruments have been preserved and form a good collection that allows a good understanding of the evolution of seismic instrumentation. Records of all instruments are also preserved. IGUC is currently doing an effort to recover its collection of seismic records – a comprehensive series of seismograms of worldwide importance. In this work we present the records and the instruments used in the study of seismology at IGUC. We also discuss their current state of preservation. Finally, we will focus on the importance of old seismic records in modern scientific studies.

ES4/MO/O2 **- THE 10TH SEPTEMBER 1919 EARTHQUAKES AT JACARILLA (SW SPAIN)**

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On the 10th September 1919 several slightly damaging earthquakes struck the town of Jacarilla (near Alicante, SW-Spain) and others nearby. Magnitude estimations for the largest two events of the series are M=5 approx, and its epicentral intensity has been evaluated as VIII (MSK). They are earthquakes of moderate size and they occur in a region where similar earthquakes occurred recently (02-02-1999 Mula; 29-01-2005 Aledo) and have been thoroughly studied.This makes these events of interest for a better definition of the regional seismicity. For this reason we decided to study a new its source from the analysis of the available contemporary seismograms and related documents. A search for seismograms has been launched and the SISMOS and EUROSEISMOS facilities have been highly useful for this goal. At the end, a total of 21 seismograms from 8 seismic stations have been collected and digitized. These seismograms contain records for the two main events and two aftershocks of the earthquake series. Finally 44 files, corresponding to 44 recorded single components from the different events have been processed. Processing of some of the records has been difficult because they were obtained from microfilm or contemporary reproductions on journals. The events have been relocated and their magnitudes recalculated. We present the results of this research and its consequences for the regional seismicity and we compare them with present earthquakes occurred in the same region.

ES4/MO/O3 **- THE GARFAGNANA (ITALY) EARTHQUAKE OF 7TH SEPTEMBER 1920: REASSESSMENT OF THE MAIN SEISMOLOGICAL PARAMETERS**

G. Vannucci[1], D. Tripone[1], B. Palombo[1], G. Ferrari[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia

The event on 7th September 1920 at 05:55:40 (GMT) located in the Garfagnana (Italy), is part of a series of strong earthquakes that, in the four-year period 1916-1920, affected an area of the Apennines from the Adriatic coast to the Northern Tuscany included within the regions of Romagna, Tuscany and Umbria, and that have been the subject of numerous recent macroseismic studies.

The Catalogue of Strong Italian Earthquakes (http://storing.ingv.it/cft4med/), classifies 756 localities for this earthquake, with an epicentral intensity of the X degree (MCS scale), and estimated magnitude of 6.5.

This event is amongst those considered to have a high priority in the list of earthquakes included in the Euroseismos project (http://storing.ingv.it/es_web). For this earthquake 52 recordings from 17 different Euro-Mediterranean observatories are today available in the database of the SISMOS Project – INGV (http://sismos.rm.ingv.it), which collects the high resolution digital scans of the seismograms recovered for each event of the Euroseismos project.

The original traces of the collected seismograms have been vectorialized, using Teseo2 software (http://sismos.rm.ingv.it/teseo/), and then corrected on the basis of the instrumental constants of the historical seismographs. That allows a re-assessment of the main seismological parameters of the event. We perform a comparison among these parameters and the macroseismic data.

ES4/MO/O4 **- SOURCE PARAMETERS OF THE 30 JULY 1926 AND 17 FEBRUARY 1927, JERSEY (ENGLISH CHANNEL) EARTHQUAKES FROM HISTORICAL SEISMOLOGICAL DATA**

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[1]Lab M2C CNRS-Univ. Caen, France

As many intraplate areas, Normandy is not a region generally associated in the public mind with active tectonics and earthquakes. The last largest well-documented event within the area has been the damaging Jersey earthquake that occurred in July 1926.

This event has been followed by a strongly felt earthquake in February 1927. Both earthquakes have been assigned magnitude values larger than 5. Until now, locations of these events and their magnitude values, as they appear in the French national historical seismicity database (SisFrance), have been estimated from macroseismic data only. We collected intensity data, analog seismograms and seismic bulletins to reappraise these two earthquakes. The reinterpretation of intensity data reveals that the macroseismic epicenter for the 1926 Jersey earthquake can be shifted to the East with respect to the location proposed in the SisFrance database. We use bulletins and analog seismograms to obtain probabilistic hypocentral locations. The maximum-likelihood point (Latitude,

49.2° N; Longitude, 1.82° W) for the 1926 Jersey event location indicates a focus to the East of the Jersey island. The epicenter is quite well constrained within a 10-km radius area. Due to fewer observations, the 1927 earthquake shows a fuzzier location, in agreement with the location proposed in the SisFrance database. The 1927 earthquake lies offshore of the Southern Jersey coast. Both 1926 and 1927 events are poorly constrained in depth from the analysis of arrival times. Regional moment tensor inversion is used to estimate faulting parameters of the 1926 Jersey earthquake. Inversion yields two interesting solutions. Our preferred one is a source depth of 12 km, Mw of 5.4 and a strike slip faulting mechanism with northwest-southeast and northeast-southwest striking nodal planes.

ES4/MO/O5 - INVESTIGATIONS OF ANALOGUE SEISMOGRAMS OF THE 1956 AMORGOS-SANTORINI EARTHQUAKE (MS=7.4, S AEGEAN, JULY 9, 1956)

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On July 9, 1956 two strong earthquakes (03:11 GMT, Ms 7.4 and 03:24 GMT, Ms 7.2, Makropoulos et al.,1989) occurred within 13 min in the central volcanic arc of the Hellenic Subduction Zone. Both earthquakes caused severe damages on the surrounding islands. Also, a tsunami with a maximum wave height of 30 m at the south coast of Amorgos, caused damages within a region of 100 km. Available focal mechanisms of the first event vary from strike-slip to normal faulting (Papazachos & Delibasis,1969; Shirokova,1972). The focal depth of the first event is estimated less than 40 km. Depth estimates for the second event are deeper than 40 km (Comninakis & Papazachos,1986, Papadopoulos, & Pavlides, 1992). It was possible to collect more than 80 analogue seismograms of 30 seismic European stations. On all seismograms the first main shock is visible in various qualities, while the second main shock can be clearly observed at 3 stations. The suitable seismograms were digitized and corrected by applying the program TESEO (Pintore et al.,2005). Seismograms of the first event show large surface wave amplitudes, while the surface waves are missing for the second event. In the spectrogram P and S wave as well as the dispersion of the surface wave of the first event can be clearly distinguished. A grid search for focal mechanism and depth of the earthquakes was carried out by comparing observed to synthetic waveforms calculated using GEMINI (Friederich & Dalkomo, 1995). Goodness of fit is measured from the maximum of the cross-correlation within a narrow time window around zero lag. For the first event, we find a few possible solutions for the focal mechanism including the one determined by Shirokova (1972).

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T/SD1 - ACTIVE DEFORMATION IN WESTERN GREECE: LINKING RIFTING, STRIKE-SLIP AND SUBDUCTION

Monday 6, 14h00-16h40

T/SD1/MO/O1 - NEW EVIDENCE ON THE EXTENSION OF THE HELLENIC NAPES AT THE BACKSTOP OF THE MEDITERRANEAN RIDGE, OFFSHORE WESTERN GREECE

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[1]Hellenic Centre for Marine Research, Athens, Greece; [2]GeoPro GmbH, Hamburg, Germany

By using large offset Ocean Bottom Seismograph (OBS) observations along 4 profiles, perpendicular to the main tectonic elements of the western Hellenides, we explored the crust and upper mantle in the Kiparissiakos gulf, south western Hellenic arc. Applying a newly developed refraction migration technique we reconstructed the fault systems at crustal depth. First we developed velocity models of the sediments and crust. Using these velocity models and migrating in depth the seismic data we delineated the main faults and associated them with the tectonic processes.

By considering the results of the OBS lines together with the onshore geology, swath bathymetry, and local microseismicity, we reconstructed the tectonic development offshore western Peloponnese. For the first time it was possible to understand how the main dextral fault systems of Cephalonia and Andravida are responsible for the deformation, the build up of the stress field and its link to the local seismicity. The block of western Hellenides extending between the Cephalonia and Andravida faults is controlled mainly by strike slip deformation of dextral orientation. This causes significant thrusting and crustal shortening and generates transtensional basins, like the one north east of the Strophades island, and transpressional blocks, like the Strophades uplift.

The limits of the Ionian to the Preapulia zone were defined in all seismic profiles. The extension of the stretched continental crust which is the backstop of the Mediterranean Ridge was delineated by the two southern profiles, at about 120 Km west of the Peloponnese coast. Previous seismic observations had located this transition at 60 Km west of Zakynthos. The crust in the backstop and the Kiparissiakos gulf is thin continental between 18 and 23 Km. Oceanic crust was encountered only west of the backstop limit, below the Mediterranean Ridge.

It was recognized that the backstop offshore Messinia peninsula, south of the North Mani Transverse Fault, is floored by the thinned continental crust of Preapulia. The Hellenic Alpine napes do not extend in the backstop domain. While the transition zone between the Mediterranean Ridge and the Preapulia backstop is intensely deformed by thrusting, the backstop itself is fractured by normal faulting.

T/SD1/MO/O2 - REFLECTION SEISMIC IMAGES FROM OBSS PROFILING ACROSS EXTERNAL HELLENIDES

E. Barison[1], G. Brancatelli[1], R. Nicolich[1]
[1]University of Trieste

Within the framework of the SEHELLARC project four seismic profiles were recorded on the continental margin of Peloponnesus with a large number of narrow spacing deployed OBSs and airgun source. The acquisition was planned for crustal prospecting to obtain redundancy in the refraction field inversion for the deep interfaces reconstruction, but here we present the OBS records processed as standard seismic reflection data utilizing only the near vertical incidence.

To do this a pre-processing step was needed with the evaluation of the static corrections for OBSs deployed in deep waters and rough sea bottom topography. Moreover the assumption of a vertical near-surface raypath adopted when static corrections are applied is not verified for acquisitions with large maximum offsets in shot-receivers design and more complex methods, such as the wave equation datuming (WED), should be used. WED was applied to relocate the OBSs from the sea bottom to the sea level (shots position). However we relocated OBSs (receivers) and shots to an intermediate datum plane at about 5-6 km depth (downward continuation). Then we moved up OBSs and shots till the sea surface (upward continuation). This intermediate depth datum solution is required to increase the number of traces which contribute to Kirchhoff summation in the WED. As a matter of fact, in OBS profiles there are more shots and closer each other than OBSs.

By tomographic inversion of the first arrivals a detailed near surface velocity model was evaluated and used in the downward and upward continuation. The refracted events let us to achieve velocity information necessary for lithological correlations, while the reflected echoes provided the images of the main reflecting markers and geological

structures.

The final sections reveal the crustal structures down to the Moho with an upper and a lower plate separated by an intra-plate detachment surface at a depth of 10 to 15 km. The stack of the thrust nappes of the External Hellenides is imaged in the upper plate, while the Ionian crust and Moho present a thickness of about 9-10 km, gently dipping from North to South and from the Ionian Sea (around 20 km depth) toward the Peloponnesus coasts where the base of the Ionian cold and brittle crust quickly reaches about 35 km depth at the collision with the Hellenic crust.

T/SD1/MO/O3 **- THE PELOPONNESUS CONTINENTAL MARGIN FROM THE ISLAND OF ZAKYNTHOS TO PYLOS. PART 1: MORPHOLOGY AND RECENT SEDIMENTARY PROCESSES**

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The Western Peloponnesus is an area repeatedly affected by large magnitude earthquakes occurring offshore and onshore mainly as consequences of the convergence and ongoing collision between the Western, previously strongly deformed, continental border of the Aegean sub-plate and the deep Ionian Sea and Apulia domains; the last significant event (magnitude 6.4) has occurred near Patras in June 2008. Among the objectives of the Sixth Framework Program of the European Commision project SeaHellArc (SEismic and tsunami risk Assessment and mitigation scenarios in the western HELLenic ARC) was to provide a detailed submarine morphological-geological background of this area of the Western Peloponnesus continental margin. The objective was to confirm that *(1)* the majority of earthquakes proceed from ruptures occurring beneath the continental slope, *(2)* their cumulated effects have generated, through geological time, specific tectonic features which affect the basement and its sedimentary cover and can be identified, mapped and tentatively dated, and *(3)* by shaking the most recent and unconsolidated sedimentary blanket, earthquakes may be generated along the continental slope where large scale submarine failures themselves are able to trigger tsunamis. To better define and evaluate the seabed morphology a detailed mapping of the bathymetric characteristics of an area of approximately 12.000 Km^2 (200 Km by 60 Km) has been performed in the Spring 2007 onboard the OGS R/V "Explora" using multibeam sonar swath mapping techniques. In addition to swath bathymetry the shallow structure, up to 100m penetration, of the recent sedimentary cover was imaged using a high-resolution sub-bottom CHIRP system. These data have been used, concurrently with the detailed morphological maps, to better assess the various active geological processes, particularly slope by-passing and failures, debris flows, and faulting that are driven by the earthquake/tectonic activity which characterises the area and are imprinted on the sea floor. Integrating the detailed morpho-bathymetric and chirp data allowed four different and contrasting domains to be identified on this segment of the active continental margin. The effects of recent and significant tectonic activity is clearly illustrated by the intense overall fracturing and the presence of deep, elongated, tilted and deformed bordering slope basins. An unexpected result has been the identification of significant large-scale marine failures and sedimentary destabilisation. In the recent (Holocene?) past major submarine failures have already occurred in the area and have probably triggered significant local tsunamis.

T/SD1/MO/O4 **- HIGH-RESOLUTION APPROACH TO THE TOP OF THE AFRICAN SLAB UNDER EASTERN PELOPONNESUS: ITS NATURE AND DEPTH FROM TELESEISMIC RECEIVER-FUNCTIONS ALONG A TIGHT ARRAY**

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In the frame of the European "Thales was right" project, several 3-component seismological stations have been deployed in Greece along the Eastern coast of Peloponnesus. The recorded data lead to new insights both on the nature of the slab, from tight constraints obtained on the nature of its crust, as well as on the geometry of the slab top under Peloponnesus to more than 60 km depth.

Teleseismic P receiver-functions (RF) have been computed for a set of stations. These RF clearly show two P-to-S converted waves: a trough followed in the newt two seconds by a peak corresponding respectively to the conversion at the top and bottom of a Low Velocity Layer (LVL) at the top of the Hellenic slab.

By analyzing the variation of polarities and arrival times of these converted waves function of the azimuth and distance of the teleseismic events, the slab dip direction and dip value have been constrained to be about N30°E and 16° under Eastern Peloponnesus. This multi-azimuthal study permits characterizing the depth and the geometry of the Hellenic slab for the first time and gives results consistent with the plate convergence direction.

In a second step, we focus on the nature of the LVL at the slab top. In order to identify if it is of continental or oceanic nature, we develop a new wavelet approach for the case of the teleseismic P-to-S converted waves. We first quantify the domain of interaction between the signal wavelength and the bed thickness. This leads us to conclude that a signal period shorter than about 1 s is necessary to characterize a LVL such as an oceanic crust. Indeed, for commonly used filters, the estimated thickness will be twice the true thickness. Having established the need for shorter periods, we apply our methodology for a very high frequency earthquake. We then show that the crust now subducting beneath Eastern Peloponnesus is of oceanic kind. This result is consistent with the fast trench retreat and South West advance of the Aegean upper plate domain over the oceanic slab of the Ionian sea basin underlying now Eastern Peloponnesus.

T/SD1/MO/O5 **- ACTIVE DEFORMATION IN THE BROADER AREA OF THE W. CORINTH GULF (GREECE)**

P. Papadimitriou[1], A. Agalos[1], A. Moshou[1], V. Kapetanidis[1], A. Karakonstantis[1], G. Kaviris[1], I. Kassaras[1], N. Voulgaris[1], K. Makropoulos[1]
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The rapidly opening rift of the Corinth Gulf is dominated by normal faults and high level of seismicity. Recently, an important number of moderate earthquakes occurred in the western part of the gulf and the surrounding region. In April 2007, 4 events with magnitudes 5.0-5.2 occurred near Trichonis Lake, in SE Aitoloakarnania. A temporary network of 12 stations was installed for 3 months. Several thousands of aftershocks were recorded and about 1200 were located with high precision. The seismicity pattern showed activation of several main and minor faults surrounding the lake. Reliable focal mechanisms indicated a complex pattern of deformation including mainly normal and strike-slip faulting. In February 2008, two earthquakes of Mw=4.6 and 4.5 occurred SE of Patras. Both the distribution of aftershocks and the focal mechanisms of the main events exhibit sinistral strike-slip faulting in N-S direction, in contradiction with the prevailing N-S extension pattern in the area. It is worth mentioning that the polarization analysis employed, revealed a decrease of the time delay values between the two split shear waves after the occurrence of the first main event, implying variation of the medium properties. On 8 June 2008, a large earthquake (Mw=6.4) occurred NE of Andravida. The focal mechanisms of the mainshock and selected aftershocks provided by body wave modeling showed strike-slip faulting. The spatial distribution of the aftershocks, as well as the calculation of the slip distribution indicated dextral strike-slip faulting in NE-SW direction. Static Coulomb stress changes were computed using the produced slip model to investigate possible stress transfer to a neighboring area and the observed large dimensions of the deforming area. The most recent seismic activity was in January 2010 near Efpalio, with the occurrence of two earthquakes (Mw=5.1). Computed focal mechanisms indicated normal faulting in an almost E-W direction, also evident by the aftershock distribution. More than 2000 aftershocks were located with sufficient accuracy and relocated using a master event method. Relocation procedure revealed a complex deformation pattern comprising of at least 5 distinct aftershock clusters. The detailed analysis of the above mentioned recent seismic sequences reveals that the central part of the Corinth gulf is dominated by normal faults striking E-W, while the area to the NW of the gulf by a combination of E-W normal and NNW-SSE sinistral strike-slip faults. The SW area of the Corinth rift is characterized by dextral strike-slip faults striking SSW-NNE.

T/SD1/MO/O6 **- THE MW 6.3 MOVRI MOUNTAIN EARTHQUAKE, JUNE 8, 2008, GREECE**

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On June 8, 2008 (12:25 UTC) an Mw6.3 strike-slip earthquake occurred in the north-western Peloponnese, with no clear relation to mapped faults. Two victims were reported, along with hundreds of injuries and extensive damage. The earthquake triggered surface ruptures, landslides, liquefactions and an aftershock sequence of moderate size events, with an irregular distribution along the SW-NE line. The aftershock sequence was composed of at least two clusters (as indicated by the double-difference method). The hypocenter was relocated at 37.94 N, 21.52 E, depth 19 km. Complete waveforms at eight near-regional stations were inverted for the deviatoric centroid moment tensor: centroid at 38.00 N, 21.57 E, depth 17 km, strike/dip/rake = 31/84/179, the double-couple percentage 90%. The relative position of the hypocenter and centroid indicated the predominant rupture propagation toward NE; their distance is of 8 km. Slip-inversion along a line fault was performed by two methods, (i) the modified iterative deconvolution, and (ii) the iterative back-propagation method. The two independent methods provided very similar results. The predominant rupture propagation toward NE was confirmed and two main slip patches were identified. The most interesting result is a temporal delay of the first patch with respect to origin time, and another delay between the first and second patch (as large as 5 sec), interpreted as a possible temporary rupture arrest. The main slip seems to occur between the two main aftershock clusters.

T/SD1/MO/O7 - CRUSTAL DEFORMATION ASSOCIATED WITH THE 8 JUNE 2008 MOVRI (NW PELOPONNESE), GREECE, EARTHQUAKE (MW6.4) FROM SEISMOLOGICAL OBSERVATIONS, DISLOCATION MODELING AND DINSAR ANALYSIS

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The Movri 2008 mainshock was the first modern, strong strike-slip earthquake in Greek mainland. The fault strikes NE-SW, dips ~85^{0}NW, the motion was right-lateral with small reverse component. There is no evidence that the fault ruptured by strong earthquakes at least in the last 300 years. Aftershock locations showed that a buried fault was activated, some aftershock lateral expansion occurred along length, the seismogenic layer ruptured from depth of 5 to 20 km. Low aftershock magnitudes along with that no gaps in the aftershock cloud appeared, indicated that no major asperities remained unbroken. This is consistent with the high *b*-value (=2.25) found particularly in the early aftershock activity indicating that it was dominated rather by creeping than by locked patches. For moment M_o=4.56x10^{25} dyn.cm (M_w=6.4) we calculated average slip=76 cm and stress drop $\Delta\sigma$ ~13 bars which is high for Greek strike-slip earthquakes, due rather to increased rigidity than to high seismic slip perhaps because of the long recurrence of strong earthquakes. It was found that the fault is neither typical strong nor typical weak. Dislocation modeling of a buried fault showed maximum uplift of ~8.0 cm in Kato Achaia (Δ~20 km), NW aftershock area, at the hanging wall of the reverse component of fault motion. No coseismic motion was detected by DInSAR analysis with the exception again of Kato Achaia where the fringes pattern showed vertical ground displacement from 3.0 to 6.0 cm. Post-event field-surveys indicated that the most important damage of intensity VIII and soil liquefaction occurred in Kato Achaia but no surface fault-breaks were observed. From the spatial correlation between intensity and ground displacement for dip-slip earthquakes in Taiwan, Greece and elsewhere, we suggested that the former is controlled by the latter. Since no surface fault-breaks and site effects were observed in Kato Achaia, an explanation of the high intensity is the high ground acceleration due to co-seismic uplift. The nearest to Kato Achaia accelerations, from 0.09 to 0.16 g, were recorded in Patras (Δ~35 km). Empirical relations predict that the critical acceleration needed to cause liquefaction in Kato Achaia is 0.08 g. Although ground displacement is dominated by low frequency compared to ground acceleration, the causal association between ground displacement and earthquake damage in the hanging wall becomes possible not only for dip-slip but also for strike-slip earthquakes with some dip-slip component, such as the 2008 one. This is a contribution of the EU-FP6 SEAHELLARC Project.

T/SD1/MO/O8 - FRAGMENTATION OF THE WESTERN PELOPONESSUS AND EVIDENCE FOR AN IONIAN NANOPLATE

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We present a series of evidence suggesting the present growth of a nanoplate boundary isolating the Ionian/Gulf of Patras region from the Peloponessus to the southeast and continental Europe to the north. To the north of the Patras gulf, major active normal faults striking EW bordering the lake of Trichonis clearly indicate NS extension in this area (e.g., Doutsos et al., 1987). Southeast of Trichonis lake, the moderate seismic activity connects to that of the western rift of Corinth (e.g. the 2007 swarm, Kiratzi et al. 2008) although the opening rate of the latter remains much larger. Seismicity recorded over the last 10 years from the Corinth Rift L aboratory array, clearly shows a northwest shift of the active zone at the root of the Psathopyrgos fault, towards this relay zone between the two rifts. To the south , the Andravida earthquake (2008) shows the existence of a major strike slip structure in the lower crust, whose extension to the north is evidenced by few moderate size earthquake in the Patras area and few strike slip small events at the western end of the Corinth rift. In continuation of the Andravida fault to the south, moderate strike slip earthquakes (e.g.,Vartholomio earthquake of *2002*,Serpetsidaki et al., 2010) seem to connect this sheared zone to the Hellenic subduction. This major sheared zone may allow to accommodate most of the differential opening rate of the two rifts to the north. In this framework, a triple junction should exist north of Patras at the western limit of the Corinth rift. The Ionian nanoplate can be seen as an essentially rigid block bounded to the south by the subduction, to the west by the Kefallonia transform fault, to the north by the Trichonis- Amvrakikos rifting system and to the south-east. by this probably recently evolving shear zone. At a larger scale, this shear zone could be seen as the southwestern tip of the western branch of the north-Anatolian fault system as suggested by regional strain measured by GPS. The mechanical origin of this shear should be linked to a stronger roll-back of the subduction to the southeast and a more compressive system to the west.

T - THE BIRTH AND DEATH OF SUBDUCTION ZONES: CASE STUDIES FROM THE MEDITERRANEAN

Monday 6, 14h00-16h40

T/MO/O1 - TOROIDAL ASTHENOSPHERIC FLOW BENEATH THE WESTERN ALPS FROM SEISMIC ANISOTROPY

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Measuring mantle deformation beneath plate boundaries where lithosphere interacts with each other such as beneath active mountain belts is an important objective of «mantle tectonics» that may bring a new view on the depth extent to the Earth's surface observations. In the present study, we analyse data from about 50 broadband stations covering the Western Alps and we provide a coherent picture of upper mantle anisotropy beneath the belt. Systematic analysis of SKS wave splitting has been performed at the various permanent and temporary broad band seismic networks: the Swiss permanent digital network provided data for 23 stations for the period 2006-2008, the Italian RSNI (Regional Seismic network of Northern Italy) provided data for 5 stations for the period 2006 to 2008, the French RLBP (Réseau Large Bande Permanent) provided data for 12 stations for the period 2000-2009 and the temporary deployment of 11 stations (Alps project P.I., H. Pedersen) has been recording during the period 2004-2007 along an EW transect between the French Massif Central and the Alps. These data allowed to perform about 2000 individual SKS splitting measurements, from which 1200 display clear evidence of splitting and 644 of which were of good quality. The resulting anisotropy pattern exhibits a continuous rotation of polarization azimuths of fast split shear waves that closely fit the trend of the Alpine belt: from EW in SE France to NS in the Jura area and NE-SW in eastern Switzerland. The observed delay times are rather high on average (1.4 s) requiring strong mantle deformation, but

interestingly, the strongest anisotropy is generally not located beneath the internal domains of the Alps but rather beneath the external units, suggesting that the mantle deformation may be not located within the lithosphere and not associated to the Alpine collision processes s.s.. Instead, it suggests that the recorded anisotropy may result from present-day or recent mantle flow in the sublithospheric mantle. We propose that the anisotropy pattern beneath the Western Alps is primarily dominated by a toroidal asthenospheric flow around the Eurasian slab presently plunging beneath the inner parts of the Alps and beneath the Apulian plate. The Western Alps could therefore join the other Mediterranean arcs characterized by toroidal asthenospheric flow around subducting lithospheres, such as the Apennines, the Calabrian, the Gibraltar and the Aegean arcs.

T/MO/O2 - STRUCTURE AND SUBDUCTION-INDUCED DEFORMATION OF TUSCANY'S LITHOSPHERE, FROM BROADBAND SURFACE-WAVE ANALYSIS

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The opening of the Tyrrhenian basin in the western Mediterranean was associated with an eastward retreat of a subduction zone where Adriatic lithosphere subducted westward. The Apennines orogen now forms the Adriatic-Tyrrhenian boundary. Whether any subducted lithosphere is still present beneath it is debated. The mechanism of extension of the overriding-plate lithosphere and the nature of sub-lithospheric mantle flow below are also poorly known.

We measure dispersion of seismic surface waves and determine shear-speed structure and the layering of seismic anisotropy beneath Tuscany. Azimuthal anisotropy in the crust shows an E-W fast-propagation direction, matching the direction of paleo-extension inferred from stretching lineations in exhumed metamorphic rocks. The anisotropy indicates fabric that is likely to be a record of pervasive flow in the middle and lower crust. We infer that it was such flow that accommodated lithospheric extension. Anisotropy in the asthenosphere shows a NW-SE fast-propagation direction, implying asthenospheric flow parallel to the Apennines (unless the relationship between strain and fabric is complicated by the presence of water). The region-average S-velocity profile shows a 60-80 km thick lithosphere. A high-velocity anomaly is detected at depths below 100-150 km and probably shows a slab remnant beneath Tuscany.

T/MO/O3 - CAN LOCAL EARTHQUAKE TOMOGRAPHY SETTLE THE MATTER ABOUT SUBDUCTION IN THE NORTHERN AND CENTRAL APENNINES?

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The many studies conducted on the Italian area led to several models to explain the present-day structural setting. Some of the most debated questions are the presence or not of continuous subduction and the presence or not of a slab detachment in the northern or in the central part of the Apenninic chain. The absence of a continuous, high velocity body beneath the Apennines has been interpreted by some researchers as an evidence of the detachment of the Apenninic slab. According to this view the Apenninic slab is expected to be inactive whether the Ionian lithosphere subducting underneath Calabria is considered to be on the verge of detaching or just detached. Other researchers however, suggest that a fairly continuous and fast slab exists beneath the Apennines and the Calabrian arc. Different geodynamical models have also been proposed for the Tyrrhenian area considering it as an active or as a passive margin.

Our working group has conducted several seismic tomographies in the search of the geometry, size and extension with depth of the subduction under the Italian peninsula. While the images resulting from teleseismic data were clearly showing a subducting slab under the Calabrian arc, they were not conclusive for the rest of the Apennines since they were showing, only in the Northern sector, a likely subduction in the shallower part apparently detached from other high velocities body in the deeper zone. At that stage it was not possible to distinguish between thrust and subduction due to the poor horizontal resolution of the applied methodology. In order to analyze in more details this apparent discrepancy, a new seismic local tomography has been conducted with a very dense grid, the selection of a smaller area to be investigated (limited to the Apennines only) and the addition of new data: all these features contributed to partly improve the results, which cannot anyway extend beyond the maximum depth of seismic events. The main limitation in this kind of experiment is the lack of seismic events deeper than 60-70 km under the northern and central Apennines although, as many authors assume, is not itself an evidence against subduction.

Analyzing different cross sections of the enhanced resolution tomography results, we do not see any slab in the northern-central Apennines in the first 80-100 km depth. The downgoing material (Adriatic plate) of this area has a rather low dip angle, as also partly shown by the distribution of the (few) deep seismic events. Along the central and also the northern part of the Apennines there are more overlapping than subducting geometries.

T/MO/O4 - THE CALABRIAN SUBDUCTION ZONE : THE PRINCIPAL TECTONIC FEATURES (PRE- AND POST-MESSINIAN PRISMS, LITHOSPHERIC TEAR FAULT ("STEP")) AND IMPLICATIONS FOR THE HISTORICAL SEISMICITY IN EASTERN SICILY

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In the central Mediterranean area, deep earthquakes beneath the Tyrrhenian Sea to a depth of 500 km, define an Ionian slab dipping towards the NW. This subduction zone is related to the active Aeolian volcanic arc, but no major thrust earthquakes have been observed during the instrumental seismic period. The Calabrian peninsula and Eastern Sicily have been among the most seismically active regions in the Mediterranean area. Several historical seismic events, such as 1169 and 1693 earthquakes, reached MCS intensities of XI and are associated with destructive tsunami. The source of these two earthquakes (among the strongest in Italy) is still matter of debate and may be related to the activity of the subduction fault plane or of the Malta escarpment.

Recently reported GPS motions suggest that the subduction of the Ionian lithosphere beneath the Tyrrhenian basin may be locally still active in particular beneath the Calabrian arc, at slow velocities (4-5mm/yr). Moreover offshore, the accretionary wedge is known to include compressional anticlines and ongoing hydrological activity (mud volcanoes).

We present results from reprocessed 96-channel seismic reflection profiles acquired during the French "Archimede" cruise (1997). The Archimede 18 and 19 profiles allow us to distinguish a Pre- and Post-Messinian prisms associated with two decollement levels both deepening to the NW. No evidence of gravitational sliding is found, invoked by some authors to explain the growth of the prism. The deformation within the Post-Messinian prism seems to be mainly controlled by accretion of the Messinian and Plio-Quaternary sediments. On the western side of the Calabrian wedge, a major normal fault affects the basement and the entire series of sedimentary deposits from the Mesozoic to the Plio-Quaternary. We interpret this large-scale fault as a NW/SE oriented lithospheric scale tear fault, which allows the SE roll-back of the Ionian slab. Our interpretation supports a continuous tectonic activity of the system, in particular close to the deformation front in the Ionian Abyssal Plain. The western junction between the prism, the Malta escarpment and the tear fault is a key region for understanding the geodynamic processes occurring during slab roll-back. This complex junction may have been the source area of the unexplained historical earthquakes. We favor a subduction fault plane origin for the 1693 and 1169 events.

T/MO/O5 - MANTLE DYNAMICS BENEATH THE GIBRALTAR ARC FROM SHEAR-WAVE SPLITTING MEASUREMENTS ON A DENSE SEISMIC ARRAY.

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Controversial evolutionary models have been proposed for the Gibraltar Arc system a complex interaction zone between the Eurasia and African plates comprising the Rif-Betic orogen and the extensional Alboran basin (Western Mediterranean). Here we derive new mantle anisotropic constraints from SKS splitting measurements on a dense network of about 90 broad-band stations deployed over South Iberia and North Morocco, within the Topo-Iberia project. The inferred fast velocity directions (FVD) clearly show a

spectacular rotation along the arc following the curvature of the Rif-Betic chain, while stations located at the South and South-East edges show distinct patterns. These results support geodynamical processes invoking a fast retreating slab rather than convective-removal and delamination models. The FVD variations along the Gibraltar arc can be explained by fossil anisotropy acquired during the Western Mediterranean Eocene subduction, while changes to the South and South-East of the Betic-Rif chain could be the imprint of a flow episode around an Alboran high velocity slab during its Miocene fragmentation from the Algerian slab.

T/MO/O6 - FROM MARADJA TO SPIRAL SURVEYS: RECENT AND ACTIVE DEFORMATION OF THE ALGERIAN MARGIN: EVIDENCE FOR ITS CONTRACTIONAL REACTIVATION

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Northern Algeria is considered as one of the most seismic active zone in the western Mediterranean. In this area, moderate to large events could occur as the El Asnam event of 10.10.1980 (Ms:7.3) and the Boumerdes event of 23.05.2003 (Mw: 6.8).

This activity is related with the convergence between the two main Eurasiatic and African plates which is mainly absorbed in the western Mediterranean in the northern part of Algeria.Seismicity is generated onshore by a series of NE-SW trending folds and reverse faults affecting Neogene and Quaternary basins and their flanks. Offshore, recent marine investigations (Maradja I and II) indicate that seismicity from the central part to the eastern part of the margin is triggered by a series of active north verging reverse faults and folds located mainly in the foot of the margin in a flat-to ramp overall geometry. In the western part, the recent deformation seems to be related to transcurrent movements.

This evidence of contractional reactivation of the Algerian margin is supporting the hypothesis of an initiation of a subduction of the neogene oceanic lithosphere under the African plate. In order to further assess the way this process is occurring and since how long it is developing, the Algerian-French Project SPIRAL was conducted in November 2009 consisting of five deep seismic transects from the shore to onshore along a distance of about 100 km. These new crustal investigations will allow us to better understand the recent tectonic evolution of the margin and to discuss the hypothesis of the incipient subduction zone and the way deformation propagates from land to sea.

T/MO/O7 - SUBDUCTION, ACCRETION AND EXHUMATION: DYNAMICS OF THE AEGEAN AND TYRRHENIAN SEAS

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A dynamic orogen displays diverse tectonic processes brought about by subduction: accretion of oceanic and continental crust, exhumation of HP-UHP rocks, and post-orogenic extension. In the Mediterranean, orogeny is strongly affected by the rollback of the subducting slab, as in the Aegean and Tyrrhenian Seas. The dynamics and inter-relationship of rollback, accretion, and exhumation, however, are disputed. In order to examine the different dynamic processes in a self-consistent manner, we perform a parametric study using the fully coupled thermo-mechanical numerical code PARAFLAM. The experiments reproduce a subduction zone in a slab pull mode, with accretion of one (Tyrrhenian case) or two (Aegean case) continental blocks that undergo, in sequence, thrusting, burial and exhumation. The modelling shows that despite differences in structure between the Aegean and Tyrrhenian Seas, the deformation mechanisms are fundamentally similar and can be described as follows.

The incorporation of a continental block at the trench beneath the suture zone begins with its burial to UHP/HP conditions and thrusting. This is followed by underthrusting and delamination of the block from the subducting lithosphere. During this process of accretion, the angle of the subducting slab increases due to the buoyancy of the continental block. When the oceanic subduction resumes, the angle of the slab decreases to reach a steady-state position. The Aegean and Tyrrhenian scenarios diverge at this stage, due to differences in their accretion history. When continental accretion is followed by oceanic subduction only, the continental block that has been accreted and detached stays at the trench and does not undergo further deformation, despite the continuing rollback. The extensional deformation is located further within the overriding plate, resulting in continental breakup and the development of an oceanic basin, as in the Tyrrhenian domain.

When the continental accretion is followed first by oceanic subduction and then by accretion of another continental block, however, the evolution of the subduction zone is different. The angle of the subducting slab increases again, following the arrival of the second continental block. The first continental block is separated from the trench completely and is strongly heated by the asthenosphere that rises to just below the Moho. At this time, the second continent undergoes burial to UHP-HP conditions, thrusting and exhumation. The extensional deformation is located in the first continental block and results in the development of metamorphic core complexes, as in the Aegean domain.

T/MO/O8 - RECENT TECTONIC REORGANIZATION OF THE NUBIA-EURASIA CONVERGENT BOUNDARY HEADING FOR THE CLOSURE OF THE WESTERN MEDITERRANEAN

A. Billi[1], A. Faccenna[2], O. Bellier[3], L. Minelli[2], G. Neri[4], C. Piromallo[5], D. Presti[4], S. Davide[1], E. Serpelloni[6]
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Both recent and old suture zones between continental plates usually consist of a complex juxtaposition of highly-deformed tectonic slices deriving from pristine paleogeographic and geodynamic domains as diverse as oceanic basins and related margins and sedimentary prisms, subduction complexes, multiple volcanic arcs, seamounts, isolated continental blocks, and backarc basins. Such a juxtaposition shows that the process occurring along destructive tectonic boundaries and anticipating the continental collision or the final suture often does not simply consist of an oceanic lithosphere steadily and cylindrically subducting beneath a continental one. Large and deep backarc oceanic basins may, for instance, develop during long periods of oceanic subduction. With the progression of plate convergence on the way to tectonic suture, these extensional structures may be inverted and even closed through the subduction of the oceanic lithosphere in the former backarc domain. One ideal region to study the tectonic processes anticipating the final suture between continents is the Mediterranean region, where the Nubian (northern Africa) and Eurasian plates meet and interact within the general framework of active convergence. The western Mediterranean (i.e., from Calabria in southern Italy to Algeria and Gibraltar), in particular, is a tectonically complex area where two small oceanic basins (Tyrrhenian and Liguro-Provençal backarc basins) occur along the Nubia-Eurasia convergent margin and are separated by the Corse-Sardinia rigid continental block. Such a complex setting imposes a segmentation and reorganization of the convergent boundary as well as a complex (i.e., non-cylindrical) distribution of the zones accommodating the contractional deformation. The particular and favorable tectonic setting of western Mediterranean may allow researchers to capture some snapshots of the very early processes of tectonic inversion eventually leading to the closure of backarc basins and final suture between continents. We address the present and recent tectonic reorganization along the Nubia-Eurasia convergent boundary in the central-western Mediterranean. To do so, we gather new and previously-published datasets constraining the present tectonic architecture and regime. We analyze and review, in particular, structural, geodetic, seismological, seismic reflection, and tomographic data. We then discuss possible tectonic models explaining the reported datasets and eventually provide some implications for future tectonic scenarios of the studied tectonic boundary.

SD4 - COMPILING THE EARTHQUAKE HISTORY OF THE EUROPEAN MEDITERRANEAN AREA

Monday 6, 14h00-16h40

SD4/MO/O1 - FAKE AND OVERESTIMATED EARTHQUAKES IN THE BALKANS

P. Albini[1], I. Cecic[2], R. Glavcheva[3]
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The historical seismicity of the Balkan peninsula is still far from being reliably described in current parametric catalogues. In the framework of the EU project NERIES Networking Activity 4 – Distributed Archive of Historical Earthquake Data, specific attention was devoted to this region and to a reappraisal of key earthquakes, selected because either their location or their size according to current catalogues were apparently not well documented.

Notwithstanding ongoing initiatives concerning the past seismicity of the Balkans, the comprehensive reference catalogue for the whole region is still the one produced in the UNESCO project by Shebalin et alii (1974). As a consequence, the investigation started from retrieving the studies at the background of this catalogue. Though often such studies are so obscurely quoted to require a good amount of imagination to find them out, the traces have been followed to get hold, as much as possible, of the original records responsible for each earthquake to be parameterized.

The case histories here presented are indicative of a comprehensive scenario of a widespread superficial analysis of the records, mostly due to the complexity of the historical context and sources for the Balkans: i) words changing their meaning from old to modern language, interpreted by inexperts as referred to earthquakes; ii) old and new or simply different calendars in contiguous modern countries, which at the time of the earthquake were split into many local governments; iii) editors of documents not trained in paleography or history; iv) change or misinterpretation of toponyms, and so on.

As a result of this reappraisal, more than 40 earthquakes were either identified as fakes or significantly relocated in time and space as well as resized. We consider this a promising achievement on the way to improve the quality of our knowledge on the seismicity of the past centuries in the Balkans and consequently the reliability of the parametric earthquake catalogues.

SD4/MO/O2 - STATUS OF THE HISTORICAL SEISMICITY CATALOGUE FOR THE NETHERLANDS

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An update of the historical seismicity catalogue for the Netherlands is ongoing. This update was required, since previous versions (e.g. Houtgast, 1991) only provided an overview of possible earthquakes without a critical analysis. The update makes the distinction between reliable events, possible events and fake events. Also, some additional events have been identified, mainly related to the North sea. In addition to the locations, the sources of information for each event, often difficult to access, are made available. The improved catalogue has been used in recent updates of the seismic hazard analysis for the Netherlands. In addition, a reassessment of intensity values for events felt in the Netherlands in the first half of the 20th century has been made.

SD4/MO/O3 - HISTORICAL EARTHQUAKES IN TYROL – FROM ORIGINAL HISTORICAL SOURCES TO EARTHQUAKE PARAMETERS

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In 2009 an INTERREG IV project "HAREIA – Historical and Recent Earthquakes in Italy and Austria" started. In the frame of this project, historical earthquakes in Tyrol will be studied in detail, which serves to complete the Austrian Earthquake Catalogue for the Province of Tyrol. This region is one of the most seismic active areas of Austria.

In order to gain a better image in terms of seismic hazard, the project aimed at the investigation of the strongest earthquakes in Tyrol covering a time window from the 16th to the 19th century.

Mostly original sources e.g. from the archives of Tyrolean monasteries, the municipal archive of Innsbruck or from the library and archive of Tiroler Landesmuseum Ferdinandeum are used in order to avoid mistakes arising from later transcriptions or editions.

Some significant examples, showing the applied procedures, from different periods will be presented. Preliminary results – the transliteration, the interpretation and the documentation of the original sources and the re-assessment of the parameters will be presented.

SD4/MO/O4 - HIDDEN EARTHQUAKES, FORGOTTEN EARTHQUAKES: 19TH AND 20TH CENTURIES ITALIAN CASE-HISTORIES

V. Castelli[1], F. Bernardini[1], R. Camassi[1], C. Caracciolo[1], E. Ercolani[1]
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It is a truth universally acknowledged that the Italian set of historical earthquake data is the best in the world. Or is it?

Admittedly, three decades of intensive historical earthquake studies allowed Italy to collect a huge set of reliable macroseismic data for a great many past seismic events. These studies have made possible to carry out a detailed characterization of the seismic activity affecting most of Italy and greatly contributed to the assessment of seismic hazard on a national and regional level. Nevertheless, the historical Italian seismicity is still far from being thoroughly defined in all its minutest details. No matter what the evaluations of the statistical and historical completeness of seismic catalogues will say, hard experience does shows, again and again that, particularly in some geographical areas and historical periods, there is still much historical earthquake evidence waiting to be discovered. This is a main issue especially for what concerns some particularly difficult historical periods as well as those geographical areas which can be considered to be marginal from a historical-cultural standpoint.

For instance, it is quite easy to lose any memory of earthquakes, even significant ones, if they chanced to occur when a war, or a plague, or even another, more catastrophic earthquake was attracting the attention of most witnesses. We present here the case-histories of three earthquakes, each of whom caused severe damage in some localities at least, but whose memory was almost or completely obliterated by more pressing contemporary events. One occurred in Abruzzo (central Italy) at the beginning of 19th century, which seems to be among the least known periods of Italy's seismic history. Another occurred in Calabria (southern Italy) in 1915 and was overshadowed by the contemporary M 7.0, Avezzano earthquake. The last and most curious case is a complex seismic sequence which took place a few years after World War II on the outskirts of Latium (central Italy), and dropped out the catalogues by a mere chance. Through a meticulous examination of contemporary newspapers and archive records, this paper pieces together the complex macroseismic scenario of three forgotten events, trying to understand exactly why they were forgotten.

SD4/MO/O5 - MACROSEISMIC DATA BASE COMPILING FOR HISTORICAL EARTHQUAKES IN BULGARIA

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This investigation deals with problems faced at compiling, in a modern way, of the macroseismic data base for historical earthquakes in Bulgaria. Such an aspect has never been exhaustively discussed among Bulgarian scientific society. An important problem related to the past earthquakes study is lack of information of Bulgarian origin on natural events till XV-XVI century. Only very severe disasters that used to impede the comercial exchange and diplomatic or war actions, happen occasionally to have been recorded. Moreover, Bulgaria is not known by frequent large earthquakes. The historical earthquake catalogue of Bulgaria is based on a seismological compilation that lies presumably on late information. On the contrary, we are presenting interpretation of information sources contemporary to seismic events in most cases. Motives toward each one decision can be directly seen in a distinct explanation which accompanies every individual case. Annexed citations and comments give possibility of independent further revision. After taking into account results of this study, erroneously read or rewritten assertions will be omitted so that the data base will be perged to a high degree. The macroseismic base compilation is facilitated after introducing the geographic principle of uniting events as the leading factor; at that, the chronologic arrangement is put on the next lower level. Such a type of arrangement allows approaching to concrete positive results in the Bulgarian historical macroseismic data base compila-

tion comparing with the background of the latest Bulgarian catalogue /restricted/:
- omission of around 13% of entries from the latest earthquake catalogue;
- distinguishing of one more seismic event thanks to careful reading of Bulgarian Service Reports;
- intensity assessment/reassessment (MSK) in all study cases; in result: all maximum intensity values coincide with the previous ones with exception of intensity increase in around 7.5% of the cases and intensity decrease in other 10% of them (δ I max ≤ one intensity unit);
- upgrade of some determinations: incorrect dating in 4 cases and incorrect epicentre position in other 6 cases (in 2 of them the epicenter seems indeterminable at present);
- uniting of two previous cases, an action which does not contradict to intensity attenuation and helps in solving the dating problem;
- enriching the intensity data base of two Vrancea earthquakes and 8 Bulgarian earthquakes;
- especially for the seismicity in late XIX century, intensity maps and isoseismal ones, when possible, are compiled and earthquake sequences are specified.

SD4/MO/O6 - THE EARTHQUAKE OF FEBRUARY 23, 1828 IN CENTRAL BELGIUM: NEW HISTORICAL DATA AND DAMAGES IN THE ARCHITECTURE INHERITANCE

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We revisited the 23 February 1828 earthquake that occurred in the central part of Belgium, northwest Europe. This seismic event was the object of different contemporaneous scientific studies, one of them resulting in one of the first published macroseismic map worldwide. We synthesized and critically assessed the information provided by those scientific studies and by the contemporaneous newspapers of the Low Countries. To improve our knowledge of the damage and the earthquake effects in the epicentral region, we undertook a systematic survey of the official, private and religious historical sources of this region. The amount of severe damages to many houses and other buildings in some of those cities suggests that maximal observed intensity is at least VII in the EMS-98 scale. As many reports described destruction in churches of the epicentral region, we conducted a specific investigation in these buildings of the architectural inheritance to identify traces of repair and pathologies that are or could be related to the 1828 earthquake. We established the first modern macroseismic map of the earthquake. From the intensity distribution, we calculated that the 0.84 percentile radius of intensity VII, VI, V and IV are respectively of 11 km, 34 km, 51 km and 140 km for the minimum estimation of intensities and 15 km, 37 km, 70 km and 156 km for the maximal estimation of intensities. The epicenter corresponding to the centroïd of the locations where intensity VII, VI and V were observed is located near the city of Hannut. The magnitude has been evaluated using the classical Ambraseys (1985) relationships. We obtained M = 5.1 ± 0.2.

SD4/MO/O7 - THE EARLIEST EARTHQUAKE RECORDS OF THE BRITISH ISLES

M. Roger[1]
[1]BGS

The UK may be an area of generally low seismicity, but the wealth of historical documentation to some extent compensates for this. The earthquake catalogue can be extended back in time into the first millennium AD. However, the quality of the information available decreases considerably as one goes back in time, and for many early events it is difficult to tell if what is being described is even really an earthquake, since many could be landslides. Curiously, most of the earliest accounts of earthquakes are from Ireland, which is almost aseismic in modern times. Medieval chronicle records are often scrupulous about describing the date of an event, but say nothing about the effects, no doubt due the interest of the chronicler being in the earthquake as a portent. Where damage is described, it is usually either to cathedrals, or generic descriptions without localities. This means that locating events and assessing magnitude tends to be difficult and associated with very large uncertainties.

SD4/MO/O8 - THE EUROPEAN ARCHIVE OF HISTORICAL EARTHQUAKE DATA (AHEAD): COMPILATION, RESULTS, AND PERSPECTIVES

A. Rovida[1], G. NERIES NA4 Working[2]
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Historical seismic catalogues in Europe have been mostly compiled on a national basis starting from historical data collected and interpreted according to different procedures and varied levels of formalization. With few exceptions, the macroseismic data that stand behind the catalogues are not available, or simply never existed. The present-day knowledge on past seismicity in Europe is consequently far from being homogeneous. This situation affected the past efforts for the compilation of homogeneous, continent-wide catalogues and still restrains the ongoing initiatives on this topic. To overcome this situation, the NERIES NA4 project realized the European Archive of Historical Earthquake Data (AHEAD). AHEAD collects and puts together in a critical way the background information supporting European earthquakes between the years 1000 and 1963. The collected information consists of the most significant, or recent, material supporting an earthquake, such as: i) studies that interpret the historical records in terms of Macroseismic Data-Points (MDPs); ii) studies that provide the historical records but not interpreted in terms of MDPs; iii) parameters from catalogues, only. AHEAD contains entries related to more than 10.000 earthquakes, and the inventoried material is made available through the web. It also provides in a standardized database the MDPs that support about the 60% of the listed earthquakes. For a large number of them such MDPs have been released for the first time by partner institutions in the framework of NERIES NA4. AHEAD is conceived as an interactive tool for representing and improving the knowledge on historical earthquakes, with the aim of making it homogeneous at a European level. Through the archive researchers can easily: 1) trace back the information supporting each earthquake in order to reappraise and improve the knowledge of it; 2) compare the different studies on each earthquake and select a preferred one. This is, for example, the procedure followed for the selection of data upon which the NERIES NA4 European Earthquake Catalogue has been compiled. 3) help keeping the archive as much up-to-date as possible, commenting studies, data, and parameters and feeding it with fresh studies.

SD4/TU/O1 - ESTIMATING EPISTEMIC UNCERTAINTY IN THE LOCATION AND MAGNITUDE OF HISTORICAL EARTHQUAKES IN EUROPE

W. Bakun[1], A. Gomez Capera[2], M. Stucchi[2]
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The location and magnitude of significant historical earthquakes, with objective estimates of their epistemic uncertainty, are important input in probabilistic seismic hazard assessment calculations. Bakun and Wentworth (1997), Gasperini et al. (1999) and Musson and Jiménez (2008) have proposed independent techniques for estimating an earthquake location and magnitude from intensity data. We adopt the calibration results for these three techniques and use the intensity assignments for historical earthquakes in some European regions that were developed as part of the module "Archive of Historical Earthquake Data" of the EU NERIES project. The EU NERIES project has already processed the data for more than 1000 events from 1000AD to 1963AD. The three estimates obtained for a given set of intensity data are almost always different. No one technique is consistently better at matching instrumental locations and magnitudes of recent well-recorded earthquakes, but each technique tends to perform better in specific situations. For example, the Bakun and Wentworth (1997) technique can provide credible locations for events occurring offshore. Rather than attempting to select one of the three solutions as best for an historical earthquake for which the instrumental location and magnitude are unknown, we use all three techniques to estimate the location and the magnitude and their epistemic uncertainties. Our goal is to provide credible estimates of location and magnitude for all events, whatever the specific situation. In addition, we seek to estimate uncertainties in location and magnitude for which there is confidence that the actual source location and moment magnitude are within the estimated bounds of location and magnitude.

The estimates are calculated using bootstrap-resampled data sets with Monte Carlo sampling of a decision tree. The decision-tree branch weights are based on goodness-of-fit measures of location and magnitude for many recent earthquakes for which satisfactory instrumental and intensity data are available. The location estimates are based on the spatial distribution of locations calculated from the bootstrap-resampled data. The locus of the maximum location spatial density is the preferred source location. The spatial density contours enclosing 67% and

95% of the locations are the perimeters of the 67% and 95% confidence region of source location, respectively. The median of the distribution of bootstrap-resampled magnitude estimates is the preferred magnitude and the distribution of magnitudes provides the confidence intervals for magnitude.

SD4/TU/O2 - THE LOCATION AND SIZING OF HISTORICAL EARTHQUAKES USING THE ATTENUATION OF MACROSEISMIC INTENSITY WITH DISTANCE: A NEW VERSION (4.0) OF BOXER CODE

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[1]Università di Bologna, Dipartimento di Fisica; [2]Istituto Nazionale di Geofisica e Vulcanologia; [3]Università di Bologna, Istituto Nazionale di Geofisica e Vulcanologia

We describe the new methods for computing the quantitative parameters of earthquakes using macroseismic data, and the uncertainties associated with these that we implemented in the new release 4.0 of Boxer code. The methods allow for the location of epicenters that are offshore or that have no intensities assigned to any points in the epicentral region, by maximizing the likelihood function of an attenuation equation with observed intensity data. In the most favorable cases, such an approach also allows the estimation of the source depth and the local attenuation coefficients. We compute the parameter uncertainties in two ways: i) using formal methods, such as the inversion of the Hessian of the log-likelihood function at its maximum, and ii) by using bootstrap simulations. We tested the performance of our methods by comparison with reliable instrumental hypocenters of onshore earthquakes, and found a reasonable agreement with the epicentral locations (within 10-15 km for more than 70% of cases) but not with the hypocentral depths, for which our results are generally underestimated by a factor of 2 or more and poorly related to instrumental estimates. This finding indicates that the use of macroseismic depths in seismic hazard and seismotectonic investigations should be treated with caution. We nevertheless found good agreement (within 10-15°) between the fault-trace orientations that were computed using the macroseismic data and the associated focal mechanisms of earthquakes with Mw≥5.7. The surprising accuracy of the macroseismic orientations obtained using this method could in some cases allow the true fault to be inferred between the two conjugate planes of a given focal mechanism.

SD4/TU/O3 - CALIBRATION METHODS FOR PARAMETERISING EARTHQUAKES 1000-1963 FROM MDPS IN EUROPE

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One of the goals of the the NA4 module - Distributed Archive of Historical Earthquake Data of the EU NERIES project was to re-assess the earthquake parameters from macroseismic data for the strongest (M≥5.8) historical earthquakes in Europe for the time-window 1000-1963.

Three independent methods have been calibrated and applied, i) Bakun and Wentworth, ii) Boxer and iii) MEEP, in a homogeneous way in six areas: Aegean, Iberia, Italy, United Kingdom, Switzerland and European Stable Continental Region (Scandinavia, Belgium, etc.). Lessons have been learnt concerning the calibration process and the application of the three methods to macroseismic data related to historical events.

In general, excellent results were obtained for earthquakes with a good amount and distribution of macroseismic data points (MDPs), e.g. post-1800 events.

The three methods are intrinsically different; therefore, we cannot expect that they always give the same results, even if the calibrations are good.

Looking at the differences, Boxer tends to perform magnitudes and locations better in onshore situations and credible locations for events with small number of MDPs; MEEP tends to perform better for events with small magnitudes, while the Bakun and Wentworth method is the best to provide locations for offshore earthquakes.

When applying the three methods to earthquakes with one MDP only, we would expect that results in terms of location and Mw do not diverge. This was not the case, so far. When applied to events with one MDP in the same region, the three methods gave results not always consistent in terms of Mw. In some cases the patterns of the differences were not comparable, showing an intrinsic weakness in the calibration.

The results are encouraging, although some problems are still to be explored. The epicentre determinations appear rather successful and not so much regionally dependent, although to date no method is completely successful in distinguishing coastal and offshore events. The magnitude determinations, which come with uncertainty estimates, strongly depend on the regional calibration; in some cases, they largely diverge, and also strongly differ from the values reported by current national catalogues. We believe that what we have learnt might help in reducing such differences, though they do represent also an estimate of the epistemic uncertainty of the process.

SD4/TU/O4 - EARTHQUAKE PARAMETERS OF HISTORICAL EARTHQUAKES IN THE IBERIAN PENINSULA

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In the frame of the NA4 module (Distributed Archive of Historical Earthquake Data) of the European project NERIES, re-assessing of the earthquake parameters is made for the strong historical events (M≥5.8) in Europe. For this purpose, several zones were defined and event parameters calibrated for each one separately; one of them was the Iberian Peninsula. Here we present the results obtained for the Iberian Peninsula.Three independent methods are calibrated for the Iberian Peninsula in an homogeneous way, (1) Boxer, (2) Bakun and Wentworth and (3) MEEP, The basis of the methods rely on grid-search, intensity attenuation-fitting and mechanics of earthquake perception. The calibration of the three methods is based on a unique set of 21 earthquakes of the 20th century occurred in Iberia peninsula for which macroseismic data points (MDPs), instrumental moment magnitude (Mw) and instrumental epicentral coordinates are available. A validation process is following i.e. epicentral determinations by the three methods were then compared with the available instrumental parameters for events not used in the calibration process. The three different applied methods perform quite well in statically sense; but they show specific problems when events are studied one by one.The three methods and the relevant calibrations are applied to 60 historical Iberian earthquakes for the time windows 1000-1963. A general trend is that Mw values calculated with the new calibrations are slightly lower that previous available ones obtained with other methods or datasets. The results are encouraging but, at the same time, show the limitations when dealing with offshore events.

SD4/TU/O5 - THE NERIES NA4 EUROPEAN EARTHQUAKE CATALOGUE (M≥5.8)

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While in the case of instrumentally recorded events earthquake parameters are determined from waveforms, in the case of historical events such parameters are determined either from intensity datapoints or from the effects accounts; in the latter case it is performed according to mostly unreported procedures. Each national or regional earthquake catalogue adopts individual procedures; the NA4 European Earthquake Catalogue has been compiled re-assessing the earthquake parameters according to uniform procedures from the best possible supporting datasets.

The European Earthquake Catalogue 1000-1963, M ≥ 5.8 covers the territories belonging to EU and neighbouring areas, approximately comprised between 13°W to 30°E and from 35°N to 65°N. For the time-window 1000-1899 the earthquake list has been obtained from the "preferred" entries of the NA4 inventory. These entries represent the selection of the most significant datasets among the inventoried ones, supporting each of the 645 earthquakes classified as "large".

For the time window 1900-1963 the procedure has been similar, with the addition that for this time-window also the instrumental datasets have been considered. The number of earthquakes is 293. As a whole, the NA4 catalogue, M ≥ 5.8, lists 938 earthquakes.

The parameters of the 627 earthquakes with MDPs have been determined with three methods based on the use of macroseismic datapoints: i) Boxer; ii) MEEP, developed within NA4; iii) Bakun and Wentworth (BW, 1997). The parameters of the events without

MDPs have been assessed through expert judgment among the participants.

Most traditional catalogues supply only one set of such parameters for each event, with little or without reference to the background data and to the methods according to which they have been processed. Opposite to this, the NA4 catalogue supplies several values of such parameters, derived from:

a) the three methods described above (BW, Boxer, MEEP), using the adopted calibration coefficients
b) Io, in the case of Mw(Io)
c) from expert judgment
d) from selected sets of instrumental parameters (when available).

NA4 EEC does not indicate a preferred value of the parameters, does not propose weights and does not average the values. Although users would prefer a catalogue with one "default" set of parameter values, only, NA4 EEC prefers to show the available variability of the parameters, leaving to users the choice of how to deal with it.

SD4/TU/O6 **– A HARMONIZED CATALOGUE OF EARTHQUAKES IN THE EURO-MEDITERRANEAN REGION (EMEC)**

R. Wahlström[1], G. Grünthal[1], D. Stromeyer[1]
[1]GFZ German Research Centre for Geosciences

The catalogue by Grünthal et al. (2009) of earthquakes in central, northern and northwestern Europe with $M_w \geq 3.50$ (CENEC) has been expanded to cover also southern Europe and the Mediterranean area and extended in time. Due to the strongly increased seismicity in the new area, the threshold has here been set at $M_w \geq 4.00$, keeping the lower threshold in the northern catalogue part, which has been updated where new and revised local catalogues exist. The new Euro-Mediterranen Earthquake Catalogue (EMEC) is based on data from some 70 catalogues and data files, some 80 additional special studies, and supplementary original M_0 and M_w data from various sources. The analysis largely followed the lines of the CENEC study, i.e., non-tectonic, non-seismic (fake) as well as duplicate events were identified and removed, polygons were specified within each of which one or more of the catalogues or data files have validity according to a hierarchy, and existing magnitudes and intensities were converted to M_w according to other priority schemes. Algorithms to compute M_w are based on relations provided locally or, more commonly, derived in the CENEC study or in the present study. Beside just testing the homogeneity of the Catalogue with respect to M_w for its different constituents, as for CENEC, M_w magnitudes for parts which were found not to harmonize according to statistical tests were revised to the largest possibly extent to achieve maximum homogeneity for the whole EMEC catalogue. The final catalogue covers the time period from the year 1000 up to recent time. For each event, the date, time, location (including focal depth if available), intensity I_0 (if given in the original catalogue), magnitude M_w, and source (local catalogue or special study) are given, as well as the strength type and value from which M_w was calculated. The main purpose of the EMEC catalogue is to provide a database for seismic hazard calculation related to ground motion parameters, but it can also be used for various kinds of seismicity studies.

ES1 - TRIGGERED AND INDUCED SEISMICITY

Monday 6, 14h00-16h40

Tuesday 7, 08h00-10h00

ES1/MO/O1 **- CORRELATION BETWEEN TURKEY SEPTEMBER 3, 2008 ATATURK DAM EARTHQUAKE (MW=5.0) AND WATER LEVEL DECREASE**

H. Eyidogan[1], V. Gecgel[1], Z. Pabuccu[2]
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3 September 2008 (02:2 UTC, Mw=5.0, ML=5.2) earthquake has occurred at the reservoir basin of Atatürk Dam and Hydroelectric Power Plant, the biggest rock-fill dam of Turkey. A series of aftershocks has followed the main-shock and two aftershocks with magnitude ML=4.6 ve ML=4.0 have occurred. The seismological characters of the September 3, 2008 earthquake, the fault zones in the region, the relationship between the excessive water level decrease in the dam and triggering of earthquakes, and the effects observed in the triggering mechanism under tectonic stress regime in the region were studied. It could be stated that the decrease in the vertical compressive stress, realized due to the fast decrease in the water level in excessive amount, and deviatoric effects of the pore pressure caused the exceeding of the critical stress level by changing the shear stress values on the rocks and consequently triggered the earthquake with the magnitude of Mw=5.0. It was concluded that the possibility that stress reactions caused by the effective strengths, created by the significant amounts of increases and decreases in the water level of the Ataturk Dam, could also trigger the seismicity of the Bozova Fault, which is significant for the vitality of the dam, needs to be considered.

ES1/MO/O2 **– PROGNOSTIC ANOMALIES OF INDUCED SEISMICITY IN KOYNA-WARNA REGION, WESTERN INDIA**

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Induced seismicity was studied in the region of Koyna-Warna water reservoirs in period 1996-2005. Detailed local catalogue for this region was used as original data. A special feature of seismicity in Koyna-Warna region is strongly pronounced cyclicity, showing up as occurrence of strong (for this region) earthquakes with M>4 on the same phases of water level variations and existence of annual and multiple harmonics in seismic activity. The frequency (number per ten analyzed years) of strong earthquakes (M>4) is abnormally large in comparison with weaker events – there is the break of the frequency-magnitude relation. Annual cyclicity is destroyed for a few years after a pair of strongest for analyzed period events with magnitude M>5 (12.03.2000, M=5.2 и 05.09.2000, M=5.3). Anomalies of seismicity typical for processes of preparation of tectonic earthquakes (prognostic anomalies) was found before these double event: seismic quiescence (RTL-anomaly), b-value bay disturbance, decreasing of fractal dimension of hypocenter set (d-value anomaly), bay disturbance of combined parameter q=ab-d (q-value anomaly). From physical point of view these anomalies indicate the process of redistribution of the failure on scales typical for scenario of preparation of tectonic earthquakes. It allows to assume that sources of induced earthquakes pass the same stages of preparation, as sources of tectonic earthquakes, and prognostic technique can be used as a tool for investigation of induced seismicity.This work was supported by Russian Foundation for Basic Research (grant 08-05-00248) and Indo-Russian ILTP project B2.59.

ES1/MO/O3 **– SPATIAL AND MECHANICAL CONSTRAINTS ON FAULT SLIP SEISMICITY INDUCED BY MINING**

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Numerical simulations of mining induced deformation and damage have been calibrated at several mines to produce a quantifiable relation between modelled energy changes on faults and in the rock mass and the location and nature of seismicity recorded using mine wide seismic systems. The mining induced seismicity is not explicitly predictable, but the probabilistic relation between the energy dissipated plastically on structures in the model and the likelihood of events in space and time compared to mining activity is useable for risk analysis and decision making within the mine. Once calibrated the expected spatial extent of induced seismicity can be forecast in terms of spatial probability isosurfaces bracketing volumes of expected zero or near zero event probability, for events of a substantive magnitude or event occurrence in general. If not calibrated, the underlying mechanics of the discontinuum, strain softening models provide a wider range of expected outcomes but one which may still be useable for many engineering purposes. The procedures, example results and limitations of the analysis are discussed in detail.

ES1/MO/O4 **– SEISMIC MONITORING OF KARST PROCESSES ACCOMPANYING FLOODING OF MINE AT UPPER KAMA POTASH DEPOSIT**

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An extraordinary event - flooding of the Berezniki-1 mine – had occurred in period 2006 – 2007 at the Upper Kama (Verkhnekams-

koye) potash deposit. The deposit is situated to the west of the Ural mountains in the northern part of the Perm region (Russia), about 250 km north of the city of Perm. Extensive mined out areas of 6 underground mines operating here pose a threat to activity of large chemical and power plants, railroads, gas pipelines and population safety as well.

On 18 October 2006 a loss of integrity of the waterproof stratum and penetration of brines from upper layers to mining excavations were identified in the western part of Berezniki-1 mine. Since the beginning of mine flooding the seismic monitoring of potentially dangerous surface area over the western part of mine was organized. The seismic network including surface, borehole and underground geophones was installed. The ISS data acquisition hardware and software (South Africa) was used. Special processing center was established for real-time monitoring. The monitoring system made it possible to get and process seismic data within 1.5 minutes after dynamic process took place in the area of interest.

From October 2006 till December 2008 the monitoring system had registered more than 10000 seismic events which could be associated with the karst processes (fracturing of rock mass) in near surface layers of the monitoring area. In a first approximation all events may be classified into two types. Events of the first type are distinguished by clear arrivals of P waves and relatively high frequency content (30-60 Hz). The arrivals of S waves are hardly identified. Events of this group are associated with fracturing at the levels of mining openings or in the consolidated part of the overlaying rock mass. Events of the second type are characterized by low frequency (5-20 Hz) long-duration (several seconds) signals without clear arrivals. This group of events is associated with fracturing in the soft part of the rock mass or rockfalls from roof and side walls of karst caves. In some cases such events may be caused by failures in foundations of surface buildings due to their extensive deformation.

Anomalous seismic activities have been observed since 20 July 2007. It took the form of swarms of events of the second type of a very high rate (100 and more events per hour) and overall duration up to several hours. On 28 July the seismicity increased sharply. Most of events in this swarm were of the second type. A large sinkhole was visually discovered on the surface at 3:30 PM. Initial size of the sinkhole was approximately 60 x 40 m. A visually observable depth was 15-20 m. The seismic activity had bumped up again on the next day (29 of July) and this burst was accompanied by severe explosion of gas released from the salt rocks. Subsequent seismic monitoring has revealed a good space-time correlation of recorded seismicity and direction of the sinkhole growth.

ES1/MO/O5 - MOMENT TENSORS OF MINING TREMORS – DETECTION TOOL OF THE MODE OF ROCK-MASS FRACTURING.

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Contrary to natural earthquakes, where the features of the geological environ without void spaces and the character of loading naturally favor shear slip, in foci of seismic events induced by man-made activities there is a physically based reason for occurrence of non-shear processes. Especially in mines, the existence of mined-out cavities enables implosive events which are improbable among natural earthquakes. In particular, great depth of excavation typically occurring in gold ore mining results in extreme loading of mine structures underground. High stress concentrations cause collapsing of excavated cavities, which is reflected by specific non-double-couple (non-DC) mechanisms. Apart from mining tremors, natural earthquakes of a tectonic origin may occur in the area where mining activity takes place. The mechanism in the moment tensor (MT) representation, in particular the DC vs. non-DC issue, is an important discrimination instrument. To develop it into a reliable methodological tool it is however vital to assess properly errors in the MT retrieval and especially errors in the non-DC component determination, which is vulnerable to possible deterioration of the quality of records, station distribution, event location and velocity structure modelling. We demonstrate the approach on data from an Australian underground mine: by inverting amplitudes of P and S waves both in spectral and time domain, we determine complete moment tensors of several tremors in situations of either a favourable or deteriorating quality of the station distribution, and discuss the reliability of the retrieval of the non-DC components by parallel evaluation of the traditional fault-plane solution and assessing the goodness of fit.

ES1/MO/O6 - SELF-SIMILARITY OF GUTENBERG-RICHTER SCALING RELATION DOWN TO MAGNITUDE -4.4 RECORDED AT MPONENG DEEP GOLD MINE, SOUTH AFRICA.

G. Kwiatek[1], K. Plenkers[1], G. Dresen[1], JAGUARS Group[2]
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We investigate the lower magnitude limits and frequency-magnitude characteristics of the microseismic catalogue recorded with a high-sensitivity seismic network at Mponeng mine, South Africa (Nakatani et al., SSA 2008 Proceedings). The network, composed of one 3-component accelerometer (50 Hz to 25kHz) and 8 acoustic emission sensors (700Hz to 200kHz) is located at a depth of 3543 m and covers the limited volume of approx. 300 x 300 x 300 m. The 3-component accelerometer was used to estimate the moment magnitude for the limited number of 135 very well recorded events (M_w ranged -4.1 to -0.3). We use the relation between the moment magnitude estimated from accelerometer data and moment magnitude calculated from acoustic emission sensors to extend the catalogue to lower magnitudes. The magnitude of completeness of selected spatio-temporal subsets of the catalogue was estimated for: (1) post-blasting activity during working days, located more than 80 m from the network and (2) aftershock sequence of a M_w 1.9 event that occurred ~30 m from our network. Both datasets follow the Gutenberg-Richter frequency-magnitude relationship with no visible deviation from self-similar behavior of seismicity between M_w -4.4 and -1.9 for the aftershock sequence and between -3.5 and -1.5 for the post-blasting dataset. We estimated the magnitude of completeness of selected subset as low as -4.3 for the aftershock sequence and -3.4 for the post-blasting activity. Differences in magnitude of completeness are attributed to location of recorded activity and site effects.

ES1/MO/O7 - STATIC STRESS TRANSFER AND EVENT CLUSTERS IN MINING INDUCED SEISMICITY

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Recent studies of mining induced seismic series from Rudna mine showed that the static stress transfer participated in the seismic generation process in this area. The static stress changes due to preceding seismicity can alter the time of mining tremors that would have occurred eventually due to mining works loading alone. These results indicate that the static stress transfer can be an additional physical mechanism explaining time-space clustering observed in mining induced seismicity.

In this work we present the results of investigation the spatio-temporal clustering of seismicity induced by mining works in Rudna mine in Legnica Glogow Copper District in Poland and its relation with the static stress changes. Spatio-temporal clustering of seismic events can be identified by the use of an equivalent dimension approach. All event parameters transformed to the equivalent dimension space are in the same scale and the distances between events are Euclidean. Here we consider events following stronger tremors. The smaller events are parameterized by the epicentral distance to the larger tremor and the time elapsed from the larger tremor. Locations of smaller events are viewed in the space of these parameters transformed to equivalent dimensions. The smaller distance from the tremor indicates the stronger link between the tremor and subsequent events. According to this feature, the families of the most connected events are identified for the strongest tremors in Rudna mine.

The Coulomb stress changes caused by the coseismic slip of the strongest tremors are resolved on a plane that corresponds to the direction of mining face. We find that recognized clusters of mining induced seismicity are mainly located in areas where the static stress increased due to coseismic slip of tremor in cluster.

This work was prepared within the framework of the research project No. N N307234937, financed by the Ministry of Education and Science of Poland during the period 2009 to 2011.

ES1/MO/O8 - ROCK DISCONTINUITIES: DEFORMATIONS' EVOLUTION AND INSTABILITIES' TRIGGERING DUE TO LOW AMPLITUDE SEISMIC LOADS

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It is well known that any artificial or tectonic stress change may trigger seismic activity. The observation of triggering at very large distances from an earthquake seems to suggest that triggering is caused by propagation of seismic waves of a remote event. There is no clear mechanism responsible for triggered seismicity. We have performed lab and field observations, which show that the low-amplitude vibrations in a stressed rock produce residual deformations localized at faults and fractures. Accumulations of small displacements at discontinuities may turn to be an important factor in the evolution of stress-strain conditions.We have investigated the dynamic effect on an element of a blocky medium in laboratory experiments. It was observed that in the absence of a constant shear load the vibration doesn't produce any residual displacements along fractures. However, even a small shear load leads to the appearance relative displacements between the blocks. The sign of residual displacement doesn't depend on the direction of wave propagation, but coincides with the direction of applied shear load. We show that a short dynamic disturbance can trigger a slow motion along a preliminarily stressed fault, whose contribution to the integral value of accumulated deformation may be great.We have performed high-precision observations over the regime of deformation of several discontinuities of natural (sections of fault zones) and man-caused (fractures in the engineering constructions) origin. We have found that seismic vibrations with amplitudes V_m varying 1 – 2 orders of magnitude may initiate close residual deformations Δ, which can be explained by different levels of static stresses in the vicinity of discontinuities. At the same time the trend of the function $D(V_m)$ demonstrates proportionality to the amplitude of vibrations.We develop a phenomenological model of accumulation of deformations on rock discontinuities due to low amplitude seismic vibrations. This effect may be explained by the specific rheology of rock discontinuities. It was shown that an asymmetry of loading and unloading of faults and fractures leads to emergence of residual displacements of discontinuity sides even under low (comparing to fault or fracture strength) amplitudes of seismic waves. Displacements accumulated due to dynamic deformation process can lead to the effect of emergence of dynamic instability at a stress level noticeably lower than the current contact strength. If static stress level is too low, the effect of consequential increase of contact unloading stiffness during repeated cycles may lead to damping of the process with time.

ES1/TU/O1 - DEVELOPMENT OF BASIC PHYSICS OF ARTIFICIAL ELECTROMAGNETIC IMPACT ON DEFORMATION PROCESSES IN THE EARTH CRUST

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Earthquake triggering by dynamic and static stress change due to an impact of strong distant earthquakes, underground nuclear and chemical explosions, water reservoir filling, fluid injection into the faults, lunar-solar earth tides, etc. is widely discussed in the scientific literature. Relations of electromagnetic phenomena and earthquake occurrence are considered mainly from point of view of possible earthquake prediction based on anomalous variations of electromagnetic signals before the seismic event. Nevertheless, recently an effect of high-power electromagnetic pulses produced by magneto-hydrodynamic (MHD) generator on the seismic regime over the Northern Tien Shan and Pamir regions has been discovered. It was found that occurrence of local earthquakes after firing runs of MHD generator became higher than before them. Based on previous field and laboratory study of seismicity triggered by high-power electric pulses injected into the Earth crust the Russian team, which incorporates researchers from Joint Institute for High Temperatures, Institute of Physics of the Earth, Institute of Dynamics of Geospheres (Moscow), Research Station in Bishkek, Kirghizia (Northern Tian Shan) of Russian Academy of Sciences started in 2009 the complex Project "Development of basic physics of artificial electromagnetic impact on deformation processes in the Earth crust" for investigation of electromagnetic triggering phenomena. The project is directed to solving the basic problem of stress release in the Earth crust by man-made impacts at the junction of applied seismology, electrodynamics, and rock mechanics. The target of project is development of physical grounds of earthquake hazard mitigation technology by artificial partial discharge of tectonic stresses due to initiation of deformation processes in the earth crust by relatively weak electromagnetic and vibration actions. The project is a continuation of interdisciplinary research of influence of high-power electromagnetic pulses on deformation processes in the Earth crust by methods of statistical analysis of field data, physical laboratory and mathematical simulations. The new basic knowledge is anticipated on mechanisms of interaction of electromagnetic field and vibrations with rocks under stressed conditions in combination with impacts of various natural factors. Preliminary results are discussed obtained to-date from statistical analysis of previous filed experiments with pulsed power systems, laboratory research of dynamics of rock deformation under low-amplitude mechanical and electromagnetic disturbances, physical simulation of seismoelectric and electroseismic phenomena in the rocks, as well as theoretical analysis of possible mechanisms of interaction of stressed rocks with electromagnetic field.

ES1/TU/O2 - IS RUPTURE DIRECTION OF GAS-FIELD TRIGGERED EARTHQUAKES DRIVEN BY STRESS FIELD GRADIENTS?

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Shallow earthquakes nucleating in the vicinity of gas or oil fields under production are often suspected to be triggered by the local depletion-induced stress field perturbation.

The rupture plane of such earthquakes samples the volume of inhomogeneous stress, i.e. regions of stress gradients and possible stress rotation.

We question whether the rupture propagation is influenced by the stress field perturbation.

The rupture directivity of two gas-field related earthquakes are studied,the 2004 Mw 4.4 Rotenburg, Northern Germany, and the 2001 Mw 4.0-4.4 Ekofisk, North Sea, event.

The rupture mode, uni- or bi-directional, and the rupture direction are compared to gradients of stress field components.

Preliminary results indicate that the rupture mode is uni-directional and that the rupture front has a tendency to grow in the direction of increasing shear stress. The size of the rupture plane may be controlled by the size of stress perturbation bowl.

The study is of interest to better estimate the potential seismic hazard of earthquakes in the neighborhood of oil- and gas fields.

It is also giving insights in the problem of uni- and bilateral rupture mode of tectonic events, and why earthquake ruptures may stop growing

ES1/TU/O3 - INDUCED SEISMICITY IN HYDROCARBON FIELDS IN THE NETHERLANDS

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Since 1986 more than 650 induced earthquakes have been recorded in the north of the Netherlands due to hydrocarbon exploration. Locations have been calculated using a regional network. The error in the epicenter locations (.5-1 km) and depth (1-2 km) is too large to connect the sources to existing faults near the fields in production. The installation of accelerometers at short distance from earthquakes in the Groningen field, the largest on-shore gas field in Europe, enables a more detailed modeling. Especially the impact of a high velocity salt layer on top of the reservoir, resulting in converted phases, could be used to constrain the depth. In addition the source mechanisms of the largest events in the Groningen field are studied, showing normal faulting, which is different from mechanisms is small fields in the same region that show reverse faulting.

ES1/TU/O4 - SOURCE MECHANISMS AND STRESS REGIME AT THE HDR SITE SOULTZ-SOUS-FORÊTS (ALSACE, FRANCE)

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Stress evaluation is an immediate benefit of determination of fault-plane solutions of events that occur on pre-existing faults within a zone of interest. In the Hot Dry Rock (HDR) facility at Soultz-sous-Forêts (Alsace, France) several hydraulic stimulation experiments were performed in 2000, 2003, and 2004 with the aim to improve the connectivity of the drilled boreholes with the natural fracture system. During each fluid injection a large number of micro-earthquakes were

induced, which track migration of the fluid into the surrounding rock mass. With the prime goal to assess the mode of fracturing during the injections, we determined mechanisms in the complete moment tensor description of a statistically representative number of events. We inverted the peak amplitudes of 45 events with magnitudes between M = 1.4 and 2.9 which occurred during the injection in 2003. Surprisingly, the mechanisms were predominantly pure shear slips, i.e. with source mechanisms typical for tectonic earthquakes. The resulting T-axes were fairly stable, trending horizontally to sub-horizontally roughly in the E-W direction. Conversely, the P-axes were ill-conditioned varying in the N-S direction from nearly vertical to nearly horizontal. To estimate the stress state within the zone of the hypocentra, we applied the approach by Angelier (2002), minimizing the slip shear stress component, advantageously avoiding a prior discrimination between fault and auxiliary plane. As anticipated from the tight clustering of T axes of the events treated, direction of the minimum stress axis, σ_3, is well constrained sub-horizontally in the E-W direction. Conversely, the locus of P axes is stretched largely in the N-S direction (from vertical to horizontal), which indicates a lower resolution of the directions of the maximum and medium stresses, σ_1 and σ_2. This is manifested by the confidence zones of the σ_1 and σ_2 directions, which infiltrate each other. In a more detail view, when considering the set of events we can trace a couple of segments, which may correspond to two fault systems in the site. Our result indicates that the stresses σ_1 and σ_2 in the two systems interchange.

ES1/TU/O5 **- INFLUENCE OF THERMAL HEATING TO ELASTIC ANISOTROPY OF GRANULITES**

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The changes of mechanical properties of thermal heated rocks were studied. Granulite spherical samples were subjected to controlled loading and heating regimes. In the first step, granulite spherical sample was subjected to confining stress loading up to 400 MPa and elastic anisotropy, measured at 132 independent directions, was determined for different stress levels. After unloading, the rock sample was gradually heated from 50° C up to 600° C. After individual heating regimes there was determined elastic anisotropy of the sample at atmospheric pressure. After final sample heating at 600° C, there was again determined its elastic anisotropy up to confining stresses 400 MPa. The original sample exhibit weak anisotropy (8 %) at atmospheric pressure. At 400 MPa the granulite sample is nearly isotropic. Heating of the sample caused significantly decrease of P-wave velocity and high increase of coefficient of anisotropy. Subsequent determination of elastic anisotropy of heated rock sample under confining stress up to 400 MPa shows significant increase of P-wave velocities in all direction, which nearly reach the P-wave velocity values of the original sample before to be subjected to heating regime.

ES1/TU/O6 **- CHARACTERIZATION OF EXTREMELY WEAK FAILURE SIGNALS GENERATED BY ACTIVE SHALLOW SUBSURFACE INSTABILITIES: NANOSEISMIC MONITORING OF CAVITIES, CLIFFS AND SINKHOLES**

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Nanoseismic monitoring techniques (Wust-Bloch & Joswig, 2006; Joswig, 2008) are able to detect extremely low-energy (ML > -4.0) signals generated by active subsurface instabilities within cavities, cliffs, landslides and sinkholes. The data is acquired by portable sparse seismic arrays, which are deployed, within minutes, in varying geometries as close as possible to a presumed zone of instability. Events detection is carried out by semi-automated pattern recognition-supported schemes that scan for broad-band energy spikes within continuous data records sampled at 200 to 500 Hz.The authenticity of source signals is verified either by true-scale simulation in the field - when possible- or through a multi-parameter validation process that uses a custom library of reference patterns. This comprehensive waveform characterization process includes full-spectral signal analysis, 3-D source location, waveform cross correlation and source magnitude evaluation.Study cases will be reviewed to show how failure generated within cavities (Tsesarsky & Wust-Bloch, 2009), cliffs (Wust-Bloch, 2009), landslides (Joswig, 2008) and sinkholes (Wust-Bloch & Joswig, 2006) can be located and characterized. Additional analyses include magnitude-time series, source time migration and event coincidence with external parameters as well as a custom calibration of source energy dissipation in unconsolidated material and in low stiffness media.

SD10 - INTERNET MACROSEISMOLOGY

Tuesday 7, 08h00-10h00

SD10/TU/O1 **- USGS "DID YOU FEEL IT?" INTERNET INTENSITY MAPS: LESSONS LEARNED FROM ONLINE MACROSEISMIC DATA COLLECTION**

D. Wald[1], V. Quitoriano[1], B. Worden[1], S. Mathias[1], J. Dewey[1]
[1]U.S. Geological Survey

For the past ten years, the U.S. Geological Survey's "Did You Feel It?" (DYFI) system has automatically collected shaking and damage reports from Internet users immediately following earthquakes. DYFI is a vast source of macroseismic data, providing quantitative and qualitative information about earthquake intensities for earthquakes in the US and around the globe. Statistics attest to the abundance and rapid availability of these Internet-based macroseismic data. Over 1.7 million entries have been logged to date; over 1,000 entries were received for each of 29 separate events in the first four months of 2010 alone. The greatest response to date is over 78,000 for the April 2010, M7.2 Baja California, Mexico, earthquake. Questionnaire response rates have reached 62,000 per hour (1,000 per min!) requiring substantial web resource allocation. Outside the US, global DYFI has gathered over 189,000 entries in 9,500 cities covering 140 countries since its inception in late 2004. The rapid intensity data is automatically used for constraints in ShakeMap systems, providing intensities near population centers and allowing for overall prediction equation bias corrections. ShakeMap has been recently refined to use macroseismic input automatically in their native form, and treat their uncertainties rigorously (see Worden et al., this meeting). A number of DYFI system improvements have been recently made. A graphical user interface allows 24X7 seismic analysts to perform most common functions, including map triggering and resizing, geocoding, as well as sorting, searching, and flagging entries. The entire archive and all incoming entries and results are now databased further facilitating research on the data by streamlining data export functionality. For example, recent quantitative analyses of uncertainties of DYFI data provide confidence in their use: Averaging ten or more responses at a given location results in uncertainties of less than 0.2 intensity units. Systems comparable or complimentary to DYFI now operate in several countries, and collaborative efforts to uniformly collect and exchange data in near real time is being further explored. From our experience, essential components of a Internet-based citizen science portal include easy-to-use forms, instant feedback and the ability to see one's contribution, and routinely addressing user comments and questions. In addition, online user-friendly tools now include common searches, statistics, sorting of responses, time-entry histories, and comparisons of event data with empirical intensity prediction equations. A number of these functions were originally recommended by users.

SD10/TU/O2 **- COMPARATIVE ANALYSIS OF THE EFFECTS DESCRIBED IN WEB AND CLASSICAL EARTHQUAKE QUESTIONNAIRES**

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After using both classical and web questionnaires in Slovenia for a number of years, a testing was done in order to see whether there exit significant differences in the answers from each kind of questionnaires, and whether one group of observers would always give descriptions of larger effects in comparison to the other. The data for 61 earthquakes from the time period 2005-2009 were analyzed. Only the cases where the questionnaires of both types were available for the same locality were taken into the account. We expected that the questionnaires sent by e-mail (immediately after an earthquake) might describe the stronger effects than those described in the questionnaires sent by regular mail (at least 2-3 days after the event). The first analysis shows that, contrary to the expectations, there is no significant difference in the answers of

both groups. That means that both types of answers can be easily combined when estimating the intensity.

SD10/TU/O3 - DRAFT STANDARD INTERNET MACROSEISMIC QUESTIONNAIRE

M. Roger[1]
[1]*BGS*

For many years an international standard for macroseismic questionnaires has been a "long-felt want". In times past it was not a realisable goal because of cultural differences in the ways that questionnaires have been circulated. The rapid growth in use of the internet as a medium for collecting macroseismic information removes that obstacle, and a standard questionnaire form becomes practical. In order to try and achieve this, the ESC WG "Internet macroseismology" held an email discussion by means of a circulating discussion document. This document contained a section for each potential feature of a macroseismic questionnaire, for instance, asking about the position of the observer, asking about rattling windows, and so on. Over several iterations, members of the WG added their ideas to each section, paying attention to such things as whether the information was useful or only collected out of habit. Finally, the lead author attempted to synthesise the discussion in the form of an actual draft questionnaire, which is still open for comment. It can be viewed at the WG's website, http://seismologist.co.uk/ESC_internet_macroseismology.html.

SD10/TU/O4 - WEB-BASED MACROSEISMIC DATA COLLECTION AND ANALYSIS FOR THE CREATION OF REAL TIME INTENSITY MAPS IN ITALY.

V. de Rubeis[1], *C. Ferrari*[2], *P. Sbarra*[1], *P. Tosi*[1]
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A new method of macroseismic survey, based on voluntary collaboration through the Internet, has been running at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) since July 2007 and recently the method used to estimate the intensity has been revised. The macroseismic questionnaire is addressed to a single non-specialist; all reported effects from a town are statistically analysed to extrapolate the probabilistic estimate of intensity. The procedure has been applied to interpret felt effects according to the Mercalli Cancani Sieberg and European Macroseismic Scale, respectively, using the same criteria. The number of questionnaires analyzed for each town and the dispersion of the effects, allow the quantification of the associated error.

The use of web-based macroseismic survey grew up with the wide diffusion of Internet connections. It presents several positive features: almost real time results, low cost survey, fast evaluation of earthquake severity, positive feedback between seismic institutions and people. The web-based method provides more data compared to a direct survey, given by the analysis of a greater number of events of low magnitude. Medium-high magnitude events receive a bigger surface extent analysis, by the inclusion of peripheral areas affected by low intensity effects, usually disregarded by direct inspection for clear cost reasons. Maps of macroseismic intensity are displayed online in almost real time and are continuously updated when new data are made available. Assigned intensities from web questionnaires are compared with those derived from traditional macroseismic surveys (following investigations done by experts): agreement was found showing the reliability of our web-based method.

SD10/TU/O5 - B-FEARS – BELGIAN FELT EARTHQUAKE ALERT AND REPORT SYSTEM

T. Lecocq[1], *G. Rapagnani*[1], *H. Martin*[1], *F. Devos*[1], *M. Hendrickx*[1], *M. Van Camp*[1], *K. Vanneste*[1], *T. Camelbeeck*[1]
[1]*Royal Observatory of Belgium*

An automatic felt earthquake alert and report system, B-FEARS, was developed around the Belgian seismic network allowing seismologists to provide the authorities, the media and the public with information on local felt earthquakes a few minutes after their occurrence. Their magnitude is sometimes as small as ML 0.6. This system is based on the analysis of the connection flow on the website of the Royal Observatory of Belgium (ROB) in parallel to an automatic control of a web macroseismic inquiry based on the "Did you feel it?" of the U.S. Geological Survey (Wald et al., 1999), available on the ROB website since 2002. This information is neither as precise nor as reliable as the one supplied by the analysis of seismic signals, but is efficient thanks to the great population density in Belgium. For all events, a manual solution is provided; if the magnitude is large enough (ML>=1.4), source parameters are also automatically determined by SEISCOMP3, which has been fine tuned in close collaboration with GFZ-Gempa. Since April 2010, the B-FEARS alert system has been extended to Germany by collaboration between the Bensberg (University of Cologne) and Royal Observatory of Belgium networks. A common «Did You Feel It?» inquiry is now stored in the same shared database.

SD10/TU/O6 - MACROSEISMIC INTENSITIES AND TESTIMONIES ON MOBILE PHONE

C. Sira[1], *A. Schlupp*[2], *M. Schaming*[2]
[1]*Bureau central sismologique français, BCSF - UMS 830, CNRS et Université de Strasbourg (EOST);* [2]*Institut de Physique du Globe de Strasbourg, IPGS - UMR 7516, CNRS et Université de Strasbourg (EOST)*

The macroseismic intensities reflect the effects perceived by the persons or observed on objects and constructions due to an earthquake. Since 2000, BCSF tested the determination of intensities by selection of an image in the internet form (www.franceseisme.fr website) dedicated to the testimonies of the individuals. The difference between «pseudo intensities» extracted from the chosen images and those based on the analysis of the answers to the questions of the form are small in the range of intensities III to VI. The experience showed that testimonies arrive at the BCSF website within the first minutes which follow the perception of an earthquake and can thus be a source of fast information on the level of the effects generated by an earthquake and the ground motion. Since 2000, the BCSF website collected more than 40 000 private individuals' testimonies on the earthquakes felt on the French territory (13,000 for the only Rambervillers earthquake in 2003, ML=5,4). Following these experience and to increase the number of received testimonies, the BCSF developed an application called «SismoCom» allowing simplified testimonies by choice of an image on «Smartphone». So, in April 2010 the first application dedicated to the testimonies was launched on Apple / iPhone-iPod Touch / Ipad platforms (more than 3 million units in France) and on Androïd systems. The objective is an automatic and fast estimation of the intensities with a result accessible in real-time. This application is then a tool of fast acquisition of data for the seismologist and information for the users. At present in two languages (French/English), it can be used whatever the geographical zone. A translation of this application in other languages would allow to estimate the intensities in any countries and to share this real-time data between the various seismological observatories. The simplified questionnaire of the application is a sequence of 5 successive pages and may be performed within one minute, the witness being geographically localized using the phone GPS. This application allows the user to write comments, to send an illustrative photo and to fill a complete questionnaire at its national observatory through its web site. SismoCom allows retrieving the location of the recent earthquakes, the intensities deducted from the received testimonies, as well as the information about tsunamis and preventive information about the behaviours to be held in case of an earthquake. A demonstration will be realized and we will present the first results.

SD1 - SEISMIC CENTERS DATA ACQUISITION

Tuesday 7, 08h00-10h00

Tuesday 7, 10h20-12h00

Tuesday 7, 14h00-16h40

SD1/TU/O1 - LOCATION PERFORMANCE OF THE ALASKA REGIONAL SEISMIC NETWORK: AN EVALUATION BY THE SNES METHOD

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Seismic networks are powerful tools for understanding the state of seismo-tectonic processes taking place in a region. Their numerous applications, from monitoring seismicity to characterizing seismogenic volumes, make seismic networks essential tools for the seismic risk assessment. Appropriately structured seismic network may also be a valuable tool for the study of deep geological structures through seismic tomography. The ability to detect small and medium sized events requires a seismic network with sufficient number of low noise stations that are optimally distributed. It is, therefore,

important to assess existing capabilities of a seismic network, to identify seismic areas that are not adequately covered, and to further ascertain measures for the network improvement. Alaska is the most seismically active region of the United States. Seismicity is associated with the subduction of the Pacific plate beneath the North American plate, with the transform boundary in the southeast Alaska, and with numerous crustal faults throughout the State. Regional seismicity in Alaska is monitored by the Alaska Earthquake Information Center (AEIC) utilizing combined regional seismic network that comprises over 400 seismic sites. In this poster we will evaluate earthquake location performance of the Alaska regional seismic network though SNES (Seismic Networks Evaluation through Simulation) method. This method analyzes noise levels of existing stations, location errors, and velocity uncertainties and produces certain metrics that allow to asses capabilities of an existing network. In particular, through SNES we have identified high and low seismic noise areas of Alaska seismic network. Through statistical analysis of P and S residual times we have assessed validity of velocity models used by AEIC in their earthquake location routines and produced empirical formulas that link travel time residual time variance to the hypocentral distance. Finally, from analysis of produced SNES maps, we will identify regions in Alaska where it may be opportune to improve the existing seismic network.

SD1/TU/O2 - NEW DEVELOPMENTS IN EARTHQUAKE MONITORING IN SWITZERLAND

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[1]Swiss Seismological Service, ETH Zurich

The Swiss Seismological Service (SED) has an ongoing responsibility to improve the seismicity monitoring capability for Switzerland. This is a crucial issue for a country with a low background seismicity but where a large M6+ earthquake is expected in the next decades. With over 30 stations and station spacing of ~25km, the SED operate one of the densest broadband networks in the world, which is complimented by a similar number of realtime strong motion stations. In parallel to the existing in-house processing tools, SeisComp3, a state-of-the-art monitoring system, is currently being tested. We are evaluating the capability of the software to detect and identify small local (>Ml1) as well as large regional events. We are also preparing a new attenuation relation for local magnitude Ml from the broadband and strong motion data-set recorded in the last 10 years. We discuss our results in terms or location and magnitude accuracy, with particular attention to the specific improvements needed from monitoring systems for improved monitoring of small regions with high quality seismic networks.

SD1/TU/O3 - PYRENEAN NEAR REAL TIME SEISMIC WAVEFORMS SERVER

J. Jara[1], J. Artero[1], X. Goula[2], E. Carreño[3], P. Dominique[4], M. Sylvander[5]
[1]GEOCAT; [2]Institut Geològic de Catalunya (IGC); [3]Instituto Geográfico Nacional (IGN); [4]Bureau de Recherche Géologiques et Minières (BRGM); [5]Observatoire Midi Pyrénées (OMP)

In the scope of the SISPyr Interreg IVa project, seismic waveforms exchange between Datacenters is planned between partners, for different purposes, which can be grouped into three types: Real Time, Near Real Time and Post Processing. Regarding Near Real Time (NRT) purposes, a specific centralized NRT Server system will be implemented.

NRT Server will receive continuous seismic waveforms streams from datacenters via Internet and data will be stored according configurable parameters during a defined time window (24 hours by default). NRT Server will support input streams from Seedlink, NaqsServer and Scream data acquisition servers.

Data will be available on demand for all partners through Internet using a specific defined protocol and format.

Clients' requests received by NRT Server will specify desired time window and different type of filters for channel selection should be defined. Available filters will be: an SCNL specified channels list using wildcards or not, a geographical area defined by a rectangle or a maximum distance from a coordinate. System will include a documented client API (Application Programming Interface) module and a sample client module to facilitate specific clients' development.

NRT Server will be developed for Windows in Visual C++ using Earthworm (USGS) tools and Oracle technologies. For system administration and monitoring, web based tools will developed and implemented using PHP and Apache2 Web Server.

System will be implemented considering different operational criteria: data reliability, service availability, data latency, data access concurrency, efficiency and communication bandwidth optimization.

Motivation of NRT Server is to allow exchanging seismic waveforms between datacenters reducing communication and maintenance costs and to provide an homogeneous seismic dataset to bring results from different organizations closer. This kind of data exchange will be useful for many data computation processes like Moment Tensor (MT) and ShakeMap calculations, where lots of data are needed in case of event. System will not support continuous output streaming for continuous data processing.

For the project, more than 50 accelerometric and Broad Band stations are planed to be received and available at the server and a client will be developed to provide data for NRT Pyrenean ShakeMap calculation. NRT Server is planned to be operational ending 2010.

SD1/TU/O4 - COMPARISON OF AUTOMATIC DETECTION AND LOCATION CAPACITIES OF EARTHWORM AND SEICOMP3 AT SEVERAL SCALES (LOCAL, NATIONAL AND GLOBAL)

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The French national short period network (RéNaSS) is in charge of the French metropolitan seismicity monitoring. The RENASS alert system and seismicity monitoring is currently being restructured. Within this framework and as the amount of real-time seismic data flows increases, we need to upgrade our old home-made automatic data processing system. We are currently testing both Earthworm and Seiscomp3 at several scales (local, regional and global), using stations from 3 different networks: a local geothermal research network (Soultz-sous-Forêt, France), a national network (real-time stations from the French short period network (RéNaSS) and the French broadband network (RLBP)), and a French global broadband network (Géoscope). The tests are performed using 75 real-time streams including data from short period sensors (1 or 3 components) and broadband sensors (3 components). We compare the automatic detection and location capacities of Earthworm and Seiscomp3, respectively including sub-network definition or grid definition with variable meshing. In Seiscomp3, we define a grid with a variable meshing associated with various parameters (STA/LTA, filters, pick association distances, ...) to integrate the 3 spatial scales (local, national and global). We also test a meshing mapped to the known French metropolitan seismicity. We succeed to detect and locate local events down to magnitude 1.

SD1/TU/O5 - THE REGIONAL SEISMIC NETWORK OF NORTH-WESTERN ITALY: THE CURRENT STATION DISTRIBUTION AND THE ACTUAL SEISMIC DATA ACQUISITION, PROCESSING AND DISSEMINATION SYSTEMS

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[1]Dip.Te.Ris., University of Genoa

Since 2007, the Regional Seismic network of North-western Italy (RSNI network, www.dipteris.unige.it/geofisica) has been significantly renewed and improved in terms of both seismic instruments, real time transmission links, data acquisition systems, automatic processing procedures and strategies for dissemination and data exchange. In the last year, in the framework of the RISE project (Réseaux Intégrés de Surveillance Sismologiques et d'Echange, Projet n° 045, Cooperation Territoriale Italie-France 2007-13) the seismic monitoring capabilities of the network in Piedmont and Valle d'Aosta regions have been strongly improved through the installation of three new stations and through the real time data exchange with the French partners of the RISE project (LGIT- Université Joseph Fourier de Grenoble, CNRS Géosciences Azur). For the time being, the RSNI network manages 29 3-component seismic stations equipped with broadband (Nanometrics Trillium 40') and very broadband (Nanometrics Trillium 240') velocimetric sensors and high dynamic digitizers (> 120 dB). Moreover, the data processing centre, located at the laboratory of seismology of the Genoa University, acquires real time data coming from both RSNI stations and from other Italian (INGV, Istituto Nazionale di Geofisica e Vulcanologia) and European (ReNaSS, Réseau National de Surveillance Sismique – France, and ETH, Swiss Federal Institute of Technology, Switzerland) networks monitoring the South Western

Alps. The State of Health of each RSNI station is continuously monitored by checking the data requested to the data-loggers in terms of GPS coverage, power supply status and data transmission quality. The data acquisition system is based on the Nanometrics interNaqs software for acquiring real time data, transmitted through satellite or cabled UTP controlled links, and for managing the event detection, as based on a STA/LTA analysis for each station and on a coincident system defining the number of data channels which must be triggering coincidentally. The data, archived as continuous waveforms into one-month long ringbuffer and cut as 240s-long time window SAC signals containing a possible seismic event, are automatically processed by RSNI home-made software able to provide P- and S-phase picks, location, local magnitude and shake maps by 5 minutes from the origin time of an earthquake. The automatically derived parameters are archived into a Postgresql database and made available through the RSNI Web site. Finally, a standard Seedlink server (Seiscomp 2.6) is used for exchanging real time data with other European data acquisition centers (such as Orfeus and ReNaSS).

SD1/TU/O6 - THE ARMUTLU NETWORK (ARNET)

B. TUNC[1], H. WOITH[2], D. CAKA[1], S. TUNC[1], T. IRMAK[1], S. BARIS[1], M. OZER[1], B. LUHR[2], E. GUNTHER[2], H. GROSSER[2]
[1]Kocaeli University - TURKEY; [2]Deutsches GeoForschungsZentrum GFZ - GERMANY

Yalova-Armutlu-Gemlik region is located on the Marmara Region and western-southwestern part of the 1999 Kocaeli rupture. This region is characterized by strong deformations and located between two main strands of the North Anatolian Fault system. The Armutlu Peninsula is believed to be adjacent to the Intra-Pontid Suture Zone or is even a part of it. This zone and region has a key role to understand neo-tectonic feature of the region and the interaction between high seismicity with high thermal activity and neo-tectonic faults originated by ongoing movement of the two branches of north and south of Armutlu. A horst and graben structure appears in this region whereby the Armutlu Peninsula represents a horst between two branches of the North Anatolian Fault System, resulting in a complex dextral zone. The study region represents rather high micro-earthquake activity, recently. To understand the relationship among the micro-earthquake activity, hydrothermal activity and tectonic structure of the region, ARNET (Armutlu Network) was installed in September 2005 by Kocaeli University Earth and Space Science Research Center (ESSRC-YUBAM). ARNET has been operated in co-operation between ESSRC and GFZ Potsdam (Germany) to monitor the chronological evolution of seismicity, and to investigate the deformation of the Armutlu Peninsula, as well as possible interactions between seismic waves and pore-pressure variations in geothermal systems.We have 25 seismic stations and 5 hydrothermal stations in and around study area at present. The network composed weak motion sesimometers and accelerometers. The Scream software is used for data acqusition and zSacWin software is used for data processing. We also installed SeisComP3 software for data acquisition and automatic location procedure at September 2009. This system is now is in the testing phase and running parallely with other systems. A borehole seismometer was installed at depth of 98m in 2008. Lennartz Le-3Dlite borehole seismometer is used battom of the well. Two types of instruments are installed at this station. One is short period seismometer (Lennartz Borehole) and the other one is acceleration on surface of the well (CMG5T Acc). We are also monitoring hydrotermal activity, pressure changes of the hot-spring and natural water wells combined with leveling, temperature and chemical content in this region to reveal the relation between micro-earthquake activity with hydrotermal reservoirs. The pressure sensor is located on the surface of the 500m depth well.ADSL data transmission system is installed at 13 seismic stations. Currently, we are in the process of installing online communication system to the remaining seismic stations in our network. For all online stations, we can control the digitizer, data communication modul and ADSL modem by power-cycle over phone line using DTMF (Dual Tone Multi-Frequency) controller.

SD1/TU/O7 - DEVELOPING SEISMIC MONITORING SYSTEMS WITH ANTELOPE AND EARTHWORM: PERSPECTIVES FROM ALASKA AND MONTSERRAT

G. Thompson[1], M. West[1]
[1]University of Alaska Fairbanks / Alaska Volcano Observatory

The University of Alaska Fairbanks office of the Alaska Volcano Observatory (AVO-F) is co-located with the Alaska Earthquake Information Center (AEIC), which is committed to Antelope and is the clearing house for all seismic data in Alaska, and the USGS office in Anchorage (AVO-A) which is committed to Earthworm. The latter enables all USGS volcano observatories to work towards a common software platform to aid data sharing and response, as recommended by the NVEWS proposal. For many years this led to heated discussions over which platform (Antelope or Earthworm) is best. Here we examine the technical merits of each system for our purposes, drawing from the author's experience with Earthworm and Antelope systems in Alaska and Montserrat, with a bias towards software development. The main advantages of the Antelope system for our purposes are: (i) it is built from the ground-up around a relational database incorporating event, waveform and station metadata, (ii) BRTT supported orb and database interfaces exist in C, Perl, PhP, Tcl and are thoroughly documented, (iii) Community supported Matlab and Python orb and database interfaces also exist. These translate to an ability to develop a wider range of applications, and do so more rapidly. The advantages of Earthworm for volcano-monitoring purposes are its free cost, wider user-base (which may ultimately translate to more contributed software), and it's integrate with Winston, SWARM and VALVE. Examples of software products we have developed including alarm systems and web-based monitoring systems will be described. A significant recent development is the ANSS Quake Monitoring System (AQMS), which is based on Earthworm but appears to add-on a relational database similar to Antelope, and Jiggle for event processing. This may make it possible to develop some products that were previously only possible within the Antelope framework, within the Earthworm framework. The way forward for AVO-F will likely to be to run Antelope and AQMS in parallel, so that we can collaborate effectively with AEIC and AVO-A partners, and to develop products that are cross-framework. A major advantage of this approach will be the ability to take advantage of any new monitoring products that become available in either framework.

SD1/TU/O8 - EARTHQUAKE PROCESSING SYSTEMS AT THE ALASKA EARTHQUAKE INFORMATION CENTER

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The Alaska Earthquake Information Center (AEIC) has the responsibility to record, locate, catalog, and alert Government and the public about the occurrence of earthquakes occurring within the State of Alaska. Currently, we catalog about 25,000 events per year in and around the State of Alaska, utilizing a network of over 550 seismic stations.

In order to handle this many stations recording such a large number of events, we have had to choose operating procedures that are both efficient and robust to be able to function with our staff of 12 people. After much evaluation of competing systems, we chose Antelope as the architecture that would allow us to best grow our capabilities in the proper directions.

In this presentation we will illustrate many of our unique implementations of the Antelope tools. In addition to simply cataloging the many events in Alaska, we are responsible for rapid notification, ShakeMaps, several local regional and teleseismic magnitudes (including regional moment tensors), early warning of critical structures such as the Trans-Alaska Oil Pipeline, and assistance with tsunami mitigation and warnings.

SD1/TU/O9 - DATA ACQUISITION, ANALYSIS, ARCHIVING AND DISTRIBUTION AT INGV NATIONAL EARTHQUAKE CENTER

S. Mazza[1], A. Bono[1], V. Lauciani[1], C. Marcocci[1], A. Mandiello[1], F. Mele[1], S. Pintore[1], M. Quintiliani[1], L. Scognamiglio[1], G. Selvaggi[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia

In the last two years INGV Earthquake National Center (CNT) has designed and implemented a new system for seismic data acquisition, analysis, archiving and distribution. Many requirements were to be fullfilled contemporarily during this renovation: while the old home-developed system was to be maintained, we had to realize a new one, more robust and versatile. We upgraded our network from 80-90 analog vertical short period stations to about 250 broad band ones, not including the stations we receive from abroad or partner institutions. It was necessary to overcome the limitations of the old concept, with a system capable to cope with the Italian diverse seismicity and to adapt to a very inhomogeneous network. We had to reach the detection level already previously afforded was to be reached on one

hand, and the capability to face a strong earthquake sequence on the other. Data distribution according to present standards was also mandatory, to make data available to research. To achive so many goals at the same time, we have decided for different tools and software packages, depending on how well they suited the single tasks and the overall mission. Our acquisition and archiving system is based on seedlink protocol, even if half of the network is collected via NAQS, while to arclink is in charge of offline distribution. INGV-CNT is following the approach of a distributed data archive, participating to the European Integrated Data Archive (EIDA), as proposed and realized in the European Project NERIES. As partners of EIDA we give access to the European Archive through our web pages at http://eida.rm.ingv.it, where data from a huge number of global, regional, national and local broad band stations are available. Automatic locations and real time analysis are mostly entrusted to Earthworm, where manual revisions and bulletin are done through existing home-developed tools. During L'Aquila seismic sequence, the system has overcome the test successfully, sometimes exceeding the expectations. Event data are published on ISIDe web pages (http://iside.rm.ingv.it), with station information and quality control. Quality control is performed in different ways, from power spectral densitities to probability density functions, as well as monitoring basic quantities such as latency, delay, time quality, offset, rms, gaps, overlaps, availability, spikes. Automatic data retrieval is active on archived data to remove gaps caused by link failures or by satellite transmission problems. A data-base has been developed to exhaustively monitor both real time location procedures and data archiving.

SD1/TU/O10 - THE GERMAN NATIONAL DATA CENTRE AT THE BGR

K. Stammler[1]
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The Federal Institute for Geosciences and Natural Resources (BGR) is the national data centre for seismological broadband data as well as for seismic and infrasound data recorded in the frame of the Comprehensive Test Ban Treaty (CTBT). The data centre receives continuous data from about 100 single stations with a total size of currently 4 GBytes/day. The archiving format is MiniSEED, data transmission is done via seedlink, for stations of the CTBT network also the CD1 protocol is used. The hardware at the stations is not homogeneous, so are currently seven different digitizers are in operation. The software for archiving, status monitoring and automatic event analysis is home grown, however, a version of Seiscomp3 is installed in parallel. The Seiscomp3 installation at the BGR aims mainly on automatic event analyses, the optimisation of the configuration for detection and analysis is currently ongoing. The available interfaces for waveform data exchange are AutoDRM, seedlink, WebDC and a home-made website.

SD1/TU/O11 - ORFEUS DATA CENTER - NETWORKING SEISMOLOGICAL NETWORKS AND DATA SERVICES

R. Sleeman[1], *G. van den Hazel*[1], *T. van Eck*[1]
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Regional and global data centers are facing new challenges towards the continuous and rapid increase in the amount of data to be handled. The growth in number of seismic stations producing continuous data and the growing interest in using higher sampling rate data streams in research put higher demands on the operations and services of such data centers, like the ORFEUS Data Center (ODC).

Data acquisition at the ODC is done most efficiently in real-time between networks and the ODC, and requires automatic processing software to monitor and preserve the highest quality of the continuous waveform data. On the other hand, the key role of the ODC focusses also towards building a complete and secured archive, both for waveform data and its metadata.

The core of the operations at the ODC is build around Antelope (R) to support real-time acquisition and processing of waveform data from the Virtual European Broadband Seismic Network (VEBSN). Within the present operations the challenges for the future are related towards improving data completeness of the archive, as well as maintaining and updating metadata between networks, regional and global data centers.

Several new services, based on ArcLink and webservices, which are in place at the ODC to provide easy access to the data will benefit from this work.

In this presentation we will discuss these different issues from an ODC point of view.

SD1/TU/O12 - SEISCOMP 3 - WHERE ARE WE NOW?

J. Saul[1], *W. Hanka*[1], *A. Heinloo*[1], *J. Becker*[2], *B. Weber*[2]
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The seismological software SeisComP has evolved within the last approximately 10 years from a pure acquisition modules to a fully featured real-time earthquake monitoring software. The now very popular SeedLink protocol for seismic data transmission has been the core of SeisComP from the very beginning. Later additions included simple, purely automatic event detection, location and magnitude determination capabilities.

Especially within the development of the 3rd-generation SeisComP, also known as «SeisComP 3», automatic processing capabilities have been augmented by graphical user interfaces for vizualization, rapid event review and quality control. Communication between the modules is achieved using a a TCP/IP infrastructure that allows distributed computing and remote review. For seismological metadata exchange export/import to/from QuakeML is avalable, which also provides a convenient interface with 3rd-party software.

SeisComP is the primary seismological processing software at the GFZ Potsdam. It has also been in use for years in numerous seismic networks in Europe and, more recently, has been adopted as primary monitoring software by several tsunami warning centers around the Indian Ocean.

In our presentation we describe the current status of development as well as future plans. We illustrate its possibilities by discussing different use cases for global and regional real-time earthquake monitoring and tsunami warning.

SD1/TU/O13 - A REORGANIZATION OF EARTHQUAKE POST-PROCESSING SYSTEMS AT REGIONAL SEISMIC NETWORKS IN THE UNITED STATES USING AQMS

P. Friberg[1], *S. Developers*[2]
[1]*ISTI;* [2]*CISN Development Team (which is too large to possibly list in an abstract)*

For many years Regional Seismic Networks (RSNs) within the United States have used Earthworm for real time earthquake monitoring, but each have built home-grown solutions for alarming and post-processing. Post-processing in this presentation is defined as the repicking and relocation of events towards building a definitive earthquake catalog and ancillary products (e.g., ShakeMaps,

Focal Mechanisms, Moment Tensors etc.). In order to concentrate efforts on a single system, the United States Geological Survey's management team of the Advanced National Seismic System (ANSS) chose to focus on an Open Source database-centric solution that originated in California and already leveraged Earthworm.

The ANSS Quake Monitoring System (AQMS) is the new defacto standard for real-time and post-processing software at the RSNs within the United States. Originating from the California Integrated Seismic Network (CISN), and wrapping Earthworm, the AQMS solution provides a complete Earthquake Monitoring solution centered on an Oracle Database. The rollout of AQMS in 2009-2010 has propagated the same solution to all of the RSNs and the results are already reaping feedback and new development that all users can take advantage of. This talk will present a synopsis of the AQMS system and the rollout by ISTI.

SD1/TU/O14 - DATA ACQUISITION, DATA INTEGRATION AND OPERATIONS USING ANTELOPE: NSF EARTHSCOPE USARRAY TRANSPORTABLE ARRAY, GSN PROCESSING TEMPLATE, ANZA SEISMIC NETWORK AND TEMPORARY DEPLOYMENTS

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The seismic data center at IGPP-UCSD is responsible for multiple seismic networks from a small regional network to one of the largest real-time networks in the world. The USArray Transportable Array (TA) is comprised of 400 deployed stations in a rolling layout across the 48 contiguous United States. We maintain the data feeds, both import and export, for the GSN processing template used by BRTT's Antelope software package. Also under our command and control is the 15 station Anza network which is supplemented by surrounding regional networks and tempora-

ry deployments. BRTT's Antelope software, is used for the delivery of all TA and Anza data (seismic, state of health and metadata) to the IRIS Data Management Center (DMC). In addition, our data center (the Array Network Facility (ANF) for the TA project) provides station command and control, verification and distribution of metadata, with remotely accessible world wide web interfaces for Array Operations Facility (AOF) personnel to access network and station state of health information; and quality control for all seismic data. Web applications use contributed Antelope software libraries and other public domain software. Supplemental tables to the CSS3.0 schema have been developed along with corresponding programs (available via the contrib repository) to extend the products and information available to end users and to track operations for the data center. To date, 875+ TA stations have been deployed with Quanterra Q330 dataloggers and Streckeisen STS-2, Guralp CMG3T, or Nanometrics Trillium 240 broadband sensors. Data for the GSN processing template is collected using orb2orb, liss2orb, slink2orb and isi2orb. Anza stations use a variety of dataloggers: K2s, Q330s, Q4120s and RT72A-08s. Additional data streams from regional networks have been integrated using orb2orb connections or slink2orb. Data return rates for the TA average above 98% (99% for Anza) through the Antelope Real Time System. Since the initiation of the TA in 2004, analysts using the dbloc2 program have reviewed over 2.75 million automatically generated arrivals for >45,000 local, regional, and teleseismic events.

SD1/TU/O15 - SEISMIC NETWORK PROCESSING WITH ANTELOPE

D. Harvey[1]
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We present how the Antelope environmental processing software has been defined, developed and utilized in the context of three of the most important characteristics of any seismic network processing system; function, performance and flexibility.

Function is usually the first characteristic that comes to mind when considering seismic network processing software. Function has evolved over time from early punch card driven programs to locate earthquakes to what we have today; a full range of interoperating software functions that support all aspects of seismic network operations. Antelope was developed to address all of the needs of a modern seismic network, including comprehensive network management (data acquisition, SOH monitoring, equipment command and control), traditional processing for earthquake locations and magnitudes (arrival detection, event association, event location, magnitude estimation), integration of external data and processing results (waveforms, association with external seismic event bulletins and catalogs), complete database-oriented archiving of waveforms and processing results, export of waveforms and professing results and the ability to extend the functionality. All of this also was implemented by Antelope to support both real-time automated processing and off-line interactive manual processing.

Performance has become increasingly important as seismic networks become larger, seismic network missions become more difficult, such as early warning and rapid assessment requirements, and seismic network funding remains static or even decreases. Antelope was developed to leverage the advancements in computational hardware and software technologies to produce a high performance processing system that could meet the requirements of large networks using relatively inexpensive hardware. Antelope was also developed to provide a highly automated environment in which a small staff could effectively manage large networks. An example of this is IRIS' USArray TA facility.

Flexibility has not traditionally taken an important role in seismic network processing systems. However, because of its roots as a system to support research networks, Antelope was developed from the beginning to be as flexible as possible. Flexibility brings many advantages to any seismic network processing system. Local size networks to regional size networks to global networks can use the same processing tools. A processing system that is highly flexible must be designed with clearly documented and generalized middleware stacks, as is Antelope. These software stacks cannot be tied exclusively to a particular format or protocol, which opens application opportunities. Flexibility implies extensibility which implies a highly modular system with clearly defined paths for developing major new functionality, an original design requirement for Antelope. We will show how the flexibility offered by Antelope has been used to evolve a wide range of new functions, from sophisticated web portals to new cutting edge research capabilities.

SD9 - TRANSPORTABLE BROADBAND ARRAYS IN SOUTHWEST EUROPE: TOWARDS A HOMOGENEOUS COVERAGE OF THE EUROPEAN CONTINENT

Tuesday 7, 14h00-16h40

SD9/TU/O1 - THE IBERARRAY NETWORK: A TOOL TO INVESTIGATE THE LITHOSPHERIC STRUCTURE OF THE IBERIAN PLATE

J. Gallart[1], *R. Carbonell*[1], *A. Villaseñor*[1], *J. Díaz*[1], *M. Harnafi*[2], *F. Mancilla*[3], *D. Córdoba*[4], *A. Pazos*[5], *J. Pulgar*[6], *P. Ibarra*[7]
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IberArray is the observational platform of the TOPO-IBERIA project (a five-year initiative funded by the Spanish Ministry of Education and Science that gathers approximately 125 researchers from 10 different Spanish research centers). IberArray network consists of 3 types of instruments: seismic (broad-band seismometers), geodetic (GPS), and magnetotelluric. The seismic network is composed of 40 new portable broad-band stations that operate together with other existing permanent and portable broad-band stations in the region, forming an approximately regular network on a 60 km x 60 km grid that will cover the entire Iberian Peninsula and northern Morocco in three successive deployments, from south to north. In mid-2009, the first (southern) deployment in Spain was completed and instruments were moved to the second deployment in central Spain. We will present the current status and future deployment of the network, its relationship with similar deployments in Morocco, Portugal and France, and the principal results obtained so far. The first study conducted using data from the IberArray seismic network, consisted in analyzing the noise characteristics of the stations. We analyzed the major sources of noise at different frequency bands and their variations related to time of day, season, weather, location and type of installation, using power spectral density (PSD) estimates and their corresponding probability density functions (PDFs). In addition we will present results of the different studies currently underway to investigate the lithospheric structure of the Betics-Rif orogenic system. These include crustal imaging from ambient noise and travel-time tomography, variations in crustal thickness from receiver functions, and mantle anisotropy from SKS splitting analyses.

SD9/TU/O2 - THE SIMBAAD EXPERIMENT IN THE AEGEA-ANATOLIA REGION: PRESENTATION AND FIRST RESULTS ON MANTLE ANISOTROPY

A. Paul[1], *H. Karabulut*[2], *D. Hatzfeld*[1], *P. Hatzidimitriou*[3]
[1]*LGIT, CNRS & Université Joseph Fourier Grenoble, France;* [2]*KOERI, Bogazici University, Istanbul, Turkey;* [3]*Geophysical Laboratory, Aristotle University of Thessaloniki, Greece*

The Simbaad (Seismic Imaging of the Mantle in the Aegean-Anatolian Domain) temporary network of 34 broadband stations was installed in Western Turkey, Greece and Southern Bulgaria from April 2007 to May 2009. It was designed to fill-in the gaps between permanent broadband stations in the area [35-42°N; 20-34°E], reducing the average interstation spacing to ~60 km in continental areas and ~80 km in the Aegean. The objective is to provide a higher-resolution image of the crustal and upper-mantle structures in a tectonically very active region, which has experienced a variety of geodynamic processes in geological history. As surface data are numerous, including constraints from structural geology and geodesy, this region is a good place to test competing hypotheses on how the surface kinematics is related to mantle structure and dynamics. To better constrain the poorly-known structure of the crust in Western Anatolia, we also installed 2 north-south transects of 23 stations each (with intermediate-period sensors, 60s) and an average spacing of 15-20 km at 28°E and 31.5°E. All data from the temporary (60 sites) and permanent (~120 sites) stations have been assembled in a common database for the time period of the experiment. The data is now being analyzed using different methods including crustal tomography from ambient noise correlations, surface-wave tomography of the upper mantle, and receiver functions

for crustal structure in W-Anatolia. This talk will focus on the azimuthal anisotropy of S wave velocity in the upper mantle using SKS splitting, which has never been mapped in the broad Aegea-Anatolia region at such a dense spatial resolution. When they are gathered with results published for Central and Eastern Anatolia, our data display a very coherent trend with anticlockwise rotation of the fast wave polarization from N42 in Central Anatolia (35°E) to N0 in W-Aegean and N210 in continental Greece (22°E). The lag times vary between 0.5 s and more than 2 s. The strongest values are measured at stations close to the North Anatolian fault. The fan-shaped pattern of fast axis orientations suggests that the measured anisotropy is an image of the mantle flow induced by the fast retreat of the Hellenic subduction. Simbaad Team: T. Afacan [2], M. Aktar [2], E. Bourova-Flin [1], L. Dimitrova [4], F. Hubans [1], D. Kementzetzidou [3], E. Karagianni [3], I. Karagianni [3], A. Komec Mutlu [2], Y. Ozakin [2], C. Papazachos [3], C. Péquegnat [1], M. Scordilis [3], S. Roussel [1], G. Salaün [1], D. Samut [2], D. Vamvakaris [3]

SD9/TU/O3 **– THE SEISMICITY IN THE GULF OF CADIZ: A COMPARISON BETWEEN THE LOCATIONS PROVIDED BY THE LAND NETWORK AND THE NEAREST OBS PASSIVE SEISMIC EXPERIMENT**

L. Matias[1], S. Silva[2], M. Romsdorf[3], W. Geissler[4], F. Carrilho[5], W. NEAREST-Working-Group[6]
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The Gulf of Cadiz offshore SW Iberia is an area that is prone to the generation of destructive earthquakes and tsunamis, like the famous 1st November 1755 Lisbon event. Besides these rare events, the more frequent tsunamis triggered by smaller magnitude earthquakes can affect the harbour operations and may cause panic among the population if they are felt along the coast. The first message and actions taken by any Tsunami Warning System rely exclusively on the fast determination of earthquake parameters computed from the real-time seismic network. However, this information can be in considerable error if, like in the Gulf of Cadiz area, the seismic stations are far from the source area and do not surround it optimally. In order to investigate the relationship between active faults and seismicity in the Gulf of Cadiz the EC project NEAREST (Integrated observation from NEAR shore sourcES of Tsunamis: towards an early warning system) conducted a passive seismic experiment in the Gulf of Cadiz where 24 BB seismometers (plus the GEOSTAR multi-parameter deep-sea observatory) were deployed for 11 months, between the summer 2007 and summer 2008. This dataset provides the ideal control for the operation of the land network at the Meteorological Institute (IM), nominated as the Portuguese Focal Point for the NEAMTWS Tsunami Warning System of Systems.Since near half of the OBS didn't synchronize the clock after recovery, we applied two different methodologies to recover the instrument time with a precision of the order of 0.1 s. We restricted the comparison of focal parameters to the events that were located inside the network where an average 1-D velocity model can be derived from known geophysical information in the area. The variation of sediment thickness and small departures from 1-D structure are accounted by one constant station correction.Comparing the land-based locations and the ones derived from the OBS network we observe that magnitudes match quite well (4.5 was the maximum magnitude recorded during the recording period). However we observed that the focal depths computed from the NEAREST network are much deeper than the one computed by IM. We also see that land located events are systematically pulled to land. Without waveform inversion it seems that the hypocenter depth will have a large uncertainty for the locations that use only land based information.

SD9/TU/O4 **– TRANSBORDER IMAGING OF DEAD SEA FAULT SEISMICITY BY PORTABLE SPARSE ARRAY CLUSTERING IN THE JERICHO – DEAD SEA BASIN**

H. Wust-Bloch[1], A. Inbal[2], A. Ziv[2], J. Al-Dabbeek[3], A. Al-Zoubi[4], Z. Ben-Avraham[1]
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Earthquakes generated by the active Dead Sea Fault (DSF) pose a transborder hazard that threatens indiscriminately Israelis, Palestinians and Jordanians. This situation is exacerbated in the the Jericho – Dead Sea basin (JDSB), where the unevaluated seismic potential of a complex pull-apart structure, hinders sustainable development and foreign investments. The subsurface structure of the JDSB is poorly constrained and thus subject of conflicting tectonic interpretations (Lazar et al., 2006; Shamir et al., 2006). Seismicity analysis and focal plane solutions for the JDSB (Hofstetter et al., 2007 and 2008) exposes fault segments with a high variability of strikes and styles. Starting in 2008, a cluster of up to six independent portable sparse arrays were deployed on Israeli, Palestinian and Jordanian soil to characterize JDSB seismicity and illuminate active fault geometry. Significantly lowering event detection threshold, enabled to achieve catalog completeness down to ML 0.5 for a target source volume of 15 km in radius (Wust-Bloch et al., 2008). The analysis of an aftershock sequence generated by an Mb 4.3 earthquake shows event decay that follows Omori law, with a p-value equal to 1. This sequence, which lasted 25 days before reaching background seismicity rate, indicates that the very weak ($-1.0 < M < 4.3$) seismicity generated within the JDSB presents identical characteristics to those displayed by stronger seismicity. Hypocentral determination is achieved by a two stages scheme whereby the results of a crude epicentral location are used as input parameter for an iterative determination of 1-D velocity model, event hypocenter and origin time (Inbal et al., 2009). High-resolution relocation of over 150 events occurring within 12 months outlines a series of compact, shallow (<4 km) N-S trending and sub-vertical event clusters located near population centers, vital lifelines and touristic infrastructure.

ES8 - NEW APPROACHES TO EARTHQUAKE PREDICTABILITY AND TIME-DEPENDENT SEISMIC HAZARD AND RISK ASSESSMENT AT LOCAL AND REGIONAL SCALES

Tuesday 7, 08h00-10h00

Tuesday 7, 10h20-12h00

ES8/TU/O1 **– THE COLLABORATORY FOR THE STUDY OF EARTHQUAKE PREDICTABILITY: PERSPECTIVES ON EVALUATION AND TESTING FOR SEISMIC HAZARD**

D. Schorlemmer[1], D. Jackson[2], T. Jordan[1]
[1]University of Southern California; [2]University of California Los Angeles

The Collaboratory for the Study of Earthquake Predictability (CSEP) established 4 earthquake forecast testing centers around the world. These centers are rigorously testing more than 100 earthquake forecast models in a truly prospective manner. Centers are operating in Los Angeles (US), Wellington (NZ), Tokyo (JP), and Zurich (CH), covering many different regions and tectonic environments: California, New Zealand, Western Pacific, Japan, and Italy. In addition to regional earthquake forecast testing, CSEP has started a global testing program which is targeting the magnitude range of destructive earthquakes that are relevant for seismic hazard and risk. This program is the first link in the chain of facilities that aim to test seismic hazard and risk models and their underlying hypotheses. To complement the current activities, CSEP is developing methods for assessing the reliability of earthquake early warning algorithms, for understanding the uncertainties and limits of earthquake source inversions, and for the prospective testing of ground motion prediction models. CSEP researchers are also working on creating testable models for many seismological hypotheses, e.g. characteristic earthquakes, maximum magnitude to fault length relation. CSEP is collaborating with large modeling efforts like the Uniform California Earthquake Rupture Forecast (UCERF3) and the Global Earthquake Model (GEM). We present the ongoing activities and give perspectives for the future development of CSEP and its global collaboration.

ES8/TU/O2 **– BUILDING SHORT-TERM EARTHQUAKE PROBABILITY MODELS: RETROSPECTIVE AND PROSPECTIVE EVALUATION OF MULTIPLE STRATEGIES**

J. Woessner[1], J. Zechar[1], M. Werner[1], S. Wiemer[1]
[1]Swiss Seismological Service, ETH Zurich

Short-term earthquake forecasting on the time-scale of hours to days remains an unresolved challenge in seismology. In the framework for the Collaboratory Study of Earthquake Predictability (CSEP) a 24h testing class for the region of the Italian National Seismic Network was launched in 2009. The EU-Testing center at ETH Zurich is cur-

rently evaluating the prospective predictive power of the submitted models. We submitted two self-consistent implementations of the Short-Term Earthquake Probability (STEP) model that produce daily seismicity forecasts; both implementations combine a time-varying and a time-invariant contribution for which we assume that the instrumental Italian earthquake catalog provides the best information. For the time-invariant contribution, we created a smoothed seismicity model from a declustered catalog. The time-varying contribution is the difference between the two implementations: 1) for one implementation (STEP-LG), the original model parameterization and estimation is used; 2) for the other (STEP-NG), we estimate aftershock productivity from the mean abundance model. In the latter implementation, earthquakes with magnitude up to M_L=6.2 are expected to trigger fewer events than in the first implementation, whereas larger earthquakes are expected to be more productive. We retrospectively tested the performance of the two implementations for the period January 2007 through July 2009 and applied likelihood tests to evaluate the consistency with observed earthquakes. We find that both implementations are consistent with observed earthquake data in space and that STEP-NG performs better in terms of forecasted rates than STEP-LG. In this presentation, we will evaluate true prospective forecasts from the first months of the CSEP-Italy experiment and report whether the results of the retrospective tests are consistent with the prospective test results for the STEP-models. In addition, we discuss results of all models submitted to the CSEP-EU testing center – including those of other researchers - based on their likelihood scores. In light of these results, we will discuss strategies for communicating these results to the scientific community, decision-makers, and the public.

ES8/TU/O3 - ARE SHORT-TERM EVACUATIONS WARRANTED? THE CASE OF THE 2009 L'AQUILA EARTHQUAKE

T. van Stiphout[1], S. Wiemer[1], W. Marzocchi[2]
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The disastrous earthquake in L'Aquila Italy about one year ago (M_w6.3, 6 April 2009) highlights again the issue of potentially reducing seismic risk by releasing warnings or initiating mitigation actions. Since earthquakes cluster strongly in space and time, periods of increased seismic hazard are known. During such seismic crises, seismologists typically convey their knowledge of earthquake clustering based on past experience, basic statistics and 'gut feeling'. However, this information is often not quantitative nor reproducible and difficult for decision-makers to digest. We introduce an interdisciplinary approach that combines probabilistic seismic hazard and risk assessment with cost-benefit analysis to allow objective risk-based decision-making. We analyze the effect of uncertainties in different components of this approach. Among various examples, we also consider the 2009 L'Aquila earthquake sequence. The analysis indicates that widespread evacuation was not warranted in the L'Aquila case, supporting the decisions made by authorities in the days and hours leading up to the mainshock. These results demonstrate that the current approach to mitigation actions should be rethought, because it will hardly ever be cost-effective. Instead, future mitigation actions must be based on the weakest buildings and the ones on the poorest soil, just as flooding evacuations are targeted to flood-prone areas only.

ES8/TU/O4 - A STRATEGY OF REAL-TIME SEISMICITY EVALUATION FOR OPERATIONAL EARTHQUAKE FORECASTING: RETROSPECTIVE APPLICATION ON THE 6 APRIL 2009 EARTHQUAKE (MW=6.3) IN L'AQUILA, ITALY

G. Papadopoulos[1], G. Minadakis[1], M. Charalampakis[1], A. Fokaefs[1]
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Desicions of civil protection authorities for earthquake countermeasures usually does not match information about non-random variations of seismicity. This often results to an underestimation of the earthquake hazard in short-term sense, that is in time intervals ranging from days to months. Therefore, significant seismicity changes in the time-space-magnitude domains are considered as a powerful tool for the real-time evaluation of the state of seismicity in a target area and at any point of time for operational purposes. Here real-time means that the time distance between the evaluation statement and the end of the seismic period which is under evaluation is about 1 day (=24 hours). To this aim we propose a methodological strategy which may comprise three main stages. In the first, a target area is selected on the basis of seismicity and/or social criteria. Then, significant seismicity changes in space (e.g. epicentral density *q*), time (seismicity rate, *r*) and size (*b*-value) are routinely monitored with appropriate statistical tools applied on daily updated earthquake catalogues, e.g. fractal dimension of *q*, *Z*-statistic for changes in *r*, *p* of Utsu-test for *b*-value changes. Finally, the significance of change of the three parameters is evaluated to characterize the state of ongoing seismicity including the forecasting information for a forthcoming mainshock. Any evaluation output of what has happened until one day ago automatically becomes an input on what one may expect in the days to come. For the strategy implementation an expert system is utilized, the learning phase of which is based on past seismicity experience in several seismogenic zones. The output could be either an alert-based scheme or a probability function for the most probable state of seismicity or both. We have developed the computer algorithm FORMA (foreshock-mainshock-aftershock) which updates automatically the earthquake catalogue, performs calculations of stage two and produces expert system outputs of stage three. Retrospective application of FORMA was performed in the case of the 6 April 2009 earthquake (M_w=6.3) in L'Aquila, Italy. A strong foreshock signal was detected 10 days before the mainshock with highly dense concentration of foreshocks in the seismic fault, drastic increase of *r* and drastic drop of the *b*-value. We show the possibilities of the proposed strategy and of the FORMA algorithm for the continuous monitoring of the state of seismicity and consequently for the evaluation of the short-term seismic hazard with promising prospects for operational use by civil protection authorities.

ES8/TU/O5 - «NEAREST»: AN EMPIRICAL, NON-PARAMETRIC, FORECASTING MODEL BASED ON NEAREST-NEIGHBOUR DISTANCES BETWEEN EARTHQUAKES

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«Nearest» is the first «alarm-based» earthquake forecasting procedure updated daily in real time. It is being tested at the Southern California Earthquake Center, within CSEP, the Collaboratory for the Study of Earthquake Predictability (www.cseptesting.org). This fully empirical, spatial forecast considers that future earthquakes are most likely to happen at the locations of previous earthquakes, or close to them.

It is based on the empirical distribution function of nearest-neighbour distances between past earthquakes. To obtain a physically meaningful distribution, the earthquakes below the magnitude of completeness of the catalogue are not taken into account. This distribution is not fitted to any model, so no parameter is used.

Following CSEP standards, each testing region is divided into latitude-longitude cells. «Nearest» assigns a probability to each cell, depending on the distance between the cell and past earthquakes, and the above mentioned empirical distribution. Cells which contain past events, or are closer to them, are assigned higher probabilities.

In the four testing regions (California, the whole Earth, Pacific NW and Pacific SW), the results confirm that earthquakes tend to happen in the vicinity of past ones. Thus, most of them occur in a small minority of cells for which the calculated probabilities were higher.

The results are particularly remarkable in California, where the earthquake catalogue is most complete, and the forecasting map is therefore most detailed. The two major earthquakes that have occurred to date during the testing period (the M6.5 Eureka earthquake of January 10, 2010, and the M7.2 Baja California earthquake of April 4, 2010) took place at cells among those with highest probabilities.

There were a few exceptions however, for which the procedure was less efficient. These were the earthquakes that took place in «seismic gaps», relatively distant from any previous, sufficiently large earthquake. An unfortunate example is the Haiti M7.0 shock of January 12, 2010.

The simplicity of the method and the overall results (based on more than 250 earthquakes) suggest that «nearest» might be used as a baseline with which to compare more complex methods. Finally, the tests point out that updating the forecast daily and using catalogues as complete as possible, seemingly contribute to improve the forecasts.

ES8/TU/O6 - EARTHQUAKE FORECASTS FOR CALIFORNIA BASED ON SMOOTHED SEISMICITY AND RATE-AND-STATE FRICTION

A. Helmstetter[1], M. Werner[2]
[1]LGIT, CNRS and University of Grenoble, France; [2]Swiss Seismological Service, Institute of Geophysics, ETH Zurich, Switzerland.

We present new methods for time-independent and time-dependent earthquake forecasting based on smoothed seismicity. Past earthquakes are smoothed in space and time using adaptive Gaussian kernels. The bandwidths in space and time associated with each event are a decreasing function of the seismicity rate at the time and location of each earthquake, in order to obtain a better resolution in areas of intense seismicity and a smoother density in areas of sparse seismicity. This method can be used for producing time-independent forecast by defining the long-term rate in each cell as the median value of the temporal history of the seismicity rate in this cell. When evaluated with California seismicity, this model produces slightly better forecasts compared to our previous method based on spatial smoothing of declustered catalogs (Helmstetter et al., 2006, 2007; Werner et al., 2010) and is much simpler (no declustering, less adjustable parameters). Spatio-temporal smoothing of past earthquakes can also be used for time-dependent earthquake forecasting by assuming that the future seismic rate will be constant and equal to its present value. When used to produce next-day forecasts for California, this new method is almost as good as the ETAS model (Helmstetter et al., 2006; Werner et al., 2010). It becomes even better than ETAS for time windows longer than a few days. Finally, we developed a more realistic and physical model based on the rate-and-state model of Dieterich (1994). The rate-and-state model is used to extrapolate the rate beyond its present value (measured by spatio-temporal smoothing of past earthquakes). This last model requires only one additional parameter, the nucleation time, which characterizes the time necessary for the seismicity rate to evolve toward its long-term rate. This last model performs better than the other models when tested with a time horizon longer than 10 days, although the results for such long time windows are not much better than a time-independent model.

ES8/TU/O7 - THE INDUCED BASEL 2006 EARTHQUAKE SEQUENCE: MAPPING SEISMICITY PARAMETERS ON SMALL SCALES.

C. Bachmann[1], S. Wiemer[1], J. Woessner[1]
[1]ETH Zurich, Swiss Seismological Service

To stimulate the reservoir for a proposed enhanced geothermal system (EGS) project in the city of Basel, approximately 11500 m3 of water were injected at high pressures into a 5 km deep well between December 2nd and 8th, 2006. A six-sensor borehole array, installed by Geothermal Explorers Limited at depths between 50 and 2700 meters around the well to monitor the induced seismicity, recorded some 15000 events during the injection phase, more than 3500 of them locatable. The induced seismicity covers an area of about two square kilometres between 3 and 5 km depth. Water injection was stopped after a widely felt ML 3.4 event that occurred on December 8th.

Here, we map in space and time statistical parameters that describe the seismicity, such as the magnitude of completeness, Mc the b- and a- value of the frequency-magnitude distribution and the local probability of large events. The goals of this analysis are: 1) To relate the observed patterns with observed and modeled physical parameters, such as known geological structures, fluid pressures and diffusion of injected fluids; 2) To test if a spatially heterogeneous model is able to forecast the occurrence of large magnitude events more accurately than a bulk sequence model.

The monitoring completeness varies from Mc= 0.5 to Mc=0.8, where the lowest M is observed for the shallowest seismicity. Higher b-values are located close to the initiation point of the injection at the casing shoe. With time, and with the gradual expansion of the seismicity, the b-values decrease near the edges of the seismicity cloud. The b-values range from 0.8 to 1.8; large events occur preferentially in regions of previously low b-value.

High b-values have ,in previous studies in volcanic regions and subduction zones, to been shown to correlate with the presence of magma and fluids. The Basel results suggest as a working hypothesis that high b-values indicate the presence of high pore pressure in EGS as well. Towards the rim of the seismicity, however, lower b-values, close to typical tectonic values, suggest that the seismicity may be caused not so much by fluid overpressure as by stress loading. We plan to test this hypothesis using other case studies and quantitative comparisons with numerical models of fluid and stress propagation.

ES8/TU/O8 - LONG-TERM SLIP HISTORY DISCRIMINATES AMONG OCCURRENCE MODELS FOR SEISMIC HAZARD ASSESSMENT

D. Fitzenz[1], M. Ferry[1], A. Jalobeanu[1]
[1]Universidade de Evora, Centro de Geofisica (CGE)

Today, the probabilistic seismic hazard assessment (PSHA) community relies on one or a combination of stochastic models to compute occurrence probabilities for large earthquakes. Considerable efforts have been devoted to extracting the maximum information from long catalogues of large earthquakes (CLE) based on instrumental, historical, archeological and paleoseismological data (1, 2). However, the models remain only and insufficiently constrained by these rare single-slip event data. Therefore, the selection of the models and their respective weights is necessarily left with the appreciation of a panel of experts (3).

Since cumulative slip data with high temporal and spatial resolution are now available, we propose here a new approach to incorporate these pieces of evidence of mid- to long-term fault behavior into the next generation of PSHA: the Cumulative Offset-Based Bayesian Recurrence Analysis (COBBRA).

Applied to the Jordan Valley segment of the Dead Sea Fault, the method yields the best combination of occurrence models for full-segment ruptures knowing the available single-event and cumulative data. Not only does our method provide data-driven, objective weights to the competing models, but it also allows to rule out time-independence, and to compute the cumulative probability of occurrence for the next full-segment event reflecting all available data.

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ES8/TU/O9 - PREDICTABILITY EXPERIMENTS WITH REPEATING MICROEARTHQUAKES NEAR PARKFIELD, CALIFORNIA

J. Zechar[1], R. Nadeau[2]
[1]ETH Zurich & Lamont-Doherty Earth Observatory; [2]Berkeley Seismological Laboratory

The experiments currently being conducted within the Collaboratory for the Study of Earthquake Predictability cover large geographic regions, focus on intermediate and large earthquakes, and emphasize spatial predictability. In this presentation, we describe an alternative class of experiments dealing with repeating microearthquakes--co-located events of approximately the same size that are inferred to break the same fault patch. In this context, we consider temporal predictability of microrepeater sequences at Parkfield by asking the question: for a given sequence, when will the next earthquake occur? Such an experiment is complementary to the current CSEP experiments and can provide a test of hypotheses regarding time-varying hazard and earthquake recurrence in a relatively short period of time.

Using cross-correlation based pattern matching scans of continuous data from the Parkfield High-Resolution Seismic Network (HRSN), we identified 34 sequences of repeating microearthquakes. These sequences are comprised of 837 earthquakes with moment magnitudes ranging from -0.6 to 2.1 that occurred between January 1987 and April 2010. We present results from the analysis of 34 sequences, each containing between 9 and 19 events--for each sequence, we construct a time-varying model based on the hazard function that best fits the first few inter-event times. Tests based on the Molchan diagram and area skill score indicate that this simple statistical model exhibits statistically significant performance. In this presentation, we describe the process of repeat identification and catalog curation in light of data quality gaps; we consider the effects of the 2004 M6.0 Parkfield earthquake; and we discuss how such forecast experiments may be conducted prospectively.

ES8/TU/O10 **- WHY THE ACCELERATING SEISMIC RELEASE (ASR) HYPOTHESIS HAS BEEN PUT IN A DRAWER AND WHY IT SHOULD BE TAKEN OUT**

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The hypothesis that large earthquakes may be preceded by a period of accelerating seismicity, or Accelerating Seismic Release (ASR), was proposed about twenty years ago. From the compilation of almost one hundred peer-reviewed publications on this topic spanning from the late 1980s to the present day, we show that the number of ASR studies increased gradually up to 2004 but significantly decreased afterwards. This negative trend is amplified by an increase in the number of studies criticizing the ASR hypothesis. We propose that what appears to be a current disinterest in the topic is due to two misconceptions: (1) the erroneous link between ASR and the c-value optimization, a straightforward but relatively weak technique to evaluate ASR, and (2) the consensus for criticality to explain the origin of power-laws such as ASR, in seismicity populations. We show that 'improved tests do NOT reveal that the ASR hypothesis is statistically insignificant', in contrast with the recent study by Hardebeck et al. [2008] on the robustness of the c-value method. We also show that the consensus for criticality, evident from an overview of the ASR literature, has grave repercussions on the verification of the ASR hypothesis. We suggest that simpler non-critical models, based on elastic rebound, give new clues on the possible origin of ASR before large earthquakes and lead to new horizons on how to evaluate its significance.

T/SD2 - EARTHQUAKE AND TECTONICS: FROM PALEOSEISMICITY TO PLATE TECTONICS

Tuesday 7, 10h20-12h00

Tuesday 7, 14h00-16h40

T/SD2/TU/O1 **- SLIP RATE DROP ALONG THE NORTHEASTERN PART OF THE ALPINE FAULT, NEW ZEALAND: IMPLICATIONS FOR SEISMIC HAZARD**

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The Alpine Fault is the major plate boundary structure separating the Pacific and Australian plates in South Island, New Zealand. Recent studies into the earthquake geology of the Alpine Fault have been focused on the northeastern tip of the 'Central segment' of the fault, which has a slip rate of c. 27 mm/yr, and to the northeast on the 'Brunner segment' of the fault, which is postulated to have a lower slip rate and earthquake potential. This talk describes new results from the Toaroha River (Central), Inchbonnie, and the Maruia River (both Brunner) sites where slip rate and paleoseismic studies have recently been undertaken. Results confirm significantly lower slip rates at Inchbonnie (c. 13.6 mm/yr) and Maruia River (c. 8 mm/yr) compared to the Central segment - though the new values are higher than previously thought for these sites. Paleoearthquake timing and rupture lengths for both the Central and Brunner segments remain difficult to determine. At the Toaroha River site, there appear to be 3 large, surface-rupturing earthquakes during the last 800 years – these could coincide with the possible AD 1717, 1620 and 1200 events estimated form landscape and dendro-chronologic studies. Despite a 50% drop in slip rate, it is possible that all three of these events also manifest themselves at the Inchbonnie site. However, results from the Maruia River site (displaced terraces) and Blue Grey River (landslides) point to only two young rupture events in the last millennium in that area. These results will be assessed in concert with other current research on the Central segment of the fault being undertaken near Lake McKerrow, Haast and Whataroa to consider the transition or step-down in slip rate and earthquake recurrence from southwest to northeast along the Alpine Fault. These results will be used to help consider the rupture length of the next Alpine Fault earthquake, an event that is expected in the next few decades.

T/SD2/TU/O2 **- A FRESH LOOK AT OLD SEISMITES**

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Strong earthquake-triggered shaking often distorts and deforms soft sediment layers at the bottom of lakes. Such seismite bearing sediments from lakes that straddled the Dead Sea Fault nearly continuously in the last 70 ka have already provided one of the longest palaeoseismic records on Earth, but several questions remain, concerning the detailed shape of the seismites and physical process that governed their formation. Our analyses show how the shape of the deformation and the thickness of the deformed layers are determined by the sediment properties, namely density and viscosity, and by the earthquake characteristics, namely size, duration of shaking, and distance of the earthquake source. Understanding the physics may be help in reconstructing the properties of past earthquakes on the basis of the observed deformation in the sediments. Observations in the spectacular seismites by the Dead Sea led us to explore one shear-induced mechanism that possibly induces sediment deformation during earthquakes - the "Kelvin-Helmholtz Instability". We realize that deformation begins due to shear at the water-sediment interface as moderate wave-like folds, evolves into asymmetric folds reclining folds, and finally the folds become turbulent, unstable and the layers are fragmented, forming a breccia layer. Field observations and numerical simulations suggest that during past earthquakes this process stopped at different stages depending on the strength and duration of the shaking. The asymmetry of the folds is caused by the shear, the sense of which was determined by very subtle slope of less than 1°. In the case of Lake Lisan (palaeo-Dead Sea) it was dictated by the location of the depocenter, as is evidenced by a regionally-coherent pattern of the fold vergence. Hence, the shape cannot be used for locating the source. Our detailed analysis of the seismites shows that some of them were affected by subsequent events. Extreme reworking of seismites might reduce the number of earthquakes inferred from simple counting. We show how careful scrutiny can help in the distinction of two earthquakes represented in one seismite in cases of incomplete reworking. However, complete reworking make the two events appear as one. These insights will facilitate the refinement and reduction of uncertainty in long earthquake histories in regions where ancient lake sediments are exposed.

T/SD2/TU/O3 **- A COMARISON BETWEEN DISPLACEMENT OF GEOMORPHIC SURFACES AND MODELING GROUND DISPLACEMENTS MEASURED WITH RADAR INTERFEROMETRY**

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The Zagros fold belt marks the present southern front of the broad Arabia-Eurasia collision zone, and the regional seismicity shows that it absorbs an important part of the overall convergence. Recent studies suggest that through the Zagros fold belt, the style of deformation is critically dependent on the resistance to sliding along basal detachment but also on the presence within the wedge of intermediate decollement levels or/and ductile units (Lavé et al., submitted). Based on vertical displacement of Pleistocene geomorphic markers along the Kol River and across the Fin synclinal structure, this work tries to constrain the spatial pattern of the Quaternary crustal deformation and to compare such vertical deformation at intermediate timescale with ground displacements measured with radar interferometry on the 25 March 2006 Fin earthquake, Mw 5.7 (Roustaei et al., in press). In the study area, the uplift of Mid Pleistocene surfaces shows evidence of internal fold reactivation under ~NS regional horizontal compressive stress. The precise location and elevation of the markers along the Kol River were measured using kinematic GPS and where accessibility was not enough, were measured using Shuttle Radar Topography Mission (SRTM-10 m). The markers and long profile helped us to image the localized or distributed pattern of deformation that results from orthogonal shortening across the study area. It is expected that Neogene marls of the upper to middle portion of the Mishan Formation has partially to completely decoupled deformation within Neogene-Quaternary sediments from the underlying sedimentary units, and it suggest that have permitted the re-activation of pre-existing synclinal structures, through upward extrusion of the syncline core. It seems upward movement is accommodated by viscous deformation same as central Zagros, but here within the middle to upper marls and partial evaporitic Mishan level. The role of the pre-existing synclinal structure, i.e. the orientation of the limbs of the syncline that present a 35°-dipping

ductile or low friction decollement at ~90° from the regional compressive stress direction represents nearly optimal conditions for reactivation of the Fin syncline (same as Baladeh syncline in central Zageos). According to InSAR data (Roustaie et al., in press), the 2006 Fin earthquake (Mw = 5.7, ~8 km centroid depth) in eastern Zagros caused a maximum of about 5.12 cm of uplift along a 30-km long profile. Comparison of InSAR data and deformed river terraces along the Fin syncline shows, however, a shift of the maximum that may indicate a limited decoupling between deformation at 8 km and close to the surface, but in an overview a total similar deformation patterns are displayed by both data sets. Such similar deformation patterns suggest that the long- to intermediate-term pattern of terrace deformation could result from the accumulation of deformation similar to that caused by the 2006 Fin earthquake. This suggests that the superficial deformation through the study area is not completely decoupled from the middle to lower sedimentary cover.

T/SD2/TU/O4 - TERRESTRIAL LIDAR INVESTIGATION OF SURFACE DEFORMATION AROUND EARTHQUAKE SURFACE RUPTURES OF JUNE 2008 IWATE-MIYAGI INLAND EARTHQUAKE, JAPAN: IMPORTANCE OF VEGETATION DATA

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We acquired high-accuracy and high-resolution topographic data using terrestrial LiDAR for the purpose of documenting surface rupture zone of the 14 June 2008 Iwate-Miyagi inland earthquake (MW 6.9), Japan, in particular, the area of exceptionally large surficial slip in densely forested mountain terrain, prior to landform modification by post-earthquake recovery efforts and natural processes. A portable tripod-mounted laser scanner system was used to digitally capture the microtopography around the rupture zone, which covers an extent of approximately 650 m long and 100 m wide. For complete data coverage and dense return data in the forested mountain slope where data shadows are produced by trees and scarps, scan positions were moved 113 times. We set up 144 points of registration reflectors used for merging adjacent scanning data. Over 1.6 billion data acquired was classified into ground, grass, and tree returns by filtering processes, and digital elevation model (DEM) with ≤10 cm of grid interval was created. This minutse DEM depicts the faulted topography masked by vegetation with unparalleled clarity, which allowing us to define extent, map geometry, and slip sense of the rupture zone in greater detail and to distinguish tectonic surface ruptures from gravity-induced landslides.

In addition to the microtopographic imagery, characteristics of non-ground data provides valuable information to define deformation pattern and width of the rupture zone. We extracted over 4,000 trees from acquired point data and obtained tree trunk orientation with eigenvalue analysis. Rupture zone was clearly distinguished by tilted trees. Moreover, since the western part of the forest consisted mainly of the young cypress trees (Cryptomeria japonica), whose trunks orientate almost vertical, we could evaluate deformation of the slope.

This study demonstrates the potential of terrestrial LiDAR as a tool for mapping and archiving fine-scale tectonic geomorphic features in forested mountainous region with vivid expression.

T/SD2/TU/O5 - LARGEST EARTHQUAKE NORTH OF THE ALPS EXCAVATED WITHIN THE VIENNA BASIN, AUSTRIA

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In Central Europe north of the Alps, active faulting during Quaternary times occurs on low displacement rates of < 1-2 mm/a and mostly even < 0.1 mm/a. Even if historic seismicity during the last ~700 years records several earthquakes, the magnitudes of those events do not exceed Mw = 6.1. In contrast, extensive paleoseismological investigations in the Cenozoic Rhine graben system excavated evidences for pre-historical earthquakes with magnitudes between 6.4 and 6.8.

Here, we present new data from the first paleoseismological investigation within the Vienna Basin which is characterized by moderate seismicity (Imax/Mmax = 8/5.2). Seismicity is focused along the NNE-SSW striking left-lateral strike-slip Vienna Basin Transfer Fault (VBTF). The VBFT delimits the basin towards the east and splits up into six fault splays crossing the whole basin. Even though those splay faults do not show any historical or instrumental seismicity, geological and morphological data reveal that they moved at very slow velocities of < 0.1 mm/a during the Quaternary. We excavated two paleoseismological trenches crossing one of those normal faults, the Markgrafneusiedl Fault. We found evidence for 5 major surface-breaking events that cut through gravels of a Pleistocene Danube terrace (~250 ka). The top of those gravels in the hanging wall is not visible in both trenches. However, borehole data reveal that the base of those gravels show a total displacement of up to 40 m. The well-defined hanging-wall strata comprises high-stage flood sediments, loess and erosional deposits from the footwall that have been dated to ages between 13 and 100 ka. Among the earthquakes excavated within the trenches, only slip associated with the youngest event is directly constrained by 15 cm of offset of layers on both sides of the fault. All others are identified by their well-developed colluvial wedges and underlying tension fissures. Slip estimates for those events are obtained by measuring the maximal height of the respective colluvial wedge. Probabilistic evaluation of the inferred single-event displacements lead to magnitude estimates ranging between Mw = 6.3 and Mw = 7.0. The latter is the largest magnitude that has been documented in a paleoseismological investigation within Central Europe north of the Alps. These results together with the fact that five additional splay faults occur close to the Austrian capital, Vienna, indicate that the discussed very slow faults cannot be excluded from seismic hazard assessment, even for the relatively short recurrence periods used for building codes (475 years).

T/SD2/TU/O6 - PALEOEARTHQUAKE EVIDENCES ALONG THE PALLATANGA FAULT (ECUADOR), A SEGMENT OF THE DOLORÈS-GUAYAQUIL-MEGASHEAR

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The Pallatanga fault is a NNE-SSW segment of the Dolorès-Guayaquil-Megashear, a large structure accomodating the dextral displacement between the Northern Andean Block and the South America Plate with a rate of 6-8 mm/y. This segment is suspected to be the source of the main intraplate earthquake of South America (1797/2/4, M=7.5; Beauval et al., submitted to GJI).A previous morphotectonic study validated the right-lateral motion of the Pallatanga fault (Winter et al., 1993, GJI). Thanks to a detailed topographic survey in the Pangor Rio area, they concluded that the fault dips 75° to the west. The Holocene displacement was estimated at 41m for the dextral component and 8m for the reverse one, leading to a cumulated striae slightly dipping to the south (11°). An hypothetical mean slip rate of 2.9 to 4.6 mm/a was finally proposed, on the basis of regional correlation.In order to (1) validate the published conclusions (2) check the occurrence of large past earthquakes; (3) quantify their number, magnitude and recurrence times, we performed in the same area a series of trenches along a short section (500 m) of the fault.Each trench shows a large fault gouge in brecciated basement, with a deformation expression up to the most recent layers. These are typical thick black organic soils of Holocene age, cut and displaced by the active fault. Fault planes have typically high dips with locally positive flower structure geometry. We could not observe any clear Holocene striation and the 3 trenches thus only gave access to the vertical component. We assess the cumulated vertical displacement of the lowest soil layer at 3 meters. Considering (before getting our ongoing 14C datings) that this layer is 10,000 years old, we obtain a 15 meters cumulated offset (with a 11° striae) leading to a mean slip rate of 1.5 mm/a. Detailed survey of the trenches revealed the occurrence of three colluvial layers interbedded within andisoils, in direct relation with the fault, suggesting the occurrence of 3 main events. In addition, the current soil horizon appears locally displaced by a fault strand or trapped within open crack, suggesting that a very recent major earthquake ruptured the surface and occurred in the historical period (possibly the 1797 event?). Individual vertical offsets associated with the identified events range between 25 and 100 cm, suggesting large earthquakes with magnitude 7.1-7.7 (accounting for the strike-slip kinematics of the fault).

T/SD2/TU/O7 - EMERGENCE OF THE MAIN HIMALAYAN THRUST AND SEISMIC RUPTURES IN KASHMIR

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The Main Himalayan Thrust is the major seismogenic feature of the Himalaya and its rupture is responsible for M > 8 shallow earthquakes. We have studied the surface expression of the Main Himalayan Thrust in Jammu-Kashmir (northwestern Himalaya), locally called the Riasi Thrust. The study area is located to the south of the Pir Panjal range that borders the Kashmir basin in the south. This thrust is in the same structural location as the Balakot Fault, which ruptured during the 2005 Mw 7.6 Kashmir earthquake (Pakistan). In the Riasi Thrust area, the Chenab and the Anji Rivers, flowing southward and westward respectively, have built large fluvial terraces. We have mapped nine abrasion terraces of the Chenab River on the hanging wall of the fault, and five terraces on its footwall. Moreover, a natural trench has been cut by a tributary inflowing stream, the Nodda River. The Nodda has deposited 2 steep fans composed of local limestone clasts. Along this natural trench of the Nodda tributary, we have observed three splays of the Riasi Thrust. Along the northern splay, Precambrian limestones are thrust over Quaternary sediments. This splay is sealed by Chenab and Nodda deposits. The second splay faults the alluvial fan, leading to a 20-m high scarp. The southern splay folds the alluvial fan into a fault-cored anticline, leading to a 30-m high scarp. We have carefully mapped the geometry of the terraces using kinematic GPS and a total station in the field, aided by satellite imagery and a digital elevation model. The terraces have been dated combining several methods: ^{14}C on charcoal embedded in the terraces, cosmogenic-nuclide dating (^{10}Be) on sandstone boulders constituting the terrace treads, and Optically Stimulated Luminescence (OSL) on fine-grained deposit levels. This work confirms that the Riasi Thrust is one of the main emergences of the Main Himalayan Thrust (i.e. the active Indian/Asian plate boundary) during great earthquakes that impact it ($M_w \geq 7.6$). In contrast, the Main Boundary Thrust is not currently active, as we have not observed any offset on fluvial terraces upstream, where the Main Boundary Thrust crosses the Ans River (a Chenab tributary).

T/SD2/TU/O8 – ACTIVE TECTONICS OF THE BINALUD MOUNTAINS, A KEY PUZZLE SEGMENT TO DESCRIBE QUATERNARY DEFORMATIONS AT THE NORTHEASTERN BOUNDARY OF THE ARABIA-EURASIA COLLISION

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In northeast Iran, the Binalud Mountains accommodate part of active convergence between the Arabian and Eurasian plates. This fault-bounded mountain range is a key region in which a detailed knowledge of active faulting is crucial to better understand the kinematics of deformation. Morphotectonic investigations in both sides of the Binalud Mountains allowed us to characterize the structural and active faulting patterns along two range-bounding structures, i.e., the Neyshabur fault systems and the Mashhad fault zone. We applied combined approaches of morphotectonic analyses based on satellite imageries (SPOT5 and Landsat ETM+), STRM and site-scale digital topographic data, and field surveys complemented with in situ-produced ^{10}Be exposure dating to determine the kinematics and rate of active faulting. Three regional episodes of alluvial surface abandonments were dated at 4.8±1.6 kyr (Q1), 94±5 kyr (Q3), and 200±14 kyr (S3). The geomorphic reconstruction of both vertical and right-lateral fault offsets postdating these surface abandonment episodes yielded Quaternary fault slip rates on both sides of the Binalud Mountains. On the Neyshabur Fault System, thanks to geomorphic reconstructions of cumulative offsets recorded by Q3 fan surfaces, slip rates of 2.7±0.8 mm/yr and 2.4±0.2 mm/yr are estimated for right-lateral and reverse components of active faulting, respectively. Those indicate a total slip rate of 3.6±1.2 mm/yr for the late Quaternary deformation at the southwestern flank of the Binalud Mountains. Reconstructing the cumulative right-lateral offset recorded by S3 surfaces, a long-term slip rate of 1.6±0.1 mm/yr is determined for the Mashhad Fault Zone. We revealed that in both sides of the Binalud Mountains, the relative motion between central Iran and Eurasia is partly taken-up by oblique-slip dextral-reverse faulting along the Neyshabur Fault System and right-lateral strike-slip faulting along the Mashhad Fault Zone. Such a faulting mechanism implies a long-term rate of ~4 mm/yr for the range-parallel strike-slip faulting, and an uplift rate of ~2.4 mm/yr due to the range-normal shortening during late Quaternary. Our data provide the first geological constraints on the rate of active faulting on both sides of the Binalud Mountains, and allow us to examine the geological reliability of preexisting tectonic models proposed to describe the kinematics of active deformation at the northeastern boundary of the Arabia-Eurasia collision. Our results favor the northward translation of central Iran with respect to Eurasia through strike-slip faulting localized along the northeastern boundary of the Arabia-Eurasia collision zone.

T/SD2/TU/O9 – THE NEW FAULT MECHANISM SOLUTIONS OF EAST ANATOLIAN FAULT ZONE, EASTERN TURKEY AND SEISMO-TECTONIC IMPLICATIONS

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One of most prominent and active faults in eastern Turkey is the NE-SW oriented left-lateral strike-slip East Anatolian Fault Zone (EAFZ) with a length of approximately 500 km. We have examined the new fault mechanism solutions and recent seismicity of EAFZ using the records of 34 3D broad-band earthquake stations established around the fault zone within TURDEP project since 2006 (http://www.mam.gov.tr/english/YDBE/projeler/Makes-Major.html). The error margins of the coordinates of recently relocated epicenters are less than ± 2 km. It is found that some clusters of earthquake epicenters have considerable offset from the field trace of EAFZ. Also, some epicenter clusters display parallel and conjugate fault activity to EAFZ. The new fault mechanism solutions of 60 earthquakes in addition to previously published 11 mechanism solutions that occurred on the EAFZ in the time period between 1966 and 2010 were studied to understand the seismo-tectonic characteristics. The new mechanism solutions of the earthquakes, with a magnitude of M_L=3.5 or more were determined by a local moment tensor solution and P-wave first motion data. Northern segment of EAFZ is very active in the last 50 years and display dominant left-lateral faulting activity as well as the seismicity associated with minor conjugate faults. It is suggested that the recent tectonic deformation of EAFZ south of Turkoglu were taken up by the left-lateral strike-slip active faults in between Amik and Adana Basins where young trans-tensional stress regime is also active.

T/SD2/TU/O10 – ON-FAULT AND OFF-FAULT MAXIMUM HORIZONTAL STRESS (SHMAX) DIRECTIONS AROUND THE ISMETPASA CREEPING SEGMENT OF THE NORTH ANATOLIAN FAULT, TURKEY

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The Ismetpasa fault segment is a 70 km long section of the North Anatolian fault (NAF) where the surface ruptures of the 1943 (M=7.6) and the 1944 (M=7.3) major earthquakes overlapped and re-ruptured by the 1951 large event (M=6.9). After the identification of a creeping event along the San Andreas fault (SAF), triangulation and creepmeter measurements studies carried out in 1970s indicated that NAFZ is not locked around the Ismetpasa segment and ongoing slip is taking place.

Several broadband seismic stations were deployed during the last few years in the vicinity of the Ismetpasa segment as a part of the National seismic network operated by Kandilli Observatory and Earthquake Research Institute. We analyze the seismic records at these stations to retrieve the source parameters of the nearby small to moderate size events using the method given at Kuge (2003). Until present we estimated the CMT parameters of 56 events most of which are confined to the upper crust. Some of the events are on the main fault zone and most of them are tens of km away from the main trace of the fault. Considering the spatial distribution of the analyzed events we divided the data set into four groups, namely, on-fault, regions A, B and C. The stress tensor inversion results obtained using the focal mechanisms at each group shows some features that were observed around the creeping section of San Andreas fault (SAF). The maximum horizontal stress direction derived from the on-fault events is directed at lower angle to the main trace of the NAF while the Shmax axes derived from the focal mechanisms of the off-fault groups A and B which lie to the south of the Ismetpasa segment are oriented at higher degree (80-85 degree) to the NAF. The Shmax derived from the off-fault events of group C is oriented at lower angles (30-45 degree) to the NAF trace. Such

an orientation of the observed Shmax around Ismetpasa suggest that the fault is weak at that section of NAF. Furthermore, the heat flow map of Turkey constructed by the researchers at MTA indicates that the heat flow at the central part of the Ismetpasa segment is lower compared to both the ends of the segment.

T/SD2/TU/O11 **- RUPTURE CHARACTERISTICS OF THE 9 AUGUST 1912 MÜREFTE EARTHQUAKE (MS=7.3) AND PALEOSEISMOLOGY ALONG THE GANOS SEGMENT OF THE NORTH ANATOLIAN FAULT (TURKEY)**

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The Ganos fault is the westernmost segment of the NAF that generated the 9 August 1912 earthquake (Ms=7.3) followed by a second shock on 13 September 1912 (Ms=6.8). We studied the surface ruptures at 45 sites to document slip distribution and cumulative offset along strike. Co-seismic offsets measurements ranging from 2 to 5.5 m showed maximum slip in the northeastern fault section. Paleoseismic trenching at Saros, Güzelköy and Yeniköy sites revealed an earthquake recurrence interval of 285±50 years and 16 to 26 mm/yr slip rates for the last ~700 to 2840 years dating paleo-channel and stream offsets. An 18 mm/yr average slip rate reveals an interseismic maximum strain accumulation of ~5 m which is in accordance with our slip measurements for the 1912 rupture. The different slip rates at different sites showed well correlation with the co-seismic slip distribution that is related to the fault segmentation pattern. Analysis of the 1912 surface rupture inland shows a minimum of 3 sub-segments limited by the Kavak, and Yörgüç pull-apart basins. In the Marmara Sea, similar structures show a significant bend (17°) near the coast and a large pull-apart basin (Central Basin) that may correspond to the eastern end of the 1912 earthquake rupture. Analysis of the 9 August and the 13 September 1912 damage distribution and seismic waveforms from instrumental records documents the relative size and characteristics of the events. The large earthquake moment ~1,27 x1020 Nm corresponds to ~120 km rupture length for the first shock and requires an offshore extension in both Marmara sea and Saros bay. The second shock with Mw=6.8 implies an additional 20 to 40-km-long rupture with an epicenter located further west near Saros Bay, that indicates the location of the western termination of the 9 August rupture. An estimated total rupture length of 150±20 km for the two earthquakes combined with onshore and offshore fault segmentation allow us to better constrain the western limit of the Marmara Sea seismic gap and related potential for producing a large earthquake that was sharply increased by the devastating 1999 Izmit earthquake in the east.

T/SD2/TU/O12 **- SEISMO-TECTONIC CHARACTERISTICS OF MARMARA REGION, TURKEY WITH FOCAL MECHANISM SOLUTIONS AND STRESS TENSOR ANALYSES**

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101 new fault mechanism solutions were calculated using the earthquakes that were recorded during the implementation of the TURDEP project (Multi-Disciplinary Earthquake Researches in High Risk Regions of Turkey Representing Different Tectonic Regimes, http://www.mam.gov.tr/english/YDBE/projeler/Makes-Major.html). These new mechanism solutions were merged with previously determined 259 solutions that were obtained by using different methods. Thus, tectonic stress tensors were calculated for the whole Marmara Region and the subtectonic areas by using the fault plane solutions of total 360 earthquakes that occurred in the time period between 1912-2009. The ongoing evolution of current tectonic activity in the Marmara Region is interpreted with the spatial distribution of the principal stress axes for the specified areas. The seismological data is not uniform in time, space and size because of the numbers, locations and capability of the operated earthquake stations in the Marmara Region in the years between 1912-2009. Reliable fault plane solutions of small earthquakes (M <5) in the Marmara Region with the higher level accuracy has emerged after 1974 following the development of MARNET, IZINET, TURDEP projects and especially, after the 17 August 1999 Kocaeli, east Marmara earthquake. The following results were obtained when the spatial distribution of the calculated stress tensor is evaluated in this study: The overall evaluation of principal stress values in the Marmara Region shows major strike slip regime (decrochement). It is suggested that the North Anatolian Fault exhibits dominant character in the North Marmara Region. Also, there are evidences for partial activity and occurrence of pull-apart mechanisms in this region. Prevalent seismic fault plane solutions and other findings such as seismicity do not give satisfactory pattern for the existence of the southern branch of the North Anatolian Fault. Çınarcık and Gemlik areas reveal dominant normal faulting character.

T/SD2/TU/O13 **- SEISMOGENIC FAULTS BORDERING TAYGETOS HORST (PELOPONNESUS, SOUTHERN GREECE): UNBALANCED GEODYNAMIC PAIR**

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Taygetos horst (Peloponnesus, southern Greece) has been individualized by uplift movements along two NW-SE trending rupture zones of entire length of about 70-80 km which are segmented by transversal fault zones trending WSW-ENE. The rupture zone bordering the eastern flank of Taygetos horst is responsible for devastating historical earthquakes of the VI-V century B.C. (M=6.0-7.2) that destroyed repeatedly the city of Sparta. On the contrary, the fault zone bordering the western flank of the horst, is responsible for several strong earthquakes during the 19th - 20th century A.D. (M=6.0-6.5) which occurred at both onshore and offshore segments of the zone.

In order to assess the geometrical parameters of these two fault zones, a morphostructural analysis was carried out using combinations of Landsat ETM+ panchromatic and multi-spectral images (bands 1, 3, 4, 5 & 7) filtered with edge enhancement 3x3, the geological maps covering the area and the Global Elevation Model (GDEM) derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery. All these data have been integrated in a GIS environment using the Greek coordinate system EGSA 1987.

The kinematic analysis based on field observations shows the following multiple reactivations with a dip-slip movement shared by these two fault zones since Pliocene: 1) an E-W extension during upper Pliocene 2) a NE-SW extension during lower Pleistocene and 3) a NW-SE extension during middle Pleistocene to the present.

The historical data as well as the instrumental seismicity (Mw≥4) for the period 1964 - 2009 show that the eastern flank of Taygetos horst is characterized by lower seismicity level than the western one. Moreover, no elongated clusters of epicenters along the fault zones have been observed neither on the eastern flank of Taygetos structure nor on the western one. Based on morphostructural analysis, the average slip rate since Early Quaternary could be estimated as 0.5 mm/yr for the eastern fault zone and 0.8 mm/yr for the western one, which allows us to characterize the faults bordering Taygetos structure as of moderate activity. The above results show that the seismogenic faults bordering active tectonic structure of Taygetos horst constitute an unbalanced geodynamic pair with different seismogenic behavior.

The Probabilistic Seismic Hazard Assessment methodology has been realised in EZ-FRISK PC software (Risk Engineering, 2005) using the geometrical (location, state of segmentation) and kinematic (slip rate) parameters of the above fault zones.

OS3 - TRANSNATIONAL RESEARCH AND INFRASTRUCTURE COLLABORATION ACTIVITIES IN EURO-MED

Tuesday 7, 10h20-12h00

OS3/TU/O1 **- EMME:EARTHQUAKE MODEL OF MIDDLE EAST**

M. Erdik[1], D. Giardini[2], K. Sesetyan[1], C. Tuzun[1]
[1]Bogazici University, Istanbul; [2]ETHZ, Zurich

It is a well known fact that earthquakes cause, not only direct damage on built environment such as buildings, infrastructure or lifeline systems and result in human life and economic losses but have also secondary effects such as social and economic losses.

As a consequence of the high probability of earthquake occurrence combined with high population growth, poor construction standards and practice and lack of proper mitigation strategies, Middle East represents one of the most seismically vulnerable regions worldwide. EMME (Earthquake Model of the Middle East Region) aims at the assessment of seismic hazard, the associated risk in terms of structural damages, casualties and economic losses and also at the evaluation of the effects of relevant mitigation measures in the Middle East region in concert with the aims and tools of GEM. The EMME will encompass several modules such as the Seismic Hazard Module, Risk Module, SocioEconomic Loss Module and the development of an IT infrastructure or platform for the integration and application of modules under consideration. The methodologies and software developments within the context of EMME will be compatible with GEM in order to enable the integration process. EMME will be a living model, rather than a static study, with a flexible, modular architecture to allow addition and updating of components and datasets, and to maintain it continuously as stateoftheart and in conformance with national developments and new international standards. As such, EMME will allow multiple user types to derive updated products and outputs, and keep up with changing requirements. The users and beneficiaries of EMME will be broad, and include all those who make decisions based on seismic risk: seismic agencies, engineers and practitioners, government officials, insurance and finance industries, emergency responders, risk professionals, homeowners, investors, and the population at large. EMME is jointly directed by Eidgenössische Technische Hochschule Zürich (ETHZ) and Kandilli Observatory and Earthquake Research Institute (KOERI) and is composed of the following work packages. The institutions participating to EMME are: Boğaziçi University, Middle East Technical University and Sakarya University from Turkey, IIEES from Iran, NDMA and NED University of Engineering and Technology from Pakistan, Yarmouk University from Jordan, Cyprus University of Technology, ACNET from Georgia, SCI from Armenia, ANAS from Azarbaijan and ETHZ from Switzerland.

OS3/TU/O2 – THE WESTERN MEDITERRANEAN SEISMIC NETWORK AND ALBORAN ISLAND UNDERWATER AND ON LAND OBSERVATORY. MULTI-PARAMETER OBSERVATIONS IN THE IBERO-MAGHREBIAN REGION: PRESENT STATUS.

A. Pazos[1], J. Martin davila[1], E. Buforn[2], J. Garate[1], M. Catalan[1], W. Hanka[3], A. Udias[4], M. Benzzeghoud[5], M. Harnafi[6], S. ROA[1]
[1]Real Observatorio de la Armada (ROA); [2]Universidad Complutense de Madrid (UCM); [3]GeoforschungsZentrum (GFZ); [4]Universidad omplutense de Madrid (UCM); [5]Universidad de Evora (UEVO); [6]Intitute Scientifique Universite Mohammed V Rabat (ISRABAT)

The plate boundary between Eurasia and Africa plates crosses the so-called «Ibero-Maghrebian» region from the San Vicente Cape (SW Portugal) to Tunisia including the South of Iberia, Gulf of Cadiz and Alboran Sea, northern Morocco and Algeria. In this area, the convergence, with a low rate, is accommodated over a wide and diffuse deformation zone, characterized by a significant and widespread moderate seismic activity [*Buforn et al.*, 1995], and the occurrence of large earthquakes is separated by long time intervals.Since more than hundred years ago San Fernando Naval Observatory (ROA), in collaboration with other Institutes, has deployed different geophysical and geodetic equipment in the Southern Spain – North-western Africa area in order to study this broad deformation zone.Currently a permanent Broad Band seismic net (Western Mediterranean, WM net) has been deployed, in collaboration with other institutions (U. Complutense, GFZ, ISRABAT, U. Evora), around the Gulf of Cádiz and the Alboran Sea, with stations in the South of Iberia and North Africa (Spanish places and Morocco). Together with the seismic stations, ROA has deployed a permanent geodetic GPS net co-installed at the same sites. Also, other geophysical instruments have been installed at ROA Headquarters at San Fernando: a SLR station, a Geomagnetic Observatory, etcThese networks have been recently complemented by installing a new submarine and on-land geophysical observatory at the Alboran Island (ALBO Observatory, Western Mediterranean): a permanent submarine observatory in 50 meters depth was installed last October (with a broad band seismic sensor, a 3 C accelerometer, a DPG, etc.), linked to the island by a 2.0 km submarine fibber-optics cable. On land, a permanent geodetic GPS station, a meteorological station, a satellite link, etc. have been also installed. Additional submarine and on land instruments are planned to be installed within next future. This work shows the present status and the future plans of these networks together with some results.

OS3/TU/O3 – AN EXAMPLE OF A MARINE RESEARCH COLLABORATION IN EARTH SCIENCES BUILT BETWEEN FRANCE AND ALGERIA: STEPS, CHALLENGES AND MUTUAL BENEFITS

J. Déverchère[1], A. Yelles-Chaouche[2], R. Bracene[3]
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We summarize the way how a joint programme in marine research was made possible between French and Algerian institutions in the field of geodynamics and seismic risk. The first step has been the shared awareness of a crucial need for addressing a scientific issue, in this case arising from a deficiency of basic data in the offshore domain of Algeria. The second step was to call up marine infrastructures (mostly, research vessels from IFREMER and IPEV and adapted, heavy scientific tools available in the French Community) and to convince the Scientific Community and people responsible in both countries to fund and support the cruises and data analyses necessary to promote this research project (examples of MARADJA 2003, MARADJA-SAMRA 2005, and SPIRAL 2009 cruises). In the course of this step, the main challenge was to organize the data sharing and to progressively involve more and more junior and senior scientists in the data analyses and interpretations through bi-lateral exchange programs (such PHC TASSILI). Finally, we show (1) how the strengthening and enlargement of the scientific objectives of the initial project has been conducted, (2) what efforts were necessary to reinforce teams involved and to consider mutual interests with a state oil company (Sonatrach, Algeria), and (3) how we are hoping to overcome the limits of the offshore-onshore interface. We conclude on the obvious mutual gain and increased scientific knowledge in geodynamics and natural hazard that result from this partnership and propose some feedbacks on the way collaborative initiatives can be developed in the Euro-Mediterranean region.

OS3/TU/O4 – RECENT SEISMIC HAZARD RESEARCHES IN IRAN (SUMMARY OF A DECADE OF COLLABORATIVE PROGRAMS BETWEEN IRANIAN AND EUROPEAN INSTITUTES)

E. Haghshenas[1]
[1]International Institue of Earthquake Engineering and Seismology

Iran as one of the very well known continental collision zone located between two Arabian and Eurasian plates which converge at a rate of 24 mm/yr has experienced more than 140 strong earthquakes with magnitude of 7.5 or more in the past centuries. In 20th century alone, 20 large earthquakes have caused extensive human and economic losses, marking Iran as high earthquake risk region. Since 1990, especially after Manjil earthquake, to ensure the sustainable development, a multidisciplinary risk reduction strategy with the objective of saving human life and resources have been initiated. A number of Iranian institutes have been incorporated, the most important are: International Institute of Earthquake Engineering and Seismology (IIEES), Geological Survey of Iran (GSI), National Centre of Cartography (NCC), Institute of Geophysics of Tehran University (IGTU), Building and Housing Research Centre (BHRC). The geologic and tectonic situation of Iran provides a natural laboratory to study the kinematics and dynamics of plate interactions, encouraged several international collaborative scientific project between Iranian Institutes and European research Institutes and Universities. Especially since 1997 a comprehensive cooperative research program was initiated by collaboration of French and Iranian Institutes, mainly by IIEES, GSI and NCC from Iran and LGIT, CEREGE and LGM from France. This program mainly financed by French Insu-CNRS and the logistic supports of Iranian Institutes had as objective, the comprehension of mechanism of continental deformation (large scale distribution and partitioning of deformation), Its propagation in sedimentary cover, the fragile and ductile crust, lithospheric mantle and comprises also an important section concerning the seismic hazard and risk in the cities like as Tehran and Tabriz. Later some other European institute such as University of Cambridge joined to this collaborative program. It was consisted of several coordinated studies on spatial geodesy, paleomagnetism, petrography, tectonics and geomorphology, seismology paleoseismology and engineering seismology implying of many researchers. Several seismological campaigns have been manipulated, two most important of them conducted along two transect of Zagros Mountain. In domain of Seismic hazard and risk a number of studies conducted especially around the capital (Tehran). These studies includes the paleoseismoligical researches on the active

faults, surrounded the city and also a study on the experimental evaluation of the effect of surface geology on the ground motion. *All of these experiences accompanying several geodetic surveys and GPS networking campaigns resulted in new signs helping us to better understanding the mechanism of deformation and crust structure of Iran and also to better know the level of risk in Tehran. This paper tries to make a summary of these collaborative researches and their results.*

OS3/TU/O5 **- RESEARCH NETWORK ACTIVITIES AND INFRASTRUCTURE IN GREECE: PERSPECTIVES WITHIN THE EURO-MEDITERRANEAN REGION FOR IMPROVED SEISMIC HAZARD AND RISK ASSESSMENT**

N. Theodoulidis[1], A. Savvaidis[1], B. Margaris[1], C. Papaioannou[1]
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Greece has the highest level of seismic hazard in Europe. Minimization of the loss of life, social and economic impact due to earthquakes depends on reliable estimates of seismic hazard, to serve as basis for land use planning, improved building design and construction, emergency plans and strategies for sustainable development. In order to mitigate seismic risk, it is important to ensure that advanced knowledge acquired worldwide is efficiently transferred to countries such as Greece. During the European Commission funded project under the Marie Curie Actions, ITSAK-GR (International Transfer of Seismological Advanced Knowledge and Geophysical Research) a network of Research organizations has been established comprised of 8 partners most of them coming from European countries. In this Transfer of Knowledge project the Institute of the Engineering Seismology and Earthquake Engineering served as the Host and the rest of the partners as training organizations. During this project more than 20 researchers were recruited into the host organization and 4 researchers were seconded into the premises of the training partners. In total 148 person-months of mobility were completed during a period of 4 years (1/6/2006-31/5/2010). The accomplished project ensured the transfer of advanced knowledge regarding all aspects of seismic-hazard evaluation, namely: (a) geotectonic properties of earth's crust, (b) earthquake source properties , (c) seismic-wave propagation and attenuation, (d) local site effects on strong-ground motion , (e) deterministic and stochastic assessment of strong-ground motion Methodologically, the efficiency of transfer of knowledge has been achieved by, (a) in-depth theoretical training in modern methods, (b) joint development/adjustment of modern methods, (c) training in the application of modern methods, (d) joint application of modern methods, and (e) joint presentation/publication of results that have reached the number of 20 publications at the date of the end of the project and we are looking forward for more to come in the near future. Parallel to that permanent strong motion network in national level as well as temporary aftershock activity arrays deployed and updated in Greece during the last 10 years could feed research teams with high quality data to develop or/and validate new methods in engineering seismology. The aforementioned network research actions and experience gained along with the existing seismological infrastructure and relevant databases in Greece could be further exploited through Euro-Mediterranean collaboration towards seismic risk mitigation.

ES7 - SEISMIC ANALYSES OF NON EARTHQUAKE RELATED SOURCES

Tuesday 7, 10h20-12h00

ES7/TU/O1 **- SEISMIC AND INFRASOUND MEASUREMENTS TO STUDY SNOW AVALANCHES**

E. Suriñach[1], A. Kogelnig[2], I. Vilajosana[3], C. Pérez[1], M. Hiller[4], F. Dufour[5], J. Hübl[2]
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Like other mass movements, snow avalanches generate seismic waves that can be detected. The characteristics of the signals depend on the source and on the distance source- seismometer. The analysis of the seismic signals in the time and frequency domains allows us to detect snow avalanches and to characterise their typology. This is important for monitoring purposes in non accessible areas or in situations with little or no visibility. Moreover, the characterisation of snow avalanches provides us with an input for the numerical modelling of snow avalanches.

Furthermore, the incorporation of the infrasound component to the seismic signals in the analysis proves to be complementary and allows us to better differentiate the different parts of the avalanche and to distinguish them from other phenomena. Examples of signals from snow avalanches at the Vallée de la Sionne experimental site (Switzerland), where seismic sensors (3D, 1Hz eigenfrequency) and infrasound sensors (0.1 Hz eigenfrequency) were placed next to each other, are presented. The distances involved are of the order of 3-4 km. The study is based on the analysis of the time series and on that of the evolution of their frequency content. The results are compared with those of other physical measurements. The suitability of the different configurations of the equipment is also discussed.

ES7/TU/O2 **- NUMERICAL MODELING OF LANDSLIDE GENERATED SEISMIC WAVES**

P. Favreau[1], A. Mangeney[2], A. Lucas[3], G. Crosta[4], F. Bouchut[5]
[1]IPGP; [2]IPGP - Université Paris Diderot 7; [3]Caltech; [4]University of Milano-Bicocca; [5]LAMA-CNRS, Université Paris-Est - Marne-la-Vallée

Gravitational instabilities such as debris flows, landslides or avalanches play a key role in erosion processes at the surface of the Earth and other telluric planets. On Earth, they represent one of the major natural hazards threatening population and infrastructure in volcanic, mountainous, seismic and coastal areas. One of the main issues in terms of risk assessment is to produce tools for detection of natural instabilities and for prediction of velocity and runout extent of rapid landslides. The lack of field measurements of the dynamics of natural landslides due to their unpredictability and destructive power, prevents investigating the mechanical properties of the flowing material that appears to be very different from experimental granular flows in the laboratory. In this context, the analysis of the seismic signal generated by natural instabilities provides a unique paradigm to study flow dynamics and discriminate the physical processes at play during their emplacement along the slope. Potentially, it is possible to infer information about the "landslide source" from the seismic signal produced during the initial collapse and the subsequent flow along the natural terrain. However, the process of reverse dynamic analysis is complex and must take into consideration the role of topography, mass of the landslide, flow dynamics, and wave propagation on the recorded signal. We use here numerical modeling of the landslide and of the generated seismic waves to address this issue. We show that (i) numerical simulation of landslide and generated seismic waves well match the observed low frequency seismic signal, (ii) topography effects on landslide dynamics play a key role in the observed seismic signal, (iii) simulation of the seismic wave makes it possible to discriminate between the alternative possible scenario of flow dynamics and to provide estimates of the rheological parameters during the flow. As a result, unique data on natural flow dynamics could be obtained through analysis of seismic signals generated by landslides of significant size that are recorded by local or regional seismic networks.

ES7/TU/O3 **- FORENSIC SEISMOLOGY: THE AZF TOULOUSE EXPLOSION OF SEPTEMBER 21ST 2001 DETAILED ANALYSIS AND MODELLING OF THE OMP RECORD WITH AN EMPIRICAL GREEN FUNCTION APPROACH**

P. Bernard[1], P. Bernasconi[2]
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We present the analysis of the 2001 OMP record of the AZF explosion in Toulouse, to provide details on the time history of its pressure source. This work was a contribution to the expert assessment (J.Curé, 2005) for the Civil Law Procedure of the AZF trial. The OMP seismogram was obtained 4.2 km from the crater on a short period (1 Hz) seismometer. As the direct path for the waves crosses very heterogeneous, 3D structures (geology and topography), there was no way to correctly model the signal at frequencies down to 1 Hz, in the absence of detailed, 3D tomographic model. Within the Civil Law Procedure, we therefore proposed an experimental approach, with Empirical Green functions, also supported by the Experts for the Criminal Law Procedure, who could

organize the experiment. The experiment consisted of explosions from shallow borehole (up to 35 kg dynamite), and dropping of large weights for controlled impact sources (20 tons falling from a 20 m height), in the immediate vicinity of the crater, and to record them at the OMP and other sites. On the records at 1 km distance, the waveform of the explosions was similar to the time derivative of the stacked (170 times) impact waveforms, which we interpreted as the effect of a single force source for the impacts, and couple of forces for the explosion. The resulting filtering effect is also clear at OMP, with a relatively larger surface wave amplitude for the impacts. However, the 2001 OMP record showed a stronger relative dominance of the surface waves, requiring an explosion duration of about 0.084 s seconds, with a simple convolution of the impact waveform with a boxcar. Scaling the explosions and impact sources provides in both cases a seismic energy of about 0.7 to 1 GJ. The similarity of the simulated and observed waveforms show that there is no need of two successive explosion to explain the two successive P wave arrivals. If any explosion preceded the main one, its energy equivalent would be less than a confined 1 kg dynamite. Using a numerical code for the modelling of dynamic pressure sources on the ground from surface explosion (AIRBLAST), we show that the reported duration implies the propagation of this pressure source towards the west, starting near the eastern end of the nitrate. The initiation of the explosion was thus located close to the entrance of the hangar.

ES7/TU/O4 **- TIME-FREQUENCY ANALYSIS OF SEISMIC RECORDS AS A USEFUL TOOL FOR INVESTIGATING AN INDUSTRIAL ACCIDENT: EXPLOSIONS IN THE AMMUNITION FACTORY IN NOVAKY, SLOVAKIA**

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On 2 March 2007, a sequence of explosions occurred in the ammunition factory in Novaky (VOP Novaky, Slovakia) and caused a major industrial accident. The origin times and number of explosions were key aspects for the state investigation team to explain the primary cause and development of the accident. An analysis of seismic records was the only way to determine reliable origin times. We were able to identify two strongest explosions directly from the seismic records. A detailed time-frequency analysis (TFA) enabled us to identify acoustic waves caused by the explosions. This led to the subsequent identification of two weaker explosions in seismic records and an indication of two even weaker explosions that were not identified in the seismic records by other means. The TFA also led us to determine that the mechanism or source conditions of the first explosion were different from those of the stronger explosions. Our results from the seismic analysis are supported by onsite investigations by the state investigation team.

SW5 - RANDOM WAVEFIELDS IN SEISMOLOGY: NOVEL METHODS AND APPLICATIONS

Tuesday 7, 14h00-16h40

SW5/TU/O1 **- GREEN'S FUNCTIONS FROM 17 YEARS OF BROADBAND SEISMIC NOISE RECORDED AT GERMAN REGIONAL SEISMIC NETWORK (GRSN)**

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The German Regional Seismic Network (GRSN) currently consists of about 25 broadband seismic stations distributed over the territory of Germany.

The network was established in 1991 and there are 10 stations, which almost continuously recorded 17 years from 1993 until today (2010).

We analyse the root mean square (rms) of ambient noise in different frequency bands in the range from 0.015 Hz to 1.0 Hz during the whole period of 17 years at these 10 stations. Statistical analysis of noise is done and seasonal as well as daily variations of noise amplitude are analysed. We use the median of the rms value of noise to measure the typical amplitude of noise in different frequency bands. Comparing the rms-value in a moving time window to the median of rms we select time windows without earthquakes and with low noise amplitude. The selected time windows at different stations are cross-correlated to construct Green's functions from ambient seismic noise. We compare the results of this 'window selection' technique to results of usual 'one-bit-normalisation' technique. Both methods to delete earthquakes from noise data give similar results in the correlograms, but the advantage of 'window selection' technique is that only linear processing steps are applied. Finally, we construct Green's functions between the 10 seismometers using different time lengths of ambient noise. We compare Green's functions from 17 years of noise to Green's functions constructed from shorter periods of ambient seismic noise such as two years and three months.

SW5/TU/O2 **- SURFACE WAVE TOMOGRAPHY USING AMBIENT NOISE AT ONSHORE-OFFSHORE NETWORKS**

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It is shown by various authors that the method of cross-correlating ambient seismic noise records is reliable in direct determination of Rayleigh wave Green functions (RWGF). Here we present the procedure in case of onshore-offshore networks.

The EGELADOS network was deployed in the southern Aegean from October 2005 to April 2007. Therefore, the seismic records of 65 three-component land stations (Guralp, Mark, STS-2) and 22 ocean bottom seismographs (OBS, only Hydrophone component) are available.

The very special conditions of the Aegean region as a seismic active area constrains the efficiency of the used method. Effects of seismic events have to be eliminated before cross correlating seismic noise to avoid the dominant autocorrelation signal of seismic events itself. We calculate and stack cross-correlations of ambient noise records at selected interstation paths to retrieve Rayleigh wave Green's functions. Besides, the slant stacking procedure gives extra information about phase velocity dispersion. Dispersion analysis of resulting seismograms provides group velocity curves which give information about the crustal and uppermost mantle structure that cannot be obtained from earthquake data. For the Aegean region considerable regional differences in crustal structure can be expected.

Particular attention is paid to the determination and analysis of dispersive signals in case of Ocean Bottom Seismographs (OBS) and hydrophones. At land stations we extract clear dispersion curves but OBS seismograms show multiple signals of different velocities. The frequency range and characteristics are dependent on surface structures between the two stations as well as their location. Ray path profiles between two hydrophones with no elevation have a strong acoustic phase with a faint surface wave signal.

For the sake of completeness we compared seismometer and hydrophone data from NEAREST project (August 2007 – August 2008), which was equipped by same OBS. Resulting spectrograms show significant analogies in narrow frequency bands dependent on bathymetry at the respective ray path.

SW5/TU/O3 **- PRELIMINARY RESULTS FOR BROADBAND SEISMIC NOISE CORRELATION ON THE CO2 INJECTION SITE KETZIN, GERMANY**

M. Delatre[1], C. Sens-Schönfelder[2], J. Manceau[1], A. Bitri[1]
[1]BRGM; [2]Institut für Geophysik und Geologie, Universität Leipzig

Monitoring CO2 storage reservoirs over long periods of time is mandatory to ensure the safety of the CO2 storage process, as the European Parliament Directive states. To ensure this goal, several methods are already available; however, they either require expensive costs (time-lapse active seismic surveys) or wells that affect the reservoir integrity (downhole microseismic instrumentation). The development of long range correlation of seismic noise allows us to consider new monitoring methods : by inferring the Rayleigh wave dispersion and its variation over time from ambient seismic noise recordings, we may be able to measure S speed variations in different layers.In order to test this method, we set up a broadband array on the CO2 injection pilot at Ketzin (Germany) and recorded 5 months of data. 14 day stacks were enough to build stable correlations and allowed us to study the Rayleigh wave dispersion between 0.8 and 6 Hz. Several Rayleigh branches were observed. We were able to invert these dispersion curves and obtained the S vertical speed profile for the first hundred meters; looking at different time periods, we looked for temporal variations of S wave speed induced by the CO2 injection. We compared these

observations to models of the influence of the CO2 plume presence on Rayleigh wave dispersion.

SW5/TU/O4 - DEPTH AND GEOGRAPHICAL EXTENSION OF THE SEISMIC VELOCITY CHANGE RELATED TO THE 2006 GUERRERO (MEXICO) SLOW SLIP EVENT

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We measure temporal change of the seismic velocity in the crust below the Guerrero region during the 2006 slow sleep event (SSE). We use repeated cross-correlations of ambient seismic noise recorded at 26 broadband stations of the MesoAmerica Seismic Experiment (MASE). The cross-correlations are computed over 90 days with a moving window of 10 days from January 2005 to July 2007. To insure measurements independent of noise source variations we use two strategies. We first take into account the travel time change only within the coda. The coda is formed of diffuse waves and thus less sensitive to source variation. Then, we measure travel time change of a cross-correlation function at a given time relative to the previous one. We thus reduce the error related to the definition of a global reference cross-correlation function, which is generally the average cross-correlation. We observe a decrease in velocity starting in April 2006 with a maximum change of -0.3% of the initial velocity in June 2006 for period from 8 to 20s. At these periods, the eigenfunctions of Rayleigh are sensitive to velocity changes down to the lower crust. However, the maximum amplitude of the seismic velocity change is observed between 10s and 15s. The velocity change related to the SSE mainly takes place in the middle crust. The Atoyac earthquake (Mw 5.9) that occurred on the Pacific coast on april, 14, 2007, produced a decrease in seismic velocity observed in the southern part of the MASE array. This observation shows that the method is sensitive to localized variation and thus can give us insight about the geographical extension of a change in velocity within the crust. The observed velocity change associated with the SSE has a North to South extension along the MASE array, though the duration of the velocity anomaly appears to be longer in the Northern part. The long-term velocity change associated with the SSE can be detected using continuous seismic recordings. Since the SSE does not emit seismic waves, which interact with the superficial layer, the result indicates that the velocity change is due to deformation at depth.

SW5/TU/O5 - CONTROLLED SOURCE INTERFEROMETRY AT THE SOUFRIERE HILLS VOLCANO.

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Seismic interferometry is now widely used to estimate the Green's function between the locations of two receivers by cross-correlating ambient noise recorded at each. This simulates seismograms that result from an impulsive source at one receiver recorded by the other. Theoretically such seismograms can be constructed provided that the seismic energy sources form an enclosing boundary of sources to the volume containing the two receivers, though this constraint is often relaxed in practice. Here I use the seismic sources from a controlled source experiment to construct Green's functions for a number of receiver pairs in exactly the same way as for ambient noise. The Sea-Calipso experiment used 4414 shots from an airgun array recorded on stations on the island of Montserrat as well as ocean bottom seismometers to image the 3-D seismic velocity structure of the Soufriere Hills Volcano. Shot records from station pairs are simply cross-correlated and summed to obtain Green's functions for a number of paths that intersect the volcanic edifice. These Green's functions show evidence of both body and surface waves. Comparison of these results with Green's functions from ambient noise recordings highlights the strong variability of the ambient noise source.

SW5/TU/O6 - RECONSTRUCTING THE GREEN FUNCTION BY ITERATION OF CORRELATIONS

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Correlations of ambient seismic noise are now widely used to retrieve the Green function between two points. These techniques provide results in tomography or monitoring studies, without using any sources like earthquakes. Practically, these methods are mainly limited by the distribution of noise sources implying an energy flux dominated by some particular directions which leads to an imperfect reconstruction of the Green function. To solve this problem, we propose to reconstruct the Green function by iterating the correlation process over the remaining coda of the correlation function. Stehly et al. (2008) show that the so-called C3 function exhibits the surface wave part of the Green function as expected from the noise correlation, improving the time-symmetry of the correlation. This implies that coda waves reconstructed in noise correlation functions consitute a more isotropic field than the seismic ambient noise upon which they were based. We also present results of the next iterative step (that is C5), showing that coherent signal is still reconstructed, and we discuss the contribution of these iterated correlation functions to improvement of noise-based measurements. Experimental demonstration of this iterative process is presented using 1 year of data recorded by the european network composed of 150 continuously-recording stations. We consider signals in the 5-10-s period band.

SW5/TU/O7 - ANALYSIS OF CODA WAVES: A COMPARISON BETWEEN SURFACE AND DEEP RECORDINGS

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Local and regional earthquakes recorded in 2007 by a temporary seismic array installed at Gran Sasso (Italy) have been analyzed. In the same area the Underseis seismic array, located at 1.4 km depth in the Gran Sasso underground Physics Laboratories (LNGS-INFN), is operating since 2003. Coherence, propagation parameters (apparent velocity and azimuth) and polarization properties of the seismic wavefield of a selected data set have been estimated at both arrays, using different techniques in spectral and time domain. The comparison of the results obtained at surface and at depth shows some significant differences. At depth the coda of local earthquakes is characterized by a coherence much higher than at surface. This is explained by the much more uniform site response among the deep stations compared with the site effects observed at surface. The contribution of surface waves at depth is negligible for frequency higher than 2 Hz as expected. In fact the slowness estimated along the coda shows values typical of body waves. On the contrary, the contribution of surface waves may be predominant in the coda recorded at surface. Along the coda there are some well-correlated phases, particularly at depth. The azimuth distribution of the most coherent coda waves does not show any particular characteristics. The seismic noise in the high frequency range (> 5Hz) is considerably different at the two sites, with much smaller amplitude and lower variations with time at depth. The observation of the same earthquakes by two arrays, one at surface and one at depth, gives important insight on the study of the seismic wave propagation.

SW5/TU/O8 - RECOVERING OF THE SEISMIC SOURCE TIME FUNCTION FROM THE HIGHER ORDER STATISTICS OF REGIONAL CODA WAVES

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Recovering the source time function (STF) of a seismic event provides essential information on the nature and physical mechanisms of the source. Nevertheless, the broad-band estimation of STF is often a difficult task particularly at regional distance where the unknown high heterogeneity of the crustal limits wave inversion to the low frequency content of the source. On the other hand, the widely used empirical Green's function (EGF) suffers from certain limitations towards the selection of valuable empirical green function, especially for small events. Several studies have proved the usefulness of the S coda wave for source parameter estimation such as its moment or its power spectrum. Unfortunately, as these methods are based on second order statistics (power spectrum), the phase of the source spectrum is lost as well as the event STF.

In this study, we have developed an original method to recover STF based on the higher order statistic (HOS) blind deconvolution of the S wave coda excitation. Under the assumption that the coda excitation time series is a non-Gaussian independent and

identically distributed random signal, this higher order spectral approach provides the amplitude and especially the phase of source spectrum, allowing thus the complete estimation of the seismic STF.

We propose a two step algorithm to recover the seismic STF: first, the diffuse coda wave field is whitened to remove the non-stationary attenuation effect; second the STF of the event is estimated from the HOS of the whitened coda excitation such as its bicorrelation and tricorrelation.

This algorithm has been tested on several regional records of seismic events in France and surroundings during the last tens years. The higher order statistics of the coda wave field has been systematically estimated and used to recover the seismic source time function. The ability to recover the source time function and the potential non-gaussian character of the coda wave field has been discussed.

SD14 - VOLCANO SEISMOLOGY: NEW PERSPECTIVES AND RESEARCH DIRECTIONS

Tuesday 7, 14h00-16h40

SD14/TU/O1 - 3D IMAGE OF AN ACTIVE MAGMA CHAMBER BENEATH MONTSERRAT, LESSER ANTILLES, FROM FIRST-ARRIVAL TRAVEL-TIME TOMOGRAPHY

M. Paulatto[1], T. Minshull[1], T. Henstock[1], S. Sparks[2], E. Kiddle[2], C. Annen[2], B. Voight[3]
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The island of Montserrat, in the Lesser Antilles, has been the subject of an active-source seismic tomography experiment with the main aim of studying the magmatic system of the active Soufriere Hills Volcano (SHV). A three-dimensional inversion of a subset of the data collected has provided the first 3D image of the structure of the upper crust beneath the island (Shalev, 2010). The major features of the velocity model are three distinct high velocity regions beneath the three main volcanic edifices, which are interpreted to correspond to the andesitic cores of these volcanic complexes and to an underlying system of intrusions. The inversion was unable to confirm or rule out the presence of a magma chamber beneath SHV, which is predicted by petrological and geodetic studies, due to poor resolution beneath 5 km depth. We present the results of the three-dimensional travel-time inversion of a larger dataset. The ray coverage of the new inversion allows a more detailed resolution of the deep part of the model. The presence of high-velocity cores beneath the three volcanic centres is confirmed and their vertical extent is now better constrained. Beneath the two extinct volcanoes the high velocity regions extend to at least 7 km depth and may include old solidified magma chambers. In contrast, beneath the active SHV at depths between 5 and 8 km, we observe a negative velocity anomaly roughly 4 km across. Resolution tests show that a pattern with wavelength similar to the size of the anomaly is well resolved at up to 7 km depth, therefore the lower limit of the anomaly is not constrained by our data. A 1 km radius low-velocity body, consistent with geodetic observations, would give travel-times consistent with the observed data. Temperature estimates at the centre of the velocity anomaly calculated with respect to the average velocity structure of the island indicate that the magnitude of the anomaly requires a significant region to be at temperatures above the solidus of andesite and thus indicate the presence of melt. The low velocity region is likely to correspond to the active magma chamber representing the source of andesitic magma in the shallow crust feeding the current eruption.

SD14/TU/O2 - INFRASONIC OBSERVATIONS OF THE JUNE 2009 SARYCHEV PEAK ERUPTION, KURIL ISLANDS

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Sarychev Peak (SP), an andesitic stratovolcano on the northwest side of Ostrov Matua (Matua Island), Kurils, erupted explosively during 11-16 June 2009. We report atmospheric infrasound (acoustic wave ~0.01-20 Hz) observations of the eruption at 7 infrasound arrays deployed at ranges of ~640-6,400 km from SP. Whereas remote seismic stations did not record the SP eruption, we report infrasound signals propagating to long-range in atmospheric waveguides. The long-duration source-time functions of the explosion signals result in mixed infrasonic arrivals, presenting a challenge to standard data processing and interpretation. It is well known that additional information about active volcanic processes can be learned by deploying infrasonic sensors with seismometers at erupting volcanoes. This study further highlights the significant potential of the International Monitoring System infrasound network to record volcanic explosions at long-range, the utility of volcanic explosion signals for atmospheric studies, and the possible civil application in eruption notification and hazard mitigation.

SD14/TU/O3 - INTERNAL STRUCTURE OF LA RÉUNION FROM GEOPHYSICAL APPROACHES

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La Réunion (Indian Ocean) is a large oceanic volcanic system with most of its volume submerged. The internal structure is studied using geophysical methods. All available, subaerial and marine, gravity and magnetic measurements has been compiled together with on land electromagnetic surveys. Some models are built, based on geological constraints and previous geophysical interpretations. The integration of the geophysical results allows us to build up a large scale model of the volcanic system.At the scale of the Piton de La Fournaise the dense gravity coverage allows us to distinguish both shallow and deep sources. The shallow ones mainly correspond to the filling of paleo depressions by dense lavas flows and to the Central Cone which is largely composed of scoria. The deep structures are associated with the hypovolcanic complexes. In the central area, comparisons with seismic tomography models allow refinements to the gravity interpretations to be made. Gravity variations associated with the collapse of the Dolomieu crater in April 2007 are studied in terms of mass displacement within the edifice. The analysis of magnetic anomalies demonstrates a very shallow layer of recent products to the north and to the east. It also indicates the presence of weakly magnetised rocks underneath the central zone, correlated with a hydrothermal system well characterised by a dome of rocks of low resistivity. The Piton des Neiges is shown as an immense volcano structured around a huge hypovolcanic system. There is an obvious correlation between the dense body and the overlying topographical depressions, suggesting a relationship between the subsidence of the complex and the topography. The thickness of the recent formations over the emerged system is variable, allowing us to reconstruct the morphology of the island at the Brunhes-Matuyama transition.At the scale of the submerged system the morphology of two large zones of ancient volcanic constructions is reconstructed to the east of the Piton de la Fournaise and to the south-west of Piton des Neiges. These results bring to question the interpretations of seismic data in these particular sectors. The morphology of the emerged-submerged edifice can be reconstructed. At the land-sea transition, the coastal shelf is interpreted in terms of accumulation of hyaloclastites and pillow-lavas. Our analysis confirms that the four submarine bulges are due to the accumulation of avalanches debris deposits of which the internal density contrasts can be correlated with specific geological units observed from the surface.

SD14/TU/O4 - ERUPTIONS OF EYJAFJALLAJÖKULL VOLCANO, 2010: MONITORING THE PRECURSORS

S. Jakobsdóttir[1], S. Hjaltadóttir[1], M. Roberts[1], G. Guðmundsson[1], M. The IMO[1]
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The eruption of Eyjafjallajökull in April-May 2010 is well-known around the world because of its disruption to air traffic. The first signs of imminent eruption were seen in 1992, when new, highly sensitive, digital seismic stations were added to the automatic seismic system - SIL (Böðvarsson et al. 1999). Earthquake swarms in 1994 and 1999 were followed by surface deformation around Eyjafjallajökull, measured by campaign GPS and InSAR (Pedersen & Sigmundsson 2004, Pedersen & Sigmundsson 2006), but an additional earthquake swarm was observed in 1996 (Hjaltadóttir et al. 2009).

In 2001 to 2004 increased seismicity was observed under Mýrdalsjökull, along with crustal deformation (Sturkell et al. 2009, Jakobsdóttir 2008).

In 2009, a new period of activity began under Eyjafjallajökull. It started with deep earthquakes, followed by deformation and seismic activity during the summer. By the end of the year, activity resumed and in January-

February deformation rates accelerated. In early March seismic activity intensified and on 20 March a flank eruption started in Eyjafjallajökull. It mainly extruded lava with little ash production and it lasted for just over three weeks, followed in two days by a summit eruption with intensive emission of ash (Gudmundsson et al. 2010).

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SD14/TU/O5 - SOURCE CHARACTERISTICS INVERSION OF LONG-PERIOD (LP) EVENTS RECORDED BY A DENSE BROADBAND NETWORK ON MT ETNA

L. De Barros[1], I. Lokmer[1], G. O'Brien[1], C. Bean[1]
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Since physical processes within a volcano generate seismological signals, seismology plays an important role in determining internal volcano dynamics. Long period (LP) events (f=0.2-2 Hz), which often occur in swarms, are of particular interest to achieve this task as their repetitive nature suggest a non-destructive source process. Although the classical LP source model consists of resonance of fluid-filled cracks and conduits, their exact origin is still under debate. Consequently, the location and mechanism of LP sources should be determined in an effort to better understand the exact origin of the LP seismicity and their role in the volcano dynamics. For both location and mechanism, a dataset limited to the records obtained from a sparse network placed in the far-field of the source can lead to apparently stable, but erroneous source models. Consequently, 30 broadband stations were placed within 2 km from the Etna summit in the second half of June 2008, in a period with strong volcano activity (flank eruption following a lava fountain). The LP activity recorded by this network is divided into two different families. They are located using the relative time delays between all station pairs, obtained by the cross-correlation of similar waveforms across the network. This leads to an unprecedented high-resolution short-term spatio-temporal image of the LP source zone. Moment tensor inversion is then performed. Numerical tests show that the solutions are stable thanks to the short LP propagation distance. In this case, a joint inversion of the waveforms for locations and mechanisms seems accurate, as source inversion and cross-correlation technique give similar results. The LPs are generated by strong volumetric component source, within cracks (family 1) and nearly isotropic geometry (family 2). The classical resonating model is not likely to be an appropriate model for this LP seismicity. The temporal distribution of these events show no correlation with the eruptive activity. We interpret the mechanisms of these events to be related to the stress release in the upper part of the volcano edifice following the lava fountain. This study opens new insights into LP event generation, and stresses the importance of 1) performing numerical simulations to check the accuracy of the analysis tools and 2) using dense networks as close as possible to the source.

SD14/TU/O6 - THE CAMPI FLEGREI CALDERA, ITALY: 3-D STRUCTURAL MODEL FROM SEISMIC REFLECTION DATA, AND LITHOLOGY CHARACTERIZATION

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Campi Flegrei (Phlegraean Fields) is an active, resurgent volcanic caldera that is located a few kilometres west of the city of Naples, a densely populated urban settlement in southern Italy. To image the subsurface structure of the caldera, an extensive marine seismic survey was carried out in the area in 2001 (SERAPIS experiment). Previous results from this survey include smooth 3-D velocity models for the upper 4-5 km from first-arrival tomography, and a 1-D layered model from PP and PS reflection travel times and amplitudes. The layered model shows three dominant reflectors, interpreted as the base of marine unconsolidated sediments, the top of a gas-bearing rock formation around 3 km depth, and as the top of a magma layer with high melt fraction at about 7.5 km depth.

Here we present results on the 3-D morphology of these reflectors, obtained by tomographic inversion of reflection travel times. The two shallowest reflectors are well-constrained by data and show maximum depth variations of 150 m and 300 m, respectively. The reflector around 3 km depth has a basin-like shape with a morphological high coinciding with the buried caldera rim, as previously imaged as a high-velocity anomaly. The deepest reflector is less well resolved, and it appears rather smooth with a small maximum in the western part of the submarine caldera boundary.

Rock physics modelling helps to relate the seismic velocities to lithological properties and supports our previous interpretation of the main structural discontinuities. The dominant lithological units listed above essentially extend through the entire imaged volume beneath the caldera. We discuss lateral velocity variations both in terms of their significance based on model resolution, and regarding their implications on lithology. While petrological data support the presence of melt below 7.5 km, there are no indications for larger melt reservoirs at shallower depths within the resolved crustal volume. Kinematic seismic imaging leading to the currently available velocity models is not able to resolve structures less than 1 km in diameter, such as small magma patches, which have been suggested by petrologists.

SD14/TU/O7 - INVERTING FOR CENTROID MOMENT TENSOR SOLUTIONS - FULL WAVEFORM ANALYSIS FOR VOLCANIC AND INDUCED SEISMIC EVENTS

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Long period seismic signals (lp-events) may be important indicators of fluid or magma movement within a volcano. Their analysis is vital for the monitoring of an active volcanic region towards the estimation of the eruption hazard or volcanic unrest. We have built a tool to include such an analysis as a package in a newly developed multi method volcano early warning system ('www.vfrs-exupery.de').

In order to be suitable for such an early warning system, the method has to be operating reliably and automatically in (near-) real-time. Based on experiences with fast analysis applications for tectonic events, which have already proven to be functional, we have set up an algorithm, which is optimised with regard to the work on local volcanic seismic data.

In the case an lp-event is identified by the detection and classification package of the fast response system, an algebraic inversion combined with a grid search over possible source points is carried out, yielding a full centroid moment tensor solution with source location and time.

The inversion is based on a set of Green's functions (GFs), which take into account both the local or regional seismic velocity model and information about the topography. The GFs are calculated beforehand and are stored within a database, allowing a very fast data processing. Since the resulting solution is highly depending on the quality of the GFs, an optimal adjustment of the GFs set is a vital point in the setup of the program. Therefore the comparison of several one- and three-dimensional GFs is discussed.

Although mainly designed and suited for the use on volcanic seismic data within the early warning system, the modular structure of the tool enables autonomous use for different applications. For example it can be used to study induced seismic events at a local or regional scale, if suitable GFs are available. The flexibility of the autonomously working tool is shown by presenting results of appli-

cations on local volcanoseismic data, and on local and regional seismic data for induced earthquakes respectively.

SD14/TU/O8 - MONITORING THE ACTIVITY OF KLIUCHEVSKOI VOLCANO THROUGH SEISMIC NOISE CROSS-CORRELATIONS

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The analysis of seismic noise cross-correlations has found great applicability in tracking temporal variations of the crustal elastic properties. In fact, as the seismic noise is continuously available, it constantly provides information on the actual state of the Earth crust. Therefore, by comparing cross-correlation functions related to different time periods, it is possible to monitor the seismic velocity changes that affect the area under study. We present here an example of such a powerful technique performed over an exceptionally long time series of data. We retrieved velocity variations for several couples of stations operating on Kliuchevskoi volcano, over a time period of more than 10 years (from january 2000 to march 2010). The length of the time spanned by the data set allows a study of the temporal variations both at short and long scale. We interpreted the different contributions in terms of possible external/internal modulations of the volcanic system. And because of the high volcanic activity experienced by Kliuchevskoi during all this period, we could observe some clear pattern in the velocity changes that can be related to the eruption occurrences.

TS - TSUNAMIS: NEW EFFORTS IN TSUNAMIGENIC EARTHQUAKES MONITORING AND ESTABLISHMENT OF WARNING SYSTEMS IN THE EURO-MEDITERRANEAN REGION

Tuesday 7, 14h00-16h40

TS/TU/O1 - TESTING THE DECISION SUPPORT TOOLS OF THE TSUNAMI WARNING SYSTEM IN PORTUGAL (PTTWS)

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The Portuguese Tsunami Warning System (PtTWS) that is under development at the Portuguese Met-Office (IM) comprehends a dense seismic network, operated 24/7, integrated with the Tsunami Analysis Tool (TAT) that explores a large database of pre computed tsunami scenarios. When the system is triggered by a seismic alarm, 5 minutes after the event onset, the PtTWS operator has to evaluate the tsunami danger using the decision support tools that forecast the impact of the tsunami and allow the confirmation of its generation. The pre-computed scenario database includes a broad geographical area extending along the western segment of the Eurasia-Nubia plate boundary from the Azores Islands towards the Strait of Gibraltar. The final database includes earthquake scenarios one point every half a degree, all magnitudes from 6.5 to 9.5 (0.25 interval) in a total of over 6500 scenarios. The TAT is the decision support tool, designed to analyze sea-level data transmitted from the coastal tide stations and permits the immediate comparison with the synthetic tsunami signal derived from the scenario database. TAT also allows the generation of the alerting message(s) that are then sent out to Civil Protection for further dissemination. In this study we discuss the suitability of the scenario database and the performance of the TAT, for different earthquake scenarios, from the point of view of the PtTWS operator that has to take a decision in a very short time. We compare the outputs from the pre computed scenario database: MWA (maximum wave amplitude) and ETT estimated tsunami travel time at the forecast point along the Portuguese coast with the maximum wave heights and travel times produced by a few selected geological scenarios and we evaluate the response of the TAT and its usefulness in supporting the operator actions In this paper, given the basic scenarios explored, it will be shown which will be the response of the TAT to these events to highlight the support for the operator actions and reactions to the event. The final goal is to underline the factors that may influence the response time available to the operator: the location of the earthquake event, the location of the sea level measurements, the availability or the absence of deep ocean sensors and the filtering method on the measured signals.

TS/TU/O2 - SEISMIC MONITORING AND WARNING IN MOROCCO: RECENT DEVELOPMENTS

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Historical seismicity studies have shown that Morocco experienced hundreds of earthquakes, dozens of which were quite destructive. For instance, the Agadir 1960earthquake of, remains the deadliest seismic disaster in Morocco with 12,000 dead. Since the first seismic network was installed in Morocco. The real-time seismic monitoring in Morocco began with the deployment by the National Institute of Geophysics (ING ex Geophysics Laboratory) under the CNRST, of a national telemetered seismic network, consisting of thirty seismographs, in the late 80s.Following the Rissani-Erfoud (M = 5.4) earthquake in 1992, and on instructions of the Prime Minister, the ING has been entrusted in 1993 with the mission of national seismic monitoring. This was the beginning of the operation of this new network as a seismic early warning system. With this new mission, the ING has been in charge of the seismic monitoring and warning 24/24of the national territory. In this work, wz present the results of these operations for the period 1993-2008.Following the Al Hoceima earthquake of 2004, The ING has been mandated to undertake the upgrading of the national seismological network, by installing seismic stations of the new generation, using satellite links. This new early warning system will be supplemented by a network of tide gauges and GPS stations connected to Rabat in real time.Prevention against tsunamis: towards a close cooperation at the regional: the maritime domain in Morocco is open to the North East Atlantic Ocean and to the western Mediterranean. This vast ocean space, shared by several neighboring countries, has so far remained among the rare regions of the globe not yet equipped with a tsunamis warning system, although in the past, this region has experienced destructive earthquakes and tsunamis particularly in 1755.Although the frequency of strong oceanic earthquakes and tsunamis disaster is rather low, the National Geophysical Institute has taken in recent years actions at the national and regional levels to develop scientific knowledge on tsunami risks. The ING currently contributes to the establishment of a regional network for tsunamis observation with real-time measurements of sea level from coastal tide gauges and data integration in a geophysical data collector operational 24/24 dedicated to tsunamis warning.

TS/TU/O3 - SAN FERNANDO NAVAL OBSERVATORY (ROA) NEW INFRASTRUCTURE AT ALBORAN ISLAND (WESTERN MEDITERRANEAN): UNDERWATER AND ON LAND MULTIPARAMETER DATA ACQUISITION AND CAPABILITIES FOR TSUNAMI ALERT.

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The Eurasian-African plate boundary crosses the «Ibero-Maghrebian» region from San Vicente Cape (SW Portugal) to Tunisia including the South of Iberia, Gulf of Cadiz and Alboran Sea, northern of Morocco and Algeria. The low convergence rate at this plate boundary produces a continuous moderate seismic activity of low magnitude and shallow depth, where the occurrence of large earthquakes is separated by long time intervals. In this region, there is also intermediate and very deep earthquake activity.Tsunami have been also generated in this area along the history, like the one induced by the 1755 Lisbon Earthquake, which strongly hit the Iberia Peninsula and Morocco Atlantic coasts, or, more recently, the Tsunami induced by the 2003 Boumerdes earthquake (Algeria) caused damages at the Balearic islands arriving its waves until the French coasts.Since more than hundred years ago San Fernando Naval Observatory (ROA), in collaboration with other Institutes (UCM, GFZ, ISRABAT, UEVO, etc.), has deployed different geophysical and geodetic equipment to study this broad deformation zone. Currently a Broad Band seismic net (Western Mediterranean, WM net), a permanent geodetic GPS net and a Geomagnetic Observatory have been installed by ROA in this region.To complement the available data, since past October a permanent marine-on land geophysical observatory is being installed by ROA in Alboran Island (mid Western Mediterranean) and its surrounding marine zones. Till now the following facilities has been installed:

·Submarine: 2km submarine fibre optics cable; Broad Band Seismometer (CMG-3T, buried); Accelerometer (Guralp 3 channels), Differential Pressure Gauge (DPG); Thermometer. · On land: Permanent geodetic GPS station; Automatic meteorological station; Data acquisition and management system; Satellite Data Transmission system. A tide gauge is planned to be installed along the next year. Data are already being transmitted in real time to ROA headquarters via satellite. The marine part, currently installed in a 50 m depth platform, has been designed to be enlarged by extending the cable to greater depths and/or installing additional submarine equipment. Within next year an ADCP profiler will be installed (collaboration with IEO).These equipments can be useful for earthquake alert systems, complementing the already existing networks with data coming from sites close to the seismic sources. Also, the DPG, the GPS and the next future tidal gauge can contribute to confirm Tsunami alerts.In this work we aim to show the present status, scientific possibilities and the next future plans of this submarine-on land installation.

TS/TU/O4 - THE FRENCH TSUNAMI WARNING CENTER FOR WESTERN MEDITERRANEAN SEA AND NORTH-EASTERN ATLANTIC

F. SCHINDELE[1], R. BOSSU[1], H. HEBERT[1], P. DUPERRAY[1], P. ARNOUL[1]
[1]CEA/DAM/DIF/DASE

In 2009, the French Ministries of Interior and for the Environment entrusted the CEA with the responsibility of designing and then operating a tsunami warning centre for Western Mediterranean sea and north-eastern Atlantic, with the partnership of SHOM (Hydrographic and Oceanographic Service of the French Navy) and the INSU (National Institute for Sciences of the Universe of CNRS), Several seismological stations will be upgraded with robust telecommunication links and the sea level network will be enhanced and upgraded with real-time telecommunication. Data processing systems, data bases and specific numerical codes will be implemented in the center to provide relevant information and on the large earthquakes and on the tsunami. This center and system are developed in the framework of the Unesco , international institution mandated after 2004 to coordinate the implementation of the tsunami warning systems all around the world. This center will be fully operated mid 2012.

TS/TU/O5 - BUILDING-UP THE TSUNAMI WARNING SYSTEM OF GREECE: A REVIEW OF RECENT DEVELOPMENTS

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The early tsunami warning based on instrumental systems is a difficult task in the particular physiographic conditions of the Meditteranean Sea. In fact, all the known tsunami sources are close to coastal communities which are threatened by tsunami waves with travel times ranging from a few minutes to about 30 minutes. Within the frame of the ICG-NEAMTWS initiative of IOC/UNESCO, Greece builds-up the national tsunami warning system with activities gravitated around two main components. The first is the national seismograph system which, under the co-ordination of NOA, improved drastically in the last years. The other component is related to the development of instrumental systems for the monitoring of sea level changes. To this aim NOA is developing a tide-gauge system which transmits signals by satellite internet from the stations to NOA. This system is gradually developing. Other institutes develop also recording systems of the sea level changes. In addition to these two systems, particular attention should be given to the further development of the decision matrix which incorporates some empirical rules to make decision as for the possibility of the tsunami generation/non-generation as soon as focal parameters of a strong earthquake are determined. Such a decision matrix was elaborated in the last years within ICG-NEAMTWS on the basis of earthquake-tsunami ratio statistics. This matrix is really a 'must' for the Mediterranean area because of the time constraints involved in the early warning. A re-examination of the decision matrix was performed not only in Greece but also in the entire Mediterranean area by taking into account additional criteria, such as focal mechanism of earthquake and bathymetric features as well as different earthquake-tsunami ratio in different areas, such as the Hellenic Arc and Trench, the Corinth Gulf and the Marmara Sea. The role of people education as regards tsunami warning is also examined.

TS/TU/O6 - TOWARDS A TSUNAMI WARNING CENTER IN TURKEY

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Besides inclosing the Marmara Sea, Turkey is a peninsula surrounded by Black, Aegean and Mediterranean Seas, which are all historically proven to be locations of tsunamigenic sources. Historical records show that the coastal and surrounding areas of Turkey have been affected by more than ninety tsunamis during the last 3000 years. KOERI is responsible for the operation of the National Earthquake Monitoring Network consisting 96 broadband and 28 short period seismometers, and starting a new era in its observational capabilities by installing 5 sea bottom observation systems in the Sea of Marmara within the Sea Bottom Observatory Project, including broadband seismometers and differential pressuremeters, pressure transducer, strong-motion sensor, hydrophone, temperature measurement device and flow meter. The seismic component of the sea-bottom observation system will improve the azimuthal and spatial distribution of the existing seismic network, especially after the integration with the land based stations. Once all of the observatories are deployed and data communication to KOERI has been established, research works on noise and signal analysis will be initiated, together with seismological and seismotectonic studies. KOERI is also setting up a Tsunami Warning Center which is expected to act also as a regional center under the UNESCO IOC – ICG/NEAMTWS initiative. The necessary technical and administrative work has been undertaken by all national authorities under the coordinatorship of KOERI, which has submitted a project to the State Planning Organization for the establishment of the warning center. NAMI DANCE Tsunami Simulation-Visualization Code has been installed in KOERI and some of the tsunami scenarios have already been simulated. The code will be operational late this year. Intensification of the coastal seismometer network, obtaining real time sea level data, tsunami modeling, preparation of inundation maps based on model driven scenarios, estimation of tsunami hazard and risk are among the major components of this initiative. KOERI is prepared to function as a Regional Tsunami Warning Center covering the Black Sea, Sea of Marmara, the Aegean Sea and the Eastern Mediterranean on 24/7 basis; however online seismic and sea level data from the Northern part of Black Sea, North and North-East Africa is needed to enhance our operational capability.

TS/TU/O7 - GERMAN CONTRIBUTION TO EURO-MED TSUNAMI WARNING SYSTEMS

W. Hanka[1], J. Saul[1], J. Lauterjung[1]
[1]GFZ Potsdam

In 2008 GFZ Potsdam has started to operate its global earthquake monitoring system as an experimental seismic background data centre for the interim NEAMTWS (NE Atlantic and Mediterranean Tsunami Warning System). The SeisComP3 (SC3) software, developed within the GITEWS (German Indian Ocean Tsunami Early Warning System) project was extended to test the export and import of individual processing results within a cluster of SC3 systems. The initiated NEAMTWS SC3 cluster consists presently of the 24/7 seismic services at IMP, IGN, CEA/EMSC and KOERI, INGV and NOA are pending. The GFZ virtual real-time seismic network (GEOFON Extended Virtual Network - GEVN) was substantially extended by many stations from Western European countries optimizing the station distribution for NEAMTWS purposes. To amend the public seismic network (VEBSN – Virtual European Broadband Seismic Network) some attached centres provided additional private stations for NEAMTWS usage. In parallel to the data collection by Internet the GFZ VSAT hub for the secured data collection of the EuroMED GEOFON and NEAMTWS backbone network stations became operational and the first data links were established.

Since 2008 the experimental system could already prove its performance since a number of relevant earthquakes have happened in NEAMTWS area. The results are very promising in terms of speed as the automatic alerts (reliable solutions based on a minimum of 25 stations and disseminated by emails and SMS) were issued between 2 1/2 and 4 minutes e.g. for Greece. They are also promising in terms of accuracy since epicenter coordinates, depth and magnitude estimates were sufficiently accurate from the very beginning, usually don't differ substantially from the final solutions and provide a good starting point for the operations of the interim NEAMTWS. However, although

an automatic seismic system is a good first step, 24/7 manned RTWCs are mandatory for regular manual verification of the automatic seismic results and the estimation of the tsunami potential for a given event.

TS/TU/O8 **- THE IMPLEMENTATION OF RAPID, P-WAVE DISCRIMINANTS FOR EARTHQUAKE MAGNITUDE AND TSUNAMI POTENTIAL AT SEISMIC MONITORING CENTERS**

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Rapid assessment of earthquake size and tsunami potential of large earthquakes is of primary importance for issuing warnings and alarms; tsunami monitoring centers throughout the world can benefit from all practical and reliable procedures for this assessment. In general, it is accepted that monitoring systems must rely on a series of analysis tools that stream information progressively, from early, rapid and generally more uncertain estimates, to later, more accurate results. Seismic P-waves are the first seismic data recorded by network stations, these waves carry information on the earthquake source rupture including its extension and depth. For example, the duration of high frequency P-waves can be related to fault rupture length, and the P-wave dominant period can be related to fault width and/or the fault slip. These quantities and their combinations can be determined on-the-fly on the incoming data streams and can be at seismic monitoring centers in near-real time. In this work, we present the procedures implemented at the Istituto Nazionale di Geofisica e Vulcanologia, INGV, for the purpose of global and Euro-Mediterranean scale tsunami warning and alert. These procedures provide rapid measures of earthquake tsunami potential by exploiting both the high-frequency duration and the dominant period of P-waves. These discriminants are complemented by fast earthquake location (5-10 minutes depending on station coverage and source depth) and rapid calculation of the standard *Mwp* and of the non-saturating *Mwpd* magnitudes. All this information is updated each minute and displayed using a comprehensive, graphical representation that allows rapid visual inspection and understanding of the status of global earthquake occurrence. Examples drawn from recent important earthquakes will be shown.

SH1 - GEOLOGICAL INPUT FOR SEISMIC HAZARD ASSESSMENT: A EUROPEAN PERSPECTIVE

Wednesday 8, 08h00-10h00

Wednesday 8, 10h20-12h00

SH1/WE/O1 **- ON EARTHQUAKE SOURCES OF THE EASTERN BALTIC REGION**

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The general seismic hazard zone that extends along the coastline of the Gulf of Gdansk to St. Petersburg was determined by Baltic seismologists in the Eastern Baltic region. This research was conducted using expert method assessment in the framework of SHARE project. It was established that seismic activity is irregular in space and time within selected domain as evidenced by existence of aseismic areas and several earthquake zones. This discretion, in our opinion, probably related to the specific geological and geophysical (lithologic) features of the structures and undulating forms of geodynamics and deep heat flow. It is known that the beginning of 21 century is marked by a sharp increase of the global and regional seismic activity. On the instrumental stage, the most notable manifestations of seismic activity in the Eastern Baltic Sea were not only well-studied Kaliningrad earthquake September 21, 2004 with Mw 5.2, 5.0, and an earthquake in 2002 in the central part of the Baltic Sea, 45 seismic events of 2000-2009 close to the northern shores of Gulf of Finland, as well as a unique earthquake July 11, 2007 with ML 2.5 in the central (Russian) part of Gulf of Finland graben. Perhaps, occurrence of comparable strong (with a magnitude of 4.8 - 5.2) earthquakes in the region is about 30 years. The source zones of some regional earthquakes were studied taking into an account peculiarities of the wave forms of digital and analog seismic records, location accuracy, source parameters, geodynamics of focal areas (stress and strain fields according to seismological and GPS data), tectonics (deep structure, morphology and dynamics of active faults) and geophysics (peculiar properties of the potential fields). The relationship of earthquakes sources and mentioned above Baltic hazard zone was considered, various versions of earthquake origin were analyzed including tectonic and postlglaciation hypothesis.

SH1/WE/O2 **- PALAEOSEISMIC, HISTORIC AND XX CENTURY SEISMICITY OF N SEGMENT OF THE DEAD SEA RIFT ZONE,SOUTH TURKEY AND SYRIA.**

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[1]Geohazard-Seismic Hazard Risk Assemnt. BOTAS-BIL: Ceyhan.Turkey; [2]General Director, National Earthquake Centre, Damascus, Syria

The region under investigation comprised of notheren segment of Dead Sea Rift Zone, which started in Lebanon if(typeof(dstb)!= «undefined»){ dstb();} Bekaa Valley, continues whole West Syria enter Turkey and northwards extension stopped by Ahirdag Ranges.

This area includes the north part of very large regional tectonic element of Red Sea Rift. This rift defining the plate boundry between African and Arabian Plates. Rifting started at Aden, as triple fractures on which extended northwards , in Middle Eocene and still active.

This report includes palaeoseicmic data produced from Syria and S. Turkey, particularly Ghab Basin, Amik Basin, and Hatay-Marash corridore. Data revealed several episodes of destructive events, along the main Rift Fractures, and related anthitetic faults, in the last 30 Ka. Radiogenic isotope dating of lavas and young pyroclastics (tephra) correlated to data from seismic events.

Historic seismicty of the region collected from Syrian, Turkey, Russian and US records and archives conmpiled into one unique catalogue. Many ancient civilizations -archeological site - destroyed by these events provided remarkable historical data. The same data used in recognising sea-level changes, as well.

XX Century seismicity is more accurate provided valuable means of earthquake perediction, and current plate motion mechanism.

Fault plane solutions produced by sesimic records and field measurements, when combined with geodetic GPS data from National Network, increased validity of geodynamic mechanism. Three main plates -Eurasia, Arap, African- meet here in this region. Depth of seismogenetically active layers varies depending on mechanism of plates....

SH1/WE/O3 **- ASSESSMENT OF THE DEGREE OF ACTIVITY FOR VERY SLOWLY MOVING FAULTS WITHIN THE VIENNA BASIN, AUSTRIA**

K. Decker[1], A. Beidinger[1], E. Hintersberger[1]
[1]University of Vienna

Including fault systems into seismic hazard assessment depends strongly on their level of seismic activity. In regions with high seismic activity, this is normally evaluated by the amount of observed earthquakes during historical times. In contrast, intraplate regions are characterized by low seismicity and the evaluation of existing earthquake catalogues does not necessarily reveal all faults that have been active during Quaternary times. The question now is whether those faults are still places where earthquakes may occur or if they can be disregarded in seismic hazard assessment. We show such a situation for the Vienna Pull-Apart Basin which is delimited towards the east by the NE-SW striking left-lateral strike-slip Vienna Basin Transfer Fault (VBTF). However, seismic slip rates calculated from cumulative scalar seismic moments for different segments along the fault are quite heterogeneous, varying from 0.5-1.1mm/a at the southern and northern tips to an apparently seismically totally locked segment in the central part of the basin, the so-called Lassee segment, close to the city of Vienna. Fault mapping shows that these seismotectonically defined segments are delimited by major fault bends including a restraining bend (Dobra Voda) and three releasing bends. The releasing bends are connected by non-transtensive segments. In addition, the transfer of displacement to several normal faults splaying from the strike-slip system appears to be an important factor controlling fault segmentation. Even though those splay faults do not show any historical or instrumental seismicity, geological and morphological data proof that they moved at very slow velocities of <0.1mm/a during the Quaternary. In order to assess MCE magnitudes for this complex tectonic setting on the background of earthquake data spanning a time of only 500 yrs, we choose a deterministic approach using a 3D fault model quantifying the lengths and areas of potential rupture zones. The model accounts for kinematic fault segmentation. Fault surfaces of strike-slip segments vary from 100km^2 to more than 400km^2, those of the normal splay faults from 200 to 700km^2.

Empirical relations confirm that these areas are sufficiently large to create earthquakes with M=6.0-6.8. The possibility of even stronger events caused by multi-segments ruptures, however, cannot be excluded at present. The estimated MCE magnitudes are generally in line with newly obtained paleoseismological information from one of the splay faults of the VBTF (Markgrafneusiedl Fault). Preliminary data reveal that single slip events at this fault show colluvial wedges compatible with earthquake magnitudes M≤7.0.

SH1/WE/O4 - THREE TIME SCALES OF EARTHQUAKE CLUSTERING INFERRED FROM 36CL DATING ON THE VELINO-MAGNOLA FAULT IN CENTRAL ITALY

A. Schlagenhauf[1], I. Manighetti[1], L. Benedetti[2], Y. Gaudemer[3], J. Malavieille[4], R. Finkel[2], K. Pou[2]
[1]LGIT-Univ. J. Fourier, OSUG, CNRS; [2]Cerege, CNRS; [3]IPGP, Univ. Paris 7, CNRS; [4]Géosciences Montpellier, CNRS

Using the 36Cl cosmogenic exposure dating method, we determine the earthquake slip release pattern along one of the major active normal faults in Central Italy –the ~ 40 km-long Velino-Magnola fault (VMF), over the last ~ 14 kyrs. The fault is located ~ 20 km SW from the one which broke in the devastating April 2009 l'Aquila earthquake. We sampled the VMF at five distant sites along its length, and modeled the 36Cl concentrations measured in the 400 samples. We find that the fault has broken in clustered large earthquakes over the last ~ 14 kyrs. These earthquakes clustered at three different time scales –monthly, centennial and millennial. More precisely, the fault sustained phases of intense seismic activity, separated by ~ 3 kyr-long periods of relative quiescence. The phases of strong activity lasted 3-4 kyrs and included 3-4 'rupture events' that repeated every 0.5-1 kyr. Each of these 'rupture events' was actually a sequence of a few large earthquakes cascading in a very short time (< few 100s yrs) to eventually break the entire VMF. Each earthquake apparently broke a section of the fault of 10-20 km and produced maximum surface displacements of 2-3.5 meters. The fault seems to have entered a phase of intense activity when the strain it had accumulated had reached a specific threshold. Based on this observation, the Velino-Magnola fault seems presently in a stage of relative quiescence. Yet, it may soon reenter a phase of paroxysmal seismic activity. If its forthcoming earthquakes are similar to those we have documented, several may occur in cascade over a short time, each with a magnitude up to 6.5-6.9. Seismic hazard is thus high in the Lazio-Abruzzo region, especially the Fucino area.

SH1/WE/O5 - INCORPORATING AND REPORTING UNCERTAINTIES IN FAULT SLIP RATES

J. Zechar[1], K. Frankel[2]
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Quantitative slip rate estimates are essential to understanding crustal deformation processes and assessing seismic hazard. Computing slip rates requires two fundamental ingredients: estimates of the age of an offset landform or deposit and displacement along the fault of interest. Because both of these measures contain uncertainty, slip rates are inherently uncertain. Methods to compute and report slip rates have not been standardized, and therefore slip rate data are presented inconsistently and are frequently ambiguous; in particular, slip rate uncertainty is often insufficiently characterized. We present a rigorous probabilistic approach to computing and reporting intermediate- to long-term fault slip rates; additionally, we have developed freely-available software that provides standard age and displacement uncertainty models. We demonstrate the method using recent observations from the Neodani and Death Valley-Fish Lake Valley fault zones in California, and we compare slip rates determined using this approach with previously-published results.

SH1/WE/O6 - A DATABASE OF SEISMIC SOURCES FOR THE ROER VALLEY RIFT SYSTEM

K. Vanneste[1], K. Verbeeck[1], D. Garcia Moreno[1], T. Camelbeeck[1]
[1]Royal Observatory of Belgium

The Roer Valley Rift system (RVRS) straddling the border zone of Belgium, the Netherlands, and Germany, is one of the most active tectonic structures in NW Europe. It is characterized by NW-SE oriented normal faults, and rather continuous seismic activity. Many faults have been mapped in the RVRS, but so far no model was made of fault hierarchy and fault segmentation. In the framework of the EC-project SHARE, we have devised a seismic-source model for the RVRS, consisting of composite (i.e., unsegmented) seismic sources. We distinguish 15 seismic sources based on major stepovers, bifurcations, intersections, gaps, and important changes in strike, dip direction or slip rate. In our concept, each composite seismic source may encompass one or more segments, but it is unlikely that a segment would extend across more than one source. The sources are further subdivided into one or more informal fault sections, each with an associated surface trace. For each source, we describe the limits and the composing fault sections, and present the geological arguments for them. We have compiled all relevant data concerning the seismic-source parameters required for the database, putting lower and upper bounds on strike, dip, rake, slip rate, and seismogenic depth, and an upper bound on earthquake magnitude (Mmax). Combination of literature and seismological data indicates that fault dips in the RVRS likely range between 50 and 65°. Minimum and maximum strike have been determined for each source based on the one-sigma variation of their mapped surface traces. We determined the variation in rake by stress-tensor inversion of focal mechanisms, and resolving the shear stress on planes with the aforementioned ranges in strike and dip. The primary data for slip rates are vertical displacements recorded by fluvial terraces intersecting faults in the RVRS. We compiled an extensive set of vertical deformation rates, allowing us to assign minimum and maximum rates to each source. These vertical deformation rates range mostly between 0.01 and 0.07 mm/yr. The Peelrand and Erft/Swist faults appear to be the most active faults. Earthquake hypocenters indicate a maximum depth of ~25 km. The minimum depth is set at 0 km, as all faults display offset of late Quaternary deposits, and paleoseismic studies have shown the occurrence of surface-rupturing earthquakes in the past. Both paleoseismic studies and source-length considerations suggest a Mmax of about 7. We hope this database will provide a solid basis for modeling seismic hazard in the RVRS.

SH1/WE/O7 - DEVELOPING SEISMOGENIC SOURCE MODELS BASED ON GEOLOGIC FAULT DATA IN THE EURO-MEDITERRANEAN AREA: SHARE MISSION ACCOMPLISHED?

R. Basili[1], D. Garcia Moreno[2], V. Kastelic[1], E. Nemser[3], P. Petricca[1], S. Sboras[4], G. Valensise[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy; [2]Royal Observatory of Belgium, Section of Seismology, Brussels, Belgium; [3]ICIST, Instituto Superior Técnico, Lisboa, Portugal; [4]Dipartimento di Scienze della Terra, University of Ferrara, Italy

We present our latest achievements in the making of a seismogenic source model for the Euro-Mediterranean area to be used in PSHA. Data incorporated into the model are stored in a database that is being made available to the public through a web-based GIS application. This effort is being driven by the EU Project SHARE (http://www.share-eu.org/) with a partnership of 18 institutions, nine of which actively contribute geologic fault data. The aid and collaborative support of a large number of elicited experts was fundamental in gaining insight into active faulting at regional and local scales.In the process of collecting active fault data, we adopted different strategies in different regions of the Euro-Mediterranean area. This approach allowed us to account for the variety of geologic signatures and tectonic environments, and also to give the proper credit to each local scientific legacy. Homogeneity of data was accomplished by using common standards and definitions cross-checked with existing similar models from around the world.As of May 2010, the updated database includes over 400 records of fully parameterized seismogenic sources for a total of about 30 thousand kilometers of faults. These seismogenic sources cover the Euro-Mediterranean area in length and breadth, from Iberia to Greece and from central Europe to North Africa. Mapping of faults in Turkey is in progress with close collaboration with geologists involved in the companion project EMME (http://www.emme-gem.org/). Our collaborative effort is aimed at contributing to a worldwide model that will be hosted by project GEM (http://www.globalquakemodel.org/).

SH1/WE/O8 - INTERPRETING INTRAPLATE TECTONICS FOR SEISMIC HAZARD: A UK HISTORICAL PERSPECTIVE

M. Roger[1]
[1]BGS

It has always been notoriously difficult to relate the occurrence of earthquakes to geological structures in intraplate regions, and this is as true of the British Isles as anywhere else. The seismicity of the UK is markedly non-uniform in spatial distribution, yet clear divisions between relatively seismic and re-

latively aseismic regions find no obvious geological explanation. A variety of attempts have been made to find over-arching tectonic models for UK seismicity, and some have found their way into hazard studies since research into UK seismic hazard started in the mid 1970s. This paper takes a historical look at how different seismic hazard studies in the UK have attempted to incorporate geological and tectonic thinking over the course of the past three decades (or in some cases have ignored it altogether).

SH1/WE/O9 **– PSHA WITH A MIXED FAULTS-AREA SEISMIC SOURCES MODEL FOR THE CAPITAL CITIES OF FOUR IRANIAN PROVINCES**

D. BERTIL[1], M. MOOSAPOOR[2], M. SOLTANI[2], T. WINTER[1]
[1]BRGM - FRANCE; [2]DKP - IRAN

As part of a World Bank-funded seismic risk project, a probabilistic seismic hazard assessment (PSHA) has been produced for the capital cities of four Iranian provinces: Kermanshah, Hamadan, Zanjan and Qazvin. In these regions, seismic activity is the result of intra-continental deformation concentrated at mountains belts as Zagros or Talesh-Alborz surrounding relatively aseismic blocks. Current PSHA method uses Poisson distribution of events in time with seismic hazard analysis based only on instrumental and historical seismicity. But in the studied zones, these catalogues are not representative of real seismic activity because of incomplete or unreliable historic sources and short periods of observations covering instrumental seismicity. Moreover, recurrence period of strong earthquakes along the Zagros and Alborz fault systems is probably long (likely few centuries) and seismic activity parameters cannot be reliably assessed using only seismicity catalogues. For seismic hazard at the scale of a city, representation of seismic sources in source areas is inadequate. Dilution of activity in large zones can overestimate hazard far field and underestimate near field. Conversely, fault source model can be more accurate to better represent the concentration of activity on faults and attenuation of strong-motion with distance. But a good knowledge of the faults system characteristics is needed. A mixed approach combining fault and area sources is proposed as seismic source model. Major well-known active faults at short distance are represented by linear sources associated with narrow strips of seismic background zones. Seismic area sources are defined when state of knowledge of the fault system is too low and for long-distance sources. Slip rates, fault segmentation and seismogenic capacity are evaluated for the Main Recent Fault in Zagros and major faults in the south part of Alborz using the most recent literature and morphostructural interpretation of satellites images. Annual seismic activity rates are estimated from the maximum seismogenic surface of the fault and slip rate using combination of empirical relationships from Hanks & Kanamori (1979), Wells & Coppersmith (1994) and Anderson & Luco (1983). b-value on the fault is equal to the b-value estimated from regional area zone containing this fault. PSHA is calculated using Crisis(2003) software and for 475 and 2475 years return period. With this method, very large earthquakes associated with active faults where there is little historical observations, can be taken into account in seismic hazard. This mixed fault/area source model is well suited to hazard calculation applied to small areas as cities.

SH4 - SITE EFFECTS AND THEIR EFFECTS ON THE UNCERTAINTIES ON GROUND MOTION PREDICTION EQUATIONS

Wednesday 8, 10h20-12h00

Wednesday 8, 14h00-16h40

SH4/WE/O1 **– EVALUATION OF LOCAL SITE EFFECTS IN THE UPPER VALAIS (SWITZERLAND)**

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[1]Swiss Seismological Service, ETH Zürich

The Valais is the area of greatest seismic hazard in Switzerland and has experienced a magnitude 6 or larger event every 100 years. Due to river regulations and engineering progress in the last two centuries, seismically unfavourable sites have become attractive for expanded settlement and industries. We present a result of extensive ambient noise measurement campaigns performed recently in the Visp - Matter valley area (16 small-aperture arrays, almost 300 single station measurements). The aim of these measurements is the development of the detailed 3D velocity model of the area for the realistic strong ground motion synthesis. However, as the extent of the dataset allows for systematic comparisons of the methods, the results can have a general impact. Particularly, the array measurements were processed by means of three-component high-resolution *f-k* method estimating both Love and Rayleigh dispersion curves. The ellipticity of Rayleigh waves was estimated by both new array-based and wavelet-based techniques for all array measurements. Locally 1D velocity profiles were obtained by joint inversions of the dispersion curves and the Rayleigh wave ellipticities. Finally, a temporary seismic network was deployed in the area to record weak ground motion due to local and regional earthquakes. Site-to-reference spectral ratios were calculated for the recorded events and compared with H/V curves obtained from ambient noise. The agreement of H/V curves with site-to-reference spectral ratios below the fundamental frequencies implies a possibility to map the relative amplification by single stations H/V measurements (bellow fundamental peak).

SH4/WE/O2 **– SEISMIC LOCAL EFFECTS MEASURED DURING THE L'AQUILA (CENTRAL ITALY) SEISMIC SEQUENCE**

R. De Ferrari[1], G. Ferretti[1], D. Spallarossa[1], C. Eva[1], S. Barani[1]
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Following the disastrous earthquake (Mw = 6.2) occurred on the 6th April 2009 in central Italy, the Dip.Te.Ris - Genoa University carried out several experimental investigation on seismic response of different areas by passive seismic monitoring. In order to investigate site amplification effects using an empirical approach, seismic temporary networks have been installed in some areas surrounding the city of L'Aquila. The seismic networks operated in the period 20 April- 2 July and collected more than 800 earthquakes with magnitude ranging between 1.5 and 4.5 and at a distance range 5-30 km. The recordings of 31 stations located in Tempera, Paganica, Bazzano and S. Gregorio areas, were archived and analyzed. The experimental study of amplification phenomena, has been carried out by using both standard spectral ratio techniques (HVRS and SSR) and different definition of amplification factor (FA) computed through PSV or PSA ratios. In detail, the seismic events recorded has been processed as follow: ° Quality check and identification of seismic phases; ° Spectral ratio computation between station and reference station for S-phases considering both horizontal and vertical component (SSR); ° Horizontal to Vertical spectral ratio computation for S-phases (HVSR); ° Estimate of ground motion parameters (PGA, PGV, PSA, PSV, Housner Intensity,. etc); ° Estimate of different scalar FA on the basis of ratios between ground motion parameters evaluated at station and reference station. The results show complex and remarkable amplification site effects affecting both the horizontal and vertical component of the ground motion. In particular the Paganica and Tempera area is characterized by significant amplification effects at frequencies between 1.0 to 4.0 Hz and Fa values ranging between 1.5 and 4.0. Indeed in some areas surrounding Bazzano village, fundamental frequencies lower than 3.0 Hz were observed. The San Gregorio area is characterized by fundamental frequency values between 2.0 and 3.0 Hz. Moreover one of the main target of this study is the discussion about the usage of empirical amplification factors for defining seismic amplification phenomena. To this aim, a sensitivity analysis was also carried out in order to investigate the variability of the FA with the respect to seismic event characteristics (magnitude, epicentral distance, depth). Finally, in order to define the best proxy for the estimate of the seismic response of the investigated areas, the variability of the Fa values has been discussed as a function of the criteria adopted for the computation of Fa (i.e. PSA, PSV, integration range).

SH4/WE/O3 **– STATISTICAL INVESTIGATION OF SITE EFFECTS WITH EMPHASIS ON SEDIMENTARY BASINS, USING EARTHQUAKE AND AMBIENT NOISE RECORDINGS**

G. Cultrera[1], V. De Rubeis[1], N. Theodoulidis[2], P. Bard[3], H. Cadet[2]
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During the last two decades, three empirical methods for assessing site effects have been widely used: the Standard Spectral Ratio (SSR), the Horizontal-to-Vertical Spectral Ratio from earthquake recordings (HVSR) and the Horizontal-to-Vertical Spectral Ratio from ambient noise recordings (HVN). The

SSR is considered the reference empirical method to detect amplification as a function of frequency, while the HVSR and the HVN realistically indicate fundamental frequency but, for the majority of the worldwide examined sites, they cannot give reliable amplification curves as a function of frequency. Given the fact that HVSR and especially HVN can be easily obtained, it is challenging to search for any correlation with SSR amplification functions. We used recordings from 168 sites worldwide, for which all three types of spectral ratios were homogeneously processed (Haghsenas et al., *Bull. Earthquake Eng.* 2008). On this data set we applied standard multivariate statistical analyses, namely, factor analysis and canonical correlation, to investigate and quantify -where it is possible- any correlation between spectral ratios for a certain number of the examined frequency bins. Results show that the correlation between HVN and HVSR is very good. Moreover, their correlation with broad band SSR can be statistically quantified and receive a satisfactory physical explanation. In addition, we looked for the correlation of SSR, HVSR and HVN collected in sedimentary basins (a subset of the previous database) with geometrical and geophysical parameters. These attempts were constrained by the limited amount of reliable in-situ data. Among many, we select 5 parameters: Vs30, Hb, Vs_average/Hb, Hb/W_valley, Hb/W_edge (where Hb is the bedrock's depth below the station; Vs_average is the average Vs from surface to bedrock; W_valley is 2D-width of the valley; W_edge is the distance from the closest valley's edge). The analysis assesses that larger are the first 4 parameters, larger is the low-frequency amplification in HVSR and HVN, and lower the high-frequency contribution. Although additional data would improve our statistical investigation and better establish quantitative correlation between spectral ratios and geophysical or/and geometrical characteristics of sedimentary basins, our results clearly show that statistical correlation between SSR and HVN-HVSR is present and modulated in specific frequency domains.

This study has been performed in the framework of the ToK ITSAK-GR EC project (2006-2010).

SH4/WE/O4 - DERIVATION OF A REFERENCE BEDROCK MODEL FOR SWITZERLAND FROM EMPIRICAL SITE AMPLIFICATION AND DIRECT MEASUREMENTS

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The definition of a reference bedrock condition representative of a region of interest is of great significance in seismic hazard assessment. It is highly beneficial when ground-motion prediction equations are referenced to a specific site condition, particularly in the case of site specific seismic hazard analyses. When known, the site effect of any given site with respect to the reference can then be applied to the predicted ground-motion. However, the choice of a reference velocity profile is not straightforward, mainly due to the high variability of the velocity structure in the shallower layers. A new method to define the regional reference rock profile is proposed, based on the quarter-wavelength representation of a shear-wave velocity profile. The method relates quarter-wavelength average velocity at a site to frequency-dependent amplification. A reference bedrock velocity profile can then be directly defined in relation to expected amplification characteristics over a number of sites. We compare 27 quarter-wavelength velocity profiles from seismic station locations in Switzerland with empirical amplification functions derived from spectral modelling. From this comparison, a set of frequency-dependent calibration relationships are established. Assuming that the reference profile is defined by a lack of any relative amplification, the quarter-wavelength velocity profile that corresponds to unitary spectral amplification can be extracted from these correlations. The reference velocity profile that is consistent with the reference amplification-velocity information can then be reconstructed through an inversion procedure and defines the reference for the ground motion prediction equations (GMPE). The proposed reference velocity profile is compared with previous reference velocity profiles for Switzerland and measurements obtained from independent methods. A good agreement is found between the different methods. Additionally, an estimation of the transfer function for the Swiss reference rock condition is provided. This can be used to correct recorded or estimated spectral amplitudes for the local response of the reference site. Finally, it is shown that the coefficients from the aforementioned correlations can be used to reconstruct a generic amplification function at any site with known quarter-wavelength velocity profile.

SH4/WE/O5 - INFLUENCE OF SITE CLASSIFICATION SCHEMES ON THE INTER-STATION SIGMA

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The most recent seismic codes recognize the significant role of site effects on earthquake ground motion and include them in the definition of the seismic action for design. Since the early 90s the weighted average of the shear wave velocity over the uppermost 30m, Vs_{30}, has become a globally accepted parameter for the classification of a site in terms of its seismic response. During the 80s, alternative classification schemes were proposed, such as the Japan Road Association classification (1980, 1990), which, in parallel to the Vs,30, used the predominant soil period to discriminate among classes. In the last decade the concept of site predominant period for soil classification has been recovered with promising results (i.e. Fukushima et al., 2007; Cadet et al., 2008). For Italian strong motion data we propose a soil classification scheme based on the site fundamental period, evaluated through the ratio between the horizontal and vertical acceleration response spectra (5% damping). The soil classification (S4-SCS) is defined by clustering the predominant frequency of a group of stations belonging to the Italian strong-motion network, used as a training set. In this work, we test this and other classification schemes, proposed in literature, and evaluate their performance through the estimate of the standard deviation associated to the predictive equation for acceleration response spectra. We use the Italian strong-motion data set (http://itaca.mi.ingv.it) and classify the stations adopting five classification schemes, from the simple soil / rock distinction, to more sophisticated classification, based on Vs,30 or soil predominant period. The trend common to all classification schemes is a larger inter-station sigma in the low period range (0.04 – 0.3s) than in the long period range (0.3 – 4s). The classifications based on the soil fundamental frequency reduce the inter-station standard deviation, especially at long periods, while the S4-SCS decreases the inter-station sigma in the entire period range. We suggest to consider the site fundamental period for the derivation of GMPEs or the definition of spectral shapes of seismic codes.

Cadet H., Bard P.-Y., Duval A.-M. (2008) A new proposal for site classification based on ambient vibration measurements and the Kiknet strong motion data set. Proceeding of The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.Fukushima Y., Berge-Thierry, C., Volant, P., Griot-Pommera, D. A., and Cotton, F. (2003) Attenuation relation for west Eurasia determined with recent near-fault records from California, Japan and Turkey, Journal of Earthquake Engineering, 7(3), 1-26.

SH4/WE/O6 - SPECTRAL ANALYSIS OF K- AND KIK-NET DATA IN JAPAN: ON THE SITE RESPONSE OF BOREHOLE AND SURFACE STATIONS

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Japan is one of the regions with highest seismic activity in the world and, at the same time, one of the most densely instrumented countries. Following the highly destructive Kobe earthquake in 1995, two strong motion networks, K-net and KiK-net, have been deployed, recording earthquakes in and around Japan on a continuous basis. In addition, the KiK-net sites are equipped with borehole sensors. This wealth of accelerometic data, covering a large range of magnitudes (ranging from about 3 to 8), makes these datasets highly valuable for obtaining new insights into highly debated topics, such as the scaling of seismic sources and issues regarding site response estimation. We analyze a dataset of about 67,000 records from 2,178 earthquakes recorded at more than 1500 K- and KiK-net stations with the generalized inversion technique (GIT) in order to separate site response, source spectra and attenuation characteristics. Data has been selected in order to provide an appropriate input to the inversion. The examination of surface-to-borehole (S/B) and horizontal-to-vertical (H/V) spectral ratios, in combination with the available seismic velocity profiles, shows that many sites are strongly affected by amplification effects at high frequencies due to the presence of considerable impedance contrasts at shallow depth. Furthermore, there is a clear presence of down-going waves in the borehole recordings, as deconvolution of borehole/surface recording pairs indicates. While strong amplification effects dominate

the site contributions for the surface sensors derived using the GIT inversion, those for the borehole ones are characterized by smaller variability. However, consistent with the observations from deconvolution of borehole/surface recording pairs, down-going wave effects are nevertheless also visible in the site contributions for many borehole stations. Finally, the site amplification functions obtained at the surface are compared with S/B and H/V spectral ratios, showing that the S/B ratios generally provide better estimates of the horizontal amplification than the H/V ratios due to amplification of the vertical component of ground motion.

SH4/WE/O7 – EVALUATION OF GROUND MOTION NUMERICAL SIMULATION RELEVANCE: MAIN RESULTS OF THE EUROSEISTEST VERIFICATION AND VALIDATION PROJECT

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Numerical simulations are often used to evaluate local ground motion amplification (site effects). Before using these approaches for civil engineering design purposes, it is necessary to evaluate their reliability. Within the framework of this evaluation effort, an ongoing international collaborative work was organized, jointly by the Aristotle University of Thessaloniki, Greece, the Cashima research project (supported by the CEA and the Laue-Langevin institute), and the Joseph Fourier University, France. We decided to focus the study on a site (1) where the site geometry and geotechnical properties are well known and (2) where accelerometric time histories are available. The EuroseisTest site, located few tens of km East of Thessaloniki, was chosen since it provides a detailed 3D model of the sedimentary basin (about 5 km wide, 15 km long, sediments reach about 400 m depth) and the signals of 8 local earthquakes with magnitude from 3 to 5, recorded on 19 surface and borehole accelerometers. The project involves more than 10 international teams from Europe, Japan and USA, employing different numerical techniques (FDM, FEM, SEM, DGM, PSM, DEM). It consists in computations of different 2D, 3D, linear or non-linear cases. Through these exercises, it is possible to evaluate (1) the accuracy of numerical methods when applied to realistic applications where no reference solution exists (verification) and (2) quantify the agreement between recorded and numerically simulated data (validation). We will present the site, the objectives, the 3D model construction strategy, the different computing cases and main results of this project. The verification work allows us to clearly identify and understand the discrepancies between the predictions of the different simulation methods. The validation work shows surprisingly good agreement for the largest magnitude event, even at high frequencies (up to 4 Hz). This last exercise has been performed for 6 local, weak to moderate magnitude events recorded by a local array of 19 surface and borehole accelerometers. In general, while the detailed waveforms do not match, the overall amplitude, duration, and spectral shape exhibit a relatively satisfactory agreement. The level of agreement is however found to be event-dependent, as a combined result of the large sensitivity of waveform details to the source location and mechanism, the geometry of the sediment-basement interface, and the internal sediment layering, and of the uncertainties in the source parameters and basin structure. The best agreement is found indeed for the largest – and thus best known- event.

SH4/WE/O8 – WHAT IS THE EFFECT OF THE ANGLE OF INCIDENCE OF THE INCOMING WAVEFIELD IN 2D-PSV NONLINEAR BASIN RESPONSE?

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Numerical studies, mainly conducted in 1D soil columns, show that nonlinear soil response is characterized by deamplification in the high frequencies. However, when analyzing the earthquake sequence from the Northridge event, Field et al. (1997) found that nonlinear response at the Los Angeles basin occurred rather at intermediate frequencies (1 – 5 Hz). They used aftershocks after the Northridge earthquake to characterize the linear basin response (weak-motion data) and the mainshock to estimate the nonlinear basin response (strong-motion). Up to date, there is no physical explanation of such unexpected result. Yet, common linear and nonlinear response analyses are performed considering vertical incidence of the wavefield. However, when the sources are close to the recording sites, the incoming wavefield may have an oblique angle of incidence as in the case of the Northridge data.Taking advantage of the development of 2D/3D nonlinear rheologies as well as increasing computational power, it is nowadays possible to analyze wave propagation in complex structures in multiple dimensions. In this sense, basin studies are quite interesting due to the geometry, wave conversion, and edge effects on earthquake ground motion. Here we present the results of 2D-PSV wave propagation considering linear and nonlinear material properties in Nice, France. The results show that nonlinear basin response is very sensitive to the angle of incidence of the incoming wavefield. The incoming energy does not trigger equal nonlinear effects for inclined angles of incidence. Using the same statistical analysis proposed by Field et al. (1997), we found deamplification at the same frequency band as in the case of the Los Angeles basin. These results show that the observed deamplification may be related to the use of local sources and hence inclined incoming wavefield. In a more general perspective, this study suggests that full 3D wave propagation including nonlinear and near-source effects should be used to better characterize the earthquake ground motion of future earthquakes in the presence of basin structures.

SH4/WE/O9 – OBSERVED AND MODELLED SITE RESPONSE FROM ISTANBUL VERTICAL ARRAY AND STRONG MOTION NETWORK

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The Istanbul Rapid Response Network is composed of 100 strong motion stations distributed more or less evenly with the metropolitan city of Istanbul. Strong-motion instruments are generally located at grade level in small and medium-sized buildings, such that the motion recorded corresponds to that on the ground in the surrounding area. Out of 100 rapid response network strong motion stations 55 stations and Ataköy vertical array which is composed of four downhole triaxial accelerometers located at the depths of 50m, 75m, 140m and one on the ground surface are located within the area where detailed microzonation study was conducted. There have been few small earthquakes in the recent years with local magnitude slightly over M=4. One of these earthquakes took place on 12/3/2008 in Yalova with local magnitude of M=4.8. Vertical array stations at 4 levels (ground surface, at depths of 50m, 75m and 140m) and 23 of the 55 Istanbul Rapid Response Network stations recorded this earthquake. The acceleration time histories recorded by the 23 Rapid Response stations as well by the Ataköy vertical array stations were used to model the recorded motion characteristics in terms of peak ground accelerations and acceleration response spectra using the recorded acceleration time histories on the engineering bedrock at Ataköy vertical array. The recorded acceleration time histories are modeled based on empirical site amplification relationships proposed by Borcherdt and based on a modified version of Shake91. The results indicate the suitability of the site response analyses in modeling the observed variation with respect to peak ground acceleration. An attempt is also made to model the recorded acceleration time histories during the M_w=7.4, 1999 Kocaeli Earthquake recorded at Ataköy, Fatih and Zeytinburnu strong motion stations located in the same area. Modeling at Ataköy station was rather successful indicating the suitability of the vertical arrays in fine tuning the measured shear wave velocity profiles for modeling and prediction at higher ground shaking levels. Preliminary modeling conducted for the Fatih and Zeytinburnu station records during the Kocaeli 1999 Earthquake using the Maslak record as rock outcrop motion gave also reasonable and promising results that could be improved once new vertical arrays are established at these two sites.

SH4/WE/O10 – INFLUENCE OF NONLINEARITY OF SOIL RESPONSE ON CHARACTERISTICS OF GROUND MOTION

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Soil response can be considered as linear one in weak motion, and in strong motion, the degree of nonlinearity depends on the intensity of oscillations. Nonlinearity of soil response leads to changes (sometimes, considerable) in spectra and amplification of ground motion. In strong motion, nonlinear damping mechanisms are turning on, which lead to weakening of high- and average-frequency components. Low-frequency compo-

nents are not weakened; they can be even amplified, because in cases when they were absent in input to soil layers they appear in the output, i.e., on the surface. Changes in spectra of ground motion related to nonlinearity of soil response appear in shifting of resonant frequencies of soil layers to low-frequency domain and in transformations of spectra to the form $E(f) \sim f^{-k}$. Amplification of seismic waves is decreased due to nonlinearity of soil response in dry soils and, in lesser extent, in wet soils. In wet soils, nonlinear damping sometimes can not compensate amplification of seismic waves resulting from (1) the transition of seismic waves to upper layers with smaller impedance values, and (2) resonant phenomena in the upper softer layers. As a whole, amplification can occur even in cases of high nonlinearity. Thus, the degree of soil-response nonlinearity depends on the composition of soil layers and their saturation with water, as well as on the intensity and spectral composition of incident (to soil layers) seismic waves. Since the composition and mechanical parameters of soils vary from place to place, any generalized dependencies of PGA (or oscillation intensity) on soils on magnitude-distance will surely possess large scatterings, which was noticed by many authors. Therefore, the correct approach in seismic microzonation is calculation of space-dependent acceleration time histories of possible future strong earthquakes accounting for soil nonlinearity. The limitations of conventional programs for estimation of soil response are: underestimation of the degree of soil-response nonlinearity in near-fault zones, disregard of the differences in nonlinear behavior of cohesive and non-cohesive soils, and disregard of changes in rheological properties of the upper soft layers in strong ground motion. Soil response should be estimated by methods of nonlinear analysis accounting for all points mentioned above.

SD7 - IMAGING THE SEISMICITY OF THE EURO-MEDITERRANEAN REGION: FROM SEISMIC NETWORKS TO CATALOGUE PRODUCTION AND INTERPRETATION

Wednesday 8, 08h00-10h00

Wednesday 8, 10h20-12h00

SD7/WE/O1 - SEISMIC DATA PROCESSING AT THE DATA CENTER OF THE IGR NNC RK

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[1]Data Center of IGR NNC RK

Data Center of IGR NNC RK receives in real-time seismic data from eight arrays and six three-component stations belonging to the NNC RK network and located on the Kazakhstan territory, data from two stations located on the Kyrgyzia territory, one Tadjik station and one Turkmen station. In order to process all this data together, the technology of real-time seismic data processing is implemented in our Data Center. This technology consists of several steps. At the first stage the automatic detection of seismic arrivals and automatic calculation of phase parameters is made (by the DP/EP program). If strong regional event occured, our operator accomplishes immediate event location and computation of event magnitude and energy class. The results of the event locations are immediately placed on the Data Center web-site (www.kndc.kz), and, starting from October 2009, these results are also sending to the EMSC web-site. At present time this is the «fastest» information about earthquakes, occurred in the Central Asia region. In parallel with real-time interactive seismic event location, the real-time automatic event location is functioning (the GBF program). The results of real-time automatic event location are also placed on the Data Center of IGR NNC RK web-site and are sending to the EMSC web-site.On the next stage of data processing the compilation of the interactive regional daily bulletin is accomplished. During the compilation of the interactive bulletin the data from NNC RK seismic network, along with two KNET stations (AAK and TKM2), and, starting from 2010, data from CAREMON (GFZ, Potsdam) are used. After that, on the base of the interactive regional bulletin and seismic arrival reports, which are send to the Data Center by operators of SEME MES RK, the joint interactive regional seismic bulletin is created. Thereby, three regional seismic bulletins – automatic, interactive and joint interactive, are compiled in a regular basis in Data Center of IRG NNC RK. Finally, with the delay of several months, on the base of the joint interactive bulletin, the bulletin with known explosions selected, is compiledAutomatic bulletin for the year 2009 has 14 788 events, interactive bulletin – 20 340 events, and joint interactive bulletin – 21 980 events. During the 2009 the real-time location of 231 strong regional events was made, and information about 2150 teleseismic events was sent to Obninsk.

SD7/WE/O2 - MICROSEISMICITY MONITORING IN IZMIR (WESTERN TURKEY) AND SURROUNDING AREAS

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The Western Anatolian region is a part of the extensive zone and one of the most tectonically active and rapidly deforming and extending areas in the world. In the Western Anatolia, city of Izmir has some important active faults. In the present study, we analyzed the micro-earthquake activity of Izmir and surrounding areas. The investigated micro-earthquakes occurred between 2008 and 2010. Data was recorded by IzmirNET local seismic network (Polat et al. 2009, Seism. Res.Lett). Locations for more than 300 events have been done by using SEISAN software package. Accuracy of the locations is generally less than 2.5 km (rms<0.3). Epicenters reveal a swarm type seismic activity near Narlidere city (South of Izmir Gulf). Other seismic activities are observed in the south of Guzelbahce, along the NW-SE direction in the Gulf of Izmir, Menemen settlement at the North, and finally Bornova-Konak cities at the East and South part of the study area. We also estimated the focal mechanisms of the events from the P-wave first-motion polarities using FocMec software. The dataset consists of 21 earthquakes recorded by at least 15 stations, resulting in a total of about 315 P-wave readings to compute the high-quality focal mechanisms for the selected dataset of the Izmir earthquakes.

As a result, the seismicity is mostly related to the normal faulting movements that have taken place in the area due to extensional tectonic behaviour of the Western Anatolia. However, some focal mechanisms solutions also reveal the presence of of NE-SW, NW-SE trending strike-slip faults and N-S trending reverse faults. This result is consistent with N-S extension associated with E-W contraction indicating pure shear mechanism. Whether most of the hypocenters concentrate at the upper part (~20 km) of the earth crust, locations exhibit up to 30 km depths in the whole study area where characterized as high seismicity. The seismogenic layer thickness reflects the strength of lithosphere. There are some relationship between the seismogenic and the shallow elastic thickness for Western Anatolia and Izmir (Pamukcu and Yurdakul 2008, Turkish J. Earth.Sci). This is coherent with the results of our study. Crustal-mantle interface was reported about ~30 km by using seismic and gravity data in the region. In addition, the seismic data approximately reverse V-shaped in İzmir.

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SD7/WE/O3 - INTERNATIONAL SEISMOLOGICAL CENTRE (ISC): MISSION AND STATUS

D. Storchak[1], I. Bondar[1], J. Harris[1]
[1]International Seismological Centre

The International Seismological Centre (ISC) is a non-governmental, non-profit making organization supported by 55 research and operational institutions around the world and charged with production of the ISC Bulletin – the definitive summary of world seismicity based on seismic reports from over 120 institutions. Jointly with World Data Center for Seismology (Denver), the ISC runs the International Seismic Station Registry (IR). The ISC provides a number of additional services available from its web-site including the depositary of the IASPEI Reference Event list (GT), EHB & ISS data collections. The ISC has a substantial development programme that ensures that the ISC data remain an important requirement for geophysical research. This programme includes bringing the ISC edited Bulletin schedule to approximately 15-18 months behind real-time as well continuing collection of preliminary reports from networks days and weeks after event occurrence to make the automatic preliminary ISC Bulletin as comprehensive as possible before the final data become available to the ISC. We aim to modernize the way the ISC computes its hypocentres and magnitudes and to attempt taking some useful measurements from waveforms widely available on-line to improve the accuracy of the ISC Bulletin. We are planning to re-produce the entire ISC Bulletin (1960-2010) by re-computing the

ISC hypocenters and magnitudes using ak135 velocity model, identifying and filling the gaps in data, correcting known errors and introducing essential additional bulletin data from research experiments and temporary deployments. The ISC also takes a leading role in compiling the GEM Instrumental Seismic Catalogue (1900-2009).

SD7/WE/O4 - IMAGE OF THE SEISMICITY FROM THE EURO-MED BULLETIN

S. Godey[1], R. Bossu[1], J. Guilbert[2]
[1]EMSC; [2]LDG-CEA

The Euro-Med Bulletin is now available for the period 1998-2008 thanks to a comprehensive collection of seismic data of the region. It is based on the collection of bulletins and arrivals provided by networks operating in a large region running from Iceland to Oman and from Russia to Azores Islands. Such a continental bulletin is important to improve data availability for the scientific community and to rapidly provide a homogeneous instrumental earthquake catalogue for the region. By covering a specific region, improved interaction with the local institutes is possible. Furthermore hypocenters location contained in the EMB are now regularly included in the ISC Bulletin. We aim at reproducing the seismicity as imaged by the local agencies when events occur within their network and to improve event location in borders regions and off-shore. This is realised by merging data from 78 contributing seismological agencies. The data collection is now comprehensive in the Euro-Med region, with recently joining networks such as Azerbaijan, Iran, Libya or Saudi Arabia. Thanks to the numerous contributions, the Euro-Med Bulletin displays a high coverage of the region with the collection of data from 2,625 stations. Moreover, thanks to close discussion with the local networks, information from more than 700 stations have been collected or updated to the International Registry of Seismograph Stations, maintained by the ISC and the NEIC. The EMSC has recently introduced two major evolutions in its Bulletin: the computation of earthquakes hypocentres using the ak135 velocity model and the removal of the magnitude threshold previously set at M>3.0. These new features have been applied for the Bulletin production of 2008 and reprocessing of the full period 1998-2007 is in progress. In addition to being a regular contributor to the ISC, the Euro-Med Bulletin has also become crucial for the Seismic Data Portal (NERIES). It is one of the entry gates to access various seismological products, such as waveforms hosted in Orfeus and accelerometric data. We first describe the data content of the Euro-Med Bulletin for the period 1998 to 2008 and the evolution over time of the data contributed by the local networks. We also present the results of removing the magnitude threshold and using ak135. We will raise several issues, such as event discrimination, magnitude computation or contribution delays which need to be addressed to improve our production in collaboration with the seismic agencies.

SD7/WE/O5 - A NEW RELEASE (3.1) OF THE DATABASE OF EARTHQUAKE MECHANISMS OF THE MEDITERRANEAN AREA (EMMA)

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The database of Earthquake Mechanisms of the Mediterranean Area (EMMA) collects mainly first-motion focal solutions available from the literature. The different formats and notations found on sources are homogenized as well as misprints, inaccuracies and inconsistencies are corrected when possible. An automatic procedure, based on objective criteria, allows to choosing the most representative (preferred) solution when more than one is available for the same earthquake. A windows-based MS-Access application allows to selecting the data and to export files suitable to be handled by the Generic Mapping Tools (GMT) and by user-written computer codes. With respect to the previous public version (2.2), the new release doubles the number of the data (more than 12500 focal solutions included) and improves the quality of the available information. In fact, we also added to each mechanism the hypocentral parameters and the magnitudes provided by available hypocentral catalogs (CSEM-EMSC, ISC, PDE, etc.) so that to evidence possible inconsistencies with the data reported on the original papers. The EMMA database allows to extending backward in time and to a lower magnitude threshold, with respect to available on-line catalogs (Global CMT, Rome RCMT, etc.), the dataset of focal mechanisms of the Mediterranean area that can be easily used for seismotectonic analyses.

SD7/WE/O6 - AN INSTRUMENTAL SEISMICITY CATALOGUE FOR METROPOLITAN FRANCE 1962-2009

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Several catalogues of instrumental seismicity have been produced over the past 40 years in France. Due to the different procedures and seismic networks used by the agencies/Universities producing instrumental data, the seismicity parameters may present important discrepancies between the published catalogues. Moreover the parameter uncertainties are difficult to assess from the published material. Focal depth and magnitude are, in particular, parameters poorly documented.

Focal depth of some events may now be reassessed thanks to progresses made in localization procedures, either from relative relocation when accurate aftershocks hypocenters are available from dense networks of portable instruments, or from teleseismic pP identifications. Systematic use of the seismic moment magnitude Mw instead of various forms of ML may furthermore be made allowing us to reduce the magnitude uncertainty and avoid biases in magnitude when compared to other recent catalogues in Europe. Tectonic/anthropogenic discrimination, which is very unevenly accounted for among existing catalogues, has also to be examined into more details.

At a time when probabilistic approaches become the basis for seismic hazard assessments in Europe (application of the EC-8 Eurocode) there is a clear need for an updated catalogue of instrumental seismicity with documented parameter uncertainties. Within this context, a 3-year project (Sismicité Instrumentale de l'Hexagone, SI-Hex) has been launched jointly by the Bureau Central Sismologique Français (BCSF-CNRS/University) and the Laboratoire de Détection Géophysique (LDG-CEA/DAM) with financial support from the French Ministry in charge of Environment (MEEDDM) within the framework of its "Plan séisme". Data and procedures used by both institutions are put together in order to address the different problems mentioned above. The aim of the project is to produce, within 3 years term, a BCSF-LDG catalogue covering the years 1962-2009. Details of the project together with preliminary results will be presented at the meeting.

SD7/WE/O7 - THE NATIONAL SEISMOLOGICAL OBSERVATION NETWORK OF TURKEY, ARCHIVING DATA AND CREATING CATALOG AND BULLETIN

F. KADIRIOGLU[1], T. KILIC[1], K. YANIK[1], S. ZÜNBÜL[1], M. KAPLAN[1]
[1]DISASTER AND EMERGENCY MANAGEMENT PRESIDENCY, EARTHQUAKE DEPARTMENT

Abstract In order to mitigate disaster losses, it is necessary to establish an effective disaster management and risk system. The first step of the management is constituted by preparedness studies before the earthquake (disaster). In order to determine disaster and risk information it is necessary to have a seismological observation network. Turkey is always in danger of being ruined by an earthquake because it's on the active fault zone, as it was seen in the last ten years.That's why a seismological observation network having good coverage is needed to research the reasons of earthquakes and reduce their damage. For this purpose, the stations which was established on the NAFS (North Anatolian Fault System) in 1989 were spread across all country and currently observation (weak motion) are made with 162 stations (144 broadband, 5 short period-three component, 13 short period-one component) and 290 accelerometers. According to years distrubition of the number of seismological observation network is examined. This networks (weak ground motion and strong ground motion) have been operated by our Presidency. This number (weak motion station) is planned to be 194 by the end of 2010. All of the stations transmit continuously their signal to the Earthquake Department seismic data center in Ankara. Capability of the network is to determine an earthquake which is minimum local magnitude ML= 2.5 generally, in some region local magnitude threshold is ML=1.2 (the places where the stations are concentrated). In addition to the manual solutions, automatic solutions programs are used as Earthworm and Seiscomp3. Evaluation of the data is archived as catalog and bulletins and shared with seismological centers. Within this scope, joint projects are carried out in cooperation with public institutions and universities, and data sharing is done. Earthquake activity in Turkey and surrounding region has been observed 7 days / 24

hours, in Earthquake Department data center in Ankara. After the manuel location of an earthquake, if the magnitude is over 4.0, system sends to SMS message automaticaly to the authorized people and immediately press, public and national-local crisis center. Scientific institutions are informed by fax and e-mail. Data exchange has been carried out to EMSC-CSEM and ORFEUS.

SD7/WE/O8 **- IMPROVED LOCATION PROCEDURES AT THE INTERNATIONAL SEISMOLOGICAL CENTRE**

I. Bondar[1], J. Harris[1], D. Storchak[1]
[1]International Seismological Centre

The International Seismological Centre (ISC) location algorithm remained virtually unchanged in the past 40 years (Bolt, 1960; Adams et al., 1982). Introducing the *ak135* travel-time predictions (Kennett et al., 1995) in event locations since data year 2006 offered an opportunity to incorporate state-of-the-art methodologies in the ISC location procedures to further improve the accuracy of event locations in the ISC bulletin. The new location algorithm uses all *ak135* predicted phases (including depth phases) in location; applies elevation, ellipticity (Dziewonski and Gilbert, 1976), and depth-phase bounce point corrections (Engdahl et al., 1998); obtains the initial hypocentre via nearest-neighbour grid search (Sambridge and Kennett, 2001); accounts for correlated model error structure (Bondar and McLaughlin, 2009a); performs iterative linearized inversion using *a priori* estimates of the full data covariance matrix (Bondar and McLaughlin, 2009a); scales uncertainties to 90% confidence level; obtains depth-phase depth via depth-phase stacking (Murphy and Barker, 2006); calculates location quality metrics for various distance ranges; and provides robust network magnitude estimates with uncertainties. The locator attempts free-depth solution only if there is depth resolution, which is defined by presence of local networks or reported depth-sensitive phases. If there is no depth resolution, the depth is fixed to a region-dependent default depth. The new ISC location algorithm was validated by relocating more than 7,000 ground truth events in the IASPEI Reference Event List (Bondar and McLaughlin, 2009b). The validation tests demonstrate improvements in hypocentre parameters (location, depth and origin time) and show that the error ellipse contains the true location 90% of the time. Furthermore, the location accuracy obtained with the new location algorithm is now comparable to that of the EHB (groomed ISC bulletin, Engdahl et al., 1998) catalogue.

SD7/WE/O9 **- OPTIMAL SEISMOLOGICAL NETWORKS FOR THE REGISTRATION OF NEAR EARTHQUAKES.**

V. Burmin[1]
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Under the optimum system of seismological observations usually refers to a system that registers the event passes without a specified magnitude of a given area with minimal errors in determining the parameters of hypocenters. The problem of optimal location of seismic stations was first considered by N.A. Vvedenskaia in 1955, which studied the dependence of errors in determining the coordinates of the epicenter of the azimuth alignment of the stations in the determination of earthquake epicenters by graph-analytical method. Then, using different approaches, the problem considered by other authors. In the paper (Burmin V.Y. *Problem of design the experiments and conditionality of systems of linear algebraic equations* // Izv Akad. Technical Cybernetics. 1976, № 2. Pp 195 - 200) introduced a new non-statistical criterion for optimal design of experiments, the criterion C - optimality (on condition). According to this criterion, the optimal experiments minimize the number of conditionality (cond(K) = ▫K▫▫K⁺▫) of the matrix system of linear algebraic equations. Based on this criterion, the problem of optimal geometry of the local network of seismic stations is solved. As an example, results of calculations of optimal seismic networks in the territory of Russia and northern Vietnam.

SD7/WE/O10 **- A REVISED LOCAL MAGNITUDE SCALE FOR THE UK**

S. Sargeant[1], L. Ottemöller[2]
[1]British Geological Survey; [2]University of Bergen

Magnitudes of British earthquakes are determined using the scale as it was originally defined for Southern California. The anelastic attenuation correction is therefore unlikely to be appropriate given that the UK is located within an intraplate region with relatively low levels of seismicity. Therefore, we have used data from British earthquakes recorded from the year 2000 onwards to develop a UK-specific local magnitude scale. We determine a separate scale for North Sea earthquakes recorded in the UK where the impact of the large graben structures on wave propagation must also be considered. Finally, we determine a new relationship between ML and Mw.

SD7/WE/O11 **- MOMENT TENSOR INVERSION OF REGIONAL EARTHQUAKES USING THE KIWI TOOLS: RESULTS FOR SW IBERIA AND ADJACENT OFFSHORE**

S. Custódio[1], S. Cesca[2], A. Domingues[3], NEAREST/WP3 Working Group[4]
[1]University of Coimbra, Portugal; [2]University of Hamburg, Germany; [3]Insituto Superior Tecnico, Portugal; [4].

A high-quality broadband network currently covers the Portuguese territory. In this presentation we will show results from the study of the regional seismicity since the deployment of the large-scale broadband Portuguese network. In particular, we will analyze the regional seismicity using the Kiwi (KInematic Waveform Inversion) tools. On three consecutive steps the Kiwi algorithm computes earthquake point- and extended-source parameters. The Kiwi package is further well-suited for near-real-time analysis. The first two steps of the Kiwi algorithm yield estimates of point-source parameters: centroid location (latitude, longitude and depth), origin time, scalar moment, and focal mechanism (strike, dip, and rake). The final step of the inversion retrieves finite-source parameters: discrimination of the true fault plane, rupture area, hypocenter location, rupture velocity, and rise time. The applicability of the Kiwi tools depends on the existing data quality and quantity. In this presentation we will show point-source results for nine earthquakes (Mw>3.5), eight of which occurred offshore. We will also show finite-source results for one earthquake (Mw 5.9). We obtain four new focal mechanisms and five focal mechanisms that compare well with the previous studies. The geographical location of Portugal creates a large azimuthal gap in the dataset, which becomes a problem in the earthquake analysis. Furthermore the Cadiz basin generates reverberations that decrease the signal-to-noise ratio of some data. These issues are carefully analyzed and discussed in our presentation. We also discuss how our results are affected by incorrect initial (catalog) estimates of the earthquakes' location. Finally, we compare our focal mechanisms with those inferred from first-motion polarity of OBS data.

SD3 - REAL TIME WAVEFORMS AND SHAKEMAPS.

Wednesday 8, 08h00-10h00

SD3/WE/O1 **- AN UPDATE ON USGS SHAKEMAP, INCLUDING THE SYSTEMATIC INTEGRATION OF MACROSEISMIC & STRONG-MOTION DATA FOR REAL-TIME & LOSS-MODELING APPLICATIONS**

B. Worden[1], D. Wald[1], K. Lin[1], D. Garcia[1], G. Cua[2]
[1]U.S. Geological Survey; [2]ETH Zurich

The recent release of a significant ShakeMap software upgrade (Dec 2009, V3.5) entailed substantial algorithmic and software enhancements. Specific improvements include faster grid-based processing, expanded choices of ground motion prediction equations (GMPEs), magnitude-based bias corrections, and optional inclusion of macroseismic intensity data in their native form. Most significant, however, is a new approach for incorporating ground motion estimates and multiple data sets as well as quantifying their collective contribution to the spatial variations of shaking uncertainties. ShakeMap now uses a weighted-average approach for incorporating observed peak ground motions and intensities, and numerical or GMPE-based estimates, into the ShakeMap ground motion and intensity estimation framework. We describe the systematic combination of data across the geographic area that weights each contribution by a spatially-varying uncertainty, and produces a total uncertainty for each point in the output. At each output point, the ground motion is calculated as the average of the (scaled) nearby observations, converted observations, and the output of one or more GMPEs, inversely weighted by each contribution's uncertainty. With grid-based calculations, ShakeMap now computes parameter estimates on a dense grid, eliminating the need for further interpolation, yet while computing results much faster than before. In the case of direct ground motion observations, the uncertainty contribution is a function of distance from the observation. For converted observations (e.g., macroseismic

intensity converted to peak ground acceleration), there is an additional component of uncertainty, due to the conversion process itself, that must be incorporated. For GMPE estimates, the uncertaintycontribution is the combined intra- and inter-event variance, modified when fault dimensions are not yet ascertained; with suitable observations it is possible to use a biased GMPE (where the magnitude provided to the equation is adjusted to minimize the misfit with the data), in which case the GMPE uncertainty contribution reduces to the intra-event variance. We demonstrate improvements in the mean misfit, variance, and computed uncertainty, through the incorporation of native and converted ground motion data, and the biasing of generic GMPEs. Finally, as a recent addition to the ShakeMap tool kit, we have developed an automated region-specific GMPE selector that takes into account earthquake faulting mechanism, source depth, tectonic framework, and subduction geometry (slab interface). Such a tool is helpful both for real-time applications as well as for assigning appropriate GMPEs for historic or synthetic earthquake catalogues.

SD11 - SCIENTIFIC AND TECHNOLOGICAL ADVANCES IN EARTHQUAKE EARLY WARNING AND RAPID RESPONSE

Wednesday 8, 08h00-10h00

Wednesday 8, 10h20-12h00

SD11/WE/O1 - EDIM - EARTHQUAKE DISASTER INFORMATION SYSTEM FOR THE MARMARA REGION, TURKEY

F. Wenzel[1], M. Erdik[2], N. Köhler[1], J. Zschau[3], C. Milkereit[3], M. Picozzi[3], J. Fischer[4], J. Redlich[4], I. Christ[5], C. Kiehle[6]
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The main objectives of EDIM (www. cedim. de/EDIM.php) are to enhance the Istanbul earthquake early warning (EEW) system with a number of scientific and technological developments that – in the end – provide a tool set for EEW with wide applicability. Innovations focus on three areas. (1) Analysis and options for improvement of the current system; (2) development of a new type of self-organising sensor system and its application to early warning; (3) development of a geoinformation infrastructure and geoinformation system tuned to early warning purposes. Development in the frame of the Istanbul system, set up and operated by KOERI, allows testing our novel methods and techniques in an operational system environment and working in a partnership with a long-standing traditon of success. EDIM is a consortium of Karlsruhe University (TH), GeoForschungs-Zentrum (GFZ) Potsdam, Humboldt University (HU) Berlin, lat/lon GmbH Bonn, DELPHI Informations Muster Management GmbH Potsdam, and Kandilli Observatory and Earthquake Research Institute (KOERI) of the Bogazici University in Istanbul. The integration of strong motion seismology, sensor system hard- and software development, and geoinformation real-time management tools prove a successful concept in making seismic early warning a novel technology with high potential for scientific and technological innovation, disaster mitigation, and many spin-offs for other fields. EDIM can serve as a model for further developments in the field of early warning on a global scale.

SD11/WE/O2 - EVALUATION AND OPTIMIZATION OF SEISMIC NETWORKS FOR EARTHQUAKE EARLY WARNING – THE CASE OF ISTANBUL (TURKEY)

A. Oth[1], M. Böse[2], F. Wenzel[3], N. Köhler[4], M. Erdik[5]
[1]European Center for Geodynamics and Seismology; [2]Seismological Laboratory, California Institute of Technology; [3]Geophysical Institute, Karlsruhe Institute of Technology (KIT); [4]Swiss Re Europe S.A.; [5]Kandilli Observatory and Earthquake Research Institute, Bogazici University

In recent years, large efforts have been devoted to developing earthquake early warning systems for earthquake-prone regions around the world. In general, one can distinguish between so-called regional systems, which are based on the seismic signals recorded by local or regional networks, and on-site respectively 'single station' approaches, which use the information carried by the P-wave at a single station to issue warnings for a given close-by user site. In the regional approach, an essential question is how to optimally configure the seismic networks in order to obtain the best possible warning behavior. This includes (a) the largest possible warning times, (b) correct alert levels following a given definition and (c) the lowest possible rate of false and missed alarms. Using the Istanbul area as a test case, we develop a methodology to optimize the location of seismic stations with respect to the requirements mentioned above. Currently, the Istanbul Earthquake Rapid Response and Early Warning System (IERREWS) comprises ten real-time strong motion sensors distributed around the shoreline of the Sea of Marmara. With our methodology, we mimic the early warning process of the current system. Different sensor configurations are evaluated in terms of their early warning capabilities, using a catalogue of synthetic earthquake records generated from the finite-fault stochastic modeling technique. The catalogue comprises 180 earthquakes with magnitudes ranging between 4.5 and 7.5. The region around the Sea of Marmara is covered by a regular grid of possible station locations and a genetic algorithm is used to find sets of optimum station locations. By including possible locations within the Sea of Marmara in our computations, the added value to the early warning behavior by using one or several ocean bottom stations can be evaluated with this optimization scheme. We show that, while the current station locations of the existing Istanbul EEW system are well chosen, its performance can be enhanced by modifying the parameters governing the declaration of warnings. Furthermore, unless using ocean bottom seismometers or modifying the current EEW algorithm, additional stations might not lead to any significant performance increase.

SD11/WE/O3 - EARTHQUAKE EARLY WARNING RESEARCH AND DEVELOPMENT IN CALIFORNIA, USA

E. Hauksson[1], M. Boese[1], T. Heaton[1], D. Given[2], D. Oppenheimer[3], R. Allen[4], P. Hellweg[4], G. Cua[5], M. Fischer[5], M. Caprio[5]
[1]Seismological Laboratory, California Institute of Technology, Pasadena, CA; [2]USGS, Pasadena, CA; [3]USGS, Menlo Park, CA; [4]Seismological Laboratory, UC Berkeley, Berkeley, CA; [5]Swiss Seismological Service, ETH Zurich

Earthquake early warning (EEW) research and development in California has been in progress since 2006. During the first three years, we focused on developing, testing and enhancing three algorithms for EEW: the t_c-P_d On-site warning algorithm, ElarmS, and the Virtual Seismologist. The real-time algorithms were implemented at the three data processing centers of the California Integrated Seismic Network (CISN) in Pasadena, Berkeley, and Menlo Park. The algorithms have detected hundreds of local earthquakes in California and Baja California with moment magnitudes ranging from 3.0 to 7.2, including the October 30 2007, Mw5.4, Alum Rock earthquake in the San Francisco Bay Area, the July 29 2008, Mw5.4, Chino Hills earthquake beneath Los Angeles, and the April 4 2010, Mw7.2 El Mayor-Cucapah earthquake in Baja California. All three algorithms provide location, ground-motion, and magnitude estimates, within seconds after an earthquake occurs. Now in the second phase of the CISN EEW project, we are focusing on specification, development and implementation of code for an operational prototype of an end-to-end integrated warning system, called CISN ShakeAlert. This represents a significant shift from real-time testing in Phase I, when three parallel systems were operating. The integration of the three methodologies requires development of new code modules and modification of others. When possible, existing modules are being adopted or modified to minimize new code development. System integration also requires a more integrated project management structure with four main components. The scientific operations team is responsible for defining the input and output parameters and the operations performed by each code module. These specifications are communicated to the technical operations team that is responsible for code development, implementation, testing and performance monitoring. The testing center independently evaluates the accuracy and timeliness of the earthquake information from CISN ShakeAlert. The user support team is identifying and developing relationships with perspective users from critical industries and institutions throughout California. These partners will assist with development of future ShakeAlert products and procedures.

SD11/WE/O4 - PRESTO: A NEW STAND-ALONE SOFTWARE PLATFORM FOR INTEGRATED REGIONAL/ON-SITE EARTHQUAKE EARLY WARNING

L. Elia[1], A. Zollo[2], C. Satriano[3], O. Amoroso[2], C. Martino[1], G. Iannaccone[4]
[1]AMRA scarl; [2]University of Naples «Federico II»; [3]AMRA scarl now at Institut de Physique du Globe de Paris; [4]Istituto Nazionale di Geofisica e Vulcanologia

PRESTo (*PRobabilistic and Evolutionary early warning SysTem*) is a software platform for earthquake early warning that integrates recently developed algorithms for real-time earthquake location, magnitude estimation and damage assessment into a highly configurable and easily portable package. The system is under active experimentation in Southern Italy on the Irpinia Seismic Network (ISNet).

PRESTo continually processes the live streams of 3-component acceleration from the stations for P-waves arrival detection and, while an energetic event is occurring, promptly performs event detection, event location, magnitude estimation, damage zone assessment and peak ground motion prediction at target sites. The peak ground motion parameters at a distance (PGA, PGV, I) can be estimated from location and magnitude using region specific regression laws. An alarm message containing the evolutionary estimate of the those parameters can thus reach a vulnerable structure before the destructive waves arrive there, enabling the recipient to initiate automatic safety procedures.

After analyzing strong motion data from modern accelerometric networks in Japan, Taiwan and Italy, we recently integrated the regional approach with a threshold-based early warning method that allows, in the very first seconds after a moderate to large earthquake, to map the most probable damaged zone (PDZ). The method is based on the real-time measurement, at near-source stations located at increasing distances from the earthquake epicenter, of two parameters: the peak displacement (Pd) and the predominant period of P-waves (τ_c), over a three second window after the P-wave arrival. The measured values are compared to threshold values, set for a minimum magnitude and instrumental intensity, based on the empirical regression analyses of strong motion data. At each recording site an alert level is assigned based on a decisional table with four alert levels according to Pd and τ_c. Given the real-time, evolutionary estimation of earthquake location from first-P arrivals, the method provides an estimation of the extent of the potential damage zone as inferred from continuously updated averages of the period parameter and from mapping of the alert levels determined at the near-source accelerometer stations. The off-line application to recent relevant earthquake records shows the feasibility and robustness of such an approach allowing a faster alert notification compared to an on-site system with sensors deployed near the target by increasing the lead-time depending on the epicentral distance and earthquake depth.

SD11/WE/O5 – SOSEWIN, A WIRELESS MESH NETWORK OF SEISMIC SENSORS. NEW PERSPECTIVES FOR SEISMIC EARLY WARNING, RAPID RESPONSE SYSTEMS, EARTHQUAKE TASK FORCE MISSIONS, AND MONITORING OF CIVIL INFRASTRUCTURE.

M. Picozzi[1], C. Milkereit[1], S. Parolai[1], J. Zschau[1], K. Fleming[2], J. Fischer[3], F. Kuehnlenz[3], B. Lichtblau[3], I. Eveslage[3]
[1]Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum, Germany; [2]Curtin University of Technology, Department of Spatial Sciences, Perth, Australia; [3]Humboldt-Universität zu Berlin, Computer Science, Berlin, Germany

A crucial point of several seismological applications as, for example, early warning and rapid response systems, task force missions and state-of-the-health monitoring of civil infrastructures is that a large number of stations to be deployed in the field is required. This opens some main issues: the costs of the standard seismological equipment to be used is generally very high; the dimension, weight and function of the standard seismological equipment make it not suitable for rapid installation of sensors within structures, especially the damaged ones, in the post-event timeframe; and the analysis of data is generally performed only in a post-survey timeframe, which represents a severe drawback for some applications, as for example the early warning and earthquake task force missions. A promising solution to these issues has been provided by the rapid improvement in telemetry and computer technology, which have literally driven a revolution in seismology and earthquake engineering. Recently, the *Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum* (GFZ) and the *Humboldt University of Berlin* (HU-Berlin) have developed an innovative, self-organizing wireless mesh information network made up of low cost sensors, with the aim of setting up a new earthquake early warning system for the mega city. This innovative system, named the Self-Organizing Seismic Early Warning Information Network (SOSEWIN) has been developed within the framework of the European projects Seismic eArly warning For EuRope (SAFER) and Earthquake Disaster Information systems for the Marmara Sea region, Turkey (EDIM), and a first test version has been deployed since July, 2008, in Istanbul, Turkey. SOSEWIN employs advances in various technologies to incorporate off-the-shelf sensor, processing and communications components into low-cost accelerometric seismic sensing units that are linked by advanced, robust and rapid communications routing and network organizational protocols appropriate for wireless mesh networks. The reduced cost of the instruments (less than one tenth of a standard instrument) and the possibility of creating dense, self-organizing and decentralized seismic monitoring networks are key aspects for new approaches to both seismic early warning, and structural engineering monitoring. These novel accelerometric stations are easy to install (and therefore very suitable for rapid deployment during emergencies) and are able to collect, store and undertake preliminary analysis of data.

With this contribution we aim to report some example and preliminary results of SOSEWIN applications in Istanbul, Turkey, and during the L'Aquila (Italy) seismic sequence, 2009.

SD11/WE/O6 – AN INNOVATIVE APPROACH FOR IMPROVED EARTHQUAKE RESPONSE

R. Bossu[1], S. Gilles[1], F. Roussel[1]
[1]EMSC

The analysis of the instantaneous traffic on web sites offering rapid earthquake information is without any doubt one of the most promising fields. EMSC demonstrated back in 2004 that widely felt earthquakes generate surge of traffic caused by people rushing to EMSC web site to find the cause of the shaking they just felt. Thanks to dedicated traffic metrics, widely felt earthquakes can now be detected in less than one minute. The geographical area where the earthquake has been felt is mapped in five minutes by statistically analysing the IP locations of the eyewitnesses and without using any seismological data. We recently demonstrated the capacity to detect and map widespread damaged area by monitoring visitors ending their sessions. This technique was successfully applied on the massive power failure which plunged large part of Chile in darkness in March 2010. There are growing indications that, at least in certain cases, information on the relative level of shaking and the direction of the wave propagation could be automatically derived from specific, real time analysis. This presentation aims at giving an overview of the potential of this technique which is today the fastest way to collect in-situ information on earthquake's effects.

SD11/WE/O7 – GLOBAL DISASTER ALERT AND COORDINATION SYSTEM

T. De Groeve[1], A. Annunziato[1], L. Vernaccini[1]
[1]Joint Research Centre of the European Commission

The Global Disaster Alert and Coordination System (GDACS, http://www.gdacs.org), established in 2004, is a cooperation framework led by the United Nations and the European Commission with the aim to consolidate and strengthen the network of providers and users of disaster information worldwide in order to provide reliable and accurate alerts and impact estimations after sudden-onset disasters (with emphasis on less resilient countries) and to improve the cooperation of international responders in the immediate aftermath of major natural, technological and environmental disasters. GDACS is comprised of three elements: 1. Automatic alert notifications and GIS-based impact estimations for earthquakes, tropical cyclones, floods and volcanoes. 2. A community of emergency managers and emergency operation centres in responding and disaster-prone countries and disaster response organisations worldwide. 3. Automatic information exchange between web-based disaster information systems. The first hazard to be addressed by GDACS was earthquakes, because of the open availability of mature and global seismological monitoring infrastructure. Tropical cyclones and volcanoes were added soon, and tsunami monitoring was added soon after the Indian Ocean Tsunami.

JRC software collects near real-time hazard information from various sources, which is combined in GIS models with demographic and socio-economic data. The software performs an automated consequence analysis with a risk formula combining the magnitude of a hazard with an element at risk (such as the amount of people in the affected area) and a vulnerability factor accounting for physical and socio-economic resilience of the affected area. For tsunamis, GDACS uses a novel tsunami wave propagation system developed at JRC, which, through 135000 pre-calculated scenarios, can provide an immediate assessment of tsunami risk. As

research in early warning and alert systems is developing rapidly, existing data and models will be outdated soon. In order to provide a robust framework for cooperation, GDACS was designed from the beginning as a system of systems. Individual components can be exchanged with newer, better components that provide more added value for emergency responders. Provided a set of information technology standards is followed (such as web service standards, geospatial standards, standard country and disaster codes, etc.), integration of new systems is straightforward.

SD11/WE/O8 **- THE LOGIC AND STATUS OF "ISTANBUL EARTHQUAKE RAPID RESPONSE SYSTEM"**

C. ZULFIKAR[1], H. ALCIK[1], O. OZEL[2], M. Erdik[1]
[1]Bogazici University, Kandilli Observatory and Earthquake Research Institute, Department of Earthquake Engineering; [2]Istanbul University, Engineering Faculty, Department of Geophysics

Following two M 7+ earthquakes in 1999 on the north Anatolian fault to the east of the Marmara Sea, and recognition of the westward migration of earthquakes toward Istanbul, have caused major concern about future earthquake occurrences in the Marmara Region. As a result of the preparations for an expected earthquake in Istanbul, an Earthquake Rapid Response System, shortly IERRS, has been established in 2002. One hundred strong motion accelerometers have been placed in populated areas of Istanbul, within an area of approximately 50x30 km, to constitute a network that will enable rapid shake map and damage assessment a damaging earthquake. After triggered by an earthquake, each station will process the streaming strong motion to yield the spectral accelerations at specific periods and will send these parameters in the form of SMS messages to the main data center through available GSM network services. Shake and damage distribution maps are automatically generated and pushed to several end users to provide an emergengy response for potentially disastrous earthquakes. This study especially focuses on the detailed explanation of the existing methodology applied in IERRS and its performance so far.

SD11/WE/O9 **- INVESTIGATION ON REAL-TIME SPECTRAL SHAPE PREDICTION FOR STRUCTURAL CONTROL PURPOSES**

C. Galasso[1], I. Iervolino[1]
[1]Dipartimento di Ingegneria Strutturale, Università degli Studi di Napoli Federico II

Semi-active variable stiffness (SAVS) control systems are utilized to modify the stiffness and thus the dynamic properties of the structure in which they are installed. These systems consist of stand-by bracings attached to selected storeys of the structure and are equipped with locking/unlocking devices which can activate (*stiff configuration*) or deactivate (*soft configuration*) the bracing. In principle, the combined use of Earthquake Early Warning Systems (EEWSs) and SAVS control may improve the earthquake performance of specific systems, and therefore it is worth to be investigated. In particular, in the structural control prospective, if an EEWS is able to predict in real-time the spectral content of the impending earthquake by the early recorded signal, it could be potentially possible to "move" the fundamental period of the structure from the most demanding part of the response spectrum of that specific ground motion. In this study, some preliminary results related to feasibility of such an approach are presented. Based on preliminary literature results, an empirical correlation between the predominant period (and thus the frequency content) of the signal measured in a few seconds after the P phase arrival and the predominant period of the final S-waves record is investigated. The dataset consists of several Italian events in the magnitude range 4-6.9. Whether this correlation, if any, may be used for EEW-driven SAVS is finally discussed.

SD11/WE/O10 **- QLARM - A SOFTWARE FRAMEWORK FOR RAPID POST-EVENT LOSS ASSESSMENT AND EARTHQUAKE SCENARIOS**

P. Kästli[1], C. Bonjour[2], P. Rosset[3], G. Trendafiloski[4], T. van Stiphout[1], S. Wiemer[1], M. Wyss[4]
[1]Swiss Seismological Service; [2]Bonjour Engineering GmbH, Swiss Seismological Service; [3]McGill University Montreal; [4]WAPMERR

After large earthquake disasters with heavily affected traffic and communication infrastructure, a full overview on ground truth on losses often needs days to be developed, making the planning of fast and adequate rescue operations difficult. Thus, humanitarian relief agencies initially strongly rely on expert tools for rapid post event loss modelling in the first minutes to dozens of minutes after an event. In the framework of the IMPROVE project, WAPMERR and Swiss Seismological Service (SED) developed the loss modelling software QLARM (eartQuake Loss Assessment for Response and Mitigation) for supporting their information services to the Swiss Humanitarian Aid Unit. The software estimates expected numbers of casualties (and limit states, e.g. different levels of injury) as a function of earthquake source, exposed population, and building stock. It follows a modular design pattern, allowing for pluggable modules for source description (currently implemented: point and line sources), attenuation behaviour (implemented different attenuation relationships for PGA, macroseismic intensity, and potentially others), ground motion source (implemented: from attennuation-based ground motion, or from USGS-style shakemap), an open list of building types, and loss models (implemented: two flavours of semi-empirical loss models). The «world data set» model (sum of exposed population and building inventory) allows for a wide range of granularity. It supports gridded data as well as settlement-oriented exposure description scaling from a single point per mega-city down to the description of small neighbourhoods or even individual buildings. The granularity may vary within one world dataset, allowing to take advantage of the best census data available for each region within a model. Exposure data may be described as varying over time in numbers as well as in granularity. First calibration exercises show that from first post-earthquake magnitude and location estimations, catastrophic events can often be distinguished from low-loss events, but not always. Accuracy of the building stock inventory (or reasonable assumptions) is crucial, while their is comparably little difference in performance between simple point source-based ground motion models and ground motion derived from even instrument-backed shakemaps. Qlarm is a client-server application written in java with a postgres-powered database backend and a web-frontend implemented using the xml publishing framework Cocoon. The software is open source and available on the SED website.

ES13 - FUNDAMENTALS OF MODERATE TO GREAT EARTHQUAKES FORECASTS

Wednesday 8, 08h00-10h00

ES13/WE/O1 **- DYNAMIC OF SEISMIC PROCESS AND EARTHQUAKE PREDICTABILITY**

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Many factors complicate earthquake sequences, including the heterogeneity and self-similiarity of geological medium, hierarchical structure of faults and stresses, small-scale variations in the forces from different sources. Several metastable areas of different scale exist in the seismically active region before the earthquake. Any earthquake is preceded by precursory phenomena of different scale in space and time. They include long-term activation, seismic quiescence, foreshocks in the broad and narrow sense, clusters of seismic events, arising of hidden periodical vibrations, effects of synchronization of seismic activity, anomalies of geophysical fields and others. The possible physical mechanisms of different precursors are considered briefly. Such phenomena indicate that the dynamic system of lithosphere is moving to a new state – catastrophe. However, all of them are not of high reliability in the prognostic aspect because there exist anomalies qualified as false. The weak fluctuations from outer and internal sources play a great role on the eve of earthquake and the occurrence time of future event depends of the collective behavior of triggers. The main task is to improve the methods of metastable zones detection and probabilistic forecasting.

ES13/WE/O2 **- A REVISITING OF THE LONG-TERM PREDICTION OF THE NEXT STRONG INTERMEDIATE-DEPTH EARTHQUAKE IN THE VRANCEA SLAB**

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The model of long-term prediction, of intermediate depth (60 - 175 km), of Purcaru (1974, 1979) made the successful scientific prediction of the March 4, 1977 earthquake (Ms7.1, MGR7.2 and Mw7.45). The foundations of the model are: 1) the historical earthquakes (1100-1974), 2) cuantification in terms of magnitude to make posible the predictin in classes, 3) 2- magnitude classes of earthquakes: M > 6.7 and M > 7.1-7.25, 4) the determinism of the prediction and

the prediction of an earthqiauke in a time interval, and 5) the repeat of a future earthhquake is established by phenomenological laws in terms of cycles (about 100 yr) and supercycles (about 300 yr) These cycles occurred in three time-bands, defined the periods 0-10, 30-40 and 70-90 years of each century. Our predictions are founded on the stability of the discoverd laws of earthquake repeat, the necesary condition for a prediction, although we found some deviations of the earthquake occurrences from the above three time bands. The prediction interval gives the prediction error. Our model predict the next strong earthquake (M about 6.7 -7) in the first band 0-10, with a repeat cycle of about 100 yr (96+-7yr), i.e. to occur about in 2000 - 2012. If it is about in this interval the prediction is scientifically successful, and if is later, then the prediction is a false alarm.

G. Purcaru,Quasi- and supercyclicity of earthquakes and time-magnitude gaps in earthquake prediction. Scienific Rept. 6-73/75, Norvegian Academy, NORSAR, p.53-55,1974.

G.Purcaru, The Vrancea, Romania, earthquake of March 4, 1977- A quite successful prediction. PEPI, Vol.18, p.274-287, 1979.

ES13/WE/O3 - MAPS OF EXPECTED EARTHQUAKES BEFORE SIMUSHIR EARTHQUAKES SERIES OF 2006-2007 (M8.3, M8.2) AND THE FUTURE KURIL EARTHQUAKES

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The report continues a series of papers devoted to results of testing of algorithm MEE in various seismoactive regions of the world. In the present work the data of the regional catalogue of Kuril Islands earthquakes for the period since 1962 to 2010 compiled by the Sakhalin Branch of Russian Geophysical Service is used. By preliminary research it has been established, that energy class cutoff level is equal K=9.5 for all period of supervision and for the largest part of territory.Following parameters were used as precursors of strong $K \geq 13.5$ earthquakes: density of seismogenic ruptures Ksr, b-value, number of seismic events N, released seismic energy $E^{2/3}$. Spatial-temporal distributions of each precursor were calculated in 3 years sliding time window with 3 months shift. For each precursor retrospective evaluation of statistical characteristics such as probability of successful prediction, probability of false alarm et al. have been calculated and alarm levels are chosen. The average waiting time of strong earthquake appeared equal Texp=4.06±1.24 years.Using these distributions and Bayesian approach Maps of Expected Earthquakes (MEE) were constructed. The set of conditional probabilities $P(D1|K)$ for all spatial cells represented in the form of isolines was called the Map of Expected Earthquakes for the time period $[t_0, t_0+\Delta T_{MEE}]$, where ΔT_{MEE} is the MEE serviceability time. Occurrence of a strong earthquake in this time interval is assumed to be equiprobable. MEE series for region of the Kuril Islands has been designed for sizes 50x50 km of space cells with 3 months shift. It covers the period since 1970 till present time. The first 8 years were a data for «tutorial» of the algorithm.Pair of Simushir earthquakes which have occurred in November, 2006 and January, 2007, was the strongest seismic events of last decades in this area. Epicenters of both strong earthquakes, their strongest foreshock (2006.09.30, M_{LH}=6.9, Kc=13.7) and the strongest aftershock (2006.12.15, M_{LH}=5.7, Kc=14.1) have taken place in zones with conditional probability more than 70%. It is necessary to note, that the zone with a level of conditional probability of 70% has appeared in a source area in 2003, approximately 3-3.5 years prior to earthquakes occurrence.The resulted example once again confirms opportunities of MEE algorithm for the medium-term forecast of strong earthquakes. In conclusion of the report the MEE for the period of 2010-2013 will be presented.Work has been executed at financial support of the Russian Foundation for Basic Research grant # 09-05-12059 and # 09-05-01166.

ES13/WE/O4 - FORESHOCKS AND THEIR VALUE FOR THE PREDICTION OF THE MAINSHOCK: THE CASE OF THE 6 APRIL 2009 EARTHQUAKE (MW=6.3) IN L'AQUILA, ITALY

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The disastrous mainshock (M_w=6.3) of 6 April 2009 in L' Aquila, Italy, was one of the most lethal earthquakes in the last years in Europe. We have searched retrospectively for precursory seismicity changes preceding the mainshock with the use of the earthquake catalogue of INGV. The catalogue segment examined extends from 1 January 2006 up to 30 June 2009 with the aim to compare seismicity changes occurring before the earthquake with the seismicity changes associated with the aftershock sequence. Investigation of seismicity changes was performed in an area of radius 50 km from the mainshock epicenter with the examination of three parameters: the fractal dimension of earthquake epicenter concentration, d, the seismicity rate, r (events/day) and the b-value in G-R. The statistical z-test and Utsu-test were applied to identify significant changes of r and b, while temporal variation of d was used to describe epicentral density. From the beginning of 2006 up to the end of October 2008 the activity was relatively stable and remained in the state of background seismicity (r=1.14, b=1.09). From 28 October 2008 up to 26 March 2009, r increased significantly to 2.52 indicating weak foreshock sequence; the b-value did not changed significantly. The weak foreshock sequence was spatially distributed within the entire area but after January 2009 the epicenters were gradually concentrating in the area of the seismic fault. In the last 10 days before the mainshock, strong foreshock signal became evident in space (dense epicenter concentration in the hanging-wall of the Paganica fault), in time (drastic increase of r to 21.70 events/day) and in size (b-value dropped significantly to 0.68). The significantly high seismicity rate, the low b-value and the dense epicenter distirbution in the entire foreshock sequence make a substantial difference from the background seismicity. Also, the b-value of the strong foreshock stage (last 10 days before mainshock) was significantly lower than that in the aftershock sequence but at the same time the density of epicenter distribution gradually decreased. Our results indicate the important value of the foreshock sequences for the prediction of the mainshock. In addition, the method proved quite successful in recognizing within 1 or 2 days from the mainshock occurrence the aftershock nature of the seismic sequence.

ES13/WE/O5 - RISK AND RETURN: EVALUATING REVERSE TRACING OF PRECURSORS EARTHQUAKE PREDICTIONS

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In 2003 the Reverse Tracing of Precursors (RTP) algorithm attracted the attention of seismologists and international news agencies when researchers claimed two successful predictions of large earthquakes. These researchers had begun applying RTP to seismicity in Japan, California, the eastern Mediterranean, and Italy; they have since applied it to seismicity in the northern Pacific, Oregon, and Nevada. RTP is a pattern recognition algorithm that uses earthquake catalog data to declare alarms, and these alarms indicate that RTP expects a moderate to large earthquake in the following months. The spatial extent of alarms is highly variable and each alarm typically lasts nine months, although the algorithm may extend alarms in time and space. We examined the record of alarms and outcomes since the prospective application of RTP began, and in this presentation we report on the performance of RTP to date. To analyze these predictions, we used a recently-developed approach based on a gambling score, and we used a simple reference model to estimate the prior probability of target earthquakes for each alarm. Formally, we believe that RTP investigators did not rigorously specify the first two "successful" predictions in advance of the relevant earthquakes; because this issue is contentious, we consider analyses with and without these alarms. When we included contentious alarms, RTP predictions demonstrate statistically significant skill. Under a stricter interpretation, the predictions are marginally unsuccessful.

ES13/WE/O6 - GLOBAL MONITORING AND FORECAST STRONG EARTHQUAKES BASED ON SEISMIC ENTROPY METHOD

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[1]*Earthquake Prediction Centre «GeoQuake»*

The proposed method of monitoring and prediction of earthquakes based on seismic entropy is practically applied to different regions of the world since 2007. Experience has shown that the problem of forecasting can't be solved within the framework of traditional views. In 1993, for a quantitative description of seismic processes in real media Akopian introduced the physical parameters of the density of states and entropy, and as the quantum - an elementary micro earthquake.It was shown that these processes occur within a specific volume of the lithosphere, called Seismic System (SS), and each SS is characterized by the parameters of the law of seismic entropy production, their minimum and maximum threshold

magnitude earthquakes. To identify the SS calculated the integral of the total seismic energy released in the volume of the geological media and its logarithm - entropy for a certain period of time.These parameters are always increasing over time and contain information about the SS as a whole. The system is considered to be definite if it satisfies the law of seismic entropy production. Each earthquake with a magnitude less than the threshold is accepted as a natural indicator of the external impact on the system - earthquake-indicator. The law of seismic entropy production - regularity between the total energy of earthquake-indicators, released in a seismic cycle, and the energies of strong earthquakes which end these cycles. This law act, where it is disrupted the Gutenberg-Richter law.Introduction to basic micro earthquake – the quantum, allowed applying methods of Synergetic in seismology. Failed to prove that the density of states equals the number of states of the seismic system, and its logarithm is seismic information entropy. Hence it follows that the larger the released total energy of earthquakes, the more information about the system we have, but even during the seismic calms information about the system always grows, because the absence of earthquakes in SS continues an irreversible process, which we missing information. This approach is new, not familiar modern seismologist. The introduction of new parameters allowed creating a quantitative description of natural processes in the Earth's lithosphere and earthquake prediction. Monitoring entropy allows on the basis of energy diagrams to predict the magnitude of the expected earthquake. Place and time of expected strong earthquakes is refined and forecasted on the basis of track diagrams. On the track diagram is separated local region (attractor), inside which SS loses stability and occur strong earthquakes. Currently, the world found more than hundred SS and subsystems. Monitoring and forecast of strong earthquakes in all these systems in real time is produced on our site www.geoq.ru.

ES12 - NATURAL AND INDUCED SEISMICITY DRIVEN BY FLUIDS: OBSERVATIONS AND MODELLING

Wednesday 8, 08h00-10h00

Wednesday 8, 10h20-12h00

ES12/WE/O1 - MICROSEISMIC EVIDENCE OF HYDRAULIC FRACTURE FAULT ACTIVATION

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The expansion of North American unconventional petroleum resources has lead to the establishment of microseismic monitoring of hydraulic fracture stimulations as a common place technology to image the fracture growth. Several thousand hydraulic fractures have been monitored in a wide variety of geological and tectonic settings, resulting in a large catalog of interesting observations of the characteristics and variability of hydraulic fracture networks. Microseismic images show variations between relatively simple fracture networks associated with a narrow fracture, to complex, wide fracture networks as the injection activates fractures in multiple directions. This variability between simple and complex fracture networks is attributed to the geomechanical details of pre-existing fractures and stress anisotropy. Furthermore, in some cases the primary hydraulic fracture with associated microseismicity results in stress induced fault activation with secondary seismic activity. In some of these cases of fault activation, various observations can be made leading to clear inference of fault activation while many are less clear cut. In this presentation, various case studies will be shown that demonstrate variation of both hydraulic fracture complexity and fault activation. In one example, microseismic imaging of multiple hydraulic fractures along a horizontal well show significant variation in the fracture geometry including both simple and complex fractures. The complexity is demonstrated by both microseismic hypocentral locations and composite fault plane solutions. Comparison with local structural geology information, sonic velocity anisotropy and injection responses point to possible causes of the variability. In a second example, a clear example of fault activation is described. In this particular example of a hydraulic fracture around a regional thrust fault, significant microseismic deformation occurred after the end of injection. The special and temporal relation of the co-injection and post injection microseismicity as well as frequency-magnitude characteristics point to fault activation. Source mechanism results show a switch from strike-slip mechanisms for microseismicity occurring during the injection, to a dip-slip mechanism on a fault plane parallel to the regional thrust fault. Supporting the seismic observations of fault activation, geomechanical analysis demonstrated that stress induced deformation resulting from the primary hydraulic fracture. The integrated information including seismic, geologic, geomechanical and injection data with this thrust fault example, serve as a clear example of stress induced fault activation. The presentation will also include contextual information and additional observations from other case studies to support the general observations and conclusions.

ES12/WE/O2 - HIGH PRECISION RELOCATION AND FOCAL MECHANISMS OF THE 2006-2007 BASEL INDUCED EARTHQUAKE SEQUENCE.

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[1]Swiss Seismological Service @ ETH Zurich, Switzerland; [2]Engineering Geology @ ETH-Zurich, Swizerland

The Deep Heat Mining project in Basel, Switzerland, was one of the first purely commercially oriented Enhanced Geothermal System (EGS) projects. Beginning on 2 December 2006, water was injected into a 5 km deep well with increasing flow rates. Because of strongly increased seismic activity, which included a ML3.4 event, the project was aborted the project.

This induced earthquake sequence is one of the most densely monitored deep fluid-injections in the world. The seismic monitoring system consisted of six borehole seismometers near the injection well and of up to 30 seismic surface stations in the Basel area.

Results of high precision event relocation and focal mechanism analysis based on waveform analysis of the borehole seismometer data will be presented.

ES12/WE/O3 - SEISMICITY INDUCED BY FLUID INJECTION INTO A BOREHOLE AT THE HDR SITE SOULTZ-SOUS-FORÊTS (ALSACE) IN 2003 AS A MODEL OF DRIVING FORCES AND RUPTURING PROCESSES IN THE WEST BOHEMIA/VOGTLAND EARTHQUAKE SWARMS

J. Horálek[1] [invited] , J. Šílený[1], Z. Jechumtálová[1], T. Fischer[1]
[1]Institute of Geophysics, Acad. Sci. of Czech Rep.

The border area between West Bohemia and Germany (West Bohemia/Vogtland) is well known by reoccurrence of intraplate earthquake swarms and by a high activity of crustal fluids. Three earthquake swarms of 1997, 2000 and 2008 with magnitudes M_L up to 3.8 took place in the Nový Kostel (NK) focal zone recently. Hypocentres of the 2000 and 2008 swarms fall precisely on the same portion of the NK fault plane, whereas the 1997 swarm was located about 1 km apart on the edge of the NK fault plane. We analyzed moment tensors of the 1997 and 2000 swarms and their time and space variations to get an idea of faulting and driving forces acting in them. We found different mechanism patterns of these swarms. In the 1997 swarm two source mechanisms occurred: a pure shear source with an oblique normal faulting in the 1st swarm phase and a combined source (possessing the shear and tensile components) with an oblique thrust faulting in the 2nd swarm phase. However, all the 2000-events were pure shears parallel to the NK fault plane. The significant non-shear source mechanisms in the 1997 swarm suggest a relevant role of fluids in driving the swarm activity, whereas the 2000-swarm mechanisms indicate a self-organization due to the stress redistribution. We took advantage of data of the swarm-like seismicity, which was induced by the fluid injection at the HDR site Soultz-sous-Forêts in 2003, with a view to infer relevance of fluids in earthquake swarms. We estimated source mechanisms and investigated their time-space variations depending on the flow rate and wellhead pressure. We found that injected fluids activated two segments of existing natural faults. The source mechanism patterns of these segments differ markedly; surprisingly all the analyzed events are pure shears without any non-shear attributes. Thus we infer that in case of the favourably oriented faults, pressurized fluids play a decisive role in decreasing of their shear strength in terms of the Coulomb friction criterion. The running swarm activity is then mainly driven by the stress changes, consequently a pure-shear rupturing occurs; this can be the case of the 2000 swarm, of the 1st phase of the 1997 swarm and also of the 2003-Soultz induced seismicity. Given that the fault is less favourably oriented, the tensile force prevails the shear traction and brings the fault to rupture, as it probably happened in the 2nd phase of the 1997 swarm.

ES12/WE/O4 - VELOCITY VARIATIONS IN THE EGS GEOTHERMAL RESERVOIR OF

SOULTZ-SOUS-FORÊTS (FRANCE) DURING HYDRAULIC STIMULATIONS: CONTRIBUTION OF THE LOCAL EARTHQUAKE TOMOGRAPHY.

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In July 2000 a stimulation test was performed in the GPK2 well of the Enhanced Geothermal System (EGS) site of Soultz-sous-Forêts (Alsace, France). During the stimulation an intense micro-seismic activity has been detected and recorded by downhole and surface seismic stations. Previous studies have shown temporal changes of the physical properties in the reservoir during the fluid stimulations through the results of a 4D seismic tomography obtained by dividing the induced seismicity into chronological subsets of a constant number of events (Cuenot et al, 2008). We present here the results of new 4D tomographies relative to this stimulation experiment. The velocity models have been obtained by rearranging the sub-sets in the light of the stimulation strategy. To obtain the final velocity model we applied the double-difference tomographic method (Zhang and Thurber 2003) and the WAM post processing (Calo' et al., 2009). The new models give clearer insights on the temporal changes of the velocities and show that their evolution is not strictly related to the induced seismicity. Our tomographies show low velocity anomalies aligned along the main strikes of the pre-existing structures and moving during the stimulation test. During the fluid injection the stress field changed in the time and space domains accommodating the strains with seismic and probably also with aseismic displacements. Indeed velocity anomalies are also detected in regions that were aseismic during the stimulation. Therefore, the volumes where sudden changes of the velocities occurred should be mainly interpreted as the expression of transient stress conditions and not as regions affected directly by the injected fluids. In this study we show how the improved tomographic models are fundamental to describe velocity and seismic structures not clearly visible previously, with the conventional seismic imaging. The resolution and the reliability of the proposed method could make the Local Earthquake Tomography a practical tool for the characterization and exploration of a geothermal reservoir.

ES12/WE/O5 **- PASSIVE SEISMIC MONITORING OF CO2 SEQUESTRATION: A CASE STUDY FROM THE MICHIGAN BASIN**

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We present evidence for a seismic source associated with degassing CO_2 during leakage along two wellbores instrumented with arrays of downhole seismometers. More than 200 microseismic events were detected in direct vicinity of the monitoring wells. The observed seismic waves are dominantly P waves and tube waves, with no (or extremely weak S) shear waves. The waveforms of these events indicate extremely rapid amplitude decays with distance across the arrays, consistent with the seismometers being in the near field of the seismic source. The frequency characteristics, first-motion polarities and S to P amplitude ratios suggest a single force source mechanism. Because the seismic arrays were located at the depth where the density of ascending CO_2 changes most rapidly, it appears that the transition of CO_2 from supercritical fluid to gas triggers an oscillation of fluid-filled cavities and fractures very close to the wellbores in which the monitoring arrays were deployed. In many aspects, the observed waveforms show a striking similarity to those modeled for degassing processes below volcanoes. We suggest that the single force represents bubble growth and resulting oscillations in cement cavities between the steel casing of the well and the rock adjacent to the wellbores and/or within fractures in the rock just outside the wellbores.

ES12/WE/O6 **- LOW FREQUENCY EARTHQUAKE (LFE) DETECTION TECHNIQUES PRODUCE FALSE DETECTIONS WITHIN NON-VOLCANIC TREMORS (NVT) CONFINING NVT TO THE DEEP LFE ZONE IN JAPAN, BUT IN MEXICO NVT ARE LOCATED IN BOTH THE UPPER AND LOWER CRUST USING STANDARD LOCATION TECHNIQUES**

A. Husker[1], E. Huesca[1], X. Novo[1], V. Kostoglodov[1], J. Payero[1], V. Cruz-Atienza[1], N. Shapiro[2]
[1]UNAM; [2]IPGP

Low Frequency Earthquakes (LFE) that occur during Non-Volcanic Tremor (NVT) exhibit S waves pulses with durations on the order of 1 second (Obara and Hirose, 2006). They are being increasingly used to determine the locations of the NVT in which they occur suggesting that NVT is made up of many LFE's (e.g. Shelly, et al., 2006; Shelly, et al., 2007). Those studies used cross-correlation of LFE templates with seismograms to autodetect supposed LFE's which are not visible within the NVT until the cross-correlations are stacked. We have found that cross-correlating noise templates produces positive detections at a rate consistent with the LFE detections in those studies. The locations of the detected LFE are more or less predetermined by the locations of the templates rendering the detection technique only effective for producing false data. The LFE templates' locations however appear to valid as they can be seen within the seismograms, but this finding reduces the evidence to support the claim that NVT is made up of many LFE's and the 2 may be distinct phenomena. Our study locates NVT by the standard technique of cross correlating envelopes of NVT, not templates of LFE's, to determine difference in arrival times. The cross correlation in this case is applied 20-50 second pulses that can be visually determined within the NVT. The NVT were recorded from 2005 to 2007 by the MesoAmerican Seismic Experiment (MASE). MASE was a 550 km profile of seismic stations placed every ~5 km running nearly perpendicular to the trench starting at the coast in Acapulco, Mexico and thus provided detailed coverage of the NVT during the 2 year period. The 1 dimensional MASE array only allowed for 2 dimensional locations of the NVT. However, due to the dense station configuration it can be determined that some NVT extend into the upper crust (< 15 km deep) unlike the LFE studies. The effect may be due to fluid leaving the slab and rising through the crust. The NVT's are detected in or close to zones of low seismic velocity as seen in tomography and high conductivity as measured by magnetotellurics.

ES12/WE/O7 **- MIGRATION AND RATE OF HYDROFRACTURE-INDUCED SEISMICITY: COMPARISON OF OBSERVATIONS WITH MODEL-PREDICTIONS BASED ON MODELED COULOMB STRESS CHANGES IN THE ROCK**

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Recently, a 2D injection model has been developed to explain the asymmetric growth of hydrofracture-induced seismicity in a gas formation (Fischer et al., 2009, GJI, 179, 634-639; Dahm et al., 2010, JGR, in review).

The theory explains nonlinear and asymmetric bi- and unilateral growth of the seismicity front and back-front with respect to the injection point.

Our model additionally predicts the time and space dependent stress field induced by the hydrofracture emplacement.

In this study, we use a rate and state dependent trigger model to simulate the spatio-temporal earthquake nucleation during the fracture growth.

We compare the predictions to observed seismicity from a gas field in Texas in order to verify whether a hydrofracture model can be linked to seismicity.

The potential of the study is to develop physics-based models for forecasting the seismic activity and its source mechanisms as a function of hydrofracture-induced loading.

ES12/WE/O8 **- FLUIDS IN BRITTLE FAULTING: ANY CLUES FROM SEISMOLOGY?**

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Seismic activity due to fluid injections became a focus of many recent seismological studies. Two principal questions arise: (1) how large seismic events can be triggered/induced by the fluid injection and (2) what seismic methods can detect the fluid involvement in triggering/driving the seismic activity. To answer both these questions we aim to better understand the interplay between the state of stress, fracture network geometry and fluid injection characteristics.

A common clue to the elevated fluid pressure is the presence of opening of the fault, which results from the tensional effective normal stress acting on the fault plane. Thus, the slip vector during the earthquake deviates from the fault surface. In terms of the

seismological terminology, this is reported as the non-double-couple component of the source moment tensor or as tensile events. However, despite frequent fluid involvement in source processes, only few source mechanisms studies show doubtless non-DC components of the moment tensors. This holds also for the microseismicity accompanying the hydraulic fracture stimulation of hydrocarbon and geothermal reservoirs.

We join the typical seismological and geomechanical approaches in order to improve our understanding of the presence of crack opening in natural and injection induced earthquakes. We analyze the relation of the shear and normal tractions on the fault plane to the occurrence of tensile events and show the reason for seldom occurrence of crack opening. We also examine the possible dependence of the size of the earthquake to presence of non-DC component to explain the rare occurrence of tensile earthquakes. Further we propose a method for assessing the fluid involvement in the fracture process using the focal mechanisms and apply it to a suitable data set of injection-induced seismicity.

ES12/WE/O9 - QUANTITATIVE MODELLING OF FLUID INJECTION AND SHEAR RUPTURE ALONG A FAULT SEGMENT WITH VARIABLE FRICTION BEHAVIOUR. IMPLICATION FOR FAULT RE-ACTIVATION AND POTENTIAL MICRO-EARTHQUAKE RUPTURE SIZE

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Heat extraction from deep 'engineered' fractured formations is currently under investigation at many places in the world. The challenge is to develop a reservoir in deep rock masses, to circulate a fluid and to recover heat for clean electricity production at the surface. In most cases, the promoted technology is to force cracks that pre-exist in deep rocks by injection of pressurised water as the effect of a pore pressure increase is to weaken fracture strength. Failure in fractures can be approximated by a linear relation in between shear stress at failure and normal stress, (the so called Mohr-Coulomb failure criterion), with two parameters, the internal friction μ and the internal cohesive strength C. When failure develops along particular fractures, frictional slip occurs. The triggered dislocations are accompanied by AE which are recorded and processed for the evaluation of the success of the hydraulic treatment. However many uncontrolled events with unwanted seismic magnitude are reported that may trouble public acceptance for this CO2 free source of energy. In this paper we are addressing the propagation of shear dislocation in a 2D fault segment due to fluid injection at one point. We use a discontinuity displacement method for 3D elastic stress transfers in the rock mass surrounding the fracture. The fault segment is meshed into a network of cells that can have variable properties (hydraulic, friction, cohesion). Far field boundaries are constant stress. As the fluid pressure front progress through the fracture, conditions for failure may be obtained at some places although other places may resist to the shear loading. At ruptured places, displacements are calculated whereas stresses are induced at places where compressive strength is enough for preventing rupture. The purpose of the present work is to analyse the spatio-temporal growth of the sheared zones At each time step, equivalent seismic moments are obtained, at the local scale of neighbouring cells where slippage occurs simultaneously and at the scale of the global structure. This will form the basis for the discussion on the significance of the variable friction failure mechanism, considered as the source of the acoustic emissions. The objective is to gain some understanding in the mechanism of large magnitude events and in the mechanism of late events, observed after the end of an injection phase. The final goal will be contribute to the design of successful hydraulic frac-tests as fault strength is also known to be scale dependent.

ES12/WE/O10 - ANALYSIS OF FLUID INDUCED SEISMICITY RESULTING FROM TIME-DEPENDENT INJECTION PRESURES

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Borehole fluid injections are often accompanied by microseismic activity. Although the nature of fluid induced seismicity is still topic of ongoing research, one hypothesis argues that its triggering mechanism can be well approximated with a diffusional process of relaxation of pore pressure perturbations caused by the injected fluid. Relating the perturbed pore pressure to the induced seismicity allows to characterize hydraulic properties of the stimulated reservoir. The pore pressure perturbation can be calculated by solving the partial differential equation of diffusion. Analytical solutions of this equation are well known for the condition of constant strength of a fluid injection source. But in some injection experiments, such as in Basel, Switzerland, the source strength is not constant over time. Here we present a solution of the diffusion equation which considers the special problem of linearly rising source strength. This solution is used to derive mathematical expressions for the seismicity rate and for the cumulative number of microseismic events. We verify the obtained equations by a comparison with the numerical solution of the diffusion equation and with synthetically generated microseismicity. We then apply methods for a reservoir characterization which utilize those equations to microseismic data collected during the hydraulic stimulation of the Basel geothermal reservoir. Our analysis result in consistent estimates of the hydraulic properties. Assuming an effective isotropic medium, we obtain a scalar permeability of about 75 microDarcy which is in agreement with estimates from hydraulic data analysis. Furthermore, we reconstruct the stability of pre-existing fractures in the reservoir. This fracture strength can statistically be described by a criticality whose upper bound (about 1 MPa) is below the maximum of pore pressure perturbation. Such a situation can result in an increase of the size of induced events even after injection stop. This phenomenon is indeed observed in Basel where events with largest magnitudes occurred after shut-in. For the lower bound of criticality we obtain rather a range of estimates (4000 Pa to 12,000 Pa). Possibly, this observation can be attributed to the two different sets of pre-existing fractures as reported for the Basel reservoir. Depending on their alignment with respect to the orientation of the regional stress field, the two fracture systems can be characterized by different criticality fields. In this case, the lower value would correspond to the fracture system which is oriented parallel to the direction of maximum horizontal stress. Borehole fluid injections are often accompanied by microseismic activity. Although the nature of fluid induced seismicity is still topic of ongoing research, one hypothesis argues that its triggering mechanism can be well approximated with a diffusional process of relaxation of pore pressure perturbations caused by the injected fluid. Relating the perturbed pore pressure to the induced seismicity allows to characterize hydraulic properties of the stimulated reservoir. The pore pressure perturbation can be calculated by solving the partial differential equation of diffusion. Analytical solutions of this equation are well known for the condition of constant strength of a fluid injection source. But in some injection experiments, such as in Basel, Switzerland, the source strength is not constant over time. Here we present a solution of the diffusion equation which considers the special problem of linearly rising source strength. This solution is used to derive mathematical expressions for the seismicity rate and for the cumulative number of microseismic events. We verify the obtained equations by a comparison with the numerical solution of the diffusion equation and with synthetically generated microseismicity. We then apply methods for a reservoir characterization which utilize those equations to microseismic data collected during the hydraulic stimulation of the Basel geothermal reservoir. Our analysis result in consistent estimates of the hydraulic properties. Assuming an effective isotropic medium, we obtain a scalar permeability of about 75 microDarcy which is in agreement with estimates from hydraulic data analysis. Furthermore, we reconstruct the stability of pre-existing fractures in the reservoir. This fracture strength can statistically be described by a criticality whose upper bound (about 1 MPa) is below the maximum of pore pressure perturbation. Such a situation can result in an increase of the size of induced events even after injection stop. This phenomenon is indeed observed in Basel where events with largest magnitudes occurred after shut-in. For the lower bound of criticality we obtain rather a range of estimates (4000 Pa to 12,000 Pa). Possibly, this observation can be attributed to the two different sets of pre-existing fractures as reported for the Basel reservoir. Depending on their alignment with respect to the orientation of the regional stress field, the two fracture systems can be characterized by different criticality limits. In this case, the lower value would correspond to the fracture system which is oriented parallel to the direction of maximum horizontal stress.

ES12/WE/O11 - INTER EVENT TIMES OF FLUID INDUCED SEISMICITY

C. Langenbruch[1], *S. Shapiro*[1]
[1]*Freie Universität Berlin*

Fluid injections from boreholes into geother-

mal and hydrocarbon reservoirs can induce a significant number of seismic events. For the complete understanding of the physical processes leading to the triggering of these events it is essential to develop statistical models describing the occurrence of fluid induced events in time and space. These models can then be used for the development of meaningful risk studies estimating the seismic impact caused by a fluid injection. Here we analyze the waiting times between subsequent seismic events induced by fluid injections into geothermal reservoirs in six different case studies at Soultz sous Forêts (France) and Basel (Switzerland). Firstly, we study the inter event time distribution during phases of stationary seismicity, that is, phases characterized by an approximately constant seismicity rate in the large time scale. Here we find that the occurrence of events can be described according to the Homogeneous Poisson Process (HPP) in time. Events distributed according to the HPP occur independently of each other; more precisely their occurrence times do not depend on the time elapsed since the last event. Regardless of the time scale, fluid induced events during stationary phases of seismicity hence occur independently of each other. In contrast to this different studies on inter event times of naturally occurring seismicity revealed a correlation of seismicity in the short time scale. We also analyze the distribution of inter event times for the complete event catalogs of the six case studies. Our analysis shows that complete seismic sequences induced by a fluid injection can be described according to the Inhomogeneous Poisson Process (IHPP), that is, as a sequence of independent events occurring at a time dependent event rate. We follow from this that all events are triggered by a guiding background process, namely the relaxation process of stress and pore pressure perturbation created at the open hole section. Thus, coupling effects between events can be neglected for the description of fluid induced seismicity. Furthermore, we show that the distribution of inter event times is independent on the magnitude range of events chosen for the analysis. By combining the mathematical description of the Poisson Process with the Gutenberg Richter relation we build a statistical basis for upcoming seismic risk studies in geothermal industry.

SW2 - SURFACE WAVE SEISMOLOGY WITH DIFFERENT WAVELENGTHS

Wednesday 8, 10h20-12h00

SW2/WE/O1 - ANISOTROPY FEATURES BENEATH THE QINGHAI-TIBET PLATEAU BASED ON THE LOVE-RAYLEIGH DISCREPANCY

Y. Chen[1], J. Badal[2], Z. Zhang[1]
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Relative SV and SH wave speeds are generally attributed to radial seismic anisotropy which can be used as the indicator of crust/mantle deformation styles. Surface wave data were initially collected from events of magnitude Ms ≥ 5.0 and shallow or moderate focal depth occurring between 1980 and 2002: 713 of them generated Rayleigh waves and 660 Love waves, which were recorded by 13 broadband digital stations in Eurasia and India. Up to 1,525 source-station Rayleigh waveforms and 1,464 Love wave trains were earlier analysed by multiple filtering to obtain Love- and Rayleigh-wave group velocity curves in the broad period range 10-105 s. We have performed tomographic inversion to obtain period-dependent group velocity and further shear wave velocity at 2°x2°-sized grid-cells of a mesh covering the model region. The models of isotropic seismic velocity in the crust and upper mantle cannot fit simultaneously the inverted group-velocity dispersion curves due to the discrepancy in the transmission velocities of Love and Rayleigh waves whose likely origin is the existence of radial anisotropy in the continental crust and topmost mantle. The strength of radial anisotropy computed from the Love-Rayleigh discrepancy and its spatial extent beneath the Qinghai-Tibet Plateau are shown as maps of percentage anisotropy at various depths down to 170 km and cross-sections along five profiles of reference. Areas in which radial anisotropy is in excess of ~ 6% are found in the crust and upper mantle underlying most of the plateau, and even up to 10% in some places. The strength and spatial configuration of radial anisotropy seem to indicate the existence of a regime of horizontal compressive forces in the frame of the convergent Himalayan-Tibetan orogen, the laterally variation of the lithospheric rheology and the differential movement as regards the compressive driving forces.

SW2/WE/O2 - PROPAGATION OF SURFACE WAVES FROM THE GREEK EARTHQUAKES ACROSS EUROPE

R. Gazdova[1], P. Kolinsky[1], J. Malek[1]
[1]The Academy of Sciences of the Czech Republic - The Institute of Rock Structure and Mechanics

Group velocities and azimuths of propagation of both Love and Rayleigh waves are determined using nearly 200 broadband stations deployed across the continent in a wide period range 5 – 70 s. The study is based on seven earthquakes which occurred in the Aegean Sea, Greece, in 2007-2008. The time period is chosen to coincide with the duration of the international passive seismic project PASSEQ which covered the territory of Germany, Czech Republic, Poland and Lithuania. For interpretation, the data from the ORFEUS database together with the PASSEQ data are used what enables us to cover the whole Europe with a special attention paid to the Central European region. The shallow Aegean Sea events with magnitude $M_w \geq 5$ generated strong surface waves which are analyzed by the multiple filtering technique. It is a standard method of the Fourier transform-based frequency-time analysis. The spectrum of each record is multiplied by weighting functions centered at many discrete frequencies. Five local envelope maxima of all quasiharmonic components obtained by the inverse Fourier transform are found and their propagation times determined. These maxima are assigned to different modes of direct surface waves as well as to possible reflected, converted and multipathed modes. Predominant directions of surface wavefront propagation of different modes are estimated by sorting the found propagation times across Europe according to their temporal and spatial correlation with implications for location of the scattering heterogeneities and reflection structures in Central Europe.

SW2/WE/O3 - LARGE-SCALE SHEAR WAVE VELOCITY STRUCTURE OF THE UPPER MANTLE BENEATH EUROPE AND SURROUNDING REGIONS

C. Legendre[1], T. Meier[2], S. Lebedev[3], W. Friederich[1]
[1]Ruhr Universität Bochum; [2]Universität Kiel; [3]Dublin Institute for Advanced Studies

The automated multimode waveform inversion technique developed by Lebedev et al. (2005) was applied to available data of broadband stations in Europe and surrounding regions.

It performs a fitting of the complete waveform starting from the S-wave onset to the surface wave. Assuming the location and focal mechanism of a considered earthquake as known, the first basic step is to consider each available seismogram separately and to find the velocity perturbations that can explain the filtered seismogram best. In a second step, each velocity perturbations serves as a linear constraint in an inversion for a 3D S-wave velocity model of the upper mantle.

We collected data for the years from 1990 to 2007 from all permanent stations for which data were available via the data centers of ORFEUS, GEOFON and IRIS, and from others that build the Virtual European Seismological Network (VEBSN). In addition, we incorporated data from temporary experiments like SVEKALAPKO, TOR and the Eifel plume project as well as permanent stations in France. We were also able to add the data recorded by the temporary broadband EGELADOS network in the southern Aegean. In this way, a huge data set of about 500.000 seismograms came about from which about 70.000 seismograms provide 400.000 linear constrains for the resulting 3D model.

The frequency content of the data associated with the sensitivitiy kernels as well as the path density in the considered region allows us to perform a high resolution tomography at a continental scale.

Tests were performed on differents parameters such as the grid spacing, the damping constrains and the smoothing factors to increase the resolution of the resulting inversion.

The resulting models exhibit an overwhelming detail in relation to the size of the region considered in the inversion. They are to our knowledge the most detailed models of shear wave velocity currently available for Europe and surroundings. Most prominent features are a narrow high velocity regions following the Hellenic arc and the Ionian trench toward the north. Even a high velocity zone beneath the Western alps can be imaged. Low velocity zones are found at depths around 130 km in the Pannonian basin, the back-arc of the Hellenic subduction zone, and the Middle East. At greater depths clear remnants of Tethyan subduction along the Eurasian-African plate boundary are ob-

served.

SW2/WE/O4 **- PHASE VELOCITY MEASUREMENTS IN THE PRESENCE OF DEVIATIONS FROM GREAT CIRCLE PATH AND MULTIPATHING; DATA AND SYNTHETIC TESTS.**

V. Maupin[1]
[1]*Dept of Geosciences, Univ of Oslo, Norway*

We present elements concerning deviation from great-circle path and multipathing of teleseimic surface waves and how this may affect estimates of phase velocities measured on regional networks.

The starting point of this study is the beamforming analysis of Rayleigh waves registered by a temporary network of 40 broadband stations from summer 2006 to summer 2008 in Southern Norway. We used about 200 Rayleigh wave fundamental modes generated by teleseismic as well as regional earthquakes to obtain an average phase velocity dispersion curve in the period range 22 to 200s.

The phase velocity is obtained by beamforming and image deconvolution of the beam by the point spread function of the network. In addition to an average phase velocity, beamforming gives us some information concerning the nature of the incoming wavefield. We detect deviations of the wave propagation direction from the great-circle paths which commonly reach 20 degrees at a period of 25 seconds for the teleseismic events. The amplitude of the deviations decreases with increasing period and with decreasing epicentral distance, as expected. The phase velocity measured by beamforming does not show any correlation with the deviation from great circle path, suggesting that deviation does not bias phase velocity measurements. We detect also significant multipathing with characteristics that vary rapidely with frequency.

How the complexity of the incoming wavefield affects the measured phase velocity is further analysed using synthetic complex wavefields propagating in different structures and by beamforming analysis of the synthetics. We find that the phase velocity measured by beamforming is usually little affected by the complexity of the wavefield except for some cases which show up as outliers.

SW2/WE/O5 **- SURFACE-WAVE IMAGING OF THE STRUCTURE AND DEFORMATION OF THE LITHOSPHERE**

S. Lebedev[1]
[1]*Dublin Institute for Advanced Studies*

Surface-wave observations in broad frequency bands constrain the layering of shear-speed structure and anisotropy in the entire lithosphere-asthenosphere depth range. Thanks to the deployment of a growing number of dense broadband arrays and the development of suitable surface-wave techniques, it is becoming increasingly feasible to image the 3-D distribution of seismic structure and anisotropy at the scale of tectonic units and tectonic processes.

Two powerful complementary approaches, in particular, enable high-resolution seismic imaging at scales from regional to global. Multimode waveform inversions are effective in constraining continental- to global-scale tomographic models of the entire upper mantle. The automated multimode inversion of surface- and S-wave forms (Lebedev et al., 2005) has been benchmarked using numerical wave propagation modelling and applied to constrain the global upper mantle structure (Lebedev and van der Hilst, 2008) and anisotropy. The large-scale anisotropy patterns revealed by the surface-wave imaging correlate strongly with predictions from geodynamic flow modelling (Becker, 2010).

Cross-correlations of surface-wave signals form the basis for another class of methods, particularly effective in applications to seismic array data (e.g., Meier et al., 2004; Lebedev et al., 2010). Studies in different tectonic environments have now shown that substantial azimuthal anisotropy is present, as a rule, in both the lithosphere and asthenosphere. Beneath currently stable continents, anisotropic fabric in the crust and lithospheric mantle is "frozen in" since the last major deformation episodes. In actively deforming lithosphere and in the asthenosphere, the observed anisotropy reveals the current and recent deformation and flow.

ES3 - RECENT SIGNIFICANT EARTHQUAKES

Wednesday 8, 14h00-16h40

ES3/WE/O1 **- RAPID CHARACTERIZATION OF THE SEISMOGENIC SOURCE OF THE 6 APRIL 2009 ABRUZZO (ITALY) EARTHQUAKE USING MACROSEISMIC DATA**

G. Vannucci[1], *D. Tripone*[2], *P. Gasperini*[2], *R. Camassi*[1], *P. Galli*[3]
[1]*INGV-Istituto Nazionale di Geofisica e Vulcanologia, Via Donato Creti, 12, I-40128, Bologna (Italy);* [2]*Dipartimento di Fisica, Università di Bologna, Viale Berti-Pichat 8, I-40127 Bologna (Italy);* [3]*Dipartimento Protezione Civile Nazionale, Via Vitorchiano 4, 00189 Rome (Italy)*

Just a few hours after the Mw=6.3 mainshock, the researchers of the QUEST (Quick Earthquake Survey Team) arrived in the epicentral area, starting the macroseismic survey. We compare the macroseismic source solutions computed by the recently released new version (4.0) of Boxer code using different intensity datasets progressively improved as a function of time elapsed after the mainshock with the focal mechanisms and the inversions of GPS, InSAR data. We show that the characterization of the seismic source obtained through the quick macroseismic survey can be almost as fast and reliable as that obtained by instrumental data. In particular, using only the macroseismic intensities estimated within 36 hours from the main shock, the parameters of the main fault section (location, size and orientation) could have been determined with an accuracy comparable to that achieved by instrumental methods.

ES3/WE/O2 **- REAL TIME SEISMIC MONITORING OF AFTERSHOCKS OF THE 2010 HAITI EARTHQUAKE**

A. Bent[1], *J. Drysdale*[1], *H. Greene*[1], *S. Halchuck*[1], *J. Adams*[1], *C. Woodgold*[1], *F. Proulx*[1], *D. McCormack*[1], *I. Al-Khoubbi*[1], *C. Andrews*[1]
[1]*Geological Survey of Canada*

Following the devastating earthquake in Haiti of 12 January 2010, the need for improved local monitoring of the seismic activity in that country has become very apparent. The Geological Survey of Canada, Natural Resources Canada has installed what is believed to be the first continuously transmitting seismograph network in Haiti. Three semi-permanent stations are installed at Port-au-Prince, Jacmel and Léogâne. Each station consists of a three component broadband seismograph and a three component strong motion instrument. The strong motion instruments have proven useful in providing clear records in cases where some of the largest aftershocks were clipped on the weak motion channels. Continuous data are transmitted by satellite in real time to Ottawa for analysis. Data are also forwarded to the USGS and the Caribbean Tsunami Warning System. Early analysis of the data has focused primarily on locating aftershocks with the expectation that longer term monitoring will result in improved seismic hazard assessments for Haiti. All aftershock locations and phase picks are forwarded to the International Seismological Centre. Magnitude recurrence curves show that the aftershock catalog is complete to magnitude 2.6. The majority of the aftershocks are located just north of the peninsula. The station geometry is not ideal for locating aftershocks. Combining our dataset with that of other stations deployed in the region following the mainshock should result in improved locations and better depth control. Focal mechanisms have been determined for many of the aftershocks by regional moment tensor inversion for the larger ones and by composite first motion solutions for the smaller ones. Both methods show predominantly thrust faulting at the western end of the aftershock zone and strike-slip faulting in the east consistent with the global moment tensor solutions for the mainshock and largest aftershock. Depths from the moment tensor inversion range from 2 to 15 km, with the majority of the events occurring between 6 and 10 km. Teleseismic receiver functions are being employed to derive improved velocity models for Haiti. Results to date are indicative of low near-surface velocities and a Moho depth of approximately 20 km.

ES3/WE/O3 **- THE JANUARY 2010 EFPALIO EARTHQUAKE SEQUENCE IN WESTERN CORINTH GULF: EPICENTER RELOCATIONS, FOCAL MECHANISMS, SLIP MODELS**

E. Sokos[1], *A. Kiratzi*[2], *A. Serpetsidaki*[1], *G. Tselentis*[1], *O. Novotny*[3], *J. Jansky*[3], *J. Zahradnik*[3]
[1]*University of Patras, Department of Geology, Seismological Laboratory, Greece;* [2]*Department of Geophysics, Aristotle University of Thessaloniki, Greece;* [3]*Charles University in Prague, Czech Republic*

On 18th of January 2010 (GMT 15:56) a moderate size Mw5.3 sequence burst close to the town of Efpalio, on the northern coast of the western Corinth Gulf. Almost immediately the seismicity expanded ~5 km eastwards where on 22nd of January 2010 (GMT 00:46) another Mw5.3 event occurred. These

two strongest events of the Efpalio sequence developed as two separate clusters and were very rich in aftershock occurrence, especially the second one, which lasted for months. Peak ground acceleration at a distance of 8 to 10 km (station SER) related to these events was 0.2g. We used a grid-search technique combined with station-differences to relocate the two strongest events. Regional waveforms were inverted at frequency below 0.1 Hz for the centroid moment tensor solution, which was further checked by forward simulation of waveforms up to 1 Hz at the nearest strong motion stations (Table 1). We used source time functions inversion to obtain the slip models. The slip for the Jan 18 event is concentrated in a single patch (5x7 km^2) extending from 2 up to 10 km, with maximum slip of 21 cm. For the Jan 22 event the slip model has two patches: a shallow (from 2 up to 7 km) main patch (5x5 km^2 max slip 20 cm) and a deeper patch (5x2.5 km^2). Directivity towards east was observed for both events. Double differences were used to relocate the sequence using additional data from a temporary network. The unambiguous identification of the fault plane for each of the strongest events is difficult mainly due to the combination of source and network geometry. Coulomb stress perturbations due to the Jan 18 event can explain the occurrence of the Jan 22 event and it seems that the same process played a role in aftershock distribution also, since the area covered by aftershocks is rather large for such moderate magnitude events.Table 1: Hypocenter (H), centroid (C) parameters and focal mechanisms for the Jan 18 and Jan 22, 2010 events

HypocenterHCentroidCNP1NP2P axisT axis (H)Depth (km)(C)Depth (km)strike°dip°rake°strike°dip°rake°az°pl°az°pl°Jan 1838.4126°N , 21.9128°E8.938.4220°N, 21.9416°E510255-8327036-100397918710Jan 2238.4342°N, 21.9472°E9.538.4490°N, 21.9645°E57252-10928242-67284741765

ES3/WE/O4 - THE 2010 HAITI EARTHQUAKE SEQUENCE AND ITS RELATIONS WITH DEFORMATION PARTITIONING

B. Mercier de Lépinay[1], F. Klingelhoefer[2], Y. Mazabraud[3], D. Graindorge[4], V. Clouard[5], B. Delouis[1], A. Deschamps[1], B. Marcaillou[6], J. Perrot[7], P. Charvis[1]
[1]Géoazur UNS/CNRS/IRD/OCA; [2]IFREMER; [3]Université Antilles Guyanne; [4]Domaines Océaniques, IUEM, UBO; [5]IPGP, Observatoire de la Martinique; [6]Université Antilles Guyane; [7]Domaines Océaniques, IUEM, Univ.Bretagne Occidentale

The January 12, 2010 Haiti earthquake that devastated the Port-au-Prince metropolitan area, ruptured a segment of the Enriquillo-Plantain Garden Fault Zone (EPGFZ), a 600 km long strike slip fault running offshore and onshore from Jamaica to Dominican Republic. The last significant earthquakes in the eastern part of EPGFZ occurred 240 years ago. Between 1751 and 1770, two large events with estimated magnitudes equal or larger than 7 ruptured several segments of the EPGFZ in the Presqu'île du Sud d'Haïti. Considering the general behavior of such strike slip fault (i.e. North Anatolian fault, San Andreas fault), we can expect that, following the 2010 earthquake, other large earthquakes will occur in the near future on adjacent segments. The understanding of the rupture process and the stress relaxation of the Haiti earthquake is required for the seismic risk assessment in the area. We show that the distribution of the first set of aftershocks is consistent with a preliminary slip model of the mainshock assuming a N264 north-dipping plane, with a major left-lateral component and a strong reverse component. These data are also consistent with the mainly compressive surface structures observed in the geology and onshore/offshore morphology of the area and focal solutions of some of the larger aftershocks.

ES3/WE/O5 - SEISMOTECTONIC SYNTHESIS OF THE 2010 MW7.2 EL MAYOR-CUCAPAH EARTHQUAKE SEQUENCE, BAJA CALIFORNIA, MEXICO

E. Hauksson[1], W. Yang[1], S. Wei[1], A. Vidal[2]
[1]California Institute of Technology, Pasadena, CA, USA; [2]Department of Seismology, CICESE, Baja California, Mexico

The synthesis of the 2010 Mw7.2 El Mayor-Cucapah earthquake sequence reveals the transtensional regional tectonics and how Pacific North America plate motion is transferred from the Gulf of California in the south into the California San Andreas fault system to the north. The Caltech/USGS Southern California Seismic Network and the CICESE Baja California, Mexico Seismic Network have recorded more than 10,000 earthquakes in the sequence. The sequence started with preshocks in March 2010, and a sequence of 15 foreshocks of M>2 (up to M4.4) that occurred during the 24 hours preceding the mainshock. The foreshocks occurred along a north-south trend near the mainshock epicenter. The mainshock that occurred on 4th of April exhibited complex faulting, possibly starting with a ~M6 normal faulting event, followed ~15 sec later by the main event, which included simultaneous normal and right-lateral strike-slip faulting. The aftershock zone that has a length of more than 120 km, extends from the south end of the Elsinore fault zone at the US-Mexico border almost to the Gulf of California coast. The aftershocks form two abutting clusters, of about equal length or 50 km each, as well as a 10 km north-south aftershock zone at the epicenter of the mainshock. The event relocations benefit from real-time waveform exchange between the two networks, and the availability of arrival time picks from the web site provided by the CICESE Baja California, Mexico Seismic Network. Even though the Baja data are included, the magnitude of completeness and the hypocentral errors increase gradually with distance to the south of the international border. The spatial distribution of large aftershocks is asymmetric with five M5+ aftershocks located to the south of the mainshock, but all the aftershocks to the north of the mainshock epicenter are smaller but more numerous M4 events have been recorded. Further, the northwest aftershock cluster exhibits complex faulting on both northwest and northeast planes. Thus the aftershocks as well as the mainshock express a complex pattern of stress release along strike. In addition, some triggered seismicity is being recorded along the Elsinore and San Jacinto faults to the north but significant northward migration of aftershocks has not occurred. The overall rate of decay of the aftershocks is similar to the rate of decay of a generic California aftershock sequence. Using the available arrival time data, we determine refined 3D Vp and Vp/Vs velocity model.

ES3/WE/O6 - THE MAULE MW 8.8 EARTHQUAKE: MODELING USING 1HZ CGPS AND STRONG MOTION DATA.

S. Ruiz[1], M. Lancieri[2], S. Peyrat[1], E. Buforn[3], C. Vigny[2], M. Astroza[1], R. Madariaga[2]
[1]Universidad de Chile, Santiago, Chile; [2]Ecole Normale Supérieure, Paris, France; [3]Geophisica y Metereologia, Universidad Complutense de Madrid, Spain

The Maule earthquake of February 27, 2010 occurred in Central Chile along a seismic gap well identified since the early 90's. The 2010 event not only broke, as expected, the area of the 1835 event (Mw 8.5), but it propagated further South, breaking the rupture area of the May 21, 1960 earthquake (Mw 7.9), and further North overlapping the December 1, 1928 event rupture zone (Mw 7.8).

In this work, we present a kinematic inversion of the rupture process using high-rate cGPS and strong motion data. The GPS data are from the network installed starting in 1999 (40 GPS survey sites and 3 cGPS stations recording at 1 Hz). The seismological observations are the near-source accelerograms recorded in Chile and Argentina. In the El Roble site where an accelerometer and a cGPS are collocated, we observe a good fitting between the 1 Hz cGPS and the integrated accelerograms for traces filtered below 0.1 Hz. Because of a strong directivity effect, the records located in the North direction have a duration of only 60 s. Whereas for the Argentina and central valley GPS stations, the duration is much longer and the two pulses coming from the different slip patches are clearly visible.

Our purpose is to explain in terms of fracture properties the observed damage distribution. That corresponds to a relatively small area of about 150 km with MSK intensity larger than VIII. Such extension is comparable with that observed for the Mw 7.8, 1928 earthquake. A first inversion was already performed using teleseismic data. The inverted rupture process consists of two main patches of slip, the main one is in the North of the rupture area between 34 °S and 35.5°S and the second one is in the South between 36°S and 37°S. Unfortunately this latter patch is less well defined especially because the lack of the accelerograms to the South. We think that the joint cGPS and strong motion slip inversion will improve the image of the northern patch of slip and will help us to understand the higher intensity damage observed in that area.

ES3/WE/O7 - THE 2009 L'AQUILA EARTHQUAKE FROM SPACE: SAR AND OPTICAL IMAGES TO INVESTIGATE SURFACE EFFECTS

S. Atzori[1], C. Bignami[1], M. Chini[1], C. Kyriakopoulos[1], M. Moro[1], S. Salvi[1], M. Saroli[2], S. Stramondo[1], C. Tolomei[1], E. Trasatti[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Italy; [2]University of Cassino, Italy

We investigated the April 6th, 2009 L'Aquila earthquake by InSAR to assess surface effect and to infer the characteristics of seismic source. A set of SAR images from Envisat, ALOS and COSMO-SkyMed satellites has been used to measure the coseismic displacement field. Moreover, thanks to the large number of SAR data, and their different geometries, we were able to focus our attention even to the post-seismic deformation. The availability of very high spatial resolution data acquired by COSMO-Skymed, allowed also to identify some local fringe patterns which have been located in correspondence with active DGSD, most probably due to their reactivation and/or acceleration after the main earthquake. In proximity of urban areas these additional movements may be relevant in terms of evaluating seismic risk. VHR optical images of the epicentral region allowed damage detection analysis in L'Aquila city and its surrounding. Finally, we deal with seismic source modeling using analytical and numerical (finite element) approaches to map the fault geometry and slip distribution.

SW6 - SEISMOLOGICAL AND STRUCTURAL STUDIES IN THE EUROPEAN ARCTIC

Wednesday 8, 14h00-16h40

SW6/WE/O1 - THE GREENLAND ICE SHEET MONITORING NETWORK (GLISN)

T. Dahl-Jensen[1] [invited] , IRIS[2], ETH[3], LDEO-Columbia Univ.[2], GFZ[4], NIPR[5], NORSAR[6], NRC[7], INGV[8], JAMSTEC[5]
[1]GEUS - Geological Survey of Denmark and Greenland; [2]USA; [3]Switserland; [4]Germany; [5]Japan; [6]Norway; [7]Canada; [8]Italy

GLISN is a new, international, broadband seismic capability for Greenland, being installed and implemented through collaboration of USA, Denmark, Switzerland, Germany, Canada, Italy, Japan and Norway. GLISN is a real-time sensor array of over 20 stations to upgrade the scarce network for detecting, locating, and characterizing both tectonic and glacial earthquakes and other cryo-seismic phenomena, and contribute to our understanding of Ice Sheet dynamics. GLISN will provide a powerful tool for detecting change, and will advance new frontiers of research in the underlying geological and geophysical processes affecting the Greenland Ice Sheet.

The glacial processes that induce seismic events (internal deformation, sliding at the base, disintegration at the calving front, drainage of supra-glacial lakes) provide a quantitative means for monitoring changes in glacial behaviour over time. Long-term seismic monitoring of the Greenland Ice Sheet will contribute to identifying possible unsuspected mechanisms and metrics relevant to ice sheet collapse, and also detect if the areas of cryo-seismic events change and expand in the coming decades. GLISN will provide a new reference network in and around Greenland for monitoring these phenomena in real-time, and for the broad seismological study of Earth and earthquakes.

The GLISN development takes its starting point in the existing stations in and around Greenland operated by members of GLISN. The network will be upgraded and expanded by installing new, telemetered, broadband seismic stations on Greenland's perimeter and ice sheet her ealso with GPS. A virtual network is established where all GLISN data are archived and freely downloaded. In collaboration with GLISN, the Global Centroid Moment Tensor Project will provide a near-real-time catalogue of glacial earthquakes. The development incorporates state-of-the-art broadband seismometers and data acquisition, Iridium and local Internet, power systems capable of autonomous operation throughout the polar year, and stable, well-coupled installations on bedrock and the Ice Sheet.

SW6/WE/O2 - LITHOSPHERE STRUCTURE IN THE EUROPEAN ARCTIC

J. Plomerová[1], L. Vecsey[1], V. Babuška[1], W. LAPNET[2]
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Several seismological experiments explored the lithosphere structure in the Northern Europe. The most recent one – LAPNET- organized within the International Polar Year – provided data for structural studies of the Arctic part. To help understanding Arctic crustal processes, we concentrate on the lithospheric mantle structure and the upper mantle processes, which govern most of the observed crustal features. Based also on data of previous experiments, we present the domain-like fabrics of the Precambrian continental lithosphere of the Northern Europe and map boundaries and thickness of the domains. By inverting anisotropic parameters of body-waves we retrieve their 3D anisotropic structure and show correlation with the surface tectonics with implications for intraplate seismicity or deposits of raw material.

SW6/WE/O3 - MANTLE STRUCTURE UNDERNEATH THE SCANDINAVIAN MOUNTAINS FROM TELESEISMIC SHEAR-WAVE ANALYSIS

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The ESF TOPO-EUROPE project TopoScandia-Deep (www.geo.uio.no/toposcandiadeep) aims at developing an integrated model to explain the present high topography of the Scandinavian Mountains. The main mountain building phase was during the Caledonide orogeny. The mountains still reach up to 2600 m altitude and display a rough and steep scenery. There are discussions that possibly much younger phases sustained the mountain building far away from present plate boundaries. Our group at KIT analyses the teleseismic shear wavefield to derive structural information about the upper mantle in this region. The waveform data were measured with i) the MAGNUS experiment with 31 temporary stations of the KArlsruhe BroadBand Array and 10 permanent broadband stations (7 NORSAR, KONO, BER and HFC2) which recorded continuously from September 2006 until June 2008; ii) the SCANLIPS1 and SCANLIPS2 experiments in 2006 and 2008/09 with up to 38 stations; iii) the permanent NORSAR, HFC2 and KONO stations. S-to-P wave conversion phases are used to study seismic velocity discontinuities. For this we processed S receiver functions and stacked these from about 100 teleseismic events. These S receiver function waveforms contain the conversions from the crust-mantle boundary (Moho) and lithosphere-asthenosphere boundary (LAB) and are used to map both discontinuities. Teleseismic shear-wave splitting analysis is carried out with the core phases SKS and SKKS to constrain the mantle anisotropy. The anisotropic pattern is interpreted as signature of geodynamic processes. In order to retrieve 3D shear-wave velocity anomalies we determine teleseismic travel time residuals. The first results are presented and their relationship with the high topography in Norway is discussed.

SW6/WE/O4 - SURFACE WAVE TOMOGRAPHY OF SOUTHERN NORWAY USING AMBIENT SEISMIC NOISE

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The TopoScandiaDeep project aims to investigate the relation between surface topography and lithosphere-asthenosphere structure in southern Norway. Within this context, we process seismic broadband data from the temporary MAGNUS network and from permanent stations (NORSAR, GSN) in order to perform a surface wave tomography of that region. Time-frequency analysis is applied to noise cross-correlation functions to measure Rayleigh and Love wave group velocity dispersion curves between each station pair. We obtain reliable velocity estimates for periods between 3 and 30 seconds, which we invert for group velocity maps at respective periods. At all inverted periods, we find positive and negative velocity anomalies for Rayleigh and Love waves that correlate very well with local surface geology. While higher velocities can be associated with the Caledonian nappes in the central part of southern Norway, the Oslo Graben is reflected by negative velocity anomalies. Furthermore, variation of Moho depths is reflected by the group velocity maps at longer period. The observations are consistent with recent results from three active seismic profiles through southern Norway (MAGNUS-REX) and with a density map obtained from surface rocks. We present first results of local inversion of dispersion curves which will be used to construct a 3D velocity model for that region.

SW6/WE/O5 - LOCAL SEISMICITY STUDIES OF ARCTIC MID-OCEAN RIDGE PROCESSES WITH SEISMIC ARRAYS ON DRIFTING ICE FLOES

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Active tectonic and magmatic processes at ultraslow spreading ridges are still poorly known because the main representatives of this class of mid-ocean ridges, the Arctic mid-ocean ridge system and the Southwest Indian Ridge, are situated in areas where permanent ice cover and adverse weather

conditions, respectively, have prevented routine exploration. The first geological exploration of Gakkel Ridge during the Arctic Mid-Ocean Ridge Expedition in 2001 showed that predictions like decreasing magmatism with decreasing spreading rate are not valid at spreading rates below 20 mm/y full rate, challenging our models for crustal generation at mid-ocean ridges. In order to gain a first understanding of active spreading processes at ultraslow-spreading ridges we deployed seismic arrays on drifting ice floes to record the local seismicity in magmatic and amagmatic segments of Gakkel ridge and Lena Trough. During four expeditions, we gathered a total of 63 days of seismicity data recorded by 3-12 stations clustered in up to three arrays. During all deployments we detected local and regional earthquakes with magnitudes well below magnitude 2 and event rates varying from three events/day in the amagmatic Lena Trough to one event/hour at the 85°E volcanic complex at eastern Gakkel ridge. At eastern Gakkel ridge, the seismic arrays recorded 200 impulsive seismoacoustic signals and their multiple reflections in the water column. We analysed the character of these signals and located the sound source near major faults at the southern rift valley wall. Contemporaneous vigorous hydrothermal discharge, a preceding unusual teleseismic earthquake swarm and abundant pyroclastic deposits at the seafloor let us to interpret the seismoacoustic signals as deep submarine Strombolian eruption bursts. A dense network of recording stations, as a result of the ice drift, which recorded more than 400 local events will enable us to study the structure of the 85°E volcanic complex using seismic tomography. At Lena Trough, our arrays drifted across the area of a recent major seismic crisis in February and March 2009 which culminated in an m_b 6.5 earthquake on March 6, 2009. We relocated the teleseismically recorded events in an outside corner setting at the junction of southern Lena Trough and the Spitzbergen Fracture Zone.

SW6/WE/O6 - SEISMIC SWARM ACTIVITY AT THE MOHNS AND KNIPOVICH RIDGE BEND WITHIN THE INTERNATIONAL POLAR YEAR (SEPTEMBER 2007 – SEPTEMBER 2008)

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One of the main purposes of the International Polar Year project "The dynamic continental margin between the Mid-Atlantic-Ridge system (Mohns Ridge, Knipovich Ridge) and the Bear Island region" was to investigate in detail the seismic activity in the wider area of the western Barents Sea margin. To achieve this, several temporary seismic installations were deployed in the region to supplement the existing, permanent, regional network. These involved a small-aperture, short-period seismic array on Bear Island and a broadband, three-component ocean bottom seismometer (OBS) and hydrophone array spreading over the mid-ocean ridges and the sedimentary wedge covering the continental margin. The data retrieved from this experiment span an interval of almost one year, between September 2007 and September 2008.

During this time period, several seismic swarms were recorded, mainly in the area of the Mohns – Knipovich Ridge bend. The application of waveform cross-correlation techniques helped to identify at least three well defined swarms (December 2007, January 2008 and June 2008) and lots of background seismicity. The larger of these events were located following an analyst review of all available records. More events from each swarm were identified with the use of a waveform cross-correlation detector on the OBS stations with the best signal to noise ratio, enabling a more complete image of the activity.

Although the achieved epicentre location resolution does not allow a safe correlation of the epicentres with particular, mapped volcano-tectonic structures on the ridge, it is in most cases adequate to assign the different swarms to specific ridge segments. A statistical analysis of each swarm, complemented with information on the frequency content and spectral structure of the signals, provides some preliminary insight to the nature of this activity.

SW6/WE/O7 - PERFORMANCE OF THE BROADBAND BEAR ISLAND OBS NETWORK AND FIRST RESULTS REGARDING THE LITHOSPHERE AND MANTLE STRUCTURE OF THE OCEANIC PLATE BETWEEN MOHNS RIDGE AND THE BARENTS SHELF

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A large aperture network of up to 12 OBS stations equipped with broadband 3-component seismometers and hydrofones was installed for about one year (September 2007 to September 2008) west of Bear Island to record local seismicity and teleseismic signals.

We evaluate the detection threshold of the network used as longperiod array for teleseismic body waves and surface waves.

Slowness and azimuth residuals are found to be small compared to the values expected from the global velocity model.

Hints for anomalous low velocities in the upper mantle between Knipovich/Mohnsridge and the Barents shelf are found from teleseismic P-wave absolute and relative traveltime residuals (relative residuals are determined with the help of nearby permanent stations on Bear Island and Spitzbergen).

Furthermore longperiod Rayleigh wavetrains (down to 100 s) are used to confirm this result by dispersion analysis and inversion of phase velocity dispersion curves.

From a few records receiver functions could be calculated which help to constrain the plate structure at a few locations further.

SW6/WE/O8 - CRUSTAL STRUCTURE BENEATH SEISMIC PROFILE MOHNS RIDGE-BEAR ISLAND AND TECTONIC IMPLICATIONS FOR THE CONTINENT-OCEAN TRANSITION BETWEEN THE MID-ATLANTIC-RIDGE AND BARENTSIA

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The area of the Northern Atlantic plays important role in the present day tectonic. The development of the passive continental margins of the Barents Sea continental platform, rifting and subsequent sea-floor spreading are processes which form the face of our planet. The subject of the paper are results of investigations along seismic refraction profile made within the 4th International Polar Year (IPY) in the frame of international project «The Dynamic Continental Margin Between the Mid-Atlantic-Ridge (Mohns Ridge, Knipovich Ridge) and the Bear Island Region». A 410 km long Ocean Bottom Seismometer profile from the Bear Island, Barents Sea to oceanic crust formed along the Mohns Ridge have been modelled by use ray-tracing with regard to observed P-waves. The northeastern part of the model represents typical continental crust, thinned from c. 30 km thickness beneath the Bear Island to c. 13 km within the Continent-Ocean-Transition. Between the Hornsund FZ and the Knølegga Fault, a 3-4 km thick sedimentary basin, dominantly of Permian/Carboniferous age, is modelled beneath the c. 1.5 km thick layer of volcanics (Vestbakken Volcanic Province). The P-wave velocity in the 3-4 km thick lowermost continental crust is significantly higher than normal (c. 7.5 km/s). We interpret this layer as a mixture of mafic intrusions and continental crystalline blocks, dominantly related to the Paleocene-Early Eocene rifting event. The crystalline portion of the crust within the south-western part of the COT consists of a c. 30 km wide and c. 6 km thick high-velocity (7.3 km/s) body. We interpret the body as a ridge of serpentinized peridotites. The magmatic portion of the ocean crust accreted along the Knipovich Ridge from continental break-up at c. 35 Ma until c. 20 Ma is 3-5 km thicker than normal. We interpret the increased magmatism as a passive response to the bending of this southernmost part of the Knipovich Ridge. The thickness of the magmatic portion of the crust formed along the Mohns Ridge at c. 20 Ma decreases to c. 3 km, which is normal for ultra slow spreading ridges.

ES5 - EARTHQUAKE SOURCES AND SOURCE PARAMETERS

Wednesday 8, 14h00-16h40

Thursday 9, 08h00-10h00

ES5/WE/O1 - M_w AND M_e: COMMON ROOTS, PHYSICAL DIFFERENCES AND RELATIONSHIPS TO THE NEW IASPEI BROADBAND STANDARD MAGNITUDES m_B(BB) AND M_S(BB)

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The scalar seismic moment M_0 is a measure of the total deformation in the source volume and thus of the earthquake "size". In contrast, seismic energy E_S measures the very small fraction of M_0 that is radiated as elastic seismic waves, thus being a measure of the source "strength" in terms of caused ground shaking. M_0 and E_S vary over more than 10 orders. This is difficult to handle in practical applications. Therefore, M_0 and E_S have been scaled to earthquake magnitude, using relationships between 20 s surface-wave magnitude M_S and E_S. Analysing the current definitions of moment magnitude M_w and energy magnitude M_e one finds that $M_e = M_w + (\Theta + 4.7)/1.5 = M_w + [\log(E_S/M_0) + 4.7]/1.5 = M_w + [\log(\Delta\sigma/2\mu) + 4.7]/1.5$, with $\Theta = \log(E_S/M_0)$, $\Delta\sigma$ – stress drop, μ – rigidity in the source volume and 1.5 – slope of the Gutenberg-Richter $\log E_S$-M_S relationship, derived via the relationships $\log E_S$ over broadband body-wave magnitude m_B as well as m_B over M_S. For Θ = -4.7, which roughly holds for average global stress-drop, $M_w = M_e$. Yet M_w and M_e may differ for the same earthquake by more than one magnitude unit, because the ratio $E_S/M_0 \propto (V_R/\beta)^2 \times (\Delta\sigma/2\mu)$ varies by more than three orders of magnitude. Accordingly, Θ ranges between about -3.3 and -6.7, being mainly controlled by variations in stress drop, rigidity and the ratio between rupture velocity V_R and shear-wave velocity β. E_S is proportional to squared ground motion velocity. The latter has its largest amplitudes at the corner frequency $f_c = c\beta(\Delta\sigma/M_0)^{1/3}$ of the source spectrum. For a given seismic moment holds $f_c \propto \Delta\sigma^{1/3}$. Modern IASPEI standard m_B(BB) is based on measuring the largest P-wave velocity amplitude in the period range between 0.2 s and 30 s, thus correlating well with M_e. This allows to estimate M_e with an RMS of only ±0.17 m.u. via the very simple to measure m_B. In contrast, the scatter between M_w and m_B(BB) is much larger since M_w is calculated by assuming constant stress drop. On the other hand, we found that the new IASPEI standard broadband surface-wave magnitude M_S(BB), based on measuring the largest Rayleigh-wave velocity amplitude at periods between 2 s and 60 s, deviates for magnitudes below 6.5 much less from M_w than $M_S(20)$. These are good reasons to strongly recommend the introduction of m_B(BB) and M_S(BB) into global seismological practice.

ES5/WE/O2 – RAPID DETERMINATION OF THE MAGNITUDE AND TSUNAMI POTENTIAL OF LARGE EARTHQUAKES, AND IMPLICATIONS FOR SOURCE PHYSICS

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We present and discuss methodologies for rapid determination of the magnitude and tsunami potential of large earthquakes. Firstly, a duration-amplitude procedure gives an earthquake moment magnitude, *Mwpd*, within 10-20 min after origin time (OT) using *P*-wave recordings at teleseismic distances. This procedure determines apparent source durations, T_0, from high-frequency, *P*-wave records, and then estimates moments through integration of broadband displacement waveforms over the interval *tP* to $tP+T_0$, where *tP* is the *P* arrival time. We apply the duration-amplitude methodology to a set of recent, large earthquakes (*MwCMT* 6.6 to 9.3) with diverse source types. The results show that a scaling of the moment estimates for larger interplate thrust and possibly tsunami earthquakes is necessary to best match *MwCMT*. With this scaling, *Mwpd* matches *MwCMT* typically within +/-0.2 magnitude units and does not exhibit saturation, even for the largest events. The explicit use of the source duration for integration of displacement seismograms, the moment scaling, and other characteristics of the duration-amplitude methodology make it an extension of the widely used, *Mwp*, rapid-magnitude procedure. The need for a moment scaling may be related to the destructive interference of *pP* or *sP* waves with direct, down-going *P* waves; in this case some of the energy released during rupture may be re-absorbed locally to further drive the rupture, and thus to make the earthquake large. Secondly, a direct procedure for rapid assessment (6-10 min after OT) of earthquake tsunami potential uses two, simple measures on *P*-wave seismograms – the predominant period on velocity records, *Td*, and the likelihood that the high-frequency, apparent source duration, T_0, exceeds 50-55 sec. For the set of recent, large earthquakes, the period-duration product TdT_0 gives more information on tsunami impact and size than *MwCMT* and other currently used discriminants. All discriminants have difficulty in assessing the tsunami potential for strike-slip and back-arc, intraplate earthquakes. *Td* and T_0 can be related to the critical parameters length, *L*, width, *W*, mean slip, *D*, and depth, *z*, of earthquake rupture. Our results suggest that tsunami potential is not directly related to the product *LWD* (the "seismic" faulting model), as is assumed with the use of the *MwCMT* discriminant. Instead, knowledge of rupture length, *L*, and depth, *z*, alone can constrain well the tsunami potential of an earthquake (the "tsunami" faulting model), with explicit determination of fault width, *W*, and slip, *D*, being of secondary importance.

ES5/WE/O3 – VALIDATION OF THE W-PHASE FAST SOURCE INVERSION FOR MODERATE TO LARGE EARTHQUAKES (MW ≥ 6.5, 1990 - 2010).

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During the last two decades, a considerable effort has been spent to speed up the source analysis of large earthquakes. As a fruitful harvest, a preliminary magnitude estimation is now available within fifteen minutes for a Mw = 6.0 earthquake occurring anywhere in the world. But until recently, it still took several hours to determine the first order attributes of a great earthquake (e.g. Mw ~ 8.0) even in a well instrumented region. The main limiting factors were the data saturation, the interference of different phases, the time duration and spatial extent of the source rupture. To accelerate centroid moment tensor determinations, we have developed a source inversion algorithm based in the modeling of the W-phase, a very long period phase (100s – 1000s) arriving at the same time as the P-wave. The purpose of this work is to finely tune and validate the algorithm for large to moderate earthquake using the three component W-phase ground motion at regional and teleseismic distances. In this perspective, the point source parameters of all Mw ≥ 6.5 earthquakes that occurred between 1990 and 2010 (778 events) are determined using FDSN, GSN and STS1 global virtual networks. The algorithm is also adapted to regional data by testing the algorithm on the F-net data set for all Mw ≥ 6.5 events between 2003 and 2010 near Japan (38 earthquakes). For each event, a preliminary magnitude obtained from W-phase amplitudes is used to estimate the initial STF half duration and to define the corner frequencies of the passband filter that will be applied to the waveforms. Starting from these initial parameters, the seismic moment tensor is calculated using the PDE (at global scale) or the JMA preliminary epicenter (for japan region) as a first approximation to the centroid. The STF half duration and time-shift as well as the centroid position are then optimized using a grid-search algorithm based on recursive subdivision and re-sampling of cells. The comparison with Harvard and Global CMT solutions highlight the robustness of W-phase CMT solutions at regional and teleseismic distances. The differences in Mw rarely exceed 0.1 and the source mechanisms are very close to each other. The events occurring in a short delay after large earthquakes (e.g. large aftershocks) is a particular matter. Since the waveforms corresponding to the two events interfere with each other, the isolated event hypothesis is no longer valid and we explore ideas to deal with such a difficult situation.

ES5/WE/O4 – DYNAMIC RUPTURE SCENARIOS OF ANTICIPATED NANKAI-TONANKAI EARTHQUAKES, USING THE SUBDUCTION INTERFACE COUPLING RATES INFERRED FROM GPS DATA TO CONSTRAIN THE FRICTION PARAMETERS.

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Hazardous earthquake (Mw>8) along the Nankai-Tonankai subduction zone (Japan) are expected in the following decades. Therefore, it is important to evaluate in advance potential strong ground motions and tsunamis that could be generated by these earthquakes. To do this, we proposed a methodology to integrate different stages in the earthquake cycle and by assimilating observed geophysical data we can provide reliable scenarios.

We use the 3D geometry of the plate interface constructed by Hashimoto et al. (2004, PAGEOPH). A laterally heterogeneous stress drop is constrained by the Hashimoto et al. (2009, SSJ meeting)'s slip deficit rate estimation on the interface, assuming that the slip deficit accumulated since the previous earthquakes (1944 Tonankai and 1946 Nankai earthquakes) will be released completely by the next earthquake.

We introduce simple assumptions for the constitutive parameters, that lead to various rupture scenarios. We discuss the dynamic propagation between the segments.

For instance, considering homogeneous static strength, and initiation of the rupture in the Kii peninsula area (where the 1944 and 1946 earthquakes initiated), we show that the Dc value in this intersegment area is a critical parameter, which controls the final size of the earthquakes. When Dc is taken the same on the intersegment as on the Nankai and Tonankai segments, then the rupture propagates bilaterally and the complete Tonankai-Nankai area breaks within a single event. When Dc inside the intersegment area is twice as large as that outside, we obtain unilateral ruptures that break either the Tonankai or the Nankai segment only, depending on which side of the intersegment the rupture is initiated at. After this two-earthquake sequence scenario, similar to the 1940's sequence, the whole Nankai-Tonankai area has been broken and unloaded.

Using the same initial conditions, we also computed ruptures that initiate at the western edge of the Nankai segment, or at the eastern edge of the Tonankai segment. Interestingly, in that case, the intersegment zone broke, and the complete Tonankai-Nankai area was broken in the same earthquake.

We showed that a smooth barrier, where Dc is larger, located between Nankai and Tonankai segments could explain the typical behaviours expected on this subduction zone. It can lead to a sequential rupture of the plate boundary, provided that the rupture initiates close to the intersegment area. Or, it can lead to a single giant rupture event if the rupture starts far from it.

ES5/WE/O5 - RUPTURE CHARACTERISTICS OF RECENT LARGE EARTHQUAKES IN THE SOUTH AMERICAN SUBDUCTION ZONE AS IMAGED BY TELESEISMIC ARRAYS

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We use stations of the global network to form large aperture arrays. Then a backprojection scheme based on broadband direct P waves and realtime data is used to image the development of the rupture for the recent Mw 8.8 event in Chile (27. February 2010). We compare the results revealed using P waves with the results for direct SH and SV waves and a combination of direct and later phases. A mainly northward rupture propagation at normal rupture speed with about 100 s duration, an overall extension of about 400 km and two strong areas of wave radiation (moment acceleration) slightly south of the hypocenter and about 150 km north of the hypocenter respectively, were found. We also present results for other major earthquakes along the South American subduction zone like the Antofagasta earthquake in 1995, the Pisco/Peru earthquake and the Tocopilla earthquake in 2007. We discuss the relationship of the energy backprojection results with those of other groups obtained from displacement waveform inversion (slip maps).

ES5/WE/O6 - THE 2010 GRANADA (SPAIN) DEEP EARTHQUAKE

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Rupture process of the Durcal, Granada), 11-04-10 deep earthquake has been studied using regional (epicentral distances less than 500 km) and teleseismic (30º data. The Kikuchi and Knamori (1991) method has been used to estimate focal mechanism from inversion of body waves at teleseismic distances. As first step, we have estimated the rupture plane and focal depth using a point source kinematic model. Best results have been obtained for 650 km depth and dip slip mechanism, with a vertical plane oriented in N-S direction and the horizontal plane with E-W direction dipping to the South. In a second step we have obtained the slip distribution over the rupture plane obtained previously, using an extended source. Both planes have been checked in order to discriminate the rupture plane. Best results have been obtained (figure 4b) for the vertical plane, with a rupture velocity of 3 km/s. The rupture process starts at 650 km with most of energy released at the first 8 s. and the rupture propagating downward. Total duration of the STF is 10 s, with scalar sesimic moment of 3.17 exp 18 Nm, that corresponds to Mw=6.3 and a dimension for the rupture of 15x20 km. These values are in agreement with the inversion at regional distances using a total of 48 traces filtered using a bandpass 0.02 to 20 Hz. Focal mechanisms of the previous deep earthquakes occurred in this area together with the 2010 shock are shown. All earthquakes have similar focal mechanisms with a vertical plane oriented in N-S direction and the pressure axis dipping 45º to the east.

ES5/WE/O7 - SPATIAL DISTRIBUTION OF AFTERSHOCKS OF THE AL HOCEIMA 2004 EARTHQUAKE; IMPLICATIONS FOR THE IDENTIFICATION OF NEW ACTIVE FAULTS

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An earthquake of magnitude M_w6.3 stroke the Al Hoceima region in northeastern Mediterranean Morocco on February 24th, 2004. This event was followed by a series of aftershocks that reached a maximum magnitude of M = 5. These aftershocks were closely monitored by deploying a field temporary seismic network that became operational one day after the main shock. In this work, we present the results of a study in which the aftershocks have been observed over a period of seven months and allowed the population and analysis of an important database. Out of the 4600 aftershocks recorded using the portable seismic network, 913 events were relocated with a good precision. The located aftershocks are distributed over a large area and fall next to the main shock area. The majority of the epicenters appear to fall within an area nearly50 km long in the N-S direction and 20 km wide.They are particularly concentrated along two prominent narrow NW-SE linear zones that are denoted BB' and AA' in this study and located to the southwest of the main shock, respectively observed during the first two days of aftershocks recording and also during the month of March. Other concentrations occur along NE-SW trends of pre-existing reactivated thrust faults that have crumbled the highly deformed and faulted thrust sheets. In fact, the Al Hoceima region belongs to a tectonic zone where shortening due to compression is predominant. Therefore, the alignment of aftershocks along topographic fronts, particularly in the NE-SW direction, and preexisting active thrust faults may reflect this tectonic activity. The correlation of aftershocks alignments with existing neotectonic accidents shows that the NW-SE AA' and BB' as well as a NNE-SSW trend do not coincide with any known faults in this area, thus, suggesting that these aftershocks alignments indicate three important accidents not yet identified through geological field work and not yet mapped. Furthermore, the NNE-SSW and the NW-SE aftershocks directions, identified in this study, comfort seismological, GPS and InSAR previous analyses that suggested these directions for the main coseismic fault planes that ruptured in the Al Hoceima 2004 main shock.

ES5/WE/O8 - HIGH-RESOLUTION STUDY OF A MICROEARTHQUAKE SEQUENCE IN SOUTHERN APENNINES (ITALY)

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On May 25 2008, a microearthquake sequence started in a very limited region of the Irpinia fault system, in Southern Italy. The sequence lasted three days, with 14 events occurring within a volume smaller than 300 m per side. The moment magnitude Mw of the events ranges from 1.0 to 2.8, with the mainshock occurring at the middle of the sequence. This sequence has been recorded by 21 stations of the Irpinia Seismic Network (ISNet) and 11 stations of the Italian National Institute of Geophysics and Volcanology (INGV). Such a dense instrumental deployment constitutes an excellent laboratory for studying the earthquake processes during the interseismic period. In particular, the observation of this peculiar sequences arises several questions about how are they related to larger-scale structures and how they contribute to the processes of fault loading and stress release. We first located the events using a non-linear global approach (NonLinLoc) and after we refined locations considering a double-difference technique (HypoDD) and using both manual picks and cross-correlation data of P- and S-waves. The resulting cluster of 14 microearthquakes has horizontal and vertical errors less than 30 and 80 meters. Additional 5 events located around the cluster were rejected since they have errors of the same size of the cluster. We studied the rupture process of the main event by first determining its focal mechanism, based on P-wave first motion polarities and S-wave polarizations, and, then, by performing a kinematic rupture modeling through the use of empirical

Green's functions, in order to retrieve the rupture length, orientation and velocity, and the average slip. Moreover we computed source parameters (seismic moment, corner frequency, source radius, …) for each event and mapped them in the volume surrounding the mainshock fault plane with the aim to investigate the space and time distribution and correlation of source properties for the events in the sequence.

The examination of this microearthquake sequence is of great interest since it reproduces at a reduced space and magnitude scale a classical foreshock-mainshock-aftershock series.

ES5/TH/O1 – SLIP-INVERSION ARTIFACTS COMMON TO TWO INDEPENDENT METHODS

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Slip inversions using low-frequency near-regional waveforms are discussed. A useful tool for revealing earthquake complexity is the iterative deconvolution of Kikuchi and Kanamori. The observed wavefield is represented by a few point-sources of relatively large seismic moments. To allow for a more realistic spatio-temporal moment distribution, the method requires a modification: whenever the residual wavefield requests a subevent of the best-fitting moment Msub, we allow only Msub * fract, where 0 < fract < 1, same for all (relatively numerous) subevents. The method works without exact prior knowledge of the hypocenter and without assuming the rupture velocity. It has been applied in synthetic tests, including two unilateral and one bilateral rupture scenarios along a 1D (line) fault. However, the tests indicated problems with a biased rupture velocity and spurious slip patches, mainly in the bilateral case. Independently, a new strategy to assess the spatio-temporal evolution of the rupture process was developed by expressing analytically the waveform-misfit derivative with respect to the slip velocity, and solving the inverse problem by the conjugate gradient method. The method resembles the back-propagation of residual seismograms towards the source. It should be initiated from a reasonably good source approximation, e.g. the centroid. Major characteristics of the source process are then gradually revealed in the iterative process. Surprisingly, the performance of this method was very similar to the previous one, particularly as regards the slip artifacts. The present paper explains this common difficulty by analyzing the roles of individual stations in the inversion by means of the so-called dynamic projection strips (DPSs). The DPSs were constructed by means of a 'signal detector', a computation tool analyzing the correlation between complete observed waveforms and partial synthetics due to trial point sources. Representing extension of the projection-line concept of the seismic source tomography, the DPSs of individual stations cross each other in a 'dark spot'. This is a region in the x-t domain commonly attracted by various inversion algorithms, inside of which they put their (non-unique) solutions. As such, the DPS concept explains why different methods may fall in the same 'trap'. The mathematical explanation of the persistence of the artifacts is in their tight relation to the leading eigenvectors in the inverse problem, as explained by the singular value decomposition (see the related poster in this session). The ideas were applied also to an Mw 6.3 earthquake in Greece. For details: J. Geophys. Res., doi:10.1029/2010JB007414.

ES5/TH/O2 – AN IMPROVED EGF TECHNIQUE TO RETRIEVE SOURCE PARAMETERS OF SMALL EARTHQUAKES

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One of the fundamental problems in source studies of small earthquakes (M<5) is the trade-off between stress drop, rupture velocity and attenuation along the travel path. While traditional empirical Green's function deconvolution techniques can remove the influence of attenuation, the trade-off between rupture velocity and stress drop remains unresolved. De Lorenzo et al. (JGR, 2006) proposed an empirical Green's function (EGF) inversion technique that resolves this trade-off. In its original form, the technique consists of searching for the best match between the observed seismogram of a target event and a synthetic seismogram, which is obtained from the convolution of an EGF with a theoretical moment rate function through a non-linear inversion procedure. The EGF is hypothesized to be an event simple and small enough so as to be representative of only the path. The inversion result is expressed directly in terms of the rupture velocity history, the source dimension and the stress drop of the target event. By inverting explicitely for the rupture velocity history, in principle this technique has the merit of removing the trade-off between rupture velocity and stress drop. The weakness is that in this way the stress drop tends to scale with the ratio of the seismic moments of the two events. To overcome this problem, we have modified the original procedure so as to invert directly for the ratio of the seismic moments of the target and EGF events, rather than for the stress drop of the target event. An advantage of this modification is that the resulting seismic moment ratio can be checked against the seismic moment of the two events determined independently. The stress drop of the target event is calculated subsequently from the source radius obtained from the inversion and the independently determined seismic moment. With tests on synthetic signals, we investigate the sensitivity of the results to the seismic moment ratio, to deviations of the source-time function of the EGF from an ideal delta impulse and to differences in take-off angle between target and EGF events. We have applied this modified procedure to obtain estimates of stress drop, source dimension and rupture velocity history of an ML 3.4 event induced in 2006 by water injection at 5 km depth during the stimulation of an enhanced geothermal reservoir below the city of Basel, Switzerland.

ES5/TH/O3 – DESCRIPTION AND VALIDATIONS OF THE SCARDEC METHOD, A NEW APPROACH TO QUICKLY DETERMINE THE EARTHQUAKE SOURCE PARAMETERS

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We present an automated method to simultaneously retrieve the seismic moment, focal mechanism, depth and source time functions of large earthquakes. This approach, referred as the SCARDEC method, is based on body-wave deconvolution. After explaining the main innovative points of the SCARDEC method, we show its results for the major subduction earthquakes of the last 20 years, with a stronger focus on the events for which our solutions differ from the Global CMT results. Because Global CMT makes use of other seismic data for large and shallow earthquakes (mostly long period surface waves), we explore the compatibility of our source parameters by forward modelling these surface waves. Two methods (full ray theory and spectral element methods) are used to simulate the long-period wavefield for the 3D Earth model S20RTS combined with the crust model CRUST2.0. We show that our solutions agree with surface waves as well as Global CMT solutions. This can be explained by the fact that most of the differences with Global CMT are linked to correlated variations of the seismic moment and dip of the earthquakes, and it is theoretically known that long-period surface waves are little sensitive to the independent effects of these two parameters for shallow earthquakes. While the SCARDEC method makes only use of body waves arriving in the 30 minutes after the earthquake origin time, this validation shows that the retrieved source parameters remain consistent with most of the subsequent parts of the seismograms. Additionally, the use of blind tests – where the wave propagation generated by an earthquake source is simulated in 3D Earth models – confirms that the SCARDEC method is able to retrieve the real earthquake source parameters.

ES5/TH/O4 – APPLICATION OF THE KIWI TOOLS: KINEMATIC STUDY OF THE 2007 MW 5.9 HORSESHOE ABYSSAL PLAIN, SW IBERIA, EARTHQUAKE

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The Kiwi (KInematic Waveform Inversion) tools are a recently-developed software package that allows the rapid inversion of point- and finite-source parameters (~20 min). On three consecutive steps the inversion algorithm is able to retrieve a simplified description of the earthquake source. The Kiwi tools take as input displacement waveforms, as well as initial estimates of the earthquake location (latitude, longitude and depth), origin time and scalar moment. Green functions are computed in advance and stored in banks. The first step that Kiwi performs is a frequency-domain moment tensor inversion that yields the focal mechanism (strike, dip and rake), depth and scalar moment. The second step is a time-domain inversion for earthquake centroid, which fine-tunes the initially-assumed centroid latitude, longitude, and origin time. The final step of this multi-stage algorithm is a simplified kinematic inversion for finite-source parameters: fault

area, hypocenter location, rupture velocity, and rupture time. The different steps of the inversion use different data passbands, data windows, time- vs frequency-domain inversions, misfit norms, and inversion algorithms (grid-walk, Levenberg-Marquardt, etc.). This highly-adapted procedure allows the use of specific data segments to extract different earthquake source information on the different steps.

The Kiwi algorithm has been applied with success at regional distances to earthquakes in Germany, Greece and Spain (down to a magnitude Mw 3.3) and is now under tests for earthquakes in Portugal. In this presentation we will show results obtained for the 2007 Mw 5.9 Horseshoe Abyssal Plain (HAP), SW Iberia, earthquake. The 2007 HAP earthquake occurred offshore, on the broad region that surrounds the Eurasia-Africa plate boundary. The current Portuguese broadband network is quite adequate for detailed earthquake studies. However, the geographical location of Portugal creates a large azimuthal gap in the dataset. The quality of the dataset is also affected by strong reverberations generated within the Cadiz basin. Thus, carefully analyzing the robustness of the inferred source parameters becomes a key issue. In this work we will study the impact of using different inputs in the inversion: regional data vs teleseismic data, complete waveforms vs body waves only, global vs regional Green functions (PREM vs regional model). We will also compute inversions that exclude data strongly affected by the Cadiz. The stability of the retrieved parameters is assessed via bootstrap. Finally, we will discuss how our results compare with previous studies and how they fit within the tectonic framework.

ES5/TH/O5 **- SPECTRAL ANALYSIS OF K- AND KIK-NET DATA IN JAPAN: ATTENUATION CHARACTERISTICS AND SOURCE PARAMETERS**

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Japan is one of the regions with highest seismic activity in the world and, at the same time, one of the most densely instrumented countries. Following the highly destructive Kobe earthquake in 1995, two strong motion networks, K-net and KiK-net, have been deployed, recording earthquakes in and around Japan on a continuous basis. In addition, the KiK-net sites are equipped with borehole sensors. This wealth of accelerometic data, covering a large range of magnitudes (ranging from about 3 to 8), makes these datasets highly valuable for obtaining new insights into highly debated topics, such as the scaling of seismic sources and issues regarding site response estimation. We analyze a dataset of about 67,000 records from 2,178 earthquakes recorded at more than 1500 K- and KiK-net stations with the generalized inversion technique (GIT) in order to separate site response, source spectra and attenuation characteristics. Attenuation characteristics are investigated in five separate regions, showing that crustal Q depicts lower values within central than in southern Japan, and a significant frequency dependence is observed in every region. The source spectra follow the omega-square model with roughly self-similar scaling over the entire magnitude range and average stress drop of around 2 MPa for crustal (depth ≤ 30 km) and 20 MPa for subcrustal (depth > 30 km) earthquakes. The moment magnitudes M_W determined from the spectral analysis show in general a good agreement with M_{JMA}. The ratio of radiated energy and seismic moment, E_R/M_0, increases with increasing M_W and shows a clear dependency on Brune stress drop. Our results are in good agreement with several previous studies of earthquake source parameters, in particular stress drop, in various regions of Japan, and provide strong indications for roughly self-similar scaling on the scale of the entire Japanese archipelago, with subduction zone earthquakes showing stress drops one order of magnitude larger than crustal earthquakes.

ES5/TH/O6 **- SOURCE PARAMETERS OF NANOSEISMICITY (-4.0 < MW < -0.8) RECORDED AT MPONENG DEEP GOLD MINE, SOUTH AFRICA: IMPLICATIONS FOR SCALING RELATIONS**

G. Kwiatek[1], K. Plenkers[1], G. Dresen[1], JAGUARS Group[2]
[1]Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences; [2].

We analyze the source parameters of nanoseismic events (M_W>-4.0) recorded with a high-sensitivity seismic network at Mponeng gold mine, South Africa. The network, composed of one 3-component accelerometer (50Hz to 25kHz) and 8 acoustic emission sensors (700Hz to 200kHz) is located at a depth of 3543m and covers the limited volume of approx. 300x300x300m. The acoustic emission sensors are calibrated relative to the 3-component accelerometer in the lower frequency band (f<25kHz). The waveform data is used to analyze the source characteristics of over 3000 events that belonged to the two datasets: (1) post-blasting activity recorded during working days, located more than 80m from the network at the stope level and (2) aftershock sequence of a M_W 1.9 event that occurred approx. 30 m from our network. The calculated values of M_W ranged from -0.8 to -4.0 with corner frequencies 0.5-17kHz (source sizes from 10m to a few centimeters). We observe a constant static stress drop release around 10MPa, indicating the self-similarity of rupture process within analyzed magnitude range. The apparent stress ranges 0.5MPa-50MPa that also seems to be independent of seismic moment. We observe strong influence of attenuation and local geological and engineered structures on calculated source parameters.

SD2 - COLLECTING THE MACROSEISMIC DATA AFTER DAMAGING EVENTS USING EUROPEAN MACROSEISMIC SCALE: A DECADE OF FIELD EXPERIENCE

Wednesday 8, 14h00-16h40

SD2/WE/O1 **- L'AQUILA DOWNTOWN: EMS98 TEST SITE**

A. Tertulliani[1], I. Leschiutta[1], F. Bernardini[1], C. Castellano[1], E. Ercolani[1]
[1]INGV

The 6 April 2009 earthquake (Mw=6.3 and Imax=9-10 MCS) struck the Abruzzi region of Central Italy producing severe damage in the city of L'Aquila and in many villages. After the event, a building-to-building survey was performed in L'Aquila downtown aiming to collect data in order to perform a strict evaluation of the damage. The survey was carried out under the European Macroseismic Scale (EMS98) to evaluate the local macroseismic intensity. This damage survey represents the most complex application of the EMS98 in Italy since it became effective. More than 1700 buildings were classified by typology, vulnerability class and grade of damage, highlighting the difficult application of the macroseismic scale in a large urban context. The EMS98 revealed itself to be the best tool to perform such kind of analysis in urban settings. The complete survey displayed evidence of peculiar features in the damage distribution. Results revealed that the highest rate of collapses occurred within a delimited area of the historical centre and along the SW border of the fluvial terrace on which the city is settled. Intensity assessed for L'Aquila downtown was 8-9 EMS.

SD2/WE/O2 **- THE L'AQUILA 2009 EARTHQUAKE: AN APPLICATION OF THE EUROPEAN MACROSEISMIC SCALE TO THE DAMAGE SURVEY IN THE EPICENTRAL AREA**

R. Azzaro[1], M. Barbano[2], S. D'Amico[1], T. Tuvè[1], A. Mostaccio[1], L. Scarfì[1]
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On April 6 2009, Central Italy was hit by a M_w 6.3 earthquake with epicentre located near the town of L'Aquila, which produced destructions and damage in a wide area of the Abruzzi region and caused 300 fatalities.

The macroseismic effects of the earthquake have been investigated by a first emergency survey aimed at defining, also for Civil Protection purposes, the general earthquake damage scenario according to the MCS scale. Nevertheless, the variability of the effects within the same urban area and the uncertainties deriving in assessing the intensity, prompted us to carry out a more detailed survey in about 70 localities of the epicentral area with the aim of applying the EMS scale. The use of this scale, enabling detailed consideration of the vulnerability of buildings and their grade of damage, has provided a more coherent evaluation of the intensity also in settlements made up of very different building typologies.

The maximum intensities have been estimated for the village of Onna (IX EMS), the historical centre of L'Aquila, Castelnuovo, Pettino and Sant'Elia (VIII-IX EMS), while numerous localities sited along the valley of the Aterno river, a few tens of kilometres apart from each, suffered severe damage (VIII EMS). By contrast, other villages in the same area have had EMS intensities lower than 1-2 degrees. The following factors have produced a higher concentration of damage in specific zones:

- extremely different conditions of building seismic vulnerability, also in the same locality;
- problems of engineering nature, such as adopted construction techniques and quality of materials;
- site effects, due to unfavourable geological conditions;
- coseismic deformation and source directivity effects along the Paganica fault system;

Finally, we discuss the differences in the intensity assessment deriving from the interpretation of the MCS and EMS scales.

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SD2/WE/O3 - TESTING THE EUROPEAN MACROSEISMIC SCALE IN GREECE: CASES OF DAMAGING AND DESTRUCTIVE EARTHQUAKES

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The 1998 version of the European Macroseismic Scale was first tested during the Athens 1999 Mw6.0 earthquake and has been applied to a number of significant greek earthquakes ever since. The scale has been used in the field, as well as via questionnaires. Photographic material supporting damage assessment and vulnerability class identification is available for each event. In the present study five earthquakes are presented: three destructive (Athens 1999, Lefkada 2003 and Andravida 2008) and two damaging (Gonnoi 2003 and Kefallinia 2007). For the destructive events, intensity has also been assessed in the MM scale, allowing thus possible comparisons. Taking into account that EMS is not the official macroseismic scale in Greece, the number of data collected and the extent of the area investigated are strongly related to the availability of research teams. In the case of Andravida earthquake, a considerable number of researchers were able to cover the damage area at a satisfying degree and to proceed even further for collection of felt reports from localities with no damage. The EMS has been used to numerous historical earthquakes and characteristic examples of its application are also presented.

SD2/WE/O4 - GUIDELINES FOR COLLECTING THE MACROSEISMIC DATA IN FIELD USING EMS - THE FIRST OUTLINE

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Despite the extensive manual that accompanies the scale and clarifies many details, the use of the EMS in field is not as straightforward as it might look. The scale itself is definitely a powerful yet complex tool, but its use in the field, especially in case of large damaging event/s, is a demanding task. Although seismologists have been collecting macroseismic data in field for more than a century, there is no manual that can help beginners to prepare and organize such survey, or serve as a to-do checklist for the experienced ones. The ESC WG 4-07 Macroseismic field work practicesis currently working on a publication that would try to solve at least some of the questions. Beside general instructions how to organize a field survey, a special care is given to the specific details connected with the EMS and its demands. The first outline of the guidelines will be presented and open for discussion.

SD6 - GPS, INSAR AND SEISMOLOGY

Wednesday 8, 14h00-16h40

SD6/WE/O1 - INSAR AND SEISMOLOGICAL OBSERVATIONS ASSOCIATED WITH THE 14 NOVEMBER 2007, MW 7.8 TOCOPILLA EARTHQUAKE IN CHILE

M. Motagh[1], *B. Schurr*[1], *J. Anderssohn*[1], *B. Beatrice Cailleau*[2], *T. Walter*[1], *R. Wang*[1]
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The Mw=7.8 November 2007 Tocopilla earthquake ruptured a subduction interface between the cities of Tocopilla and Antofagasta in North Chile. Here we investigate source parameter and slip distribution associated with this earthquake using satellite radar interferometry data in combination with seismic aftershock data recorded by 8 new local seismic stations. Combining two satellite viewing geometries, acquired in Envisat's Wide Swath and Image modes, we observe decimeter-scale deformation. The maximum line-of-sight displacement is found to be about 40 cm, located at the Mejillones Peninsula. Slip inversions using elastic half-space models with geometry constrained by aftershocks suggest that an area of ~ 160 km by 50 km along the Nazca–South America convergent margin, between latitudes 22° S and 23.5° S, ruptured during the mainshock. Towards the south, the region of slip broadens, and reaches a peak slip of about 2.5 m to the northeast of the Mejillones peninsula. The depth of faulting is estimated to be between 30 and 50 km. The total geodetic moment is estimated to be about 5.01×10^{20} Nm (Mw=7.8), assuming a shear modulus of 30 GPa, close to the seismological estimate of 4.77×10^{20} Nm.

SD6/WE/O2 - AN AUTOMATIC NEURAL NETWORK APPROACH FOR RETRIEVING SEISMIC SOURCE PARAMETERS FROM INSAR DATA

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The retrieval of the geometric parameters of active faults is still an open issue, although some approaches are available. Since 1992 InSAR technique has been widely applied to the measurement of surface effects due to moderate to strong earthquakes and to the retrieval of the coseismic displacement pattern. The differential interferogram obtained by InSAR contains useful information to define the fault geometry (dip and strike angle; width and length), the extension of the rupture, the slip distribution on the fault plane. We propose a novel approach to perform the inversion operation dealing with the use of InSAR and Neural Networks. These are composed of an ensemble of nonlinear computational elements (called neurons) connected by the so called synapses, each characterized by a synaptic weight. Compared to other methods, the use of NN is often effective because they can simultaneously address nonlinear dependencies and complex physical behaviour with reduced computational efforts and without the need of any a priori information. The approach requires the generation of a statistically significant number of synthetic interferograms necessary for the network training phase. Each of them corresponds to a different combination of fault geometric parameters. After the training, the network is ready to perform in real time the inversion on new differential interferograms. We have tested our approach in some recent earthquakes where differential interferograms were available. The outcomes have been compared with inversion results already present in literature to evaluate their effectiveness.

SD6/WE/O3 - SAN FERNANDO NAVAL OBSERVATORY CONTINUOUS GPS ARRAY: SYNERGIES WITH THE VBB SEISMIC ARRAY

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San Fernando Naval Observatory (ROA) has deployed a Continuous GPS (CGPS) array around the Gulf of Cadiz and the Alboran Sea, and extended it to the Balearic Island. Today there are up to ten stations recording and delivering their data files to the Observatory.

After the installation of the SFER CGPS, included in the International GNSS Service (IGS) network in 1996, three stations were deployed and are recording satellites data files since 1998. They are located in Mahon, at the Balearic Island, Melilla in the Northern Coast of Africa and Cartagena, in the SE of the Spain Mainland. From then, new CGPS stations were placed at Granada, in 2001, Ceuta, 2003, Velez de la Gomera, in 2005, Chafarinas Islands, in 2008, and also in 2008 a CGPS was mounted at the Averroes Observatory, close to Casablanca in Morocco,

with the support of the Scientific Institute of Rabat (ISRABAT). The last one was installed at the Alboran Island Lighthouse in January 2009. As Melilla, Ceuta, Velez de la Gomera, and Chafarinas Island CGPS are located at the Mediterranean Northern Coast of Africa. The most of the CGPS are colocated with Very Broad Band seismic devices in order to monitor the dynamic behavior of the area.

Data files sampled at 30 seconds are collected in a daily basis at ROA. They are analyzed with the GIPSY OASIS II software, developed by the NASA's Jet Propulsion Laboratory (JPL). Orbits, clocks and Earth rotation parameters are retrieved from the JPL server.

Time series from the daily data files provide velocity vectors of tectonic plates, both in the horizontal plane and in the vertical direction, as well as stations relative displacements in respect of those in their vicinity. Then, stress accumulation can be inferred from those results.

We are also recording high rate GPS data, sampled at 1 Hz, to be used in combination with seismometer records. In this case, relative movements among stations are computed and analyzed by detecting vertical and horizontal deformations of the Earth surface in the event of a large magnitude earthquake, with an accuracy of millimeters. Because, GPS 1 Hz data is less sensitive to noise contamination than seismic data, the complementary use of GPS and VBB shall be very useful to get rapid assessment of natural hazards, including tsunami early warning or ground failures.

SD6/WE/O4 **- GEOIDETIC NETWORKS AROUND SEISMOGENIC ZONES IN NORTHERN ALGERIA**

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Northern Algeria, located along the Eurasiatic-African boundary plate is characterised by a moderate to strong seismic activity. During History, some violent earthquakes occurred mainly in the Atlas region, particularly in the Tellian area, leading sometimes to destruction of major cities of Algeria (Algiers, 1716; Oran, 1790; Blida, 1825; El Asnam, 1980; Boumerdes, 2003…). In order to improve the knowledge of the deformation pattern of the Atlasic region, and more globally of the African-Eurasiatic plate boundary along the Algerian margin, the Research Center of Astronomy, Astrophysics and Geophysics (CRAAG) started since two year to implement two major projects:1/ The first one is the REGAT (REseau Géodésique de l'Atlas), which consists on a set of 20 continuous GPS stations deployed in the Atlas region, from the coastal area to the Sahara Platform. At this time (1st phase), eleven stations have been already installed. The first stations (Algiers-Bouzaréah, Tamanrasset…) of this basic network are producing data since 3 years. First time series are analysed. In 2010, in the 2nd phase of this project, it is projected to extend this network by another set of 50 stations which are mostly collocated with the seismological stations. 2/ The second project consists in the deployment of semi permanent GPS networks around four seismogenic basins and active fault areas. Many surveys have been already carried out in the following region: Oran region, west Algeria, the Chelif basin (El Asnam region), the Mitidja basin (from Tipaza to Dellys), the Ain Smara fault (Constantine region).

SH3 - GLOBAL, REGIONAL AND LOCAL INITIATIVES ON SEISMIC HAZARD ASSESSMENT: TOWARDS SETTING NEW STANDARDS

Thursday 9, 08h00-10h00

Thursday 9, 10h20-12h00

Thursday 9, 14h00-16h40

SH3/TH/O1 **- THE VALUE OF SSHAC LEVEL 3 AND 4 PROCESSES FOR COMMUNITY-BASED SEISMIC HAZARD ASSESSMENTS**

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Probabilistic assessments of ground-shaking seismic hazard are conducted for a variety of reasons, from building code zonation maps to site-specific safety assessments for critical facilities such as nuclear power stations. In those applications for which the consequences of inadequate performance under seismic shaking are more severe, it becomes increasingly important to demonstrate that epistemic uncertainties in all of the inputs have been effectively captured. Since epistemic uncertainty implies the need for expert judgements, the likelihood of capturing the centre, the body and the range of legitimate and defensible models is increased through the participation of several experts in the assessment. A structured process is required to define the roles of different experts and the nature of their interactions, and to ensure rigorous review of both the technical assessments and of the process itself. The procedures defined by the Senior Seismic Hazard Analysis Committee (SSHAC) provide precisely such a framework to capture the centre, the body and the range of interpretations of the available geological, seismological, geophysical and geotechnical data. The SSHAC guidelines define four different levels at which probabilistic seismic hazard analyses (PSHA) can be conducted, increasing in complexity and rigour (and hence also in cost, effort and duration) with the level selected. Although intended primarily to provide high levels of regulatory assurance at the sites of critical facilities, Level 3 and 4 studies can also be conducted at regional or national levels to provide seismic source characterization (SSC) and ground motion (GM) models that can then be used either for mapping exercises or as the basic input to site-specific PSHA studies. Particularly in stable regions of relatively low seismicity, such an approach provides a basis for all PSHA studies to be developed through a process that facilitates broad participation and makes full use of the body of geological and seismological expertise. Although this level of effort may not be warranted for hazard mapping for building code (or similar) applications, in which much shorter return periods are used, if a regional or national SSHAC Level 3 or 4 study is carried out then it automatically provides the required input for all applications; it can be simplified for building codes or can be further refined locally for site-specific applications. This approach can ensure consistency both between national hazard maps and site-specific assessments, and from site to site for safety-critical facilities.

SH3/TH/O2 **- GEM GLOBAL INSTRUMENTAL SEISMIC CATALOGUE (1900-2009)**

D. Storchak[1]
[1]International Seismological Centre

Currently there is no stable quantification of seismicity for all regions covering a time period of at least 100 years. There is a need to compile an improved reference global instrumental catalogue, covering the year 1900 to present to serve as a primary tool to characterize the spatial distribution of seismicity, the magnitude-frequency relation and the maximum magnitude within the scope of GEM. The ISC in cooperation with the IASPEI put together a team of international experts to produce such a catalogue using the best data and techniques available within the budget given by GEM. The Team includes Bob Engdahl (Colorado University), Antonio Villaseñor (IES Jaume Almera), Willie Lee (USGS, emeritus), Peter Bormann (GFZ, emeritus), Istvan Bondar (ISC), Dmitry Storchak (ISC), Graziano Ferrari (INGV/SISMOS), Peter Suhadolc and colleagues from Japan, Germany, US & UK as observers on behalf of the IASPEI. Deliverables of this two year long project (ending in June 2012) will be:

- 110 years of re-located earthquake hypocenters with uncertainties;
- Re-computed M_S values with uncertainties for re-located events based on the data of historical seismic station bulletins;
- M_W values based on seismic moment where possible (mainly 1980-2009) and proxy values in other cases using appropriate empirical relationships between M_W and other types of magnitudes;
- Database with the above information and references to original sources including scanned historical station bulletin pages.

SH3/TH/O3 **- THE GEM1 GLOBAL SEISMIC HAZARD MODEL: SUMMARY AND OUTLOOK**

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GEM is a public/private partnership initiated and approved by the Global Science Forum of the Organization for Economic Co-operation and Development (OECD-GSF). GEM (www.globalquakemodel.org) aims to be the uniform, independent standard to calculate and communicate earthquake risk worldwide. With committed backing from academia, governments, and industry, GEM will contribute to achieving profound, lasting reductions in earthquake risk throughout the world. As the first step in GEM development, GEM1 was designed as a focused pilot project to generate GEM's first products and develop GEM's initial IT infrastructure. GEM1 formally started in January 2009 and ended on March 31 2010. ETH Zurich was appointed

as the leading institution, with the EUCENTRE, GFZ, NORSAR and the USGS as contributing partners. As was built up within GEM1, the GEM IT infrastructure is concentrated around three interrelated modules: (a) Data Capitalization: tool to capitalize and manage the data generated by research, including seismic source models, events catalogue, buildings inventory, vulnerability datasets, damage distribution, population exposure, seismic hazard, risk and loss information; (b) Hazard and Risk Calculator: a new generation of hazard and risk calculators that requires incorporation of shared information technologies to enable the high-end computation of the seismic hazard and risk; (c) Web-Portal Development based on Java portlet technology: pluggable user interface (UI)-based services intended to enable easily publishing and displaying information. The same infrastructure will also be customized and used for the SHARE project (www.share-eu.org) that aims at creating an updated, living seismic hazard model for the Euro-Mediterranean region. Here we report on the progress made during GEM1 towards creating a global probabilistic seismic hazard model. The main GEM1 hazard goals were to: (1) collect and implement in a common model infrastructure a set of relevant regional PSHA input models as a baseline for global coverage, (2) develop, implement and validate a customized seismic hazard engine, and (3) compute a preliminary hazard model at a global scale. Furthermore, we outline the next steps planned at the GEM Model Facility, located at ETH Zurich, to create the final GEM IT infrastructure and global hazard model.

SH3/TH/O4 - PROBABILISTIC SEISMIC HAZARD IN ECUADOR: ESTABLISHING THE BASIS FOR AN IMPROVEMENT OF ALL STEPS LEADING TO ITS ESTIMATION

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Since 2007, a French-Ecuadorian effort is carried out to improve all steps required for estimating probabilistic seismic hazard over the territory of Ecuador. First efforts have been concentrated on the building of an earthquake catalogue covering the last 5 centuries, integrating historical and instrumental earthquake solutions. GPS, broad-band, and accelerometric stations are currently being installed over the whole Ecuadorian territory. The first data available will be used for selecting among published ground-motion prediction equations the ones best adapted to the tectonic context (subduction and crustal events). Based on recent studies on the potentially active faults distribution, a seismo-tectonic zoning has been developed, taking into account the recent findings on general geodynamics and the distribution of strain due to the displacement of the Northern Andean block with respect to South America. First calculations of probabilistic seismic hazard have been carried out, relying on modeled earthquake recurrences in all identified source zones. Future efforts will focus on proposing alternative methods for calculating probabilistic hazard and on the quantification of the impacts of input uncertainties on the hazard estimates.

SH3/TH/O5 - SEISMIC HAZARD IN JAVA, INDONESIA: APPROACHES TO SEISMIC HAZARD AT THREE DIFFERENT SCALES

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As a consequence of the incentive and goad provided by recent, large, varied and destructive earthquakes in Indonesia (Aceh 2004 (tsunami earthquake), 9.0 M_w; Nias 2005, 8.6 M_w; Padang (Pariaman) 2009, 7.5 M_w), and specifically the remarkably building-destructive Bantul, Yogyakarta 2006, 6.3 M_w earthquake, a team has been investigating determination of seismic hazard at different scales. The three scales under consideration are: 1) national or Java Island scale, 2) provincial or Yogyakarta Special Province (YSP) scale and 3) local or sub-province Regency scale. Different analytical skills and property-sampling requirements are needed. Ideally there should be a coherent thread or overview connecting maps prepared by different means at different scales and usually for different aspects of mitigation and resilience strengthening. For instance, national scale for macrozoned viewing of seismic hazard directed at guidance through building codes, provincial scale for general understanding of regional geology influencing the seismic hazard, and local for specific, detailed microzoned advice on areas at risk and related development.

This work has resulted in: 1) Monte Carlo based seismic hazard maps for all Java, 2) estimation of expected incremental-intensity amplification referred to igneous rock basement in YSP and 3) surveyed and mapped microzoned seismic hazard in three regencies of YSP. The first two scales and styles of seismic hazard maps are reviewed and briefly explained, the third is described in more detail for the Bantul locality of YSP. Microtremor surveys, geotechnical borehole drilling, SPT testing, S-wave velocity sampling, earthquake wave form modelling, were all carried out for the Bantul region in Southern Yogyakarta Depression Area. Ensuing data analyses allow preparation of a suite of maps showing amplification factor, predominant period, sediment thickness, PGA and PGV. These maps can be validated and interpreted with respect to damage distributions observed during the Bantul earthquake. These results indicate contrasting outcomes, for example, high amplification regions with severe damage and lower amplification areas where high damage is generated by high PGV and PGA. Such combined information will help to diagnose and mitigate future seismic risks in the YSP and aid understanding of earthquake impacts elsewhere.

SH3/TH/O6 - SEISMIC HAZARD HARMONIZATION IN EUROPE (SHARE): TOWARDS A COMMUNITY-BASED LIVING HAZARD MODEL

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Probabilistic seismic hazard assessment (PSHA) is one of the most useful products that seismology can offer to society. PSHA characterizes the best available knowledge on the seismic hazard of a study area, ideally taking into account all sources of uncertainty. Results form the baseline for informed decision-making, such as building codes or insurance rates and provide essential input to each risk assessment application. Several large scale national and international projects have recently been launched aimed at improving and harmonizing PSHA standards around the globe. SHARE (www.share-eu.org) is the European Commission funded project in the Framework Programme 7 (FP7) that will create an updated, living seismic hazard model for the Euro-Mediterranean region. SHARE is a regional component of the Global Earthquake Model (GEM, www.globalquakemodel.org), a public/private partnership initiated and approved by the Global Science Forum of the OECD-GSF. GEM aims to be the uniform, independent and open access standard to calculate and communicate earthquake hazard and risk worldwide. SHARE itself will deliver measurable progress in all steps leading to a harmonized assessment of seismic hazard - in the definition of engineering requirements, in the collection of input data, in procedures for hazard assessment, and in engineering applications. SHARE scientists are creating a unified framework and computational infrastructure for seismic hazard assessment and are generate an integrated European probabilistic seismic hazard assessment (PSHA) model and specific scenario based modeling tools. The results are envisioned to deliver long-lasting structural impact in areas of societal and economic relevance, they will serve as reference for the Eurocode 8 (EC8) application, and will provide homogeneous input for the correct seismic safety assessment for critical industry, such as the energy infrastructures and the re-insurance sector. SHARE covers the entire European territory, the Maghreb countries in the Southern Mediterranean and Turkey in the Eastern Mediterranean. By strongly including the seismic engineering community, the project maintains a direct connection to the Eurocode 8 applications and the definition of the Nationally Determined Parameters, through the participation of the CEN/TC250/SC8 committee in the definition of the output specification requirements and in the hazard validation. SHARE will thus produce direct outputs for risk assessment. With this contribution, we provide an overview of the goals and focus on current achievements and first results of the project.

SH3/TH/O7 - ENGINEERING REQUIREMENTS FROM SHARE: COMPATIBILITY WITH EUROCODE 8 AND ANTICIPATION OF FUTURE REQUIREMENTS

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The Seismic Hazard Harmonisation in Europe (SHARE) project aims to implement a comprehensive and up-to-date seismic hazard model for the European region. It offers an opportunity to appraise European seismic hazard output, and the extent to which it fulfils the current needs of the engineering community. Seismic hazard must be defined in terms that are compatible with the current Eurocode 1998 standard, and sufficiently flexible as to allow for modification of the definition of seismic input in accordance with Nationally Determined Parameters. Elements of the seismic hazard analysis that may need to accommodate modification include the return period, the strength of the ground motion, the classification of the site and the characterisation of the elastic design spectrum. Dissemination of the SHARE output should provide a means of defining the seismic input requirements of Eurocode 8 to the fullest extent. Whilst compatibility with current code requirements is an essential condition under which SHARE is undertaken, the project also allows the opportunity to anticipate future needs for the definition of seismic input within European seismic code design. A review of seismic design provisions for many countries around the globe offers an insight into the relative merits and weaknesses of Eurocode when considered alongside other state-of-the-art design codes in current use. It also allows for appraisal of the seismic input provisions in the context of seismic hazard best practice. The expected output from SHARE should exceed the relatively limited requirements found in current European codes. This will provide a basis upon which future revisions can be formulated. Particular focus is placed upon the definition of the response spectrum in Eurocode and its relation to the uniform hazard spectrum defined from the hazard analysis. Other critical elements of the analysis include the identification of hazard-compatible scenario earthquakes, which are required in several parts of the code. Consideration should also be given to performance based design requirements and the extent to which these result in a homogenous margin of safety against damage and collapse. This may be achieved using techniques such as risk-targeted seismic hazard or via cost-benefit based approaches. It is expected that these topics will be explored further as the project progresses.

SH3/TH/O8 - COMPILATION OF ACTIVE FAULT DATA IN IBERIA FOR USE IN REGIONAL-SCALE SEISMIC HAZARD ASSESSMENT

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Active fault databases provide essential input data for robust probabilistic seismic hazard analysis (PSHA) studies that integrate both seismicity and active fault data into the hazard calculations. In the context of project SHARE (Seismic Hazard Harmonization in Europe), an EC-funded initiative (FP7), we are compiling a fully-parameterized active fault database for Iberia and the nearby offshore region. This database incorporates a wide range of geological and geophysical observations on active seismogenic sources, and is being developed in parallel with IBERFAULT, another ongoing effort to develop a database of active faults in the Iberian region.

The principal goals of this initiative are for fault sources in the Iberian region to be represented in project SHARE and incorporated into a source model intended for seismic hazard maps at the European scale. This large effort relies heavily on input from many regional experts (the 2010 Working Group on Iberian Seismogenic Sources), who are contributing their data in a standardized format to facilitate the development of the database and the goal of utilizing the database for PSHA applications. In addition to the data contributed directly from researchers, the database also incorporates existing compilations, updated according to the most recent publications, and includes sources compiled from the literature. The Iberian seismogenic source model derived for SHARE will be the first regional-scale source model for Iberia that includes fault data and follows an internationally standardized approach. This model can be used to improve both seismic hazard and risk analyses and will be appropriate for use in Iberian- and European-scale assessments.

SH3/TH/O9 - THE SHARE EUROPEAN SEISMIC SOURCE ZONE MODEL

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As a part of the SHARE project a new European seismic source zone model (SSZM) for seismic hazard has been constructed. The model stretches from the Mid-Atlantic Ridge, the Azores and Iceland, in the west, to Romania and Turkey in the East. The model has been constructed from existing and new local models. New areas from the previous SESAME model are, the Azores, Iceland and intermediate seismicity in the Cyprean Arc. Homogenization of the SSZM has been made with focus to geological and seismological boundaries. The whole area has been defined with source zones. In total nine workshops all over Europe were held in order to build a consensus model. The presented model will together with a diffuse seismicity based model and a fault model be used for computing seismic hazard for the European area. It will also be the basis for the European GEM model.

SH3/TH/O10 - CAN THE 2009 L'AQUILA EARTHQUAKE BE USED TO VALIDATE ITALIAN SEISMIC HAZARD MAPS?

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The 6 April 2009 L'Aquila earthquake was the first strong event in Italy after the release in 2004 of the seismic hazard map and the adoption in 2008 of the new Italian building code (NTC08), based on that probabilistic assessment, and fully operative only after the earthquake. The L'Aquila event was also one of the most recorded events in recent history in Italy and the numerous recordings of the L'Aquila earthquake have led to a number of comparisons being made between the recorded spectra and spectra found in design codes, such as the Eurocode 8 and the NTC08. These comparisons have shown in some cases that the recorded ground motions were a lot higher than those from the Italian code spectra, especially at low spectral periods. The first consideration in this work is whether comparisons between design spectra and recorded ground motions are meaningful and if they can be used to "validate" design code spectra. Of course, the only meaningful test of a probabilistic seismic hazard map is to ask, assuming that it is for a 475-year return period, whether over a 50-year period more than 10% of the national territory experiences ground accelerations higher than those mapped. Even then, it can be demonstrated that to make this test robust would require several consecutive 50-year periods of observation, in the same way that we need much longer than 475 years of acceleration recordings to validate the hazard estimate at a single location. Nevertheless, some of the comparisons that can be undertaken between the observed ground motions and the hazard model used for the NTC08 design code have been performed and have shown that the assumptions and modelling choices made in the Italian hazard study are in line with the observations. In the light of our work, we can conclude that significant changes to the spectra in NTC8 would not be recommended based on the evidence of the L'Aquila earthquake. However, the possibility of including the epistemic uncertainty in the code somehow, perhaps through an explanation of this uncertainty so that the engineer may decide which percentile to use in design, could be explored for future updates to the code. Finally, it appears that further research is necessary to explore the differences between the displacement spectra in NTC08 and those proposed in recent national studies, undertaken before the L'Aquila event.

SH3/TH/O11 - CORRECTING A POTENTIAL BIAS IN PROBABILISTIC SEISMIC HAZARD ASSESSMENT: SEISMOTECTONIC ZONATION WITH FRACTAL PROPERTIES.

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A critical step in Probabilistic Seismic Hazard Assessment (PSHA) is the accurate definition and characterization of relevant seismic sources. This is particularly challenging in low-seismicity regions, because observation periods are relatively short, seismicity is often diffuse, and active faults are difficult to identify. For these reasons, large source zones are commonly used with spatially uniformly distributed seismicity inside. Observed seismicity, however, is generally not uniformly distributed, but reflects seismotectonic forces and tectonic structure. Rather, observed seismicity even in subregions defined as seismic sources is clustered in space: seismicity tends to aggregate on or close to

major fault structures. Thus the hypothesis of uniform distribution of events inside a source zone does not relate well to observed seismicity and could overestimate or underestimate the value of ground-acceleration on the PSHA.

Seismicity is a classical example of a complex phenomenon that can be quantified using fractal concepts. In particular, fault networks and epicenter distributions are know to have fractal properties. The fractal dimension is an extension of the Euclidean dimension and measure the degree of clustering of earthquakes.

In this study, we move towards a more realistic characterization of spatial distribution of seismicity within each source zone. We quantify differences between different spatial characterization of seismicity and validate a more realistic method for the generation of synthetic seismicity on a source zone as input for PSHA, extending the concepts described in Beauval et al. (BSSA, 2006).

We first calculate differences in terms of hazard curves and hazard maps for synthetic catalogs characterized by a uniform (D = 2.0) or a clustered (fractal, D < 2.0) distribution of events on a hypothetical square source zone. We find that the assumption of D = 2.0 overestimates the resulting hazard in some parts of the source zones. This overestimation is larger for low probability levels; it can typically reach 10 percent. We then apply the fractal scaling approach to the test case Switzerland, were the question of low probability hazard is highly relevant in the context of the PEGASOS study (Coppersmith, Swiss J. Geosciences, 2009). We measure the fractal dimension of instrumental seismicity for the past 25 years as D = 1.5 and, using synthetic catalogs, build a seismic zonation and hazard model using this value. We find that the assumption of uniform distribution of events overestimates the resulting hazard in most of Switzerland. This bias increases systematically for lower probability levels.

SH3/TH/O12 - EMPIRICAL TESTING OF PROBABILISTIC SEISMIC HAZARD ESTIMATES

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Several probabilistic procedures are presently available for seismic hazard assessment (PSHA). These result in a number of different outcomes (hazard maps), each generally compatible with available observations and supported by plausible physical models. To take into account this inherent uncertainty ("epistemic"), outcomes of these alternative procedures are combined in the frame of logic-tree approaches by scoring each procedure as a function of the respective reliability. This is deduced by evaluating exante (by expert judgements) each element concurring in the relevant PSH computational procedure. This approach appears unsatisfactory also because the "value" of each procedure depends both on the reliability of each concurring element and on that of their combination: thus, checking the correctness of single elements does not allow evaluating the correctness of the procedure as a whole. An alternative approach to scoring is here presented that is based on the expost empirical testing of the considered PSH computational models. This is performed by comparing the probabilistic "forecasts" provided by each model with empirical evidence relative to seismic occurrences (e.g., strong-motion data or macroseismic intensity evaluations) during some selected control periods of dimension comparable with the relevant exposure time. In order to take into account the inherent probabilistic character of hazard estimates, formally coherent procedures have been developed that are based on Likelihood estimates and Counting protocols. Some results obtained by the application of these testing procedures in Italy will be shortly outlined.

SH3/TH/O13 - SEISMIC HAZARD ASSESSMENT IN HIGH-EXPOSURE AREAS: AN EXAMPLE FROM SOUTH-EASTERN SICILY (ITALY)

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[1]Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano-Pavia

The SE sector of Sicily is one of the areas of Italy with highest seismic hazard in the reference national PSH map (MPS04). Since this area is characterized by high exposure, both in terms of cultural heritage and of critical industrial facilities, a detailed hazard study was carried out based on the most updated information about regional seismic sources and ground-motion attenuation.

Computations were performed through the CRISIS code (2010 version), which is essentially based on the standard Cornell's method for PSHA and allows for two types of seismicity models: Poissonian or characteristic.

According to common international practice in PSHA, a logic-tree approach was followed to consider the epistemic uncertainties associated with the input elements of the computational model.

Special care was devoted to define the regional source zones model by taking into account different hypotheses. In particular, 4 alternative models were considered, which share the zones defining the boundary conditions of the study area, but differ in the seismotectonic characterization of SE Sicily: 1) ZS9: the same source zone used for the reference MPS04 hazard map; 2) ZS4: 2 zones, the former along the Ionian coast (including the largest mainly normal-fault earthquakes of the area) and the latter corresponding to the Iblean front (characterized by minor mainly reverse-fault events); 3) ZS9+Monte Lauro fault: zone of model 1 was retained but, according to the DISS database of seismogenic faults, the largest earthquake of the area (in 1693) was related to the Monte Lauro compressional fault; 4) ZS9+Malta Escarpment fault zone: the same as model 3, but the 1693 event was attributed to a larger offshore extensional structure (Malta Escarpment). For the faults in models 3 and 4, a characteristic behaviour was assumed.

Seismicity of source zones was characterized from the CPTI04 catalogue, considering only its complete portions for different magnitude ranges. To this purpose, 2 alternative sets of completeness time-intervals (one assessed from historical considerations and one from statistical analysis, i.e. those adopted in the MPS04 map) were used.

As concerns ground-motion predictive equations, 3 recent models were considered: Akkar and Bommer (2007), Boore and Atkinson (2008), Cauzzi and Faccioli (2008). Seismic hazard was then assessed in terms of PGA, PGV and of acceleration and displacement elastic response spectra on rock for 4 return periods (30, 50, 475, 975 years). A disaggregation analysis was also performed for some sites of interest.

SH3/TH/O14 - TECTONIC AND INDUCED SEISMIC HAZARD ANALYSIS IN THE NETHERLANDS

F. Goutbeek[1], D. de Vos[1], T. van Eck[1], B. Dost[1]
[1]KNMI

The latest comprehensive seismic hazard study for tectonic seismicity in the Netherlands was presented in 1996 and based on Intensities. Since then mostly site-specific studies have been done for structures like storage tanks and energy plants. Although there is no official earthquake building code (Eurocode8) currently in force in the Netherlands, companies are becoming more aware of their responsibilities and request site specific seismic hazard analyses. An extra trigger to the increased attention to seismic hazard is the occurrence of earthquakes in the northern part of the Netherlands due to gas production. Although small, some are felt very well by the population and have caused minor damage to buildings. To prepare for future assignments and Eurocode8 implementations, and to accommodate new data and new scientific developments 2 different strategies are followed at the moment: a) For tectonic earthquakes in the southern part of the Netherlands a revised seismic hazard analysis incorporating a new approach is carried out based on ground acceleration. The Probabilistic Seismic Hazard Analysis (PSHA) of Cornell (1969) is used and an alternative approach based on a Monte Carlo simulation by Musson (2003). This last method is used in the new proposed national Eurocode 8 Annex in the UK (Musson and Sargeant, 2007) and seems, as an alternative approach, well suited for a low seismicity country like The Netherlands. b) For induced earthquakes in the northern part of the Netherlands we are investigating the content of a National Annex to the Eurocode8 and implications for minor or not yet explored hydrocarbon reservoirs elsewhere in The Netherlands, given the observed induced seismicity in the northern part of The Netherlands and similar regions in the world. The characteristics and response spectra of induced events are different from the standard EC8 approach. Induced earthquakes have been observed at shallow depth (2-3 km) with magnitudes up to ML=3.5. The recorded peak ground accelerations are usually short in duration but have incidentally reached 0.3g.

SH3/TH/O15 - PROBABILISTIC SEISMIC HAZARD ASSESSMENT FOR THE AREA OF GREECE: EVALUATING THE CONTRIBUTION OF COMPLEX GEODYNAMIC ENVIRONMENTS

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Probabilistic analysis (PSHA) remains the main seismic hazard assessment methodology during the last decades since its development in the late seventies. A highly complex seismotectonic environment described by neotectonic basins, where the epicenters of destructive earthquakes are observed, and the existence of an active subduction interface, makes seismic hazard calculation for the area of Greece a demanding task. In attempting to include the contribution of the aforementioned geotectonic features since the non-instrumental era of seismology, seismic source models for the PSHA methodology are re-evaluated. Individual fault source model activity is connected with linear seismic sources related to either high or low seismicity rates. The activity of fault sources is assumed to be governed by bounded Gutenberg-Richter law behavior. The calculation of rates of exceedance of various ground motion levels imposes a Poissonian earthquake occurrence model. However, using only a fault-source seismicity model appears to be far from adequate since a significant percentage of seismic activity cannot be attributed to a causative fault. The above reasoning leads to the introduction a smoothed-gridded seismicity model into the seismic hazard calculations, which allows for the calculation of seismicity parameters for hypothetical point and linear seismic sources. The role of the smooth-gridded seismicity model is to account for the possibility that future strong earthquakes might occur in areas of moderate historical seismicity, and that a percentage of earthquakes of considerable magnitude occur off known faults. Finally, a uniform background zone accounts for the seismicity attributed to the on-going subduction of the African lithosphere in the Aegean region. A three dimensional grid with varying hypocentral depths is used to describe the intermediate depth seismic activity of the outer and back-arc region, characterized by different attenuation characteristics and seismicity rates. For each source model the seismic hazard calculation at a particular site is described through the total seismic hazard curve, which has been developed after stacking the seismic curves that correspond to individual seismic sources. The total hazard for each site of the grid is determined as the weighted sum of the ground motion levels of each seismic source model. The estimated ground motion levels, for given rates of exceedance, include peak ground acceleration and velocity, as well as spectral acceleration for discrete period estimators. Recognizing the necessity for site specific seismic hazard evaluation, constant shape design spectra as well as uniform hazard response spectra for given return periods have been produced for three sites corresponding to major cities of Greece, including Athens metropolitan area.

SH3/TH/O16 - ESTIMATION OF SEISMIC HAZARD IN TERRITORY OF FINLAND

J. Saari[1], P. Heikkinen[2], P. Varpasuo[3], M. Malm[1], E. Turunen[1], K. Oinonen[2], O. Valtonen[2], M. Uski[2]
[1]AF-consult Ltd; [2]Institute of Seismology, University of Helsinki; [3]Fortum Ltd

Estimation of Seismic Hazard in Territory of Finland*J. Saari[1)], P. Heikkinen[2)], P. Varpasuo[3)], M. Malm[1)] , E. Turunen[1)] , K. Oinonen[2)], O. Valtonen[2)] and M. Uski[2)] [1)] ÅF-Consult Ltd, P.O.Box 61 01601 Vantaa, Finland, www.af-consult.com , [2)] Institute of Seismology, University of Helsinki P.O.Box , 00014 University of Helsinki Finland, www.seismo.helsinki.fi, [3)] Fortum Ltd POB 100, FI-00048 FORTUM, Finland, www.fortum.com* This presentation is based on the working report contracted by the Radiation and Nuclear Safety Authority of Finland (STUK). The report provides background information for the upgrade of the STUK's regulatory guide YVL 2.6, which deals with seismic events and nuclear power plants ((http://www.edilex.fi/stuklex/en/lainsaadanto/saannosto/YVL2-6). This guide gives general requirements for the design and demonstration of seismic resistance at nuclear power plants as well as for the monitoring of earthquakes and their effects during the operation of the nuclear power plants. The aim of the study is the estimation of seismic hazard in territory of Finland covering the area south from the Polar Circle (66.56º N). The applied probabilistic seismic hazard assessment (PSHA) methodology was standard approach utilizing Poisson process assumption of earthquake occurrence. Special attention is paid to areas of possible new locations of nuclear power plants in Finland. The earthquake data were taken from the Fennoscandian earthquake catalogue (FENCAT), which is compiled and maintained by the Institute of Seismology of University of Helsinki. In areas of low seismicity - like Finland - determination of seismic zones includes much more uncertainties than in seismically active areas. Because of that, we have used in this paper two different approaches to seismicity. In the first approach each seismic zone has its own characteristic seismicity. The second approach represents a concept of regional diffuse background seismicity. The final PSHA is a combination of the two approaches.There are no registered broadband strong motion acceleration recordings of Finnish earthquakes available for the purposes of attenuation modelling. Therefore frequency dependent attenuation equations from regions with similar seismotectonic and geological characteristics are utilized. Attenuation examination includes ten different frequency points from 0.3 Hz to 100 Hz of longitudinal and transversal components of acceleration.Median ground response spectra and median hazard curves for 100 000 years return period together with 84% fractile were calculated for four selected sites. The sites have their own characteristic median PGA values and the shapes of the response spectra as well as the median hazard curves. Median peak ground acceleration contour maps for 100 000 years return period and 5% damping are based on 56 estimated PGA values. The estimated PGA values are from 0.05g to 0.31g. The study shows that that seismic hazard is strongly site specific inside the territory of Finland.

SH2 - MAGNITUDE SCALING AND REGIONAL VARIATION OF GROUND MOTION

Thursday 9, 08h00-10h00

SH2/TH/O1 - REGIONAL DEPENDENCE OF MAGNITUDE SCALING ON GROUND MOTION ATTENUATION IN SHALLOW CRUSTAL REGIONS

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Seismic hazard results obtained in small regions have traditionally been the derivation and use of local ground motion prediction equations (GMPEs) often based on insufficient data. In order to assess the hazard at global, regional and national scale, there is a need for efficient and robust GMPEs. The magnitude-scaling function in a GMPE has generally the most influence on its prediction. In this study, expanded NGA (Next Generation of Attenuation) database, which has about 3500 time histories (including recent M.7.2 Baja, Mexico earthquake), is examined to address: (i) the influence of magnitude scaling on PGA (peak ground acceleration); (ii) the influence of magnitude scaling on response spectral shape (that is, response spectrum normalized by PGA). This examination is conducted separately at regional and global scale to identify (if any) regional variations of magnitude scaling on ground motion attenuation. The magnitude scaling functions of several recent GMPEs, including Graizer and Kalkan, 2007; 2009 and NGA relations (Abrahamson and Silva, 2008; Boore and Atkinson, 2008; Campbell and Bozorgnia, 2008; Chio and Youngs, 2008), are tested against the trends observed from the actual data. At the global scale, it is demonstrated that the spectral peak shifts gradually from□0.15 s for the lowest magnitude earthquake (M4.9) to 0.5 s for the largest events (M7.6 to 7.9). Maximum amplitudes of the average spectral shape are relatively stable varying from 2.3 to 2.6, with higher amplitudes at smaller magnitudes. In general, events with larger magnitude yield wider spectra. These observations are consistent with all empirical and theoretical models of Fourier and response spectra.

SH2/TH/O2 - RANKING OF SEVERAL GROUND MOTION MODELS FOR SEISMIC HAZARD ANALYSIS IN JAPAN

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In this study the goodness of fit of ground motion models developed based on Japan strong motion data are evaluated by using maximum likelihood approach of Scherbaum et al. (2004) and information-theoretic approach of Scherbaum et al. (2009). The strong motions recorded by K-NET and KIK-NET during 12 recent crustal earthquakes in Japan with magnitudes larger than 5.5 are consistently processed. The selected dataset is not considered in developing selected attenuation models, and therefore can represent the applicability of the models to predict strong motions in Japan. The causative fault-plane geometry of selected events is well studied. Such information is used to estimate several model parameters considered as essential inputs for attenuation models.The results show in spite of simple functional form of selected ground-motion models, the general model performances are fairly well.

SH2/TH/O3 **- BEST PRACTICES FOR USING MACROSEISMIC INTENSITY AND GROUND MOTION TO INTENSITY CONVERSION EQUATIONS FOR HAZARD AND LOSS MODELS**

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[1]Swiss Seismological Service, ETH Zurich; [2]United States Geological Survey; [3]Geoscience Australia; [4]Synergetics Inc.; [5]GNS Science New Zealand

Macroseismic shaking intensity is a fundamental parameter for the development, calibration, and public dissemination of earthquake hazard models, and is a necessary input parameter for empirical (direct) and semi-empirical (indirect) earthquake shaking loss methodologies. Macroseismic data also quantify damage from past and present events, and facilitate communicating ground motion levels in terms of human experiences and incurred losses. We summarize and recommend "best practices" for the use of macroseismic observations and the estimation of macroseismic intensity in conjunction with hazard maps (particularly ShakeMaps) and as input to associated loss models. Our goal is to determine, on a global scale, how to best predict shaking intensity, taking into account factors such as tectonic regime, magnitude and distance dependencies, site amplification effects, and default GMPEs for a given region. In particular, we evaluate the use of direct intensity prediction equations (IPEs) and the combination of ground motion prediction equations (GMPEs) and ground motion to intensity conversion equations (GMICEs) in predicting intensities in the ShakeMap Atlas dataset, which contains intensity and ground motion observations from significant global earthquakes since 1973. In addition, we compiled an aggregate ground motion-intensity dataset from various active crustal regions (ACRs), which we use to derive a GMICE that is constrained over a larger intensity and ground motion range than previously available relationships, and to investigate possible regional dependence of GMICEs. Results from this study will be incorporated into the Global Earthquake Model (GEM) and Global ShakeMap efforts.

SH2/TH/O4 **- PREDICTION OF GROUND MOTION IN SWITZERLAND AT A CHARACTERISTIC REFERENCE ROCK SITE AND THE IMPACT OF LOCAL SCALE SOURCE AND SITE VARIABILITY.**

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We present the results of the deconvolution of source, path and site effects for earthquakes in Switzerland, undertaken as part of the PEGASOS Refinement Project. The resulting magnitude scaling, path attenuation and site specific effects are used for ground-motion prediction using the stochastic method. A combined empirical-theoretical approach is used to define ground-motion with reference to a derived Swiss velocity profile based on the quarter-wavelength approximationand corresponding site-specific amplification.

Two methods are used to define stress-drop and attenuation characteristics. The first is a combined grid-search and direct minimisation approach which includes a depth dependent Q model and consideration of amplification due to Moho reflections and the generation of surface wave phases. The second method is a spectral stacking approach that exploits the redundancy of the dataset to separate source, path, and receiver effects. Differences are found between the methods in terms of the absolute values of parameters, indicating that the strong trade-offs between source, path, and site are resolved differently by the two methods. However, similarities in the relative variation of source and attenuation parameters show strong regional variations between the Swiss Alpine and Foreland. We compare pseudo response spectral acceleration (PSA) from the Swiss region with our rock-reference model using stochastic simulations. Estimates of source, path and near-surface site terms obtained from both spectral deconvolution methods are used as input for ground-motion predictions. We find that, despite the difference in absolute values, the two methods yield similar results.

It is shown that the use of site specific amplification functions (originally used to define the reference rock condition), in addition to site-specific near surface attenuation, significantly reduces the uncertainty of predictions. Residual analysis of recorded PSA is undertaken to ascertain the contribution of prediction uncertainty in terms of site and source. Strong regional trends are found.It is shown that the inclusion of the derived site-specific amplification and attenuation functions to the reference rock model significantly reduces the uncertainty contribution of site variability. This shows that we are able to correct all recordings in Switzerland to a common site condition, and as such, single site variability of ground-motion can be obtained. Finally, site specific parameters are correlated to measures of Vs30, such that given either shear-wave velocity profiles, or Vs30 values, we can adapt the reference rock-profile to provide a site specific prediction.

SH2/TH/O5 **- ON THE USE OF SMALL EARTHQUAKES TO PREDICT THE GROUND MOTIONS GENERATED BY LARGER ONES**

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Estimation of ground-motion that could be generated by an earthquake is a key point in seismic hazard analysis. We propose to combine an empirical Green's functions (EGF) method and ground-motion prediction equations (GMPE) to simulate a set of realistic seismograms on instrumented sites. Steps of the method are :

- Find at least one small earthquake that occurred in the source area and that has been well recorded by seismological stations in the region of interest.
- Determine the seismic moment and the corner frequency of this event (directivity effect will be discussed).
- Generate a population of 500 equivalent source time functions (ESTF) that can take into account the source process variability (Kohrs-Sansorny et al, 2005)
- Generate 500 simulations at each station by a simple convolution of the ESTFs and the EGFs.
- Calibrate the stress drop ratio variability (stress drop of the large event / stress drop of the small one) by using a comparison of the simulation levels with GMPE at rock sites.

We present tests of the method on data from l'Aquila (Mw 6.3, 2009) and les Saintes (Mw 6.4, 2004) earthquakes as well as blind simulations of historical and future earthquakes in the south of France. The questions concerning nonlinear effects, near source stations and directivity effects are then discussed.

SH2/TH/O6 **- A HIERARCHICAL GLOBAL GROUND MOTION MODEL TO TAKE INTO ACCOUNT REGIONAL DIFFERENCES**

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In this work we present a hierarchical global ground motion model that includes regional differences in ground motion scaling in a principled way. For this purpose, we make the assumption that the scaling of ground motion intensity parameters with earthquake source, path and site parameters is similar, but not necessarily identical in different regions. In particular, we assume that models for individual regions are sampled from a global distribution of ground motion models. Thus, we set up a multi-level/hierarchical model, where the coefficients for each region are connected by so-called global hyperparameters. Via these hyperparameters, data from one region is also used to determine the coefficients in other regions, though with less weight. That way, it is possible to determine a model even for regions with a scarce amount of data. The global model is set up as a graphical model, which allows for an intuitive understanding. The coefficients are determined in a Bayesian setting using Markov Chain Monte Carlo simulation. This offers a systematic way to include prior knowledge and provides an estimate of the epistemic uncertainty of the parameters. It also allows to update the model once new data is available. The model is learned on a global dataset, divided into 11 regions. In the dataset, there are large differences in the amount of earthquakes and records between the regions. The analysis shows some differences in ground motion scaling between regions with a lot of data, while the scaling in other regions is closer to the global average.

SW3 - FINITE FREQUENCY TOMOGRAPHY - THE FIRST TEN YEARS.

Thursday 9, 08h00-10h00

Thursday 9, 10h20-12h00

SW3/TH/O1 **- MULTIPARAMETER ELASTIC FULL WAVEFORM INVERSION: 2D SYNTHETIC APPLICATIONS**

R. Brossier[1], S. Operto[2], J. Virieux[1]
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Full waveform inversion (FWI) is becoming a powerful and efficient tool to derive high-resolution quantitative models of the sub-

surface using the full wavefield recorded by multiple components sensors. Since 20 years, the major FWI applications have been performed using the acoustic approximation for active seismic data. However, using P-waves but also converted P-to-S-waves and multi-scattering waves, the method can potentially reconstruct both the P-wave and S-wave velocity (V_P and V_S) models of the subsurface with a resolution limit of the order of half a wavelength. The misfit between the recorded and the modeled wavefields is minimized through the resolution of a local optimization problem based on the gradient computed with an adjoint technique. In the frequency-domain, computationally efficient FWI algorithms can be designed for wide-aperture acquisition geometries by limiting inversion to few discrete frequencies. However, FWI remains an ill-posed and highly non-linear data-fitting procedure that is sensitive to noise, inaccuracies of the starting model and definition of multiparameter classes.

In this study, we show that elastic FWI allows to reconstruct both V_P and V_S models in the synthetic realistic environments of the onshore SEG/EAGE overthrust model and the shallow-water Valhall model. Application are performed with a massively-parallel 2D elastic frequency-domain FWI algorithm. Multiparameter imaging success is ensured thanks to an efficient optimization scheme based on the quasi-Newton L-BFGS method that provides an economic estimation of the Hessian, but also to hierarchical inversion procedures. A data-driven hierarchy is applied in order to judiciously choose data-type (hydrophone or geophone) and model parameters (V_P alone, or joint V_P and V_S) for offshore imaging. Moreover, a two-level hierarchical algorithm is implemented to mitigate the non-linearity of the inversion in complex environments. The first outer level consists of successive inversions of frequency groups of increasing high-frequency content. This level defines a multi-scale approach while preserving some data redundancy by means of simultaneous inversion of multiple frequencies. The second inner level used complex-valued frequencies for data preconditioning. This preconditioning controls the amount of the data involved in the inversion from the first-arrival time and allows us to mitigate the weight of the complex late arrivals during the first iterations of the inversion.

SW3/TH/O2 – A MULTI-SCALE APPROACH OF FINITE-FREQUENCY, TRAVEL-TIME TOMOGRAPHY WITH APPLICATION TO P- AND S-WAVE DATA FROM CENTRAL TIBET

S. Hung[1] [invited] , W. Chen[2], L. Chiao[3]
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In the past decade, the advance in seismic travel time tomography in terms of theoretical aspects has two folds. First, more sophisticated wave theory has been developed for taking into account the frequency-dependent nature intrinsic to travel-times and for efficient forward calculations of the Fréchet derivatives (or data kernel) which relates travel-times, precisely measured at different frequencies by cross-correlation of waveforms, to 3-D perturbations in seismic wave-speeds for the whole Earth. Second, more appropriate parameterization for the inversion of 3D models of seismic velocity structures using unevenly-distributed data has been introduced to obtain the models with spatially-varying scales of heterogeneities and data-adaptive resolutions. Here we present a multi-scale approach of finite-frequency, travel-time tomography that combines both the innovative developments applied to imaging the 3-D variations in P- and S-wave velocity ($\delta\ln V_P$ and $\delta\ln V_S$) and Poisson's ratio ($\delta\ln(V_P/V_S)$) beneath central Tibet. The Hi-CLIMB dataset used is comprised of a dense-spaced, north-northwest trending linear array and a broad, east-west regional network, and well-suited for exploiting multi-scale characteristics in the observed travel times and resolved structures under the Himalayan-Tibetan collision zone. A wavelet-based multi-scale parameterization decomposes the non-stationary, V_P and V_S structures to be solved into a natural hierarchy of components on various length-scales. Depending on the local constraints of available data across different scales, the optimal $d\ln V_P$ and $d\ln V_S$ models are synthesized from robust long-wavelength components and then successive addition of resolvable details at shorter wavelengths. Long-wavelength features emerge on the coarsest scale, with the demarcation between positive and negative anomalies farther to the north of the Bangong-Nujiang suture, which marks the leading edge of the advancing Indian lithosphere. Fitting of data progresses steadily as finer-scale features appear, resulting in two disjointed low V_P and V_S throughout the crust near the Indus-Yarlong Suture along the north-south trending active Lunggar rift with high $\delta\ln(V_P/V_S)$ and Yadong-Gulu rift with very small $\delta\ln(V_P/V_S)$. The discernible difference in $\delta\ln(V_P/V_S)$ between these two anomalies suggests that they may have a different origin or be at a different stage of evolution. A slab-like, sub-horizontal positive anomaly in $\delta\ln V_P$ and $\delta\ln V_S$ concentrated between depths of ~100-250 km, associated with a negative anomaly in $\delta\ln(V_P/V_S)$ above 200 km, extends over a distance of 600 km under much of the Lhasa terrane, consistent with the notion that a chemically refractory mantle lithosphere of the northern Indian shield is being underthrust beneath southern Tibet.

SW3/TH/O3 – TOWARDS ADJOINT TOMOGRAPHY FOR A GLOBAL CRUSTAL MODEL

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We are now at a stage where we can simulate the wave propagation in realistic 3-D Earth models at either regional or global scales using numerical methods, such as the spectral element method, which constructs the forward part of the seismic tomography problem. This has two major consequences for seismic tomography: 1) the full non-linearity of wave propagation can be taken into account in the forward problem, 2) the Fréchet kernels can be computed numerically in 3-D background models. Adjoint techniques provide an elegant way to incorporate 3-D wave propagation in seismic tomography where the Fréchet derivatives can be computed through the interaction of a forward wavefield with its adjoint wavefield which is generated by back-propagation of measurements on data. Tomographic images will eventually improve in an iterative scheme based on a gradient method.

Adjoint tomography based upon the spectral element method has been successfully applied to some regional scale problems whereas it has so far remained a challenge for global tomography. Our aim is to use the same technique to obtain a global crustal model which is becoming feasible with the current computational facilities. As an initial model, we use the 3-D anisotropic mantle model S362ANI (Kustowski et al. 2008) with 3-D crustal model Crust2.0 (Bassin et al. 2000) on top. At the first step, a new mesh has been implemented in the spectral element code which honors 3-D Moho variations in Crust2.0 if the crustal thickness is less than 15 km or greater than 35 km. This provides a better sampling of the crustal model, particularly the very thin oceanic crust, in the numerical simulations. Our strategy will be to invert crust and upper-mantle together to avoid any bias introduced into upper-mantle images due to crustal corrections. 3-D simulations dramatically increase the usable amount of data which will help close the gap in data coverage. Our measurements will be based on travel-time difference between observed and synthetic seismograms measured at different frequencies. We start computing finite frequency sensitivity kernels for a set of selected earthquakes combining long period surface waves (T > 60 s), where it is easier to handle non-linearities due to crust, with shorter period body waves (T > 17 s), which are more sensitive to deeper parts of the mantle. We will present our preliminary results for this project.

SW3/TH/O4 – GLOBAL MULTIPLE-FREQUENCY S-WAVE TOMOGRAPHY OF THE EARTH'S MANTLE

C. Zaroli[1] [invited] , E. Debayle[2], M. Sambridge[3]
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We present a globally distributed dataset of ~400,000 frequency-dependent SH-wave travel times. An automated technique is used to measure teleseismic S, ScS and SS travel times at several periods ranging from 10 to 51 s. After correction for physical dispersion due to intrinsic anelastic processes, we observe a residual travel time dispersion on the order of 1-2 s in the period range of analysis. This dispersion occurs differently for S, ScS and SS, which is presumably related to their differing paths through the Earth. Our results suggest that a residual structural dispersion is observed in our data. We incorporate this new observable in a global multi-band S-wave tomography of the Earth's mantle. We present our first S-wave tomographic model and show that frequency-dependent travel times provide additional constraints on the 3D elastic structure of the mantle.

SW3/TH/O5 – A NEW EFFICIENT APPROACH FOR MODELING AND INVERTING WAVE-

FORMS IN 3-D HETEROGENEOUS REGIONS

N. Fuji[1] [invited] , S. Chevrot[1], D. Komatitsch[2], M. Vadim[1]
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In the past two decades there have been enormous improvements in seismic waveform modeling. The spectral-element method (SEM: Komatitsch & Tromp, 1999, 2002ab) now allows us to accurately calculate synthetic seismograms inside an heterogeneous earth model without any approximation. On the other hand, the direct solution method (DSM: Geller & Ohminato, 1994; Kawai et al., 2006) provides an efficient algorithm to calculate synthetic seismograms for 1D anisotropic earth models. Following recent theoretical developments and taking benefit of the abundance and quality of data from dense broadband arrays, waveform inversion has been attempted to recover 1D regional structures in the mantle transition zone and D» region (e.g., Kawai et al., 2007ab; Fuji et al., 2010). The next step for improving these imaging methods is to move toward higher frequencies (~1Hz) and 3D waveform inversions. However it is still very expensive to model waveforms inside a 3D heterogeneous globe. We thus develop a new hybrid approach that takes advantage of both SEM and DSM. The idea is to embed a 3D heterogeneous box inside a laterally homogeneous earth. With the DSM, we calculate displacement and traction at every point located on the surface of the box in the background 1D earth model. The SEM computes the solution inside the heterogeneous box. This hybrid method will allow us to efficiently model and invert short-period waveforms for the imaging of fine 3D structures. In this talk, we will present some preliminary forward-modeling results.

SW3/TH/O6 **- FREQUENCY DEPENDENCE OF OBSERVED P-WAVE TRAVELTIMES AND AMPLITUDES, AND THEIR PREDICTION BY MULTI-BAND FINITE-FREQUENCY TOMOGRAPHY**

K. Sigloch[1], G. Nolet[2]
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Body wave observables become frequency dependent when waves interact with structural heterogeneities on the length scale of the seismic wavelength. For the purpose of multi-band finite-frequency tomography, we condense the information contained in a broadband waveform into a handful of traveltimes from cross-correlation, measured in distinct frequency passbands, and into the same number of amplitude measurements. These traveltimes dT and amplitudes dA/A thus become frequency-dependent if the wave encounters heterogeneity roughly commensurate with its own wavelength.

We observe significant and spatially systematic frequency dependence in a global data set of P-wave traveltimes and amplitudes, which spans the frequency range of 0.03 to 1 Hz. We compare to predicted traveltimes and amplitudes, for the subset of data that was used in a recent tomographic study of North America (Sigloch et al. 2008). Spatial patterns of fits and misfits are beautifully evident on the dense station grid of the USArray. We show spatial patterns of dispersiveness for dT and dA/A (highest minus lowest frequency band) and compare to dT and dA/A themselves.

At most stations, the dispersiveness of dT is a few tenths of a second -- (i.e., almost an order of magnitude smaller than dT itself) -- but can be much larger in tectonically active regions. Finite-frequency tomography predicts this dispersion, although not to its full magnitude. There is a tendency for data from one earthquake to either fit or not fit as a whole. This signals room for improvement of the tomographic model from specific azimuths by putting more emphasis on fitting the frequency dependence of dT.

Similar conclusions hold for amplitudes. Although dA represents a noisier observable, its relative dispersiveness is much stronger than that of dT, so that we fit or misfit the dispersive pattern of dA/A almost as clearly as dA itself.

SW3/TH/O7 **- NON-LINEAR WAVEFORM INVERSION OF BODY WAVES: EXTRACTING DATA FOR FINITE-FREQUENCY TOMOGRAPHY**

R. Garcia[1], S. Chevrot[2]
[1]Université de Toulouse, Observatoire Midi-Pyrénées, Laboratoire de Dynamique Terrestre et Planétaire; [2]CNRS, Observatoire Midi-Pyrénées, Laboratoire de Dynamique Terrestre et Planétaire

Body-wave finite-frequency tomography relying on measurements of delay times by cross-correlation of real data with synthetic seismograms is limited by two important problems. The first one is the interference of body waves arriving at similar times on seismological records. The second one is the limited ability of synthetic seismograms to reproduce observed waveforms, owing to the complexity of source time functions at high frequency. The method presented in this study addresses these two problems by performing a non-linear inversion of body waveforms, taking into account the interferences of body waves and inverting the high frequency content of source time functions. The inversion method, based upon simulated annealing, will be presented in detail, and applications to different earthquakes recorded at teleseismic distances will be shown. The current status of the travel times and source time function data base will also be presented, with a validation of the inverted source parameters by comparison with other methods for inverting source parameters. Body-wave finite-frequency tomography relying on measurements of delay times by cross-correlation of real data with synthetic seismograms is limited by two important problems. The first one is the interference of body waves arriving at similar times on seismological records. The second one is the limited ability of synthetic seismograms to reproduce observed waveforms, owing to the complexity of source time functions at high frequency. The method presented in this study addresses these two problems by performing a non-linear inversion of body waveforms, taking into account the interferences of body waves and inverting the high frequency content of source time functions. The inversion method, based upon simulated annealing, will be presented in detail, and applications to different earthquakes recorded at teleseismic distances will be shown. The current status of the travel times and source time function data base will also be presented, with a validation of the inverted source parameters by comparison with other methods for inverting source parameters.

SW3/TH/O8 **- GLOBAL SEISMIC SENSITIVITY: A MULTIPLE-FREQUENCY STRATEGY TO EXPLOIT FULL WAVEFORMS**

T. Nissen-Meyer[1] [invited] , K. Sigloch[2], A. Fournier[3]
[1]ETH Zurich; [2]LMU Munich; [3]IPG Paris

The step from the geometrical ray approximation towards frequency-dependent volumetric sensitivity of seismic data with respect to model variations has enjoyed much momentum in recent years. In this light, together with a surge in global data availability, accurate numerical methods for wave propagation, and high-performance computing, we present a full-wave strategy to address the seismic forward and inverse problem at the global scale, with a specific focus on high resolution in the lowermost mantle via diffracted waves:

1) A spectral-element method tackles 3D wave propagation through spherically symmetric background models up to any desirable resolution. This is accomodated by a 2D computational domain. 2) Resultant space-time wavefields embody the crux to exact sensitivity kernels. Our specific approach distinguishes itself from the adjoint method in that it requires no knowledge about data structure or observables at the time of forward modeling, hence a complete kernel database for a given model can be constructed a priori. 3) Original multiple-frequency, cross-correlation measurements of diffracted P waves are assembled into different passband bins, including high-quality waveforms down to seismic periods of 5 seconds and spanning the entire global distance range. 4) A global matrix inversion based upon these measurements is in process; we present excerpts of the dense, high-resolution coverage of the lowermost mantle and kernels that will warrant unprecedented resolution in 3D images.

To obtain a direct view of the interconnection between surface displacements and earth structure, we also examine the time-dependent sensitivity of the seismic signal to 3D model perturbations. Being highly sensitive to such parameters as epicentral distance, earthquake radiation pattern, depth, frequency, receiver components and time windows, this effort suggests criteria for data selection to optimally illuminate a specific region within the earth. The multiple-frequency approach allows us to selectively draw only upon frequency bands with high signal-to-noise ratio. We discuss the selection and usability of data for such a Pdiff tomographic setting, coverage maps and target regions. Moreover, we touch upon related projects such as the quantification of the applicability regarding a 1D reference model and the universally utilized first-order Born approximation.

SW3/TH/O9 **- PARAMETER SENSITIVITY**

ANALYSIS OF A NONLINEAR LEAST SQUARES OPTIMIZATION-BASED ANELASTIC FULL WAVEFORM INVERSION METHOD

A. Askan[1], V. Akcelik[2], J. Bielak[3], O. Ghattas[4]
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The fundamental problem of seismic inversion is to recover information on physical properties of the Earth using seismic observations. Full-waveform inversion is one of numerous modern methodologies for solving inverse problems in seismology. Since the pioneering work of Tarantola (e.g. [1,2]) and Tarantola and Valette [3] on the full waveform nonlinear seismic inversion using a least-squares objective function and adjoint operators, the adjoint full-waveform inversion method has been extensively used both in the time domain (e.g.[4,5]) and in the frequency domain (e.g. [6,7,8,9]). In a recent article ([10]), we introduced an anelastic full-waveform seismic inversion methodology for estimating shear wave velocity and attenuation in large basins from surface observations of ground motion. The methodology was tested through synthetic inversions for the shear wave velocity and attenuation profiles in a cross section of the shear wave velocity model for a sedimentary soil medium within the Los Angeles basin obtained from the Southern California Earthquake Center (SCEC) Community Velocity Model. We presented inversion results obtained for a well-chosen set of parameters and options in the inversion method. However, the choice of parameters and options can have a strong influence on the performance of the inversion method. In this study, we perform a number of experiments to study the effects of these parameters on the numerical and qualitative performance of the inversion. These experiments include the sensitivity of the inversion to the type of regularization functional, value of the regularization parameter, receiver density, preconditioning, data noise, and the multilevel technique. We present here results of inversion experiments performed for only one inversion field, the shear modulus, but the conclusions extend to inversion with more than one inversion field.

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SW3/TH/O10 **- FINITE-FREQUENCY TOMOGRAPHY AND THE CONCEPT OF TRAVEL TIME**

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Despite growing interest in waveform inversions, global tomography remains even today dominated by travel time (or phase) data inversions. There are good reasons for that: the linearity of travel time inversions is much stronger than that of waveforms. However, in the process we have often blurred the lines between the two approaches. In particular, waveform distortions lead to shifts in travel times estimated by cross-correlations.

A review of our definition of travel time (or wave velocity) is in order. Many of the conceptual aspects of this problem were studied long ago by Sommerfeld and Brillouin for electromagnetic wave propagation. The commonly implicit assumption that group and phase velocities of a body wave are equal, and locally equal to the material velocity of the rock, is not valid in the real, heterogeneous Earth. A sharp onset or first break of a body wave is best inverted using ray theory, yet its bias in the presence of noise has a volumetric dependence on Earth structure very much like the one encountered in banana-doughut theory. The more stable delay estimates from cross-correlation are influenced by dispersion effects much like group velocity. Locally, a group velocity vector may have a direction unrelated to the great-circle, and even be perpendicular to it.

Inversions of travel times therefore need to take into account the peculiarities of the measurement procedure, and this usually implies taking waveform changes into account. Multiple-frequency tomography combines the best characteristics of waveform and travel time inversions.

SW4 - AMBIENT VIBRATION SEISMOLOGY

Thursday 9, 08h00-10h00

Thursday 9, 10h20-12h00

SW4/TH/O1 **- QUARRY BLASTS ASSESSMENT AND THEIR IMPACTS ON THE NEARBY OIL PIPELINES,SOUTH EAST HELWAN, EGYPT**

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Ground vibrations induced by blasting in the cement quarries are one of the fundamental problems in the quarrying industry and may cause severe damage to nearby structures and pipelines. Therefore, a vibration control study plays an important role in the minimization of environmental effects of blasting in quarries. This research paper presents the results of ground vibration measurement induced by blasting at the National Cement Company (NCC) south east of Helwan, Egypt. The aim of this study is to investigate the influence of the quarry blasts on the oil pipelines of Sumid Company. The seismic refraction either for P-waves and surface waves (MASW) are used to evaluate the closest site of the two pipelines to the quarry blasts. The results demonstrate that the pipelines site are of class B according to the International Building Code (IBC) and the safe distance is 770 m follow the deduced Peak Particle Velocity (PPV) distance relationship ($PPV=11054\,D^{-1.1261}$) In the light of the prediction analysis, the maximum charge weight per delay was found to be ≤ 2000 kg.inmm/sand the Air Blast formula (Air Blast=133.39-0.0194D) in dB. Key Words: Peak particle velocity; Air blast; Seismic refraction; MASW and site evaluation

SW4/TH/O2 **- SHALLOW CRUSTAL STRUCTURE OF SOLFATARA VOLCANO FROM MICROTREMOR DATA**

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From 2 to 6 April 2007 we carried out a seismic survey at Solfatara volcano to record the background noise. We installed a total of 5 seismic arrays, sampling different areas of the crater. Each day we deployed a circular array and about 1-hour of seismic noise was recorded for each configuration. We combined the results from several techniques with the aim of extract a detailed definition of the shallow crustal structure. The frequency peaks of the H/V curves was found analysing the 1-hour-long samples of seismic noise daily recorded by 5 representative stations. A map of the resonance frequencies and peak amplitudes was obtained by using an inverse-distance-to-a-power gridding method that interpolates the H/V data. Frequency values relative to the different sampled sites range from 3.6 to 7 Hz. We used three different methods to estimate the dispersion curves of Rayleigh waves propagating through the array: the

Frequency–Wavenumber (f-k) technique, the Spatial Autocorrelation (SPAC) technique and the Modified Spatial Autocorrelation (MSPAC) technique. The dispersion curves obtained from the 3 methods are comparable. The phase velocity ranges from 100 m/s at high frequency to about 1000 m/s at frequency of 2 Hz. Since the MSPAC curves are affected by smaller errors, they were chosen to be inverted for the S-wave velocity model, jointly with the corresponding H/V peak frequency. We used the neighborhood algorithm carry out by Wathelet *et al.* (2008) to obtained 1-D velocity model underneath each array. To check the robustness of the obtained models we analyzed the influence of the number of layers and of the half space depth on the inversion procedure. We used the 5 obtained S-waves velocity models to infer a 3-D model for the Solfatara volcano. We applied a kriging gridding method to combine the velocity values in the volume below the 5 arrays and organized a velocity map for all the velocity discontinuities encountered. By applying a Montecarlo algorithm, we checked the significance of the superficial depth differences, the stability of the most likely velocity models and the progressive losing of details as depth increases. Finally we investigate the polarization properties of the seismic noise by applying the covariance matrix method and the following parameters are estimated: the rectilinearity, the azimuth of the polarization vector and the incidence angle. Polarization of seismic noise has been determined to look for a possible correlation with the orientation of the faults cutting the volcano.

SW4/TH/O3 - AMBIENT VIBRATION ANALYSIS OF UNSTABLE MOUNTAIN SLOPES

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Field experiments with small aperture seismic arrays were performed on the unstable rock slopes in the Matter valley in the southern Swiss Alps. The aim of these experiments was to constrain the seismic response of a potential future rockslides using ambient vibration recordings. The noise recordings were analyzed by means of high resolution *f-k* method, site-to-reference spectral ratios, and time-frequency dependent polarization analysis. The wavefield within the unstable rock mass was found to be dominated by normal modes of the rock blocks rather than horizontal propagation of seismic waves. A fundamental frequency of the unstable rock mass was identified, which can be used to constrain either the extent or the effective material properties of the instability. The polarization directions estimated from ambient seismic vibrations are in good agreement with the deformation directions obtained by geodetic and in situ measurements. No directionality of ambient vibrations was observed at sites within the stable part of the slope. Techniques developed in this work could be used in the future to quickly and inexpensively map certain structural features of rock slope instabilities, as it is possible to distinguish unstable areas, the direction of bulk slope deformation, and the activity of surface cracks.

SW4/TH/O4 - SITE CHARACTERIZATION OF IZMIR METROPOLITAN AREA USING EQUIVALENT LINEAR DYNAMIC SITE RESPONSE AND REFERENCE STATION METHODS

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Preliminary results of weak motion analyses performed within the scope of an earthquake hazard investigation project sponsored by Turkish National Science Foundation is presented in this study. Dokuz Eylul University (Izmir) and National Disaster and Emergency Management Presidency (Ankara) are engaged in pursuit of the project which involves installation of a strong motion station array (IzmirNET) in metropolitan Izmir Area and extensive study of dynamic soil characteristics by means of field and laboratory tests. Dynamic soil models of 16 station locations were based on field and laboratory data including those of the bender element and ultrasonic pulse wave tests. Limited use of empirical correlations was also made in the soil models. The earthquake database of IzmirNET utilized in this study belongs to a time period of two years covering small scale earthquakes that took place between 2008 and 2009. Results of one-dimensional equivalent dynamic site response analyses are compared with weak motion records and soil models are calibrated accordingly. The outcome of the analyses performed using the reference station method and the one-dimensional site response are also compared and discussed. Spectral amplifications at each strong motion station were computed and mapped considering spectral frequencies up to 3 Hz. It was concluded that such a consideration was in accordance with the current skyline of the city where 3 to 10 storey high buildings dominate the building stock. Amplification maps revealed that the city area could be zoned into three distinct areas with respect to computed site amplification ratios, which are in good correlation with the geology of the city as well as observations aftermath previous earthquakes that caused some damage in the city of Izmir. The study showed that site characterization could be made effectively by making systematic use of weak motion records. Keywords: Site characterization, site response analysis, reference station method, weak motion Acknowledgement: This study was supported by TUBITAK-KAMAG (Project Nr. 106G159)

SW4/TH/O5 - THE POTENTIAL OF AMBIENT VIBRATION MEASUREMENTS: EXAMPLES OF APPLICATIONS IN SWITZERLAND

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Ambient vibration single station and array measurements are applied in many fields of engineering seismology and structural engineering. The classical application is the use of single station H/V spectral ratios to map the fundamental frequency of resonance over a region of interest and to use the shape of the ratios for microzonation. Such measurements provide qualitative information about the amplification as a function of frequency and can be used to identify possible 2D resonance phenomena. Array measurements target the determination of dispersion curves of the fundamental and higher modes Rayleigh and Love waves from the three-components of recordings, and to detect the different modes of eigen-vibrations in 2D structures. 3D resonance can be detected but remain a challenge. In general only segments of dispersion curves can be identified so that we are confronted with the problem of assigning mode numbers to the segment or to identify mode jumping in apparently continuous dispersion curve. Methods using active sources can be used to extend the dispersion curves to higher frequencies and to reduce the possible structural models during the inversion. The resolution limit at lower frequency is often difficult to assess even if we might have the impression of resolving the dispersions curves. In such cases the combination of different array processing techniques might help. Additional information is contained in the ellipticity of Rayleigh waves that can be used to further reduce the model space in the inversion. Different methods have been developed to retrieve ellipticity from single station H/V spectral ratios and array measurements, and the methods were successful in synthetic tests. Testing all these single-station and array methods for ellipticity in real cases is part of on-going research. Ambient vibration methods, also used in civil engineering, have found their way into the field of earthquake engineering for the characterization of the dynamic response of structures (vibration modes of buildings), the major challenge remaining the non-linear effects affecting the resonance frequencies. Finally engineering geology offers new fields of application of ambient vibration techniques to identify instable rock-slopes, and to estimate their size and movements. Still there is potential for further methodological development and new fields of application.

SW4/TH/O6 - THE USE OF RAYLEIGH WAVE ELLIPTICITY FOR SITE-SPECIFIC HAZARD ASSESSMENT AND MICROZONATION WITH APPLICATION TO THE CITY OF LUZERN, SWITZERLAND.

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Evaluation of the seismic response of soft sediment environments is a key issue in probabilistic hazard assessment. Sites with strong velocity contrasts with respect to the assumed reference bedrock can lead to large deviation in the expected ground motion. Consequently, this might reflect into an underestimation of the final computed risk. The sediments underlying the city of Luzern (Switzerland), consisting in fluvio-lacustrine deposits of Quaternary age, have the potential to produce strong amplification of the seismic wave-field. Large sand lens are here alternate to coarsely selected gravel layers, with a consequent extremely low seismic velocity with respect to the beneath bedrock. Secondary phenomena like liquefaction are also expected. For these reasons, together

with the evidence of a dense population of the area, a seismic characterization of the area is of primary importance. Adequate risk mitigation measures, in case of earthquake, can be therefore undertaken. To obtain a reliable estimation of the subsoil structure, we combine different methodologies based on ambient noise recording, such as single station horizontal to vertical ratios, time frequency analysis and three components high-resolution beamforming. The main goal is to optimize the use of the Rayleigh wave ellipticity information from different techniques to better constrain the velocity structure of the basin, especially at the depth of the bedrock. In particular, a multi-station inversion scheme is presented. Such procedure bases on the use of the ellipticity peak from time-frequency analysis of single station measurements to map the bedrock geometry over large areas. The output velocity model is then used to compute the local seismic SH amplification by means of pseudo-3d modelling (gridded 1D approximation). Finally, as an additional outcome of the analysis, we compare the results from the different methodologies to provide a qualitative evaluation of their capabilities and limitations.

SW4/TH/O7 - SOME NEW THEORETICAL CONSIDERATIONS ABOUT THE RAYLEIGH-WAVE ELLIPTICITY (H/V) IN THE LIGHT OF SIGHT-EFFECT STUDIES IN ISRAEL AND MEXICO

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It is well-known that ground motion amplification due to soft soils, common in urban areas, is a major contributor to increasing damage and number of causalities. Indirectly, the study of Rayleigh-wave ellipticities has recently gained considerable popularity in the context of studying ambient seismic vibrations for seismic hazard analysis. The output can be integrated into the inversion process for the velocity structure. Due to the strong impedance contrast in the shallow subsurface structure, local site effects are often fairly well predicted by simple models. Therefore, a thorough theoretical understanding of even a single layer over half-space (LOH) is not only of theoretical but also of considerable practical interest. Adding to this argument is the fact that an accepted theoretical model for the interpretation of *H/V*-measurements from ambient vibrations, still has to be developed. A useful starting point for the theoretical investigation of the ellipticity of Rayleigh waves is the exact formula derived by Malischewsky and Scherbaum (2004). It can be shown, that already the simple LOH model is able to produce a great variety of *H/V*-versus-frequency curves with different character. We cite observations from Israel and Mexico as an example of *H/V*-curves with more than one maximum. This phenomenon is usually contributed to additional layers, where the first maximum is connected with the shear-resonance frequency of the first layer and the secondary maximum with a resonance frequency of a deeper layer. We demonstrate that already the simple LOH model yields two peaks in a certain range of Poisson ratios. However this simple model cannot explain the experimental curves under consideration, where more complex models and higher modes are necessary. These considerations can yield constraints for Poisson ratios which are otherwise less controlled. In conclusion, such theoretical investigations of analytical or half-analytical character are necessary for a better understanding of the behaviour of the ellipticity of Rayleigh waves and its use for site effect studies.

SW4/TH/O8 - ARRAY MEASUREMENTS REVEAL LOVE WAVE CONTRIBUTION TO AMBIENT VIBRATION H/V CURVES

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The horizontal-to-vertical (H/V) spectral amplitude ratio technique is a widely used tool for site effect estimation from ambient vibration recordings. It is commonly assumed that the curves represent the frequency-dependent Rayleigh wave ellipticity. For the detailed interpretation of amplitudes or the inversion of the curves, it is therefore necessary to estimate and correct for the contribution of other wave types to the ambient vibration wavefield. Theoretical simulations as well as comparisons of measured and modelled H/V curves suggest that the influence of Love waves is significant.

We investigate this issue by using ambient vibration array measurements to estimate the relative contribution of Love and Rayleigh waves to the horizontal component wavefield. This is done by comparing the propagation directions obtained from frequency-wavenumber (FK) analysis and the horizontal polarisation directions. A quantitative estimate of the relative amount of Love and Rayleigh waves on the horizontal components is obtained and we study its variability with frequency, with special focus on the H/V peak frequency.

Tests with synthetic data demonstrate the feasibility of this approach, at least in the presence of dominant source regions. Analysis of data from 12 measurements at nine European sites, which include shallow as well as deep locations that span a wide range of impedance contrasts at the sediment-bedrock interface, indicates that the relative contribution of Rayleigh waves varies widely with frequency, from close to 0% to more than 70%. While most data sets show relative Rayleigh wave contributions between 40% and 50% around the H/V peak, in agreement with values commonly used for correction, there are also examples where Love waves clearly dominate the wavefield at the H/V peak. Longer-term measurements at one site indicate temporal variations in the relative Rayleigh wave content between day- and nighttime.

Results calculated with our method were also compared to results of MSPAC and, for the synthetic cases, SPAC-L, and generally show a good agreement. SPAC and FK methods to determine the relative Rayleigh wave content might be used in a complimentary fashion, as both rely on different properties of the ambient vibration wavefield. The field examples with dominant Love waves around the H/V peak frequency stem from sites with rather different characteristics, indicating that there is no general rule that allows to predict a large Love wave content of the wavefield based on a priori site information. This makes additional array measurements to characterise the horizontal wavefield the more useful.

SW4/TH/O9 - STRUCTURE OF AMBIENT VIBRATION WAVE FIELD IN THE FREQUENCY RANGE OF ENGINEERING INTEREST ([0.5,20] HZ): INSIGHTS FROM PHYSICAL MODELLING

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The expected power spectrum structure of ambient vibration wave field was explored by the application of a full wave field physical model in the hypothesis that seismic noise is the effect of a uniform distribution of random independent point-like harmonic sources located at the surface of a flat weakly dissipative layered Earth. The comparison of the results provided by this model with those coming from specialized models allows to evaluate the respective role of body and surface waves, of Rayleigh and Love waves, of fundamental and higher modes. This analysis reveals that these features strongly depend on the frequency range of interest, on the subsoil structure and on the distribution of sources around the receiver. In particular, three different domains are identified: below the fundamental resonance frequency for S waves, between this frequency and below the resonance frequency for P waves and above this last frequency. Spectral structure and seismic phases composition of ambient vibrations in these ranges show different sensitivities to the subsoil features (seismic impedance contrasts in the subsoil, VP/VS ratios, and thickness of the uppermost soft sedimentary layer) and to distribution of sources around the receiver. This result in a number of possible configurations that can account for heterogeneous results provided by experimental studies. The results obtained also provide useful limitations to the use of simplified models based on the assumption that surface waves dominate wave field, that are currently used for inversion of ambient vibration measurements in engineering applications.

SW4/TH/O10 - SEISMIC WAVEFIELD DECOMPOSITION: APPLICATION TO THE ANALYSIS OF AMBIENT VIBRATIONS

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The analysis of ambient vibrations represents a valuable tool in seismic microzonation, engineering seismology, and other fields. An extensively used approach for the study of ambient vibrations is the use of array processing techniques. Array processing techniques currently in use present several limitations, such as: measurements from different components of the seismometer are processed separately; wavefield parameters are not estimated jointly; superposition of

different wave phenomena is not accounted for. We have developed a novel technique for the analysis of the seismic wavefield and show an application to the analysis of ambient vibrations. We derived maximum likelihood estimators for the parameters of the different wave types, considering all the measurements simultaneously. Our method works in the time domain and addresses wave superposition. This enables us to separate the contribution of Love and Rayleigh waves as well as fundamental and higher modes. The proposed technique relies on a particular type of probabilistic graphical model called factor graph. A factor graph allows to represent the joint probability of a number of random variables and provides a structure for computing marginal probabilities. By means of an iterative message passing algorithm (i.e. the sum-product algorithm), we are able to efficiently compute the likelihood function of different wave types and then perform maximum likelihood estimation. We assess the performance on SESAME synthetic models and compare results for surface wave propagation with state of the art techniques. We show that the proposed approach allows to detect weaker signals from higher modes, even when they are not visible with traditional techniques. This leads to a more accurate estimation of the dispersion curves, potentially over a broader frequency range and including larger portion of higher modes. In addition, we estimate Rayleigh wave ellipticity with a maximum likelihood estimator and estimate the retrograde vs. prograde behavior of the particle motion. Future work includes taking into account other wave phenomena, such as resonances or body waves, within the same theoretical framework. Moreover the non stationary nature of the wavefield will be addressed.

ES2 - INTRAPLATE SEISMICITY OF CENTRAL AND NORTHERN EUROPE

Thursday 9, 10h20-12h00

ES2/TH/O1 - INTRAPLATE EARTHQUAKE SWARMS IN WESTERN BOHEMIAN MASSIF (CENTRAL EUROPE) – CORRELATION WITH REJUVENATED PALEOPLATE JUNCTION

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Geodynamic activity in the region of west Bohemia (Czech Republic) and Vogtland (Germany) is characterized by re-occurrence of earthquake swarms, mostly of magnitude $M_L < 3.5$ at focal depths between 4 and 20 km (Horálek and Fischer, Studia Geoph. Geod. 2008). The region is also known by several Quaternary volcanoes and by present-day high gas flow manifested by moffetts rich in CO_2 and helium of mantle origin (Weinlich et al., Geochim. Cosmochim. Acta 1999). We suggest that positions of the seismic and volcanic phenomena correlate with a "triple junction" of three mantle lithospheres distinguished by different orientations of seismic anisotropy consistent within each unit (Plomerová et al., GJI 2007). The three mantle domains most probably belong to the originally separated micro-plates - the Saxothuringian, Teplá-Barrandian and Moldanubian - assembled during the Hercynian orogeny. The rigid part of the crust, characterized by the presence of earthquake foci, decoupled near the junction from the mantle most probably already in Hercynian times. Cenozoic extension reactivated the junction and locally thinned the crust and mantle lithosphere. The boundaries (transitions) of the three mantle domains provided open pathways for Quaternary volcanism and the ascent of ^3He- and CO_2-rich fluids released from the asthenosphere. The deepest earthquakes, marking an upper limit of the brittle-ductile transition in the crust, are shallower above the junction of the mantle blocks (at about 12 km) than above the more stable Saxothuringian mantle lithosphere (at about 20 km), probably due to a higher heat flow and presence of fluids (Babuška et al., J.Geodyn. 2007). We suggest that many intraplate earthquakes in other continental regions may also be located at more or less healed paleoplate boundaries.

ES2/TH/O2 - THE FIRST AFTERSHOCK SEQUENCE OBSERVED IN DENMARK

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A moderate size earthquake with a magnitude of 4.3ML (4.4mb) occurred in the North Sea near the coast of Jutland, Denmark, on the 19th FEB, 2010.The tremor from the earthquake was felt in a large part of western Denmark, with intensities up to 4. 342 macroseismic observations were reported to the Geological Survey of Denmark and Greenland. Earthquakes in this part of Denmark are not unusual, since this area is considered the most seismic active part of this generally low seismic region. The unusual about this earthquake was the 4 small aftershocks that occurred in the following weeks, since it is the first documented aftershocks sequence in Denmark. These aftershocks measured 2.4, 2.1, 2.4 and 1.9 ML and have been located within 15km of the main event. Results from the analysis of the main shock and the aftershocks are presented.

ES2/TH/O3 - ARE FAULTS IN THE EASTERN PART OF THE LOWER RHINE EMBAYMENT ACTIVE?

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The Lower Rhine Embayment (LRE), part of the Rhine Rhone Rift System, is a young sedimentary basin. Paleoseismological studies have revealed several surface-rupturing earthquakes, which occurred here during Holocene. The intraplate seismicity of the LRE shows return periods of these surface-rupturing earthquakes of 3000-5000 years. Displacement rates of the active faults, which are predominantly of normal faulting mechanism, are smaller than 0.1 mm per year. However, only a few selected sections of the 400 km of known surface fault lines have been paleoseismically investigated. Especially in the eastern part of the LRE, the erosion of youngest sediments by the current Rhine River and the extremely dense urban and industrial development hinder paleoseismic trenching. Surveillance of micro earthquakes is therefore not only important to fill the low magnitude end of earthquake frequency scales, precise location and source studies can also help to decide whether faults known from their surface traces are active.

While current geologic and tectonic maps show active fault lines in the western LRE, all faults in the eastern part are classified as inactive. However, well expressed faults exist and a key question to be answered for the evaluation of the seismic hazard of the city of Cologne and its surroundings is whether faults on the right bank of the Rhine River can be the source of damaging earthquakes.

Historic and instrumental seismicity of the LRE concentrates on the border faults of the Rur Valley Graben in the western LRE and neighbouring parallel fault lines. The eastern part shows a much lower activity level, both during the historical and instrumental periods. Nevertheless single earthquakes and small earthquake series have been detected in recent times by the dense seismic network in the eastern part of the LRE, also on the right bank of the Rhine River. In this work we present a detailed analysis of these earthquakes, including relocation, similarity analysis, and source studies.

ES2/TH/O4 - CRUSTAL IMAGING IN AN INTRAPLATE CONTINENTAL REGION : SEISMOLOGICAL AND POTENTIAL FIELD DATA ANALYSIS IN THE EASTERN TENNESSEE SEISMIC ZONE (SE UNITED STATES)

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The Eastern Tennessee Seismic Zone (ETSZ) is an intraplate continental region located in the eastern part of North America and constitutes, after the New Madrid Seismic Zone, the second most active region of the continent east of the Rocky Mountains. It consists of a NE-trending, 300 km long and 100 km wide, belt of diffuse seismicity and is characterized by relatively low magnitude earthquakes occurring at mid-crustal depths. As a consequence, the rupture never propagates up to the ground surface and no obvious relationship seems to exist between the earthquake distribution and the faults known from geological mapping. Yet, that distribution appears to be significantly correlated with seismic velocity variations inferred from body-wave tomography and with observed potential field anomalies, thus suggesting some control of the seismicity by geological contrasts at depth. In this work, we attempt to investigate the possible links between the seismic activity of the ETSZ and its crustal structure by means of potential field data analysis. We applied Euler deconvolution technique to total magnetic field intensity data. The preliminary results provide magnetic basement depth estimates which can be compared to the variations of the velocity field inferred from tomographic inversion. These results, as well as information compiled from surface geology, available seismic profiles and well-log data, will ultimately be integrated into a geospatially referenced database and will be used to

constrain structural models of the region.

ES2/TH/O5 - THE SEISMIC SEQUENCE NEAR BRUSSELS SINCE JULY 2008

T. Camelbeeck[1], T. Lecocq[1], K. Vanneste[1], K. Verbeeck[1], M. Van Camp[1]
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A seismic sequence started in the region of Ottignies-Court-Saint-Etienne (20 km to the southeast of Brussels) on 12 July 2008. The most important earthquake occurred on 13 July 2008 and had a magnitude ML=3.2. Up to May 2010, 300 earthquakes have been recorded with magnitudes as low as ML=-0.5. These earthquakes are the first to be reported in the region since the end of a similar sequence between 1953 and 1957. The largest event during this sequence occurred on 06 January 1953 with a magnitude ML4.0. Surprisingly, even earthquakes of magnitude smaller than ML=1.0 have been observed (felt, heard) despite the fact their focal depth, well-constrained by a mobile seismic network, is around 5 km. These very small events are not necessarily recorded by the Belgian permanent monitoring network, but well located thanks to the temporary local network installed during the summer 2008. We present a preliminary analysis of the numerous collected data and observations. We will interpret them in the framework of the seismotectonic model of stable continental Europe. This seismic sequence demonstrates the difficulty to assess seismic hazard in these tectonically stable continental regions and the importance of conducting detailed specific studies of past earthquakes that occurred before the development of modern seismic networks.

ES6 - PHYSICS OF SEISMICITY: FIELD, LABORATORY AND THEORETICAL STUDIES

Thursday 9, 10h20-12h00

Thursday 9, 14h00-16h40

ES6/TH/O1 - BULK ELASTIC ANISOTROPY OF A FOLIATED BIOTITE GNEISS FROM THE OUTOKUMPU DEEP DRILL HOLE: 3D VELOCITY CALCULATIONS AND LABORATORY SEISMIC MEASUREMENTS

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The fine-grained biotite gneiss of a core sample from the Outokumpu Scientific Deep Drill Hole exhibiting strong crystallographic (LPO) and shape preferred orientation (SPO) of the biotite minerals provides an excellent material to investigate the relative contribution of oriented cracks, crystallographic (lattice) preferred orientation (LPO) and shape preferred orientation (SPO) to P- and S-wave velocities, bulk anisotropy and shear wave splitting.Different experimental and theoretical approaches were used for investigating the nature of elastic anisotropy. The crystallographic preferred orientation of minerals (CPO) was determined by means of neutron diffraction measurements at the time-of flight texture diffractometer atDubna, Russia. Using the orientation distribution function (ODF) as a parameter to characterizing the CPO of the constituent minerals, the seismic properties of the bulk sample were calculated from the corresponding properties of major minerals. 3D velocity calculations together with laboratory seismic measurements on a sample cube in a multi-anvil pressure apparatus (Universität Kiel, Germany) as well as on a sample sphere in a pressure vessel (Institute of Geology, Prague) provide the basis for interpreting the nature of the bulk anisotropy. Measurements of compressional (Vp) and shear wave (Vs) velocities in the three foliation-related structural directions (up to 600 MPa) of the sample cube and of the 3D P-wave velocity distribution on the sample sphere (up to 200 MPa) revealed a strong pressure sensitivity of Vp, Vs and P-wave anisotropy in the low pressure range. At conditions of high pressure (>150MPa) where most of the low-aspect ratio cracks are closed, the residual velocity anisotropy is mainly caused by crystallographic (CPO) and shape preferred orientation (SPO) of minerals. Most important is biotite which displays the strongest preferred orientationand also the strongest anisotropy of single-crystal velocity, compared to the constituent quartz and plagioclase.The calculated bulk velocity anisotropy is significantly smaller than the experimentally determined anisotropy. We suggest that the experimentally determined Vp-anisotropy of the compacted aggregate can not be explained by the crystallographic preferred orientation of major minerals alone. Other effects, such as the strong SPO of biotite, grain boundary effects and compositional layering may also contribute to the apparent anisotropy.The work was supported by the Russian Foundation for Basic Research, Grant No.10-05-00722.

ES6/TH/O2 - THE EFFECT OF WATER INJECTION ON ACOUSTIC EMISSION IN A LONG-TERM EXPERIMENT

G. Sobolev[1], A. Ponomarev[1]
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The long-term experiments on the biaxial compression of the models prepared from basalt sand, crushed limestone, and cement are carried out. The volume of the models exceeded 4 x 10^ cm^3. At different grades of load, water was infused into the model through the borehole. The volume of the infused water was less than 0.1 % of the volume of the model itself. Water infusion resulted in the activation of the acoustic emission with a particular time lag. The initiation of the acoustic emission is connected with the local reduction in the strength and with the increase in the stresses near the ends of the cracks, which does not contradict the trigger mechanism. The hypocenters of the sources of acoustic signals initiated by water infusion lay in the vicinity of the boreholes. Within the time interval between weak events, pulses with higher energy appeared, which has an analogy with the swarm of earthquakes. The growth and extinction of the acoustic emission after the stepwise additional load and with the initiation by water infusion is significantly different. In the first case, the Omori law is obeyed. In the second case, the intensity of acoustic emission has a pronounced maximum. The equations of the kinetic concept of strength in solids make it possible to describe the dynamics of the acoustic emission caused by water infusion. In addition, the models were subjected to periodic electric perturbations. Syncronization of the acoustic pulses was noticed in such cases.

ES6/TH/O3 - OSCILLATING LOAD-INDUCED ACOUSTIC EMISSION ON LABORATORY SCALE: THE CHANGING SYNCHRONIZATION

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A pre-fractured cylinder of granite was loaded in a triaxial machine at 160 MPa confining pressure until stick-slip events occurred. Spatial and temporal patterns of acoustic emission (AE) were studied. The experiments were conducted at a constant strain rate of 10^{-7} s^{-1} that was modulated by small-amplitude sinusoidal oscillations with periods of 175 and 570 seconds. Amplitude of the oscillations was a few percent of the total load and was intended to simulate periodic loading observed in nature. (e.g., earth tides, water level of reservoirs and so on). More than 65,000 AE events were recorded and located during this experiment. We observed a correlation between AE response and sinusoidal loading. A time-space spectral analysis for a point process was used to investigate details of the periodic AE components.The magnitude of the response is not stable – sometimes it becomes very small and almost disappears. Prior to stick-slip events that represent dynamic failure of the entire fault surface and produce Omori-type aftershock sequences, AE rate correlates with the applied stress oscillations. During these intervals, AE activity did not correlate with imposed stress oscillations. As AE activity increased due to reloading of the sample following the co-seismic stress drop and aftershock decay, AE rate again correlated with the imposed stress oscillations. This memory of past stress history is similar to the known Kaiser effect. “Significant” large-amplitude AE events were identified that produced Omori-type aftershock AE activity. Unlike stick-slip aftershocks, aftershocks of large AE events show strong correlation with stressing cycles.The stick-slip events involved slip of the entire fault surface and resulted in an overall reduced stress state. In contrast the large-amplitude AE events did not reduce the overall stress on the fault as measured by the total applied axial load. Instead, the drop in stress in the source region of the large AE events simply transferred stress to the remainder of the fault surface resulting in a transient increase in overall AE rate.These observations are consistent with a model in which AE activity becomes increasingly sensitive to stress perturbations as the stress level in the sample is raised and the fault is driven close to failure. If this is a general property of natural fault systems, it may be possible to identify instability and impending failure by the response of the fault to periodic stressing. It would seem reasonable to search for these effects during

real aftershock series.

ES6/TH/O4 - PARTITIONING OF SEISMIC AND ASEISMIC SLIP DURING CREEP: INSIGHTS FROM ACOUSTIC EMISSIONS AND OPTICAL MONITORING

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We aim at analyzing the partitioning of seismic and aseismic deformation during slow crack propagation along complex fault zone. For this purpose, we present results from a mode I crack propagation experiment at laboratory scale where a rupture front propagates between two transparent plexiglass plates along a weak interface with local disorder of the material strenght. This propagation is monitored both by a fast speed, high resolution camera and a set of acoustic transducers. We show that advances of the crack front, monitored by the optical system, exhibit large size and velocity fluctuations which spans several order of magnitudes and are characterized by power law distribution comparable to the Gutenberg-Richter law for earthquake size. Despite difference in the fracturing mode and in the range of time- spatial-scales, exponent of these two distributions are similar to those obtained from earthquake catalog. An abundant acoustic emission activity is also recorded continuously during the crack propagation at a sampling frequency up to 5 Mhz. Acoustic monitoring offers a high time resolution on the ongoing process. It also permits the characterization of the rupture process at the crack front and the identification of seismic events. Localization of acoustic emission suggest that they are associated with front moves and that events are distributed along a wide range of amplitude. The intermittent dynamics of the crack propagation, and the large scale distribution of both seismic and aseismic deformations suggest that the front move is controlled by elastic interactions due to local disorders within the material both in the creeping and brittle regimes.

ES6/TH/O5 - PHOTO-ELASTIC AND ACOUSTIC INVESTIGATION OF SUB-SHEAR AND SUPERSHEAR RUPTURES IN COLUMBIA RESIN

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We combine ultrasonic acquisition and high speed photography in order to characterize the radiation from spontaneous dynamic rupture propagation on laboratory faults in a transparent, birefringent, hard resin slab. In our laboratory earthquakes, transducers detect the wavefield both close and away from the fault, allowing to:

1) discriminate between sub-shear and supershear ruptures and compare their respective radiation patterns. 2) determine the instanteous rupture velocities in between stations. 3) characterize the amplitude and the decay of the mach wavefront emitted during supershear ruptures.

In our records, the mach wave is clearly visible and becomes dominant as distance from the fault increases. This observation is obtained here for fractures which have spontaneously nucleated and propagated. In several natural eaqrthquakes, ruptures are believed to have propagated at supershear velocit, however the expected strong mach arrival has never been identified on real faults yet.

ES6/TH/O6 - HIGH ORDER SYNCHRONIZATION OF STICK-SLIP PROCESS: EXPERIMENTS ON SPRING-SLIDER SYSTEM.

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Last years it has been shown that the synchronization and triggering of dynamic events by weak external forcing is ubiquitous and is observed in biological systems, lasers, electronic networks etc. In the present paper new experimental data on the phase synchronization in frictional system induced by a weak electromagnetic or mechanical periodic forcing are analyzed. For quantitative analysis of stick-slip time series modern tools of nonlinear dynamics were used. Stick-slip events were identified by recording acoustic emissions, which accompany slip displacements. The spring-slider system in stick-slip regime is considered as a proxy of active tectonic fault, generating earthquakes. The intensity of forcing needed for synchronization is very low and this can explain the recently discovered effect of remote dynamic triggering and synchronization of SA by strong earthquakes. Effect of high order synchronization of stick-slip events by weak electromagnetic or mechanical periodic forcing was discovered. We found that not only the onsets/maxima of a definite kind of AE signals are synchronized with forcing, but also AE wave train terminations. There were two kinds of high order synchronization: i. one or more AE bursts during one forcing period and ii. one AE burst during many forcing periods. It was found that the onset time of the synchronized slip events delay behind the forcing phase; the delay is smaller for stronger forcing. The results obtained point to possibility of revealing some new fine details in the stick-slip process which can be very useful for refining the physical mechanism of frictional motion in general. These findings can also help to find new regularities in seismic time series.

ES6/TH/O7 - A THEORY FOR THE EXPERIMENTAL MEASUREMENT OF THE FRICTIONAL SLIDING MEMORY LENGTH

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The rate-and-state formulation of friction is well established as a phenomenological yet quantitative description of friction dynamics, in particular the onset of stick-slip instabilities corresponding to an oscillatory bifurcation. However, the experimental determination of the evolution law of the interfacial state is still a matter of debate. A major issue lies mainly in the experimental identification of the memory length which governs the characteristic slip length required for the friction coefficient to reach its steady-state value in response to a sudden velocity jump. By first discussing the microphysical foundations of two theories for the derivation of friction coefficients used in rate-and-state models, we show that it is possible to distinguish experimentally which friction coefficients may be physically relevant from the careful analysis of their control of the supercritical/subcritical nature of the stick-slip bifurcation given by a weakly nonlinear theory. Secondly, from assuming a general expression for the state evolution law in the form of a first-order kinetics which describes the relaxation to a velocity-dependent equilibrium interfacial state $\Phi_{ss}(v)$ (defined dimensionlessly), we show that this unknown relation $\Phi_{ss}(v)$ can be estimated directly from the experimental measurements of the steady-state friction coefficient and the critical stiffness of the onset of stick-slip behaviour of a spring-block system. Using a specific experimental dataset, we finally illustrate that this method also provides the experimental measurements of the apparent memory length $L_a(v) = v\, t_r\, \Phi_{ss}(v)$ and the constant characteristic relaxation time t_r of the interface healing. As a result, the complete state evolution law is experimentally determined.

ES6/TH/O8 - DAMAGE AND RUPTURE DYNAMICS AT THE BRITTLE/DUCTILE TRANSITION: THE ANOMALOUS CASE OF GYPSUM

N. Brantut[1], A. Schubnel[1], Y. Guéguen[1]
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Triaxial tests on gypsum polycrystals samples are performed at confining pressures Pc ranging from 2 to 95 MPa and temperatures up to 70 C. During the tests, stress, strain, elastic wave velocities and acoustic emissions are recorded. At Pc <10 MPa the behaviour is brittle, with a single shear fracture plane. Few hundreds of acoustic emissions (AE) are recorded prior to and during rupture. Above 10 MPa, the macroscopic behaviour is ductile. Only scarce, high frequency, non impulsive AE are recorded and elastic wave velocities decrease linearly with deformation. This is interpreted in terms of microcracks accumulation. Surprisingly, ductile deformation and strain hardening is also accompanied by small stress drops from 0.5 to 6 MPa in amplitude. Microstructural observations after the tests suggest that these stress drops correspond to the generation of single shear bands, formed by microcracks and kinked grains. At room temperature, the stress drops do not produce AEs. At 70 C, the stress drops are larger and systematically correlated to a mostly low frequency (10 kHz), high amplitude AE. These low frequency signals also include a high frequency content, which is attributed to dynamic damage accumulation. These are processed to retrieve the duration of the event, which ranges from 0:3 to 1 ms, i.e. an average rupture velocity from 50 to 200 m/s. These observations show an anomalous behaviour of gypsum, since stress drops amplitude and velocity increase when temperature is increased.

ES6/TH/O9 - LABORATORY MODELING,

FIELD VERIFICATION AND MATHEMATICAL SIMULATION OF TRANSIENT SEISMIC PROCESSES

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The transient processes in seismicity are considered as a response to the quite powerful influences of different origin, which disturb stationary state of seismicity. Investigation of the transient process allows to study regularities of seismicity excitation and relaxation and to reveal physical factors controlling the dynamics of seismicity. A series of laboratory experiments for modeling of transient processes in seismicity was carried out. Laboratory results was verified by field experiment in Soultz-sous-Forets (France) hot dry rock area and analysis of natural seismic swarms in Corinth rift. Physical interpretation and mathematical simulation for found regularities was suggested. The aim of the experiments was to understand the character of excitation and relaxation of the failure, triggered by the external influence. The failure initiated by step-wise strain or force impacts results in transient acoustic emission similar to aftershocks and swarms. When increasing quickly, such impact generates processes similar to aftershock sequences; when increasing gradually, it generates swarm-like activity. The parameters of the induced activity change in a regular manner with increasing acting stress level: the stronger the stress, the later the activity starts to decay; Gutenberg-Richter b-value decreases with stress increasing; parameters of the Omori's law changes too. b-value varies in time during excitation and relaxation of acoustic activity (for given stress level): it decreases when activity is increasing and increases when activity is decreasing. This indicates a transition of failure at the increase stage from lower to higher levels (crack grows and fusion scenario) and from higher to lower levels at the decay stage (aftershock scenario). Similar regularities was found in natural conditions: in the experiment of seismicity generation by the water injection into a borehole (Soultz-sous-Forets, France) and in seismic swarms in Corinth rift. A hypothesis of excitation and depletion of some «failure reservoir» is suggested for explanation of obtained regularities. Mathematical simulation has confirmed the validity of this hypothesis. The work is supported by RFBR grant 08-05-00248 and project 08-05 of IPGP – IPGM collaboration.

ES6/TH/O10 **– SYNCHRONIZATION PHENOMENA OF LOW-FREQUENCY MICROSEISMS.**

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The vertical seismic records with sampling rate 1 Hz obtained from global IRIS broadband seismic network (1988-2009, 131 stations) and Japan F-net (1997-2010, 83 stations) were analyzed by estimating their multi-fractal parameters: the width of singularity spectra support, generalized Hurst's exponent and coefficient of singularity spectra asymmetry. Besides that linear predictability index of waveforms, spectral exponent and logarithm of variance were estimated as well. These statistics were calculated within adjacent «short» time windows of the length 30 minutes for initial 1 Hz data and for time windows of the length 1 day for records after coming to 1 minutes sampling.The seismic stations were split into a number of spatial clusters (7 clusters for global IRIS network and 5 clusters for F-net). The median values of all parameters were taken from stations in each cluster. A multiple correlation measures for different combinations of parameters were estimated within moving time window of the length 1 and 2 years for these median time series with uniform sampling time interval 1 day. Using of long time windows for estimating multiple correlation measure allows to average influence of storms and hurricanes.The sequence of waves of microseisms noise essential global synchronization was extracted. The most strong synchronization effects correspond to time interval 2003-2007 and the 2nd one started at the beginning of 2008 and is continuing till now. The microseisms field at Japan islands transfers to high level synchronization of its parameters starting from the middle of 2002, one year before the Hokkaido earthquake, 25 of September, 2003, M=8.3. This high level of synchronization keeps rather constant up to the current time. Based on the statement of the theory of catastrophes that synchronization is one of the flags of an approaching catastrophe, it may be suggested that the Hokkaido event, notwithstanding its power (M=8.3), could be only a foreshock of a still stronger earthquake at the region of Japan's islands. The cluster analysis of 7 median daily statistics from the whole network indicates a strong linear trend of cluster exponent starting from 2007 which is continuing till now. This trend peculiarity is similar to the trend before 2003 event. The peculiarities of correlation coefficient estimate within 1 year time window between median values of singularity spectra support width and generalized Hurst exponent indicates that starting from July of 2010 Japan islands come to the state of waiting strong earthquake.

ES6/TH/O11 **– A STUDY OF TEMPORAL VARIATIONS IN 'B' VALUE AND MAGNITUDE OF COMPLETENESS FOR THE HIMALAYAN REGION.**

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The Himalayan arc region is one of the most seismically active region of the world. An earthquake catalog containing over 3812 earthquake events with 622 events having more than 5.0 magnitude for the Himalayan region for the period 1964-2007 is considered. In this study, earthquake data are collated for the period 1964-2007 from International Seismological Center (ISC), National Earthquake Information Centre (NEIC) and HRVD. This catalog is analyzed to determine the variations in the seismic parameters and magnitude of completeness in time. Seismic parameters have been determined by two different methods namely, Maximum Curvature method (Wiemer and Wyss, 2000) and Entire-Magnitude-Range method (Woessner and Wiemer, 2005). A moving time window of 10 years has been taken to fix the starting year of sub-catalogs. It can be seen from the values given in table below that 'b' and 'a' values of the Gutenberg-Richter frequency magnitude recurrence relation gradually increase in values with time implying increase in seismicity with higher proportions of lower magnitude events. The variation in the magnitude of completeness and its uncertainty for the three catalog periods 1964-2007, 1974-2007 and 1984-2007, obtained from the two methods have been compared and are given in the table below. The comparison reveals that the value decreased from a higher value for 1964-2007 period to a lower value in case of 1984-2007 period indicating better detecttability of the seismic events with time in this region. The lowest value of 4.1 for is given by the method of Maximum Curvature with a lower uncertainty value of 0.02. The improvement in the value for the earthquake catalog of the Himalayan region for the period 1964 to 2007 has important implications with regard to 'b' value determination and accurate estimation of seismic hazard for the region. 1964-20071974-20071984-2007Maximum Curvatureb=0.913 ± .01, a=7.36Mc=4.3±.01b=0.99 ± .001, a=7.66Mc=4.3±.01b=1.12 ± .01, a=8.14Mc=4.1±.02Entire Range Magnitudeb=0.96 ± .012, a=7.61Mc=4.4±.15b=1.01 ± .09,a=7.77Mc=4.3±.09b=1.16 ± .11, a=8.33Mc=4.3±.06

ES6/TH/O12 **– PROPERTIES OF SEISMICITY IN A NON EXTENSIVE STATISTICAL PHYSICS FRAMEWORK.**

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Statistical physics has a remarkably successful work record in addressing the upscaling problem in physics. It is natural then to consider that the physics of many earthquakes has to be studied with a different approach than the physics of one earthquake and in this sense we can consider the use of statistical physics not only appropriate but necessary to understand the collective properties of earthquakesThe application of non extensive statistical physics offers a consistent theoretical framework, based on a generalization of entropy, to analyze the behavior of natural systems with fractal or multi-fractal distribution of their elements. Such natural systems where long - range interactions or intermittency are important, lead to power law behavior. We note that this is consistent with a classical thermodynamic approach to natural systems that rapidly attain equilibrium, leading to exponential-law behavior. It is well known that the Gutenberg-Richter (G-R) power law distribution has to be modified for large seismic moments because of energy conservation and geometrical reasons. Several models have been proposed, either in terms of a second power law with a larger b value beyond a crossover magnitude, or based on a magnidute cut-of using an exponential taper. In the present work we point out that the non extensivity viewpoint is applicable to seismic processes. In the frame of a non-extensive approach which is based on Tsallis entropy we construct a ge-

neralized expression of Gutenberg-Richter (GGR) law. The power law behaviour is derived as a special case, leading to b-values being functions of the non-extensivity parameter q. Examples from Global and South Aegean seismicity are given discussing the influence of Great events (e.g., the Sumatran earthquake) in the basic statistical laws of seismicity.. Acknowledgements: This work is partially supported by the "NEXT EARTH" project FP7-PEOPLE, 2009-2011

ES6/TH/O13 - TOWARDS REALISTIC SELF-ORGANIZED CRITICAL MODELS FOR EARTHQUAKES

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The concept of self-organized criticality (SOC) was introduced by Per Bak and his co-workers in 1987. Since then a very large class of natural phenomena was shown that follow the principle of self-organized criticality, i.e, exhibit power-law frequency-area statistics in a very robust manner. The classic example is earthquakes. Indeed, the last decades a large number of publications emerged in literature explaining the occurrence of the well known power law of Gutenberg-Richter by means of cellular automata models exhibits SOC when simulate well known mechanical models for earthquakes such that the Burridge-Knopoff model or the Olami-Feder-Christensen model. It is our aim to address generic weaknesses of the above mentioned self-organized critical models which even thought qualitatively predict the occurrence of power law behavior they cannot reproduce quantitative measures during earthquakes. As an example we refer to the problem of b values of the Gutenberg-Richter law, and their variation before and after the main shocks. Indeed, the existing SOC models for earthquakes even thought they predict almost correct b values (but in the limit of their validity) they cannot predict the variation of b values for pre- and after- shocks. In this work we propose a new self-organized critical model for earthquakes where we introduce appropriate internal variables in order to address the weaknesses of the previous models in reproducing experimentally observed quantitative measures during earthquakes. The main idea of the proposed formalism is to incorporate material and process non-uniformities during earthquakes by means of the proposed introduction of internal variables. In this way e.g. structural properties of seismogenic zones as well as depth and/or different earthquake source mechanism may be modeled in a robust manner. In the context of the present work a first simplified model incorporating structural non-uniformities as an internal variable is given. It is analytically explaining how these non-uniformities affect the expected b values. More over a simulation code for the proposed SOC model incorporating the evolution of internal variables was built. Some first simulation results are presented where the variations of b values for pre- and after-shocks are predicted. As a result, in the context of the proposed self-organized mode by the aid of the notion of internal variables, the hypothesis that the structure and stress non-uniformities at the seismogenic zone is both theoretically (analytically) and by means of simulation results verified in a robust manner.

ES9 - APPROACHES TO MODELLING SEISMIC SCENARIOS

Thursday 9, 14h00-16h40

ES9/TH/O1 - STUDY ON THE NEAR-FIELD / FAR-FIELD BOUNDARY IN FINITE-FAULT STRONG MOTION SIMULATIONS

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Near-field (NF) and far-field (FF) terms represent different properties of the wave-field: the near-source motions are more sensitive to the spatio-temporal details of the rupture process, while far-field terms carry the overall signature of a point-source. However, there is no clear distinction between far-field and near-field terms as their relative importance is frequency dependent. Due to their longer propagation path through complex Earth structure, the far-field wavefield is generally strongly affected by media properties and dominates at high frequencies. In contrast, the near-field terms have higher amplitudes at low frequency. In this study we compute full-wavefield near-field synthetics for a suite of earthquake scenarios, and compare those to corresponding finite-fault ray-theory seismograms that lack the near-field terms. This allows us to define the region around a fault in which NF-terms exert a strong influence on the radiated motions, and hence cannot be ignored. We analyze the simulations in terms of peak shaking levels (PGA, PGV, PGD) and response spectral values, but also consider the waveform characteristics in order to examine the engineering aspects of near-field and far-field components of the seismic wavefield.

ES9/TH/O2 - STRONG GROUND MOTION SIMULATION OF THE 12 MAY 2008 M 7.9 WENCHUAN EARTHQUAKE, USING VARIOUS SLIP MODELS

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On 12 May 2008, a devastating earthquake of Mw 7.9 occurred in the Sichuan Province of China. The earthquake had disastrous consequences and cost more than 69 000 lives. The rupture occurred along a 300 km long fault dipping north-west along the Longmenshan Fold and Thrust Belt, which separates the Longmenshan Mountains of the Tibetan plateau in the north-west from the Sichuan Basin in the south-east and is associated with a significant change in the crustal thickness. We simulate the ground shaking due to the Wenchuan earthquake by applying a hybrid broadband frequency strong ground motion simulation technique, which combines deterministic simulation of low frequencies (0.1-1.0 Hz) with semi-stochastic modeling of high frequencies (1.0-10 Hz). We use three available finite fault slip models obtained from waveform inversion as input models for the earthquake scenarios. The resulting simulations reveal large variations in ground shaking due to the rupture complexity in terms of e.g. the location of asperities and the width of the fault plane. The applied methodology successfully reproduces the strong ground motion distribution and frequency content of the seismic waves. The simulated ground motions, when calibrated with the recorded data, can also be used to verify the finite fault slip models based on different teleseimic data and inversion schemes. Comparison with the damage distribution from reconnaissance field observations confirms the fault rupture complexity. The applied simulation methodology provides a promising platform for predictive studies.

ES9/TH/O3 - BROADBAND STRONG MOTION SIMULATION OF THE MW 6.6 2007 NIIGATA EARTHQUAKE USING HYBRID METHOD

M. Delatre[1], H. Aochi[1]
[1]BRGM

In order to propose realistic earthquake scenarios required by quantitative seismic risk evaluation, various hybrid methods try to reproduce reasonable input ground motions : they aim to get accurate arrival times for low frequencies as well as correct frequency content and randomness for high frequencies. It was recently proposed to model great earthquakes as a combination of small omega-squared sources, each one with a low-frequency deterministic phase and a high-frequency stochastic phase (Hisada 2008). Each phase is then propagated to the observation point by Green functions generated by a 1D layered model, and the final ground motion is calculated by adding the two phases with lowpass/highpass filters. Based on this formulation, we model the 2006 Mw 6.6 Niigata Chuetsu-Oki earthquake using a finite kinematic source model (Aoi et al., 2008), in order to test this method on a more complex earthquake than the 1994 Northridge case shown by Hisada (2008). We introduced an exponential time decay of the high-frequency source, in order to better model the high-frequency earthquake duration. Results show that the frequency content is consistent with the observations for high frequencies and that arrival times are overall correct. This hybrid method, by putting the randomness into the source time function, allows great flexibility for propagation methods, and shows acceptable robustness for seismic risk scenario assessments.

ES9/TH/O4 - FORECASTING SEISMIC SCENARIOS IN THE MT. ETNA REGION (SOUTHERN ITALY) THROUGH PROBABILISTIC INTENSITY ATTENUATION MODELS: A BAYESIAN APPROACH

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The evaluation of a seismic scenario is heavily influenced by how the attenuation of the macroseismic intensity is modelled given epicentre and epicentral intensity (or equivalent magnitude). At Mt. Etna, like other volcanic zones, the seismic attenuation is much quicker than in purely tectonic areas, and this may determine over-estimates of the expected effects if regional attenuation laws are used. In the past, we faced this problem through both deterministic and probabilistic approaches by assuming a decay symmetric and referred to a point source. In the framework of the volcanologic project V4-FLANK we developed the analysis to the following aims: i) modelling non-symmetric decays due to the finite dimension of a fault by exploiting information collected from the previous studies on symmetric cases, and ii) simulating seismic scenarios to be applied for real-time surveillance (intensity shake map). We started from an explorative analysis of a set of macroseismic fields representative of the Italian earthquakes among which we have identified three different decay trends by applying a hierarchical clustering method. Quantifying the uncertainty involved in the assessment of the intensity at site by a binomial-beta probabilistic model, we updated the model parameters according to the Bayesian paradigm and adopted the mode of this probability distribution as estimator of the intensity at site so as to generate future seismic fields. Then we considered a set of Mt. Etna earthquakes in which the anisotropic trend of the attenuation is clearly determined by the linear extension of the source. First we transformed the plane so that the ellipse having as maximum axis the length and the azimuth of the fault is changed into a circle with fixed diameter, and then we applied the previous procedure to the so modified data. In this way we obtained the probability distribution of the macroseismic intensity at any site for different epicentral intensities according to the isotropic and anisotropic models. The results can be also presented as the probability of exceeding a fixed intensity value or the intensity that can be exceeded with a fixed probability. Both representations provide good input data to be used for simulating seismic scenarios in terms of macroseismic intensities for simulating seismic scenarios. A computer application will soon run at the acquisition centre of Catania for the seismic surveillance of Mt. Etna volcano, to produce in real-time detailed intensity shake maps using the instrumental parametres calculated by the earthquake automatic location system.

ES9/TH/O5 - FLAW IN THE EPRI PROCEDURE FOR MAXIMUM EARTHQUAKE MAGNITUDE ESTIMATION AND ITS CORRECTION

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It has been shown that the EPRI procedure for the estimation of the maximum regional earthquake magnitude m_{max}, (Cornell, 1994; EPRI NP-4726), provides a value of m_{max} which is systematically underestimated. The underestimation can reach a value of 0.5 unit of magnitude. The bias is caused by the fact that one of the components of the posterior likelihood function is a sample likelihood function, for which the range of observations (earthquake magnitudes) depends on the unknown parameter m_{max}. The dependence violates the fundamental rules of the applicability of the maximum likelihood procedure. This is because such a likelihood function has its maximum at the maximum observed earthquake magnitude, not at the required, maximum possible magnitude - m_{max}. Two alternative ways to correct the flaw of the procedure are presented and discussed.

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ES9/TH/O6 - A STUDY ON THE ATTENUATION AND UNCERTAINTIES IN THE INTENSITY ASSESSMENT DAHUIYEH, ZARAND, IRAN EARTHQUAKE OF 22 FEB 2005, MW 6.5

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We studied the Dahuiyeh, Zarand, Iran earthquake of 22 Feb 2005, M_w=6.5 that struck a region of south-central Iran near Zarand, about 60 Km north of the city of Kerman. This earthquake was a devastating event with a total fatality of more than 600 people and 3 villages have been destroyed totally. A macroseismic intensity of VIII hit the epicentral region. The impact of uncertainties in parameters is investigated using a logic tree algorithm. We investigated the influence of parameter uncertainty and variability of intensity assessment. The importance of lack of information causing the epistemic uncertainties was very high in this region. Since the geotechnical instabilities (landslides) were the main cause for ground shaking and deformation in Dahuiye 2005 earthquake. It is concluded that in the mountainous seismic active regions, the negligence of geotechnical effect may cause a great source of errors in the intensity assessment. Comparing to the attenuation models developed and published for Iran, the attenuation rate in this region seems to be higher. We used empirical law previously developed for intensity values using the EMS 98 scale and developed new relation coefficients for intensity attenuation in the fault normal and fault parallel directions. The general trend of attenuation of intensities in the Dahuiyeh- Zarand 2005 earthquake fallows the attenuation of intensities in central Iran. The sigma for the attenuation of intensity was obtained to be between 0.7- 0.85.

ES9/TH/O7 - MODELING LOCAL SEDIMENT STRUCTURE IN THE VEGA BAJA REGION (SE-SPAIN) FOR THE GENERATION OF EARTHQUAKE SCENARIOS.

M. García-Fernández[1], *M. Jiménez*[1]
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The "*Vega Baja*" region, located in the Lower Segura River Basin, is one of the Neogene-Quaternary depressions developed in the Betic Cordillera, SE of the Iberian Peninsula. The sedimentary fill is post-orogenic and its youngest materials, in general, are cohessionless or very soft silts and clays, mainly in the central part of the basin. Earthquake activity in the region is moderate at present, although the historical record contains references to several damaging events. The strongest earthquake occurred in 1829 and it is known as the Torrevieja earthquake, with a maximum EMS-98 intensity of IX-X. Both the very recent rapid growth of urban developments together with the increase of population in the area has greatly increased seismic risk. Geological, geotechnical, geophysical and ambient noise data have been used to develop a model for the subsurface sediments in terms of resonance frequencies, shear-wave velocities and thicknesses of the sediment layers. The ambient noise horizontal-to-vertical spectral ratio HVSR technique has been applied in order to determine first, resonance frequencies and then these have been used to obtain thickness / depth relationships. In a final step, the model obtained has been validated by a) analyzing three profiles across the region (each profile includes the information from the ambient-noise measurement sites located on a strip 1 km wide on both sides) using the main parameters of the HVSR curves (predominant frequency and maximum amplification) and those derived from the final –thickness of C-type soils, depth to rock, and average shear-wave velocity over the C-type soil-model– and b) crosschecking the resulting layering with direct observations form geotechnical boreholes. Mapping of the main characteristics of sediments has been carried out showing the variations of predominant frequency, soft sediment thickness, and depth to rock.

ES9/TH/O8 - SCENARIO EARTHQUAKE LOSS ESTIMATION AT REGIONAL AND URBAN LEVELS

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Modeling shaking intensity is the first step in loss estimations computed for scenario and/or just-occurred earthquakes. Uncertainties and errors introduced at this stage of computations for loss estimations may be decreased by taking into account regional peculiarities of shaking intensity attenuation based on past strong earthquakes properly documented. Simulated circular isoseists are stretched along the active tectonic faults or according to source mechanism solution in order to take into account anisotropy of the medium and source line extension. Expected shaking intensity maps are computed taking into account various regional coefficients of macroseismic field equations used for simulation, different orientations of ellipse axes, as well as empirical data about ratio *k* of ellipse major and minor semi-axes (for different values of *k*). Empirical data on depen-

dency of ellipse major and minor semi-axes on magnitude *M* of event and source depth *h* obtained by different investigators could be used for different regions. The paper addresses the procedure used for shaking intensity and loss simulation. Uncertainties introduced by using different input parameters are analyzed and results are compared to reported intensities. Examples of shaking intensity simulations for different earthquake prone areas as well as scenario events loss estimations are discussed.

ES11 - THE STATE OF EUROPEAN STATISTICAL SEISMOLOGY

Thursday 9, 14h00-16h40

ES11/TH/O1 - A REVIEW OF STATISTICAL SEISMOLOGY STUDIES IN GREECE: PAST ACHIEVEMENTS AND CURRENT TRENDS

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The seismicity in Greece and the surrounding areas, which is the highest in Western Eurasia, favoured the development of the statistical seismology since the 60's. The first studies were devoted to the investigation of the statistical properties of foreshocks and aftershocks, including the study of induced seismicity as well as of swarm activities. The use of statistical methods for the seismic hazard assessment found extensive applications since the 70's. In the 80's and 90's statistical tools were introduced in earthquake prediction studies but also in the examination of fundamental problems such as the randomness/non-randomness of the earthquake activity and the time-space-size fractal properties of seismicity. The acceleration of seismicity as a long- term precursory model was introduced by the first author in the mid 80's. The re-activation of the ESC WG on Statistical Seismology after 1990 facilitated the development of that field in European and EU-funded research projects were initiatiated, such as ASPELEA (Assessment of Seismic Potential in European Low Earthquake Areas) under NOA's leadership. In parallel to this, the acceleration seismicity model was developed further by other research groups producing several earthquake prediction statements. In the last years, a systematic effort was undertaken in NOA in the field of statistical seismology particularly in the area of earthquake predictability. A computer tool under the name FORMA (foreshock-mainshock-aftershock) was developed to monitor and evaluate on a continuous, automatic basis the state of seismicity and the recognition of precursory signals, such as foreshocks, from significant seismicity changes with the use of statistical tools. Positive retrospective performance in Greece (Samos, 2005) and in Italy (L' Aquila, 2009) encouraged the real-time, daily evaluation of the strong seismic sequence of the January 2010 in Corinth Gulf, Greece. In addition, Poisson Hidden Markov models (PHMM) were introduced to model temporal seismicity changes with applications in Greek seismicity. In PHMM the unobserved sequence of states is a finite-state Markov chain and the distribution of the observation at any time is Poissonian with rate depending only on the current state of the chain. Thus, PHMM allows a region to have varying seismicity rate. Simulations of data from the assumed model showed that PHMM describes quite well the true data. The very recent drastic improvement of the national seismograph system of NOA, which among others results in increasing drastically the completeness of the earthquake catalogue, opens a new era in the field of statistical seismology in Greece.

ES11/TH/O2 - SEGMENTATION OF FAULT NETWORKS: IDENTIFICATION OF EARTHQUAKE CLUSTERS USING A PATTERN RECOGNITION APPROACH.

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The spatial disorder of the complex geometry of fault networks is then taken into account by defining faults as probabilistic anisotropic kernels, whose structures are motivated by properties of discontinuous tectonic deformation and previous empirical observations of the geometry of faults and of earthquake clusters at many spatial and temporal scales. Combining this a priori knowledge with information theoretical arguments, to take account of our lack of knowledge, we propose the Gaussian mixture approach implemented in an iterative Expectation-Maximization procedure to fit an earthquake catalog with a set of kernels, whose number is chosen by the user. A cross-validation scheme is then used to provide the number of kernels that should be used for an optimal data clustering. This step takes naturally into account both earthquake location uncertainties and the finite number of events.

This three-steps approach is applied to synthetic catalogs as well as to high quality relocated catalogs of seismicity in California, such as the seismicity following the 1986 Mount Lewis (M_l=5.7) event. In this last case, we find that events tend to cluster along planar patches of about 2km^2, comparable to the size of the main event, which may reveal a typical segmentation scale of the local network. This mixture method is also a natural tool to study the anisotropy properties of clusters, and provides evidence for three main directions of active faulting in this area. The finite thickness of the Mount Lewis clusters (about 290 m) suggests that events do not occur on well-defined euclidean fault core surfaces, but rather that a damage zone surrounding the fault core may be seismically active at depth. More specific statistical features of individual clusters (such as their associated b-value) are also discussed. Finally, we propose a connection between our methodology and multi-scale spatial analysis, based on the derivation of a spatial fractal dimension of about 1.8 for the set of hypocenters in the Mnt Lewis area, consistent with recent observations on relocated catalogs.

ES11/TH/O3 - DO TRIGGERED EARTHQUAKE PATTERNS DEPEND ON TRIGGER FAULTING STYLE ?

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The seismicity rate triggered by the Muzaffarabad, Kashmir, 2005 Mw=7.6, Ms= 7.7 earthquake appears as above normal when analysing the aftershocks sequences in the India-Asia collision belt, 1973-2008. To quantify this patterns we compare the aftershock patterns triggered by the 18 Ms >=7.0 earthquakes which occurred in 20 degree latitude and 40 degree longitude box size, centered on the Muzaffarabad, Kashmir, 2005 epicenter.After normalizing by the mainshock size and by the magnitude range of observations for each aftershock sequences, the Ms=7.6 Kashmir and the Ms=7.0 Khurgu (Iran, 1977) aftershock rates are above the 1-2 standard deviations of the 18 aftershocks rates. We test how Omori's law parameter and background rate, and the space and time patterns of the sequences interplay to produce the huge aftershock productivity. The anomaly of Kashmir sequence rate is not driven by a single Omori law parameter. It appears as a combination of many parameters that leads to a relatively longer sequence duration, higher density, in a larger background rate setting(pre stress conditions) than the others western Asia sequences, respectively. For the Khurgu sequence, the anomaly in large rate emerges as driven by a large aftershocks productivity, as measured from the normalized K value of the Omori law. Also this aftershock cascade develop further away in space, above a two standard deviation significance level, than for the other sequences respectively.Beyond the specific anomalies of Khurgu and Kashmir aftershock sequences, i.e. above two standard deviation for the productivity and size the first event and for duration for the later event, respectively, the other major result we robustly quantify for Western Asia Ms>=7.0 events, is the dependence of aftershock productivity to faulting styles. We resolved the strike slip event productivity to be 4 times smaller than the thrust faulting productivity, for average value respectively. We further test such pattern on global M>7 data set.

ES11/TH/O4 - BUILDING THE COMMUNITY ONLINE RESOURCE FOR STATISTICAL SEISMICITY ANALYSIS (CORSSA)

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Statistical seismology is critical to the understanding of seismicity, the testing of proposed earthquake prediction and forecasting methods, and the assessment of seismic hazard. Unfortunately, despite its importance to seismology - especially to those aspects with great impact on public policy - statistical seismology is mostly ignored in the education of seismologists, and there is no central repository for the existing open-source software tools. To remedy these deficiencies, and with the broader goal to enhance the quality of statistical seismology research, we have begun building the

Community Online Resource for Statistical Seismicity Analysis (CORSSA). CORSSA is a web-based educational platform that is authoritative, up-to-date, prominent, and user-friendly. We anticipate that the users of CORSSA will range from beginning graduate students to experienced researchers. More than 20 scientists from around the world met for a week in Zurich in May 2010 to kick-start the creation of CORSSA: the format and initial table of contents were defined; a governing structure was organized; and workshop participants began drafting articles. CORSSA materials are organized with respect to six themes, each containing between four and eight articles. This presentation will serve as the official unveiling of the CORSSA web page, www.corssa.org, with an initial set of approximately 10 to 15 articles available online for viewing and commenting. Each article will be peer-reviewed and will present a balanced discussion, including illustrative examples and code snippets. Topics in the initial set of articles will include: basic statistical tests and their role in seismology; an introduction to the fundamental features of seismicity; understanding seismicity catalogs and their problems; basic techniques for modeling seismicity; and methods for testing earthquake predictability hypotheses. A special article will compare and review available statistical seismology software packages.

ES11/TH/O5 - C-VALUE MAPS

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Considering that aftershocks result from a step-like perturbation of the state of stress in the neighborhood of a triggering event, theoretical models for aftershock production state that the amplitude of the perturbation is inversely proportional to the time delay before the onset of the power-law aftershock decay rate. According to the Modified Omori law, the parameter c is often used to described such a non-power law behaviour over short times. Here, the idea is to use small earthquakes and their aftershocks to characterize the evolution of the state of stress from variations of the c-value. With this objective in mind, we propose a statistical method based on (1) a Bayesian estimation of the c-value for a single sequence of aftershock and (2) a k-means local likelihood estimator for space-time c-maps. We present our results for California to study the loading rate along the San Andreas fault system.

ES11/TH/O6 - NONPARAMETRIC ESTIMATION OF THE PROBABILITY DISTRIBUTION OF THE INTEREVENT TIME: INFLUENCE OF THE DEGREE OF COHERENCE BETWEEN MODEL ASSUMPTIONS AND INPUT DATA.

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Despite the large number of studies on the time-dependent seismic hazard a commonly accepted model does not exist yet, but there are some more shared conjectures like the dependence on the time elapsed from the last occurrence. From the probabilistic point of view this means to consider a renewal process. It is appropriate to model sequences of large earthquakes after which one can assume that the stress accumulation process starts over again so as the times between consecutive large seismic events can be considered as realizations of independent, identically distributed random variables. Various probability distributions F have been proposed for the intervent times in the literature but the results do not seem completely satisfactory, also because the data, generally sparse and irregular, are difficult to fit through parametric models. A radical solution could consist in assuming that F is a random function modelled by a Polya tree process which, under mild assumptions, assigns probability one to the space of the continuous functions. It relies on a binary tree partitioning of the domain (real positive semi-axis), obtained through the quantiles of a generalized gamma distribution, family of distributions properly including the most used ones for the recurrence time: gamma, Weibull, lognormal. The parameters of such a distribution are themselves gamma-distributed random variables chosen on the basis of prior knowledge of the phenomenon. The definition of this Bayesian hierarchical model is completed by assigning to each F(B), being B any set of the partition, a beta distribution with parameters guaranteeing the continuity of F. The estimation technique is based on a MCMC sampler using Metropolis-Hastings within Gibbs sampling.

This methodology has been applied to the Italian earthquakes with magnitude at least 5.3 drawn from the CPTI04 catalogue and associated with the seismogenic areas of the database DISS, subdivided into eight tectonically homogeneous regions. By estimating, for each region, the density of the intervent time, occurrence probabilities at different forecasting horizons have been obtained.

Weak points of the method have been pointed out by a backward validation of the results on the seismic activity recorded in past tens.

Moreover, some areas in DISS are much larger than the others; this can make the physical assumptions underlying the renewal process not satisfied. To test this fact the same procedure has been repeated by partitioning these areas in different ways.

ES11/TH/O7 - PROBABILITY-BASED MAGNITUDE OF COMPLETENESS AND GUTENBERG-RICHTER ANALYSIS OF THE JAGUARS CATALOG (-5 < M < -1) RECORDED IN THE MPONENG DEEP GOLD MINE, SOUTH AFRICA

K. Plenkers[1], D. Schorlemmer[2], G. Kwiatek[1], G. Dresen[1], JAGUARS Group[3]
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We analyze the completeness of the JAGUARS (Japanese-German Underground Acoustic emission Research in South Africa) catalog using the probability-based magnitude of completeness method (Schorlemmer and Woessner 2008) as well as Gutenberg-Richter analysis.

The JAGUARS network is located at 3.5 km depth in a complex observational volume with geological heterogeneities and cavities. The recording of events is directly influenced by the surrounding heterogeneities. Therefore a spatial-varying completeness is expected.

We take into account spatial heterogeneities by extending the method of Schorlemmer and Woessner to take into account the direction of recording. By doing so we are able to demonstrate that the heterogeneities reflect strongly in the detection probabilities. For example low detection probabilities are found near tunnels. The magnitude of completeness M_p varies in space and ranges from -2.9 to -4.7. Lowest M_p are found, as expected, in the center of the network.

For comparison, we calculate the completeness magnitude based on Gutenberg-Richter analysis. We demonstrate the problem that the Gutenberg-Richter analysis is not automatically resolving spatial variations in completeness. Values of both methods agree only if appropriate subsets for the Gutenberg-Richter analysis are chosen.

We conclude that the extended probabiliy-based magnitude of completeness method is able to resolve spatial variations in completeness even in the presence of strong heterogeneities.

The JAGUARS catalog contains seismic events in a magnitude range from $-5 < M_W < -1$. Events were recorded on a 3C accelerometer as well as on acoustic emission sensors in a frequency range from 700 Hz to 180kHz. A total of about 20,000 events were used for the analysis.

ES11/TH/O8 - ASSESSING LOCATION UNCERTAINTIES IN EARTHQUAKE CATALOGS

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Earthquake location is inherently a non-linear problem. Methods to solve this problem are either based on linearization of the equations relating predicted arrival times to the location through Taylor expansion involving partial derivatives or on direct-search algorithms sampling the entire solution space. Uncertainties in earthquake locations can be classified into formal errors (precision) and systematic errors (accuracy). The former is introduced due to 1) errors in measuring arrival times and 2) errors associated with the precision of the algorithm used to compute predicted arrival times. Systematic errors are introduced due to the coupling of earthquake locations and seismic velocities. For linearized methods, formal errors based on the F-statistic or on the chi-square statistic are used to compute location uncertainties, such as error ellipsoids. Direct-search methods allow the ability to compute individual confidence regions, which can be irregular in shape and multi-modal. Systematic errors can only be assessed by relocating sources with known locations, such as mine blasts or explosions. If an earthquake cata-

log does not include information on formal errors, some selection criteria describing network geometry such as azimuthal gap, distance to the closest station and the number of observations, are often used to asses location uncertainties.

In this study, we investigate how network geometry affects location uncertainties by means of synthetic data. For a given distribution of stations and earthquakes we compute synthetic arrival times, add Gaussian distributed arrival times errors, and relocate each event using a direct-search algorithm that computes the posterior probability density function (pdf). By computing the difference between relocated and true hypocenter locations we can assess how network geometry affects location uncertainties. For the case of using the true seismic velocities, our results show that uncertainties in epicenter are mainly controlled by the azimuthal gap, whereas uncertainties in focal depth are mainly controlled by the distance to the closest station. If seismic velocities do not reflect the true velocities, our results indicate that azimuthal gap is the main factor controlling uncertainties in epicenter and focal depth. Formal errors derived from only the pdf include the true locations, if the true seismic velocities are used.

SD13 - MACHINE LEARNING IN SEISMOLOGY AND HAZARD ANALYSIS

Thursday 9, 14h00-16h40

SD13/TH/O1 - A NEW CHI-SQUARE BASED TEST STATISTIC FOR THE DETECTION OF SEISMIC EVENTS AND HOS BASED PICKERS' EVALUATION

A. Lois[1], E. Psarakis[2], V. Pikoulis[2], E. Sokos[1], G. Tselentis[1]
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Automatic P-phase onset identification problem involves the solution of two well defined sub-problems; the detection and the picking. Regarding the first one we propose a new parameter free Chi-Square based statistic and its use in a sequential hypothesis testing framework. The main theoretical aspects concerning the proposed detector and its important features are also presented. Among them, the fact that its performance does not depend on the Gaussian noise assumption, as the majority of existing detection schemes do, is pointed out. Furthermore, we compare the performance of the proposed detector against the well known STA/LTA detector, by applying the rivals in a large number of manually identified seismic events. In most cases the proposed detector outperforms its rival. Regarding the picking sub-problem, using the above mentioned dataset, we evaluate the performance of a number of well known Higher Order Statistics (HOS) based pickers in terms of their accuracy in picking the correct P-onset time. Several issues concerning the performance of the above mentioned pickers are discussed and alternative solutions are proposed.

SD13/TH/O2 - USING HIDDEN MARKOV MODELS FOR THE FAST BUILD-UP OF A VOLCANO-SEISMIC EVENT SPOTTING SYSTEM

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The classification of seismic signals of volcanic origin is an important task in monitoring active volcanoes since the number and size of certain types of seismic events usually increase before periods of volcanic crisis. Due to the advantage of providing consistent, objective and time-invariant results automatic classification systems are preferred. The discipline whose aim is the automatic classification of objects into a finite number of categories is called pattern recognition. It works in two steps. The first step is the feature extraction: a set of parameters is extracted from the input objects. The second step is the classification: based on the features extracted before, the object is associated with one category. Wavefield parameters, extracted from a continuous seismic data stream, build the input for hidden Markov models (HMMs), which are used for the development of a novel seismic event spotting system. While this technique was originally developed in speech recognition, it already showed great promise when applied to volcano induced seismic signals. In contrast to other machine learning algorithms like neural networks or support vector machines, hidden Markov models contain the time dependence explicitly and thus provide a more appropriate representation of seismic signals. Classical techniques like cross-correlation methods are also useful for the detection of repeated occurrences of very similar seismic waveforms but unlike HMMs they cannot cope with heterogeneous waveforms belonging to the same signal class. Due to their stochastic approach HMMs are able to handle the great variability of seismic signal characteristics (e.g. regarding the signal length). The goal in the approach presented here is to provide a robust event classification system based on a minimum number of reference waveforms and thus allowing for the fast build-up of a volcanic signal classification scheme as early as interesting events have been identified. The parameters (here polarization and spectral attributes), extracted in the first step, are used to extract a fixed number of clusters in the feature space. Based on this general description of the overall data set we start building particular event classifiers from a single waveform example based on the cluster description learned before. The results of our automatic classification approach for seismic signals from datasets acquired at different volcanoes show very high detection/classification rates and the system performs sufficiently robust to be applied in volcano early warning systems.

SD13/TH/O3 - SEMI-SUPERVISED LEARNING FOR SEISMIC CLASSIFICATION

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A recurring challenge in the field of seismic monitoring is the classification of repetitive sources. For example, these events can be routine mining explosions or aftershocks occurring after a previous large earthquake. When events occur at the same place and with the same source mechanism, and approximately the same size, the waveforms recorded at one station are very similar. Therefore, a way to to classify a repeating source is to use this similarity. The goal of this paper is to realize the classification task by using a waveform similarity distance combined to a semi-supervised technique borrowed from the Machine Learning field.

In particular, we will study the use of a graph-based label propagation algorithm where the similarity between the waveforms is defined as a function of their estimated steering vector.

SD13/TH/O4 - INSIGHTS INTO THE USE OF GENETIC CLUSTERING TO DELINEATE SEISMOGENIC SOURCE ZONES FOR INPUT INTO PROBABILISTIC SEISMIC HAZARD ANALYSIS

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The delineation of seismic sources for input into probabilistic seismic hazard analysis (PSHA) is a process that unfortunately can be applied inconsistently from region to region. In many areas of high seismic risk, seismogenic sources, be they areal zones, geometric fault segments or distributed point sources, may often be delineated via the best judgement, or even a compromise judgement, of a team of experts. Whilst much expertise may be applied in this process, the zone models themselves may often better represent a compromise of judgement rather than "natural" phenomena, and in doing so they may also lack objective means of validation and reproduction. Traditional methods of cluster analysis have previously been applied to this task, which, whilst more objective, are limited in the extent to which they can utilise other forms of geological and seismotectonic information. A genetic clustering approach, in the form of a modified genetic K-medoids algorithm, can provide a framework by which seismogenic sources are spatially partitioned according to objective judgements regarding the role of different sources of information. Evolutionary-based clustering allows the algorithm identify "better" partitions from a population of seismogenic source models, guiding the generation of new partitions on the basis of the fitness criteria. The fitness function provides a tool for integrating different forms of seismotectonic (e.g. focal mechanism) and geological data (e.g. rupture plane), and can attempt to optimise the cluster analysis in such a manner as to best reconcile the observed seismicity with the additional data. An additional clustering heuristic is also used to achieve this objective. Example applications illustrate how this approach can maximise the information used in the development of seismogenic sources models, which often depends heavily on the region in question, as well as the role that expert judgement can play within the objective framework. The algorithm is applied to idealised earthquake data, in addition to real earthquake data from different areas of the globe. Issues in the development of this

prototype framework for source delineation are addressed, including the translation of seismicity partitions into source zones and means of validation.

SD13/TH/O5 - REASONING ABOUT TSUNAMI IMMINENCE BASED ON SEISMIC SOURCE PARAMETERS

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[1]*University of Potsdam*

Emergency managers in tsunami warning centers face a difficult task: based on few seismic source parameters prone to large uncertainties they have to decide under extreme time pressure about releasing a warning or not. Common decision support systems provide a (set of) possible tsunami scenario(s) fitted to the seismic source parameters estimated in real-time. The various inherent uncertainties are disregarded thereby. We present a probabilistic automatic Bayesian Network (BN) alert level system supporting emergency managers at tsunami warning centers by evaluating the likelihood of tsunami imminence taking the uncertainties of seismic source parameters into account. BNs are probabilistic graphical models capable to describe and visualize complex systems and providing efficiently a logical basis for reasoning under uncertainties. The BN analysis of the real-time estimates of the seismic source parameters provides immediately important information to officers on duty by quantifying site-specifically tsunami probability distributions given the parameter estimates, their uncertainties as well as prior information. The probabilistic analysis of the tsunami situation is updated instantly whenever new evidences are available. A set of BNs has been developed for the test region Sumatra. A BN consists of nodes and connecting arcs depicting the conditional (in)dependences between the nodes. To construct a BN first the set of variables (nodes) has to be defined, then the structure (arcs) and the parameters quantifying the strength of the conditional dependencies have to be either defined by an expert or learned from data. The required complexity of a BN system for tsunami early warning entails a huge amount of parameters to be specified exceeding the feasibility of expert elicitation. The number of well recorded historical tsunami events is highly insufficient to learn a BN from. Therefore, we have developed a new approach for learning BNs based on a set of well established empirical and physical formulas describing the whole process from earthquake rupture to tsunami wave shoaling at the coast in combination with prior information (e.g. bathymetry or prior probability distributions of variables). With an ancestral sampling mechanism we compiled a synthetic database large enough to learn a highly resolved tsunami BN from. The real-time evaluations of the seismic source parameter estimates of recent large earthquakes offshore Sumatra have demonstrated powerfully the capability of BNs in (tsunami) early warning.

SD13/TH/O6 - VERTICALLY INTEGRATED SEISMOLOGICAL ANALYSIS

N. Arora[1], *S. Russell*[1], *P. Kidwell*[2], *E. Sudderth*[3]
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As part of its Comprehensive Test Ban Treaty (CTBT) verification efforts, the International Data Center (IDC) analyzes seismic and other signals collected from hundreds of stations around the world. Current processing at the IDC proceeds, like many other large-scale monitoring and surveillance systems, in a series of pipelined stages. From station processing to network processing, each decision is made on the basis of local information. This has the advantage of efficiency, and simplifies the structure of software implementations. However, this approach may reduce accuracy in the detection and phase classification of arrivals, association of detections to hypothesized events, and localization of small-magnitude events.

In our work, we approach such detection and association problems as ones of probabilistic inference--that is, computing posterior probabilities of seismic event histories given evidence from observed waveforms. Inference is applied to a generative probability model that describes event occurrence, signal propagation, and signal detection by sensors. In simple terms, let X be a random variable ranging over all possible collections of events, with each event defined by time, location, magnitude, and type (natural or man-made). Let Y range over all possible waveform signals recorded jointly at all detection stations. Then P(X) describes a generative prior over event histories, and P(Y|X) describes how the signal is propagated and measured. Given observed recordings Y=y, we are interested in the posterior P(X|Y=y), and perhaps in the value of X that maximizes it--i.e., the most likely explanation for all the sensor readings. An additional focus of our work is to robustly learn appropriate model parameters for P(X) and P(Y|X) from historical data.

Our inference algorithm takes in a continuous stream of parameterized detections (as produced by the IDC's station processing) and outputs a corresponding event bulletin. The algorithm proposes new events by direct inversion of the incoming detections and then attempts to improve the localization of these events and their association to detections as well as the parameters of the detections to produce the best explanation as per the probabilistic model. The model also dictates which events are rejected for lack of sufficient evidence. This takes into account the detection as well as mis-detections of an event at all available stations.

Our analysis demonstrates that we are able to produce significantly improved bulletins compared to the existing automated system. In addition, we are able to detect events which are missed by even the human analysts.

SD13/TH/O7 - MACHINE LEARNING METHODS FOR PHASE CLASSIFICATION IN SEISMOLOGY

J. Schneider[1] *[invited]*
[1]*School of Computer Science, Carnegie Mellon University*

The CTBTO International Data Centre (IDC) has been collecting, analyzing, and storing seismological data for over a decade. Most importantly, the classification and association of every detection has been done both automatically and checked and corrected by human experts. This data now represents a vast store of knowledge that can be leveraged in future analysis if we can devise learning algorithms to extract it.This talk focuses on the task of phase classification from parametric features computed from the waveform of each detection. We first describe basic supervised classification algorithms that learn from the historical data. The methods are applied independently for each station and are trained using the historical data from that station.We show empirically that these methods can increase the accuracy of the automatic IDC phase labeling system by over 20% on 3-component stations. We go on to present multi-task learning algorithms that simultaneously learn separate classifiers for each station but try to further improve their performance by learning from the combined data of all stations.Additional information is available that might further improve the accuracy of phase labeling. This includes the classification of temporally nearby detections both at the station for the current detection and at other stations in the network. We will finish by describing methods for learning and exploiting the relationships between nearby detections.

OS4 - SEISMOLOGY AT SCHOOL

Friday 10, 08h00-10h00

Friday 10, 10h20-12h00

OS4/FR/O1 - THE UK SCHOOL SEISMOLOGY PROJECT

P. Denton[1]
[1]*British Geological Survey*

The UK school seismology project launched in 2007 with a set of resources aimed at science and geography teachers in secondary schools (pupil ages 11-18). At the heart of the project is the belief that actively engaging young students with observational seismology will enthuse and excite them and eventually lead to an improvement in the participation rates for science and geosciences at university level. The approach taken in the UK has been to encourage and support as many schools as possible to use a very simple (and inexpensive) mechanical seismometer which can be used by the teacher to demonstrate the basic physics of seismometery but is also sensitive enough to detect signals from large teleseismic events. To date over 400 of these simple seismometers have been provided to schools across the UK and into Ireland and elsewhere.

This presentation will outline the strategies and rationale underlying this project and demonstrate how the UK schools network has merged their online database of submitted event files with similar projects in the USA and Ireland using simple webservices.

OS4/FR/O2 - "LOOKING FOR EARTHQUAKES": A HIGH-SCHOOL WORKSHOP ON SEISMOLOGY

J. Diaz[1], *M. Ruiz*[1]

[1]ICTJA-CSIC

The main objective of this activity is to present the main aspects of seismology to high-school students, with a special attention on the instruments used to record and locate earthquakes. With this purpose, we benefit from the SEP seismometer developed by British Geological Survey, that provides an excellent tool for introducing young people to the seismological world. The background idea is not to present an exhaustive explanation of the different concepts involved, but try to stimulate the interest on earth sciences. The workshop has three distinct parts. In a first session, the main conceptual points (what is an earthquake, where they occur, how frequent are, how to locate them…) are briefly introduced, trying to retain the attention of the public using spectacular pictures and animations and connecting the theory with the last earthquake news on the media. Then the SEP seismometer is installed and the physical properties of the instrument (pendulum mechanics, electromagnetic induction) are introduced, again trying to connect with the audience relating the seismometer principles to every-day devices (car airbags, ipods or even electric guitars…). After this session, the seismometer remains installed in the school laboratory during a period of about one month. Finally, the third part of the workshop is a computer hands-on session in which the students must first look for the seismicity during the recording period that could have been recorded on place and then try to recover those events from the SEP seismometer records. We think that this activity, started the past academic year, has an interesting potential, as it allows to establish relationships between different fields (from geology to physics, natural risk or even economy or history).

OS4/FR/O3 - THE GREEK EDUCATIONAL SEISMOGRAPH AND ITS USE IN SCHOOLS

P. Fountas[1], N. Germenis[2], E. Sokos[2], G. Fermeli[3], S. Alexandropoulou[4]
[1]Industrial Systems Institute; [2]Faculty of Geology, Seismological Laboratory, University of Patras; [3]Department of Hist. Geology and Palaeontology, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens; [4]Buraue of Environmental Education - Messinia Prefecture

A specially designed, low power and cost effective digital acquisition system for use in educational seismological applications in Greek schools is presented. The seismograph consists of three parts, a sensor, a digitizer and a personal computer. The sensor is based on an inexpensive geophone that converts earth motion to an analogue signal. The digitizer converts analogue signals to digital data that are being sent to the personal computer, via serial port. The result is the digital form of the analogue signal.The digitizer is based on a powerful, wide dynamic range delta-sigma analogue-to-digital converter, with very low noise characteristics and excellent power supply rejection. The sampling rate is selectable and the timing is based on a real time clock and a phase locked loop circuit, which generates a pulse per second (PPS) signal. The first sample of data is aligned to the PPS signal. The time reference for both circuits is provided by a 12 channels GPS receiver.Three software applications, assist in data processing: Data Monitor receives data from the serial port and stores them in files. A new file is created every 10 minutes, Helicorder displays 24-hour period graph of data. DataViewer allows the user to process the data. It provides features like zoom in and out in a graph, epicentral distance estimation, based on phase picks, for the seismic event, magnitude estimation, and more.Currently there are four systems running in schools under the frame of a seismology school network, called "Egelados"(http://egelados.sch.gr/) *. Future plans include the further development of the main web page to serve as a portal of School Seismology in Greece, enhancement of manuals with extra activities to be carried in school and connection with similar networks in Europe. Key words:* geosciences *education, earthquakes, seismograph, environmental education, Egelados network.*

OS4/FR/O4 - TOWARD A NEW WAY OF THINKING ABOUT EDUCATIONAL SEISMOLOGY

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Increasing our knowledge about the earthquake phenomena and their effects at the earth surface is an important step toward the education of population in high seismic risk regions and can contribute to raise the awareness about the earthquake risk and possible mitigation actions. In this direction two viable paths have been experimented in seismic risk educational efforts. The first one has an immediate impact, and it is strongly based on traditional communication supports as booklets, brochures, web sites, videos, large public seminars and conferences. The alternative approach is instead grounded on advanced technologies by the implementation and use of web-oriented accessible tools, which provide a direct link with the modern laboratory systems of data analysis and modeling. This approach is addressed to a more "specialized" public willing to make students the main actors of the scientific experience about earthquakes, by leading them along the laboratory research trail, made of seismogram observation, measurement, analysis and interpretation. These are exactly the principle and basic ideas of the EduSeis project. However the experience gained in this project leads us not to neglect problems and difficulties in the application of structured projects like Eduseis in the Italian school system, in particular the requirement for a big involvement of teachers and seismo-lab researchers. With the enormous advances in technology and informatics during last decade, it may be the time for the educational seismology to move a step forward, from «data sharing» to «sharing methods for data analysis and modeling». This new view will provide teachers and students with new user-friendly tools for massive seismological data analysis, mapping and interpretation and introduce new approaches in teaching and learning the earthquake risk. In this direction, we mention the possibility to introduce seismology in schools through the modern technologies for teaching and learning the scientific knowledge based on e-learning platforms. Driven by the high-tech development of earthquake observation systems, the educational seismology in schools can represent a suitable, integrated environment which makes students, active users of modern technologies rather than passive consumers and the selected vehicle for such training is the seismological observation. Although difficult to implement, this new approach to science education and dissemination will certainly contribute to train the tomorrow's environmental citizens, preparing them to cope with natural risks and solutions for mitigating their damaging effects.

OS4/FR/O5 - SEISMOLOGY IN SCHOOLS, AN INTEGRATED APPROACH TO FUNDING, DEVELOPING AND IMPLEMENTING A COORDINATED PROGRAMME FOR TEACHERS AND HIGH SCHOOL STUDENTS.

T. Blake[1], A. Jones[1]
[1]School of Cosmic Physics, Dublin Institute for Advanced Studies

he Section's Seismology in Schools pilot programme is proceeding very strongly, with now seismometers installed in over forty-six schools across the State. Although this number is small, given that the population of Ireland is 4M, this number of 1 per 87,000 compares very favourably with the the U.K. (70 in a population of 70M, 1 per 1M) and the U.S.A. (200 in a population of 300M, 1 per 1.5M) with an penetration of 15-20 times greater. Statistics in Ireland show that Physics at Advanced Level in Secondary Schools, is declining in popularity and is the most likely subject to be first cut from the curriculum in a curriculum readjustment. In an attempt to attract students to study earth science and seismology the School of cosmic Physics DIAS embarked in 2008 on an outreach programme to promote earth science and seismology in schools. Since then the Seismology in Schools programme has proceeded very well, with seismometers installed in over forty-six schools across the State. Although this number is small, given that the population of Ireland is 4Ms, this number of 1 per 87,000 compares very favourably with the the U.K. (70 in a population of 70Ms, 1 per 1Ms) and the U.S.A. (200 in a population of 300Ms, 1 per 1.5Ms) with an penetration of 15-20 times greater.

The phenomenal success of our Seismology in Schools programme has been helped significantly by the support we have received from the British Geological Survey(BGS), and IRIS (Incorporated Research Institutions for Seismology), in terms of hardware, software and advice. Similarly, the programme would be a pale reflection of what it is if the Directors of the Educational Centres (ATELIER, Association of Teacher's/Education Centres in Ireland) across Ireland had not become enthused and funded the purchasing of 34 additional seismometers. Also, the funding support from the Discover Science and Engineering (DSE) was absolutely critical in order for us to roll out this hugely enlarged programme. As this programme is an initiation into seismology for students, it is important to stress that the seismometer, is not used in the schools as a comercial recording instrument but helps students visualize what seismology and the recording of earthquakes

comprises. It was essential to the success of the programme to target teachers who would be committed to its implementation and promotion in the school. Strong emphasis by DIAS was placed on providing teacher training days on the set-up and implementation of the seismometer and they were also trained in various animated software programmes used to enhance the learning capacities of the students in the classroom. Participating schools become affiliated to the IRIS International Schools Seismic Network site and uploads the seismic data in sac format for the recorded seismic events at their school to share with schools internationally.

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OS4/FR/O6 - PROMOTING CLASSROOM SEISMOLOGY IN THE U.S. VIA THE IRIS EDUCATION AND OUTREACH PROGRAM

J. Taber[1], T. Bravo[1], M. Hubenthal[1], J. Johnson[1], R. Butler[2]
[1]IRIS; [2]University of Portland

IRIS E&O has developed a multi-faceted approach to address the need to increase both the extent and sophistication of seismology-related instruction in middle and high schools. For the broadest audience, activities and tools have been developed that use seismic data to explore such topics as Earth structure, seismicity, and wave propagation. To increase teacher confidence, IRIS provides a professional development program including in-person workshops, online materials, and a resources DVD. Electronic resources include simple animations to illustrate specific concepts and short video lectures and demonstrations to support classroom presentations of earthquake science. Teachers want to relate content to current events, but they lack the time to synthesize web-based material into a coherent package, so IRIS and the University of Portland have developed Teachable Moments PowerPoint presentations that provide short summaries of current earthquakes for quick and easy use in the classroom. The presentations are available within a day of the earthquake and include a variety of content allowing educators to customize the information for their classes. Motion sensors, such as those in iPhones, laptops, or USB sensors available from the Quake Catcher Network provide greater engagement. These sensors provide kinesthetic understanding of seismograms and allow students to connect personal experience to actual earthquakes via online USGS shakemaps. For greatest involvement, a seismometer in the classroom promotes awareness of earthquake activity around the world and engages students and teachers in collecting, analyzing and drawing conclusions from seismic data. Over 150 schools have received seismographs and training and a recent priority for the program has been improving the connectedness of users. We have developed an online interface enabling educators to share and make use of seismic data while communicating with other users. Users can view and compare near-real-time displays of participating schools, upload and download data, and use the "find a teacher" tool to contact other schools. To promote program participation the site features a discussion forum for technical issues as well as discussions of seismology. IRIS has also been collaborating with the UK and Ireland networks to provide web-based tools that leverage the underpinning IRIS web structure to support educators in their own communities. We provide tools on our website that allow educators around the world to easily establish an online presence for their own regional networks. Currently over 300 educational seismic stations worldwide are networked via the Seismographs in Schools web site.

OS4/FR/O7 - FEELING THE EARTH SHAKE… AT SCHOOL - EDUSISMO : THE FRENCH EDUCATIONAL SEISMOLOGICAL NETWORK

J. BERENGUER[1], F. COURBOULEX[2]
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Earthquakes are both troubling and fascinating because of their suddenness, the terrible destruction they can wreak and because they still remain largely unpredictable. This is why emphasis must be placed on preparation, especially in the school system where causes and effects of these hazards are studied. But trying to explain earthquakes, scrutinizing the earth's depths, taking on the planet's internal dynamics… entail moving into the inaccessible. In this respect seismology is a source of complexity and fascination. Scientific culture is thus at the heart of seismic risk instruction. All this is what is involved in the "SISMOS à l'École" curriculum, that implements an educational programme allowing a natural risk culture to be engaged through a scientific and technological approach. The original and innovative aspect of this programme stems from giving students the opportunity to install a seismometer in their school. The recorded signals, reflecting regional or global seismic activity, feed into an on-line database, a genuine seismic resource centre and a springboard for educational and scientific activi-

ties. The network 'EduSismo' (numbering some sixty stations installed in metropolitan France, the overseas departments and territories and a few French high schools abroad) is the outgrowth of an experiment conducted in the Alpes-Maritimes Department some twelve years back. Since then, the programme implemented has gone beyond simply acquiring seismic signals, which could have been procured by research and monitoring centres. By appropriating a scientific measurement, the student becomes personally involved and masters complex concepts about geophysics and geosciences. The development of simple devices and the design of concrete experiments associated with an investigative approach make it possible to instill the students, these future citizens, with a high-quality scientific culture and an education about risks. Today, this programme is expanding. New initiatives with Italian and Swiss partners are being put in place to extend the network and to, above all, strengthen, beyond the diversity of teaching practices in Europe, common tools related to scientific culture and education of natural risk.

Keywords : earthquake, scientific culture, awareness of earthquake hazard, network, teaching, education

OS2 - EARTHQUAKE EDUCATION FOR RISK REDUCTION: EUROPEAN AND NON-EUROPEAN EXPERIENCES

Friday 10, 08h00-10h00

Friday 10, 10h20-12h00

OS2/FR/O1 - THE EARTHQUAKE EDUCATIONAL FRAMEWORK FOR SEISMIC RISK REDUCTION IN GREECE THROUGH EARTHQAUKE PLANNING AND PROTECTION ORGANIZATION'S ACTIONS

A. Kourou[1], C. Gountromichou[1], K. Makropoulos[2]
[1]Earthquake Planning and Protection Organisation; [2]Earthquake Planning and Protection Organization [President]

Working towards seismic risk reduction, Earthquake Planning and Protection Organization (E.P.P.O.) as the competent authority in Greece, has already developed an earthquake educational framework for all citizens. The main scope is to shield people against a destructive earthquake having the minimum consequences to themselves and to their environment.

The framework is consisting of a number of actions which are being undertaken. The E.P.P.O.'s main actions are the following: - Dissemination of knowledge regarding earthquake protection measures - Lectures on earthquake protection measuresThese lectures aim at familiarizing students, teachers, educators, with the earthquake as a physical phenomenon and how they can cope in case of a disastrous event. - Educational materialThe E.P.P.O.'s educational material is consisting of several brochures, posters, books, CD-ROM's, games, a textbook with guidelines for people with disabilities, and an interactive unit in E.P.P.O's website for students and teachers. - Specific earthquake-material for hotels and touristsE.P.P.O. is developing material for hotels and tourists. This action is under process and mainly aims to inform travellers, about the appropriate actions to be taken in case of a destructive earthquake that may happen during their staying in Greece. Earthquake emergency plans and drillsIn order to enhance the preparedness of the pupils, in every school three earthquake drills have to be contacted every year, according to their emergency plan. E.P.P.O. is providing the guidelines for those plans.Earthquake Training Programs- "Earthquake and Protection measures at schools"Its aim is to train teachers and educators through regular 2-days seminars, in every region of the country. - "Seismopolis - Pilot integrated System for Public Familiarization with Earthquakes and information on Earthquake Protection""Seismopolis" is a Centre, addresses to students, adults, elderly people, emigrants and people with disabilities and aims to the improvement of public earthquake behaviour, through new technologies, like earthquake simulation and virtual reality systems. - «Protecting myself and the others»E.P.P.O. is one of the main stakeholders of this program which aims at training volunteers to acquire skills for risk and crisis management and emergency response. All actions are oriented towards well informed and motivated people for building a culture of earthquake resilience, since Greece is one of the most seismically active countries of the world.

OS2/FR/O2 - EARTHQUAKE EDUCATION FOR RISK REDUCTION IN ROMANIA: THE BALANCE BETWEEN SEISMOLOGICAL INPUTS, VULNERABILITY OF BUILDINGS AND PUBLIC RISK PERCEPTION

E. Georgescu[1]
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The paper presents the issues of earthquake education, as it is related to the patterns of seismicity and risk perception in Romania, where seismic areas cover 65% of the territory, including almost 75% of population. The Vrancea intermediate earthquakes of November 10, 1940 (M_w=7.6) and March 4, 1977, (M_w=7.4) are benchmarks for seismology and engineering. Next Vrancea earthquakes of August 30, 1986 (M_w=7.2) and May 30, 1990 (M_w=7.0) were not as strong as to produce large damage and victims, and thus be a public memory; in fact, about 50% of the nowadays population does not have the experience of stronger earthquakes. After the 1990's, the likelihood of Vrancea source major events became closer to „The Big One" deadline, as it results from statistical prognostics, thus the vulnerabillity and risk reduction became imperative. There was an increased practice to use concrete for foundations and collar beams in rural houses after 1940's, while for urban buildings the earthquake design code was enforced since 1950's. In terms of earthquake preparedness and education, since 1990, we developed posters and illustrated folders, booklets for citizens and institutions, manuals and short documentary films, for children and school staff, staff of kindergartens and nursery, and many are available on-line. After each earthquake, the media focuses its coverage on rumors, meanwhile, some earth physics researchers are feeding the public feeling about an imminent capability to predict earthquakes and other public needs are virused by clairvoyants warnings. The earthquake vulnerability is higher in case of tall reinforced concrete structures built before 1940 and for some structures built before 1977. In Bucharest,383 buildings have been rated as first class risk, out of which some 120 condominia are high-rise, but only a handful were strengthened. Taking into account the reluctant response of apartment owners to official requirements for strengthening buildings at high-risk, it is difficult to judge the extent of public perception's in attained active attitude for seismic risk mitigation. As a conclusion, although the local seismicity benchmarks are important, and awareness exist, the seismic risk perception in Romania of some communities is biased and especially may reach a crisis situation in Bucharest, should a strong earthquake strike. New tools are necessary to convince communities about the needs and ways of immediate risk mitigation and some of them are discussed in the paper

OS2/FR/O3 - THE EARTHQUAKE EDUCATION: THE ALGERIAN EXPERIENCE

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[1]CRAAG

Northern Algeria located along the eurasiatic-african plate boundary is a seismic active zone where strong earthquakes could occur. During history, several destructive events caused the death of thousand people and important damages to cities as Algiers (1716), Oran,(1790) Chleff (1954,1980), Boumerdes(2003). This explain why the earthquake education of the population remains an important issue to reduce the risk in Algeria.For the Algerian strategy for risk reduction to be efficient, earthquake education is mentioned in the law 04-20 for prevention of major risks.In practise, earthquake education is carried out by several institutions as the Civil Defence, the CRAAG, the CGS, the Red Crescent or newspapers.In the education sector, lessons are made for pupils at schools or students at universities. Some post graduate courses also exist at Universities of Algiers, Setif or Mostaghanem.For the future, it is planed to made efforts for an education at large scale using TV channels or involving local authorities.This allows a better awarness of the algerian population which still suffers of the occurence of moderate to large seismic events

OS2/FR/O4 - EARTHQUAKE PUBLIC EDUCATION EXPERIENCES GAINED BY IIEES IN IRAN

M. Mahdavifar[1], F. Parsizadeh[1]
[1]International Institute of Earthquake Engineering and Seismology (IIEES)

Iran is one of the most seismic countries in the world with complex geology. During 1980-2008, more than 120,000 people killed and 30,000,000 people affected by earthquakes in Iran. Public Education Group of International Institute of Earthquake Engineering and Seismology (IIEES) has conduc-

ted some extensive programs for earthquake risk reduction by increasing of public awareness of earthquake. The programs cover all groups of society such as managers, experts, children, and adults. The activities includes producing educational films for broadcasting in national TV, publication of booklets, pamphlets, and posters, conducting annual national-wide earthquake drills, organization of workshops and exhibitions, and etc. Several studies have been performed to assess the effectiveness of the educational programs, which show the improvement of the public knowledge compared to the period before Manjil earthquake (1990). Nevertheless there is still a long way to go to achieve a fully prepare community in Iran.

OS2/FR/O5 – L'AQUILA, EARTHQUAKE OF 6 APRIL 2009: A TURNING POINT IN THE EDUCATIONAL STRATEGIES FOR SEISMIC RISK REDUCTION.

M. Crescimbene[1], F. La Longa[1], R. Camassi[1], C. Nostro[1], F. Bernardini[1], E. Ercolani[1], V. Castelli[1], M. Rossi[2]
[1]Istituto Nazionale di Geofisica e Vulcanologia; [2]Protezione Civile di Scurcola Marsicana (AQ)

This work compares the experience of the EDURISK Project (www.edurisk.it), educational programs on risk reduction, achieved before and after the L'Aquila (Abruzzo, Italy) earthquake of April 6, 2009. The main elements of the educational process proposed in «peacetime» are critically analyzed and compared with the experience of the emergency (April-September 2009). On this basis, new educational programs have been developed to answer to the new cognitive and emotional needs of schools and people in the post-earthquake. The study also presents preliminary results of a survey on perception of risk conducted after 2009 April 6th earthquake in 4 affected areas in Abruzzo (Italy) on a sample of about 500 teachers (12 schools of all types and levels). The research design combines a quality life, psychometric, and cultural theoretic approach. The subjects were assessed using: the brief version of the World Health Organization Quality of Life Assessment (WHOQOL-Bref); a Post-Ante Earthquake Questionnaire (F. La Longa and M. Crescimbene), to compare some aspects of daily life and opinions before and after the earthquake; Input and Output EDURISK Project Questionnaire, given at the beginning and at the end of the Project. Data on risk perception and awareness is considered to be fundamental to determine the behavior towards risks and decision making, in order to develop effective information and risk educational programs.

OS2/FR/O6 – RESIDENTS' AWARENESS OF SEISMIC RISK: THE 6 APRIL 2009 EARTHQUAKE OF L'AQUILA, ITALY.

F. Appiotti[1], F. Marincioni[1]
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On Monday April 6, 2009, a Mw 6.3 earthquake hit the city of L'Aquila, Italy, leaving 308 deaths and 1500 injured. The extend damages on the built environment left 22,000 people homeless and temporarily displaced another 65,000. Field studies and surveys were carried out in the aftermath of such disaster to clarify local population's perception of seismic risk, and the adopted mitigation strategies. Pre-impact communication and exchange of earthquake knowledge between the citizens and the governmental organizations, responsible for emergency management, were also analyzed. It emerged that despite the long record of historical earthquakes that struck the region, and the swarm of foreshocks that hit the region since 4 months before the main quake of April 6, the residents of L'Aquila had a rather low seismic risk perception. Prior to the event, very few people acknowledge the possibility that a very strong earthquake could occur in L'Aquila, and even less planned for auto-protective behavior. Also, the traditional knowledge and earthquake myths appeared to have strongly influences people's perception and response to the seismic event. These findings were also corroborated by a broader survey, executed away from the earthquake region, highlighted an unjustified confidence in the seismic safety of Italy's built environment (houses and infrastructures in general). In L'Aquila, such a low perception of earthquake risk, and mistaken belief of buildings' structural resistance, appeared to have inhibited emergency planning at the individual, family and community level. Indeed this false sense of security also reduced dialogues among friends and within families about earthquake mitigation and preparedness strategies. Remarkably, school activities about earthquake risks, initiated during the foreshock period, appeared to have sensibly increase risk awareness among students, who in turn encourage family discussions about earthquake emergency planning and survival strategies. School programs about earthquake risk, backed up by public education campaign, field exercises and drills organized by the local emergency management agencies, could help individuals and household integrating and updating the lingering outdated traditional earthquake knowledge. Vernacular narrative, museum expositions, or itinerant shows could promote education and outreach for seismic risk reduction, foster a culture of safety, and coalesce groups and create earthquake resilient communities.

OS2/FR/O7 – IS IT POSSIBLE TO ATTENUATE SOME "POST-SEISMIC VIBRATIONS" AMONG THE PUBLIC? EXPERIENCE FROM THE MW 6,3 L'AQUILA EARTHQUAKE.

C. Nostro[1], R. Camassi[1], M. Moretti[1], F. La Longa[1], M. Crescimbene[1], A. Govoni[1], M. Pignone[1], G. Selvaggi[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia

This work describes all the activities of information, following the earthquake of April 6, 2009 L'Aquila (Central Italy), aimed to the Department of Civil Protection (DPC), to the operators involved in emergency, to the people affected by earthquake and teachers of schools opened immediately after the earthquake and in September. These initiatives arise from different experiences and skills gained in recent years in seismic risk reduction projects and in the field of information and emergency management. Just after the April 6 earthquake, the COES (Centro Operativo Emergenza Sismica, Seismological Emergency Operational Center) has been installed in the DICOMAC (Directorate of Command and Control - which is the central structure of the DPC that coordinates the emergency activities in the areas affected by the earthquake) in the Guardia di Finanza headquarters in Coppito (L'Aquila). The COES has been a reference information point for all people involved in the crisis management and has provided also psychological support to the rescuers and to the earthquake affected population. Other targeted initiatives have been organized: 1) the EmerFOR project targeted to the teachers living in the first aid tent cities (April-June 2009); 2) the "La Terra tretteca… Ji No!" project targeted to the L'Aquila residents living in the first aid tent cities (April-August 2009); 3) the "La Terra tretteca… Ji No! – Ritorno a scuola" project targeted to the schools in the most damaged areas (September 2009). These initiatives has been extremely useful to answer to the informative needs of the general public on three main topics: 1) basic knowledge on seismology and Italian seismicity to better understand the seismic sequence evolution in Abruzzo; 2) a detailed scientific information on the seismic sequence evolution (but anyway easy to understand); 3) basic knowledge on the emotional response to catastrophic natural events like earthquakes and, if necessary, psychological support to the people shocked by the earthquake. This experience shows the importance of efficient communication by specialists during emergency period because they can provide answer to scientific topics that would otherwise remain mysterious or poorly explained. This information activity has proved to be extremely effective during the post-earthquake period (when aftershocks are possible) and also some months later the main earthquake, when normal activities have been started.

OS2/FR/O8 – ANTI-SEISMIC SAFETY OF SCHOOLS: FROM TECHNOCRATIC APPROACH TO DEMOCRATIC SOLUTIONS?

S. CARTIER[1], L. COLBEAU-JUSTIN[2]
[1]CNRS PACTE; [2]independant

Anti-seismic safety of schools: from technocratic approach to democratic solutions? During a trans-disciplinary scientific program we develop a global approach of seismic safety in schools: anti-seismic buildings and trained users.The study is based on a field survey in the Alps area and Martinique about the safety management in schools:- public building owners, builders, administrations, safety management professionals - users : National Service of Education, schools directors, teachers, training observation- comparison with international experiences of coping with quake and management of seismic safety.This contribution focus on international comparison of political implication in seismic safety of schools: how to engage collective action to avoid buildings collapse?Considering international panel of safety policy in public schools, we can admit that safety is a consensual aim. Each country invests in school buildings according its financial capacity. But school building management is very different according the country: national investment, community investment. Most of countries try to bring more school facilities to a grower child population. The level of safety depends also

very much of local tradition of protection to hazards and dangers.Anti-seismic expertise provides technical safety for new building according the self capacity of the country. The progress of seismology and civil engineering help to design buildings adapted to local constraints. Commonly, the mobilization for seismic safety follows a catastrophic situation in schools. But we can also observe the influence of international agencies, public or private, to bring models of management. The development of an international monitoring from Japanese experience to UNESCO and OCDE guidelines: frame of governance: education investment, safety of children, national expertise, communities empowerment, financial transparency, local control, social and economical studies.The gap between local building skills and international technical standards explain most of the difficulties to apply anti-seismic codes. For every country, the interrogation about the control of safety for public buildings leads to examine the power distribution among national administrations and local communities.The challenge is to achieve safety dealing with:
- 1) capacity of national rules (technical patterns, legal frame, financial management)
- 2) to admit community adaptation (local materials, traditional architecture, technological innovation, community investment and control)
- 3) to local constraints (topography, site effects)
- 4) without weakness in safety control, public finance and professional liability?

OS2/FR/O9 - SPARKLING SCIENCE – TECHNICAL AND NATURAL CATASTROPHES

C. Hammerl[1], U. Mitterbauer[1], G. Wotawa[1]
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Sparkling Science is a research programme from the Federal Ministry of Science and Research in Austria. One special feature of the programme is where experienced Scientists work side by side with young people on research projects in which the young colleagues are not just involved as observers; they actively participate and even work independently on parts of the research.

An interdisciplinary group of meteorologists, seismologists and historians of ZAMG are going to submit a project in the frame of Sparkling Science dealing with Technical and Natural Catastrophes.

Atomic radiation is a very difficult topic. Radiation is invisible, odourless and unperceivable by any of the human senses. High radiation doses may lead to severe injury and death, while lower doses may have long-term health effects more difficult to link to a cause.

We will work together with schools and students to investigate perception as well as a-priori information related to the topic of nuclear disasters. Furthermore, we will establish how information and knowledge on the issue can help to enhance the level of preparedness, taking into account also experiences gained during and after the Chernobyl nuclear disaster and the general information made available on the topic by the Austrian radiation protection authorities.

One topic in the frame of an INTERREG IV project – HAREIA Historical And Recent Earthquakes in Italy and Austria – is the investigation of historical earthquakes in Tyrol/Austria. Students will be involved in the research activities, e.g. to collect information about the structure of houses in Tyrol and about the history of owners of those houses in Innsbruck or Hall, which were damaged by the historical earthquakes.

Students will produce information material and leaflets regarding nuclear emergency response and earthquake preparedness that will be used in schools.

Another important topic of the project will be the reflection on selected themes of earth sciences, which will support children's and students' interest for natural phenomena. By simple hands-on experiments natural laws can be understood and the practical experience can be transferred to other processes.

Experiments will be designed so that children/students can experience forces forming the Earth. The aim is to develop children's curiosity and awareness of earth processes. Children are fully involved in measuring processes, data collection, analysis, and discussion of the obtained results by carrying out classroom experiments. The active participation of the children provides a good basis for effective learning.

OS2/FR/O10 - THE "O3E" PROJECT: AWARENESS ON NATURAL HAZARD AT SCHOOL OBSERVING THE ENVIRONMENT THROUGH SEISMIC, METEO AND HYDRO MEASUREMENTS

G. Ferretti[1], C. Eva[1], D. Scafidi[1], A. Sornette[2], S. Solarino[3], J. Berenguer[4], F. Courboulex[5], E. Baroux[5], J. Le Puth[5], R. Cremonini[6]
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The "O3E" project (European Observatory for Education and Environment) is established after 10 years (1997-2007) of regional, national and international programs ("«Sismos of the Schools", "Rinamed Medocc"), and from Italian ("Edurisk") and Swiss experiences ("climAtscope", "Seismo-at-School") concerning environment tools for education. The project, that is a cooperation between France, Italy and Switzerland, is born to promote a responsible behaviour of citizens in front of the evolution of a society where scientific information is promptly available. The main objective of the project is the raising awareness on Natural Hazards at school. To this aim, more than 20 schools in the Alpine and Ligurian areas have been equipped with environmental sensors for measuring the movement of the ground (seismology), the temperatures, relative humidity, solar radiation, precipitations and wind characteristics (meteorology), some chemical and physical parameters of seas, lakes and rivers (hydrogeology). The students have learned to install and use the instruments, to collect and process the recorded data and to make their findings and data available through Internet to the entire educational community. From the operative point of view, seismic and meteorological networks, composed by respectively 22 and 19 stations connected in real time to the "O3E" servers, have been installed and currently collect data suitable for studying the recent seismicity (in terms of both local and teleseismic earthquakes) and the weather characteristics and evolution. Students and teachers learn to analyse and interpret seismograms and meteo data under the guide of the researchers through the educational and computer equipments provided by the "O3E" partners. In particular, all participating schools have been provided with educational books on natural hazard and risk prevention designed for different school levels, interactive USB keys with software specifically selected for data management and education purposes, cook-books for teachers. A multi-language interactive website acts as a data repository and document center, allowing both teachers and students to work on real-time data incoming from all instruments installed in the schools.

OS2/FR/O11 - NEEDS ASSESSMENT OF BAM STRICKEN - PEOPLE DURING THE FIRST 30 MONTHS OF EARTHQUAKE

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For the first time after a major earthquake in Iran, problems, comments and issues of affected people has been analyzed through a local newsletter. This paper will provide a brief description of needs of earthquake stricken people in Bam by reviewing the news values of different variables in a local newsletter within a period of two years. After the Bam earthquake on December 26 of 2003, the affected people needed a media in order to express their experiences, comments and difficulties and also to be aware of activities around them. For dissemination of information among the people many pamphlets and newsletters have been distributed in the city after an earthquake, but one newsletter has been published systematically for exchange of information in the region. In this article the news values of different issues and variable of this newsletter for a period of two years will be reviewed by content analysis.

OS1 - EARTHQUAKES AND SOCIETY: IS THE WAY SEISMOLOGISTS COMMUNICATE SATISFACTORY?

Friday 10, 08h00-10h00

Friday 10, 10h20-12h00

OS1/FR/O1 - EARTHQUAKE COMMUNICATION IN EIGHTEENTH CENTURY SWITZERLAND

M. Gisler[1], S. Fritsche[1], D. Fäh[1]
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The trend in the sciences over the last decades has been toward high barriers to effective dialogue between experts studying high-risk environments and the people living

in them. In seismology, the tendencies in this respect do not differ. In our contribution we aim to lay out the landscape of an eighteenth century discussion on earthquakes and how an inclusive discourse became exclusive towards its end. In the first few decades of the century, the amalgamation of reason and faith produced a dynamic that generated the modern forms of scientific thinking. The divide between experts and amateurs was not yet firm, and conversations between the interest groups were not yet hampered by specialization and technical jargon. Rather it was a running negotiation between an abstract, universal, and technical knowledge and the values and experiences of the particular groups. By the end of the century, everything had changed. With the claim to enhance and refine science, a disciplinary distinction was the result, and the scientific discourse became hence exclusive. The divide between science and society took its course.

OS1/FR/O2 - REAL-TIME AND POST-EVENT RESPONSE TO A LARGE EARTHQUAKE NEAR A DENSELY INSTRUMENTED REGION IN SOUTHERN CALIFORNIA: THE 2010 MAGNITUDE 7.2 BAJA CALIFORNIA, MEXICO EARTHQUAKE

R. Newman[1], F. Vernon[1], D. Kilb[1], J. Eakins[1], L. Astiz[1], C. Clark[1]
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The M7.2 earthquake that took place on April 4th, 2010 at 22:40 UTC occurred just south of a region with a high density of broadband seismic instrumentation operated by both Scripps Institution of Oceanography (SIO) at UC San Diego and a cooperative seismic network project of Caltech and the United States Geological Survey. The epicentral region and extended region (within +/- 50 miles of the mainshock) continues to experience aftershocks, with our SIO-operated Anza seismic network recording over 2500 earthquakes within the first month of the event, of which > 400 were magnitude 3.0 or above. This large regional earthquake and the subsequent media and public response allowed us to assess a joint seismologist and communications-specialist system that has been in place for over 4 years. Our system has two approaches:

1. An automated real-time response that sends alarms to the relevant personnel and updates web-based interactive maps and tables for immediate consumption

2. A post-event reviewed response that provides the following materials to the media:

- contact information for both seismologists and communications specialists;

- downloadable media including real time event maps, interactive web-based Google maps of the region, and Google Earth (KML) files;

- 3D time-lapse animations of the event that include regional historical seismicity since 1982;

- 3D visualizations that allow the user to interactively explore the spatial extent of aftershock locations;

- social media updates including Facebook and Twitter;

- time slots for live telecasting with a roster of in-house seismologists

In the weeks following the M7.2 event, scientific information was broadcast (e.g. via television, radio, internet and print) across the United States to over 20 different media outlets, often with repeat broadcasts relaying the latest information. Internet traffic to our web-based educational materials went up by over 1,600%, with approximately 53,375 page views (up 2,600%) of the materials. In this session we will discuss our response system to this notable earthquake, including what was successful and what could be improved.

OS1/FR/O3 - DEVELOPMENT OF AN EARTHQUAKE IMPACT SCALE

D. Wald[1], K. Marano[1], K. Jaiswal[1], M. Hearne[1], D. Bausch[2]
[1]U.S. Geological Survey; [2]Federal Emergency Managment Agency

With the advent of the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) system, which rapidly assesses earthquake impacts, U.S. and international earthquake responders are reconsidering their automatic alert and activation levels as well as their response procedures. To help facilitate rapid and appropriate earthquake response, we propose an Earthquake Impact Scale (EIS) based on two complementary criteria. One, based on the estimated cost of damage, is most suitable for U.S. events; the other, based on the estimated ranges of fatalities, is generally more appropriate for global events, particularly in developing countries. Simple thresholds, derived from the systematic analysis of past earthquake impact and associated response levels, turn out to be quite effective in communicating predicted impact and response needed after an event, characterized by alerts of green (little impact), yellow (regional impact and response), orange (national-scale impact and response), and red (international response). Corresponding fatality thresholds for yellow, orange, and red alert levels are 1, 100, and 1000, respectively. For damage impact, yellow, orange, and red thresholds are triggered by estimated losses reaching 1 million, 100 million, and 1 billion USD, respectively. The rationale for a dual approach to earthquake alerting stems from the recognition that relatively high fatalities, injuries, and homelessness dominate in countries where local building practices typically lend themselves to high collapse and casualty rates, and it is these impacts that lend to prioritization for international response. In contrast, it is often financial and overall societal impacts that trigger the level of response in regions or countries where prevalent earthquake resistant construction practices greatly reduce building collapse and resulting fatalities. Any newly devised alert, whether economic- or casualty-based, should be intuitive and consistent with established lexicons and procedures. Useful alerts should also be both specific (though allowably uncertain) and actionable. In this analysis, we make an attempt at both simple and intuitive color-coded alerting criteria; yet, we preserve the necessary uncertainty measures by which one can gauge the likelihood for the alert to be over- or underestimated. The essence of the proposed impact scale and alerting is that actionable loss information is now available in the immediate aftermath of significant earthquakes worldwide based on quantifiable loss estimates. Utilizing EIS, PAGER's rapid loss estimates can adequately recommend alert levels and suggest appropriate response protocols, despite their uncertainties; demanding or awaiting observations or loss estimates with a high level of accuracy may increase the losses.

OS1/FR/O4 - MEDIA COMMUNICATION ON SEISMIC HAZARD IN MOROCCO

T. Mourabit[1]
[1]Abdelmalek Essaadi University

Communication through Media has a great function in seismic hazard social sensitization. Several cases experimented with different media ways (Radio and News papers) in Morocco show the difficulties to establish a fruitful communication with public at large. Language plurality, Analphabetism, Technical difficulties and security fairs are the most important impediments toward an effective and positive awareness in Morocco. Examples related to 2004 Alhoceima Earthquake are given and discussed.

OS1/FR/O5 - SEISMOLOGISTS AND THE WEB: IS WIKIPEDIA AN ALLY OR AN ENEMY ?

S. Solarino[1]
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When dealing with the search of a topic over internet, Wikipedia is often at the top of the list of sites which can provide the required information. As known, Wikipedia is a free, web-based, collaborative, multilingual encyclopedia supported by a non profit project. Its 15 million articles (over 3.3 million in English) have been written collaboratively by volunteers around the world, and almost all of its articles can be edited by anyone with access to the site. Wikipedia was launched in 2001 and is currently the largest and most popular general reference work on the Internet. Wikipedia began as a complementary project for Nupedia, a free online English-language encyclopedia project whose articles were written by experts and reviewed under a formal process. Unfortunately, the times for editing and correcting the articles were too long and Nupedia only published 24 articles before being abandoned.

There are several advantages and disadvantages in a project like Wikipedia. Among the first, one should mention the rapidity in publication, the chance to enlarge a primitive article in further steps, the availability to many more people than printed documents, the free character.

On the other hand, the many disadvantages are also evident. One over all: the philosophy of publishing an article without review and in successive steps may be the source of misunderstanding and mistakes. The errors contained in an article are in fact removed time after time, however the original form is available to the public for several days, which often coincide with the period of major accesses in the search for information.

Moreover, the compilation and review made by non-experts may be not completely correct and exhaustive, but the user (which is not familiar with the topic) has no clue to distinguish a good from a fair article.

In this presentation a few examples will be given to show failures and merits of Wikipedia together with some suggestions on how to correctly approach the information contained within. The results are then used for a critical analysis on the relationships between seismologists and the web.

OS1/FR/O6 – WEB-MEDIATED COMMUNICATION EXPERIENCES AT ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA (INGV)

G. Rubbia[1], F. Mele[1]
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The newer communication tools have changed the relationship between science and society. Internet pervasiveness led citizens to rapidly inform through on line sources, and, on the other hand, to provide themselves information. From an institutional communication perspective this new sociotechnical landscape forces scientists to rapidly adequate to web population requirements.

Questions and comments posted to INGV web sites during the 2009 L'Aquila (Italy) seismic sequence gave significant hints about demand of information. They included: questions concerning possible evolution of the sequence; clarifications about news reported by media, asking for detailed explanations and/or qualified opinions; requests for help in providing information to population; notices about information available on INGV web sites; communication of felt seismic effects.

People who post questions to INGV institutional web sites are themselves information suppliers, in providing: what they felt, in case of posting macroseismic effects; what they heard about the earthquake from other sources; how they feel (worried, confident, grateful ...); what they know and what they want to know; what they actually understand from the scientific website.

From the point of view of a scientific organization, this kind of web-mediated communication is precious in that it can reveal and provide many clues about: 1) public expectations and understanding of on going scientific activities 2) to what extent information dissemination, communication and outreach activities can be considered effective or to which extent they need improvements.

A mutual approaching is needed. Seismologists acting as responders during an emergency perform a delicate job: they have to be transparent and make themselves understood; comprehension of scientific information would benefit of appropriate outreach activities carried on during all the time.

Consisting the INGV web disseminating system of several institutional and thematic web sites, similar patterns of questions and comments emerge: «network effect», when questions are posted at the end of a navigation session through different web sites, and may not pertain to the content of that specific website; «resonance effect», when more questions about earthquakes are posted soon after a big one. A «welcome» effect is also manifest, as experts providing accurate replies in a timely fashion stimulate web visitors in posting new questions.

Case studies of web-mediated communication will be discussed, as experimented by the Institute through the nodes of its web disseminating system.

OS1/FR/O7 – EARTHQUAKE INFORMATION TO AUTHORITIES, MEDIA AND THE PUBLIC IN SWITZERLAND

F. Haslinger[1], J. Clinton[1], E. Ballarin-Dolfin[1], P. Kästli[1], U. Kradolfer[1], D. Giardini[1]
[1]Swiss Seismological Service SED, ETH Zurich

Switzerland is a country of moderate seismicity and corresponding moderate seismic hazard. M ~6 events occurred in the past every 60-100 years in the Valais region, and the largest event documented north of the Alps (M ~6.6) took place in Basel (northern Switzerland) in 1356. The chance of damaging earthquakes, together with the density of population and vulnerable infrastructures, leads to a significant earthquake risk in Switzerland, despite the moderate hazard. Felt earthquakes occur a few times per year, and regularly even M ~4 events create significant public and media interest. Since many years the SED has set up and continues to improve an alerting system based on automatic near-real time earthquake detection and location, automatic dissemination of initial alert information to authorities and media, and automatic publishing of information via the internet, with optional manual updates. However, the demand of today's 'information society' on timeliness of information is ever rising, increasing the load on internal resources, and require careful balance of the scientific need for a complete analysis of an event with the request from public and media for immediate event information. A second, rather recent development is the increased requirement to respond to 'public interest' projects (geothermal energy, deep geological waste repositories, CO_2 sequestration). While the scientific accompainment of such projects is a core task of SED as the Swiss federal agency for earthquakes and earthquake hazard, particularly the reporting of seismic events in the vicinity of these projects (which may be related to the project activity or not) is politically sensitive and requires special care. In this presentation we will describe the current processes and procedures of earthquake alerting at SED, outline envisioned future developments, and discuss challenges that we see for the future of earthquake communication.

OS1/FR/O8 – MEDIA AND SEISMOLOGISTS IN OCCASION OF THE 2009, L'AQUILA EARTHQUAKE

M. Stucchi[1], C. Meletti[1]
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Generally speaking, seismologists are not experts of risk communication. Seismologists are, in most cases, seismologists. However, after a destructive event it happens that media force seismologists out of the fridge where they have been kept during the seismic quiescence and put them in front of cameras, questions interviews, etc. It is then hard for seismologists to refrain from jumping in the pitfall; although they know that everything they will say can be cut in pieces, reorganised and even manipulated, they usually consider their duty to release ideas, views, etc. The recent, 2009 L'Aquila earthquake was a turning point with respect to this aspect. Triggered by the problem of the presumed, unlistened earthquake forecast, media, bloggers and individual started searching for «responsibilities» of damage and casualties. It was then the case of accusation for: «true» magnitude value being kept secret, or lower than the reported one, to allow repair contribution to be kept as a minimum (great confusion between magnitude and intensity, as usual in Italy, by the way); aftershocks not being revealed, for the purpose of not informing or alerting the public; l'Aquila area being kept by the Regional Administration in seismic zone two instead of one, thus allowing damage to be higher; etc. This earthquake also showed a very high increase of information demand, in many cases presented in the blogs or the dedicated web pages in a very aggressive way, by fellows who discovered themselves as potential, when not well expert seismologists. On the other hand, geologists and seismologists, even if non necessarily expert on risk communication or without direct information about the earthquake, discovered the occasion for appearing on TV and newspapers, increasing the amount of wrong interpretation. We believe that, in such a way, the risk communication has to be reconsidered. As a matter of fact, earthquakes are not only a scientific affair; they have to do with the safety of the people. As such, the main source of information should be few, official ones: Civil Protection above all, and large, scientific institutions speaking through officials. During an earthquake sequence individual seismologists should refrain from being adopted by media and from running after them for benefitting from the opportunities. They should better keep their expertise and patience to help society not forgetting about earthquakes when earthquakes seem to give the floor to other issues.

OS1/FR/O9 – COMMUNICATING TIME-DEPENDENT SEISMIC HAZARD AND RISK: SHOULD SEISMOLOGIST TELL PEOPLE TO SLEEP IN A TENT AFTER A MODERATE EARTHQUAKE IN THE NEIGHBORHOOD?

S. Wiemer[1], M. Gerstenberger[2], J. Woessner[1], T. vanStiphout[1]
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Earthquakes cluster strongly in space and time. Consequently, the most hazardous time that seismologist can identify with confidence is right after a moderate to large earthquake has happened. There is a 0.05-5% probability that such an event will be followed by a subsequent 'aftershock' which happens to be as large or larger than the initiating event, or smaller true aftershock large enough to cause damage itself, especially to already weakened structures. Immediately after a quake is also the time of heightened interest in earthquake information: the public, media and decision makers are 'demanding' answers to simple yet

scientifically challenging questions such as: Will there be large aftershocks? When will the next big one come? Is it save to stay/travel to certain areas? Should I stay outside for some time?

It was a widely accepted practice in Italy in the 17th century to remain outside of buildings for two days after a moderate to strong earthquake, in order to avoid casualties due to subsequent events. Today, the state of the art science in time-dependent hazard and risk assessment, supported through cost-benefit analysis, would in almost all cases suggest that no actions, and certainly no evacuations, are required. This is despite the fact that during such seismic crises, the risk is elevated by several orders of magnitude. The communication challenge seismologist face is considerable: how to explain to the media and public in an understandable language earthquake clustering and its implications for risk? How to best give time-dependent probabilistic hazard and risk information to decision makers and civil defense? This contribution will review briefly the state of the art in time-dependent seismic hazard and risk assessment and compare the communication and deciosn strategies and platforms available now and planned in the near future, for example as part of the EU FP7 project NERA. Examples include the Short Term Earthquake Probability (STEP, earthquake.usgs.gov/earthquakes/step/) web page in operation in California now for about five years, a case study for Switzerland, and suggestions drawn from the L'Aquila earthquake.

MONDAY 6, TUESDAY 7

SD5 - EARTHQUAKE-INDUCED LANDSLIDES AND APPLICATION OF SEISMIC MONITORING TO CHARACTERISE LANDSLIDE DYNAMICS

SD5/P1/ID1 - LOCALIZATION OF SEISMIC SIGNALS ASSOCIATED WITH MICRO-EARTHQUAKES AND ROCKFALLS ON THE SÉCHILIENNE LANDSLIDE, FRENCH ALPS

P. Lacroix[1], A. Helmstetter[1]
[1]LGIT/CNRS/UJF

The Séchilienne rockslide, in the French Alps, has recently been instrumented with three seismic arrays. This network has recorded numerous rockfalls and local micro-earthquakes. Because the media is highly fractured, it is difficult to identify and pick first arrivals.

Beam forming methods were therefore used to locate these events. The method has been adapted to take into account the heterogeneity of seismic waves velocities. The location accuracy has been estimated to be about 50 meters for epicenters by applying the method to calibration shots.

This method of location has been first applied to rockfalls and allowed the rockfalls localization and the estimation of their trajectory and propagation speed. Finally, 55 micro-earthquakes have been located. Micro earthquakes are located within the first 250 meters below the surface. Two zones are seismically active. Most micro-earthquakes are located in the most active part of the rockslide whose velocity has increased from 0.5m/yr in 1996 to 1.4m/yr in 2008. These events are located close to three faults that delimit a mass of about 3.6 million m3. Other events are located close to the summital scarp, in a zone moving at a few cm per year.The western part of the rockslide, which moves more slowly, did not produce any event large enough to be detected simultaneously by all stations. This suggests that this zone deforms aseismically.

SD5/P2/ID2 - SEISMIC MONITORING OF SNOW AVALANCHE : ONSET, PROPAGATION AND RUNOUT STYLES

P. Lacroix[1], J. Grasso[1], A. Helmstetter[1], J. Roulle[2], J. Navarre[2]
[1]LGIT/CNRS/UJF; [2]CEN/CNRM/GAME

The avalanche activity assesment is usually based on visual observation. To improve the detection of snow avalanches and therefore to better constrain the models used for natural avalanches forecasting, seismic detection has been developped by CEN group for the last twenty years, using a single 3 component sensor.

To improve the single 3 component sensor monitoring, we installed during the 2009-2010 winter, a seismic antenna in Saint Christophe en Oisans, 80km away from Grenoble, in the French Alps. The antenna is composed of six vertical and one 3-component sensors. This array aims at i) localizing the snow avalanches during the initiation and propagation phases, ii) studying the triggering factors of snow avalanches, iii) comparing rockfall and avalanche signals.

The array worked during 40 days in January and February 2010, and recorded different events including avalanches, rockfalls and local micro-earthquakes. More than 90 avalanches signals were identified based on their signal spectrum and signal length.

The snow avalanche sources were located using two different methods: a beam forming and a polarization analysis method. The beam-forming method allows to follow the avalanches during their propagation. We finally present preliminary analysis on the influence of weather (temperature and snow fall) on the dynamics of avalanche activity.

SD5/P3/ID3 - SEISMIC MONITORING OF SÉCHILIENNE ROCKSLIDE (FRENCH ALPS): ANALYSIS OF SEISMIC SIGNALS AND THEIR CORRELATION WITH RAINFALLS

A. Helmstetter[1], S. Garambois[1]
[1]LGIT, CNRS and University of Grenoble, France

In the French Alps, Séchilienne rockslide presents a high risk in terms of socio-economical outcomes. This rockslide has been recognized as active for a few decades and has been instrumented since 1985. The current very active volume is estimated to be up to 3 millions m3, and is located on the border of a slowly moving mass reaching 50 to 100 millions m3. The velocity of the most active zone has reached 1.4 m/yr in 2008, about twice the value of 2000. To complement the monitoring system, presently based on displacement measurements, a seismic network was installed in May 2007. It consists in three seismological stations deployed as antennas with 37 velocimeters. The seismological network has now recorded several thousands events, mostly rockfalls but also hundreds of local (within the rockslide) and regional earthquakes. The recorded events can be classified as rockfalls, micro-earthquakes, or external earthquakes from their signal characteristics, such as frequency, duration, location and apparent velocity. A few of the largest rockfalls detected by the seismic network were also recorded by a camera facing the landslide. The camera provides a rough estimation of the rockfall volume, which can be used to calibrate the seismological network. Rockfalls and micro-seismicity occur in burst of activity, which are weakly but significantly correlated with rainfall. Rockfall occurrence increases linearly with precipitations, with however strong fluctuations of the numbers of rockfalls for the same rainfall intensity. No minimum threshold was found for rainfall triggering, even one mm of rain being enough to trigger rockfalls. Rockfall activity starts immediately during a rainfall episode and lasts for several days after the rainfall.

Micro-earthquakes are less clustered in time and the correlation with rainfall in weaker than for rockfalls. Rockfall activity is also correlated with the rockslide displacement rate, probably because both the rockfall activity and the displacement are activated by rainfall.

SD5/P4/ID4 **- PREDICTION OF EARTHQUAKE- INDUCED LANDSLIDES IN IRAN**

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A principal cause of earthquake damage is landsliding, and the ability to predict earthquake-triggering landslide displacements is important for many types of seismic-hazard analyses and for the design of engineered slopes.In this studyNewmark's method is selected for predicting approximate landslide displacements as an indicator for earthquake-induced landslides hazard. To avoid the computation complexity and difficulties of selecting an appropriate earthquake time-history, the simplified Newmark model (Jibson et al. ,1998 and Jibson, 2007) was used. According to Mahdavifar et al. (2008), and Rajabi et al.(2010), a GIS-based platform is developed by which shaking intensity and seismic landslide hazard zonation maps can be generated for Iran territory. For testing the system, earthquake-induced landslides hazard map of the Manjil earthquake affected area (1990, MS=7.7) is produced. It is shown that the map could predict high hazard regions in an acceptable level.

SD5/P5/ID5 **- DELINEATING AREAS PRONE TO EARTHQUAKE-INDUCED ROCK FALL USING GIS-BASED METHODS: CASE STUDY OF MOUNTAIN SKOLIS, GREECE**

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Abstract The potential of a slope failure, triggered by an earthquake, can be mainly evaluated by three methods; the pseudostatic, the statistical and the permanent analysis. The latter accesses the landslide hazard by providing information regarding actual slope stability based on accepted characterization of earthquake-shaking severity. The advantage of the Newmark's displacement approach over more recent developments is that the only additional information beyond that required for static stability analysis is the acceleration time history. The permanent-displacement approach models a landslide as a rigid block that slides on an inclined plane. Movement of the block occurs when the sum of the static and dynamic driving forces exceed the shear resistance of the block. In particular, the block has a known critical (or yield) acceleration, ac, which is simply the threshold base acceleration required to overcome shear resistance and initiate sliding. Thus, permanent deformation occurs when induced accelerations exceed the critical acceleration In this study, a method proposed by Newmark (1965) was applied in order to estimate the slope failure potential in an earthquake prone area in NW Peloponnesus, Greece where a shock of magnitude Mw=6.5 occurred in June 8, 2008. The GIS-based approach resulted to maps where the predicted displacement and the probability of slope failure are shown. Visually comparing the resulting maps with the distribution of the earthquake-induced rock falling phenomena is shown that the source areas of rock falls could be delineated, thus, the structural damages caused by the slope failure could be predicted.

SD5/P6/ID6 **- SPATIAL PATTERNS OF EARTHQUAKE-TRIGGERED LANDSLIDES**

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We perform a comprehensive comparison among five landslide space distributions, for landslides triggered by the Chi-Chi Mw7.6 earthquake (Taiwan), by the Mw7.6 Kashmir earthquake (Pakistan), by the Mw7.2 Fiordland earthquake (New Zealand), by the Mw6.6 Northridge earthquake (California) and by the Mw5.6 Rotoehu earthquake (New Zealand). We use landslide densities and distances to epicenter and to fault trace, these two latter being normalized by the earthquake size. We also use the aftershock distance distribution of each triggered sequence as a metrics to compare different sequences to each other. It allows to remove some of the specificity of the source effect for a given earthquake trigger. These cross analyses allow to compare the landslide distribution data in a sensible and consistent way. The results we derive here question some of the earlier findings. The analysis for the Chi-Chi earthquake-triggered landslides demonstrates that the landslide density does not cluster around the epicenter but is high in the vicinity of the fault rupture. This pattern is recovered for the five sequences. The most surprising result is the very clear relationship between the distance probability density function of the landslides and that of the aftershocks. This is unexpected, asking serious questions about the current understanding of co-seismic landslide spatial distributions. Besides, from our analysis, the landslide distributions differ for earthquakes on faults with surface expressions and those that are blind. When we review the mechanics that possibly reproduce these observations, without any definitive answer of the possible explanations, we show that peak ground displacement gives a better correlation with the landslide distance distribution than the peak ground velocity or acceleration, as suggested elsewhere for the Chi-Chi sequence. Last, deviations from the average distribution in space appear as driven by the local settings such as antecedent rainfalls and geology.

SD5/P7/ID7 **- SLOPES INSTABILITY OF THE DOLOMIEU CRATER IN LA REUNION FROM SEISMOLOGICAL OBSERVATIONS AND NUMERICAL MODELING.**

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The intensity of volcanic activity and seasonal rains associated with the instability of the natural slopes has caused many rockfalls in the Dolomieu crater located on top of the volcano Piton de la Fournaise in La Reunion Island. These phenomena, that involve individual blocks up to larger volumes, are expected to be related to the volcanic activity. The unpredictable nature and destructive power of gravitational flows make in-situ measurements extremely difficult. The seismic signal generated by these slope instabilities provides thus a unique tool to trace back these events and retrieve their characteristics (volume, duration, localization, …). The permanent seismic network set on Le Piton de la Fournaise volcano is particularly well suited to the study of seismic signals related to gravitational collapse and of their relation to volcanic activity. Using this network and the new seismic broadband stations recently installed, the seismic signals generated by slope instabilities have been acquired and analyzed. In a first step, signal processing techniques have been developed to distinguish the seismic signal generated by rockfalls from that generated by other seismological events that affect the Piton de la Fournaise Volcano. We focus on the 2006-2007 period, during which the crater has undergone a major collapse. This event has considerably destabilized the Dolomieu crater edges, providing a good opportunity to study the evolution in time of the rockfall activity. Analysis of the seismic signal and simple scaling laws for granular flows made it possible to derive interesting relations between the energy of the seismic waves and the characteristics of rockfalls. The role of the local topography in these relations has been investigated using numerical modeling of dry granular flows and the Digital Elevation Model of the Dolomieu crater constructed by photogrammetric techniques. Good agreement is found between the scaling laws obtained theoretically and those derived from seismic observation providing insight into the effect of the source parameters on the generated seismic signal. The detection methods and the scaling laws developed here provide useful tools for monitoring of rockfall activity, in particular in relation with the volcanic activity. These works were conducted within UNDERVOLC project.

SD8 - DEVELOPING STANDARDS AND PROTOCOLS FOR THE NEXT GENERATION OF RAPID EARTHQUAKE INFORMATION SYSTEMS

SD8/P1/ID8 **- ON THE RAPID AVAILABILITY OF SEISMIC WAVEFORM DATA AT HE ORFEUS BROADBAND SEISMIC DATA COLLECTION CENTER**

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The key data collection operations of the ORFEUS Data Centre (ODC) are build around the Antelope ® software to support real-time data acquisition and processing for the Virtual European Broadband Seismic Network (VEBSN). Within the operations the automatic quality monitoring of the waveform data is crucial as to detect problems in data in an early stage. The detection and event association within Antelope ® is applied within

the VEBSN to compare the data quality from individual stations in a rapid, uniform way. On the other hand, results from this process are used to improve the detection and association process. Although detecting and locating earthquakes is not the primary goal at ODC it is our goal to do this accurate for the purpose of quality control and the (automatic) rapid generation of event-based waveform data. Our experience with Antelope ® applied on a dense, inhomogeneous European-scale seismic network is presented.

SD8/P2/ID9 - TIMELINESS OF THE ISC BULLETIN

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The main mission of the International Seismological Centre (ISC) is to produce and distribute the ISC Bulletin that serves as the definitive summary of global seismicity. The ISC Bulletin is the longest continuous and uniform set of bulletin data. To produce this Bulletin, the ISC receives and processes parametric data for natural and non-natural seismic events from over 120 seismic networks worldwide.Preliminary hypocentre solutions and arrival data from networks (that passed an initial review by seismologist locally) arrive at the ISC in days to weeks after seismic event occurrence. These data are grouped daily as they arrive to form the preliminary Bulletin available from the ISC website. No ISC hypocentre solutions or magnitudes are computed at this point.Final network bulletins arrive at the ISC approximately 12 months after event occurrence and at this time, the corresponding preliminary solutions and arrivals are discarded. The ISC editors analyze approximately 20% of events (mostly those above magnitude 3.5) once all data has been collected. The ISC's own hypocentre solutions and magnitudes are computed and thoroughly reviewed at this point. The Final ISC Bulletin is a result of this analysis, currently performed less than 24 months behind real time. We plan to reduce this delay to approximately 15-18 months despite a constant sizeable increase in the number of station reports.

SD8/P3/ID10 - TOWARD THE DETERMINATION OF AN AUTHORITATIVE LOCATION AT EMSC

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The EMSC publishes rapid earthquakes information on its web site. We know that the differences in the source parameters that EMSC and the other agencies' publish (especially the local agency) can create confusions among the users (e.g., the public, journalists…). It is therefore necessary to determine, among the available locations, which one prevails, i.e. the authoritative location. The authoritative location would be a reliable location which accuracy cannot be significantly improved and which can be used as the reference location by other agencies especially for public information. The EMSC automatically merges phase pickings provided, in real time, by 65 data contributors and relocate each event that has been reported by several agencies. We propose an authoritative location scheme based the principle that the EMSC should not relocate a reliable and accurate location provided by a single agency. A location is considered as reliable if is reproducible and accurate if it fits the Ground Truth (GT) criteria (Bondar et al.; 2004) for a 5 km epicentral accuracy. The advantage is that GT criteria have been independently determined from seismic events with known location (nuclear tests, controlled explosions) and are based on the geometry of the reporting stations. We searched among 12 months of locations provided by the real time data contributors which ones are GT locations and if they are reproducible. It appears that the GT criterion on the closest station which is mostly necessary for hypocentral depth determination, is the most restrictive. We show that discarding this criterion allows to dramatically increase the number of GT locations without decreasing their reproducibility. Indeed, among 54,571 locations provided by a single data provider 10% are GT locations if we do not consider the criteria on the closest station and 98.2% of these GT locations are automatically reproducible within 15 km. The other cases are explained by large station residuals, or station code issues. Only 3 locations can not be reproduced within 15km. They all lie outside the Euro-Med region. A number of issues still need to be addressed for example when, for policy reason an agency does not report all the picks it has used. A second issue is how to credit the source of the authoritative location. This authoritative location procedure will be implemented before the end of 2010 after approval by the EMSC General Assembly.

SD8/P4/ID11 - THE NEW EMSC WEBSITE – NEW SERVICES TO IMPROVE EARTHQUAKE INFORMATION

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Internet is now an essential source of information where users should easily find what they are looking for. EMSC website attracts approximately 1 million visitors per month. This increasing visibility requires making the website as user-friendly as possible in order to answer to users' expectations. In particular, we have focused on improving access to photos provided by witnesses, this information being very popular for the web visitors. Therefore the EMSC website developed a new web site, tailored to the different end-users, the seismologists and the general audience. The web development was made to offer quicker, more intuitive and better information. Among the different new features, earthquake data (pictures, witnesses' reports and their comments) are linked to the earthquake catalogue and searchable. A new witness's location method (based on Google geolocation tools) is proposed. For our macro-seismic questionnaire, 28 languages are now available and 3 others by automatic translation. All comments posted by witnesses in different languages are automatically translated in the web user's language. In order to help the users to easily find the earthquake they just felt, new services are available such as "*Earthquakes Near You*" which provides earthquake information around the user's location. Significant and felt earthquakes will automatic be highlighted on the home page. When a significant increase of our website traffic will be detected, a temporary scrolling banner will come up few minutes after an earthquake occurrence and show that an event has probably been felt in a specific region. This banner will be extremely useful to answer the public needs during the very first minutes after the earthquake occurrence, when people rush on the website to find out more information whereas no seismological information is available yet. Finally, to ensure the 24/7 availability of these services, the EMSC put a lot of efforts to improve the security of this website.

SD8/P5/ID12 - CREATING A UNIQUE CATALOGUE OF SEISMICITY FOR THE NERIES SEISMIC DATA PORTAL. OUTCOMES AND LESSONS.

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The seismic data portal developed during the NERIES project provides access to different seismic data products (waveforms, parameters and accelerometric data) related to the same event. Such uniform access is only possible if a common identifier links the different products. Each institute produces its own data which are useful depending on the type of studies and the area of interest. The Unique Identifier (UNID) aims at linking the information about the same event provided by different institutes which archived their data using their own identifiers. In practice, the creation of the UNID was required for the automatic update of the catalogue displayed on the NERIES portal (www.seismicportal.eu).The EMSC publishes real time earthquake information (RTS) based mainly on automatic phase pickings as well as the Euro-Med Bulletin (EMB) based on manually revised information. The portal is first populated using the RTS information and it is then automatically superseded when EMB information become available. Specific procedures were developed at EMSC to associate in a robust manner RTS and EMB hypocenters.The main principle for this association is to test the compatibility of arrival times in the RTS with the EMB location. A simple search in space and time proved unreliable, mainly because uncertainties can be large in real time. Alternatively, locations from the EMB are considered as reference locations. The compatibility of RTS arrival times is assessed by computing the time residuals for the reference locations. The comparison of the EMB and RTS catalogues proves to be a good opportunity to characterize the EMSC real time information system capabilities. Firstly, events appearing only in the EMB give information about the RTS local magnitude detection threshold. The task is more complicated for events appearing only in RTS. Several reasons could be identified: It may be artificial events (e.g. quarry blasts) that the local networks do not report in their revised bulletin or fake automatic events. By identifying them, an improvement of the RTS data selection is possible. Moreover, automatic phase picking quality of each institute can be assessed by comparing, for each event, picks and phase identifications at stations found in RTS and EMB catalogues. Here, pro-

cedures used to merge the two catalogues and analysis of associated events for the period 2004-2007 will be presented.

SD8/P6/ID13 - QUAKEML: STATUS AND APPLICATIONS OF THE XML-BASED SEISMOLOGICAL DATA EXCHANGE FORMAT

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QuakeML is an XML-based data exchange standard for seismology that is in its fourth year of active community-driven development. The current release (version 1.2) is based on a public Request for Comments process that included contributions from ETH, GFZ, USC, SCEC, USGS, IRIS DMC, EMSC, ORFEUS, GNS, ZAMG, BRGM, Nanometrics, and ISTI. QuakeML has mainly been funded through the EC FP6 infrastructure project NERIES, and will be adopted as a data interchange format in the successor project NERA.

Currently, QuakeML-enabled services and applications are being installed at several institutions around the globe. These include earthquake catalog web services (GNS Science, EMSC, Geoazur), transport of parametric data through EIDS (EMSC, ORFEUS, USGS/NEIC), the event-based waveform retrieval tool Joque (ORFEUS), the Earthquake Data Portal developed within NERIES (seismicportal.eu), the Collaboratory for the Study of Earthquake Predictability (CSEP) testing center installations (SCEC), and QuakePy, an open-source Python-based seismicity analysis toolkit (ETH). Furthermore, the QuakeML data model is part of the SeisComP3 package from GFZ Potsdam.

QuakeML is designed as an umbrella schema under which several sub-packages are collected. Specifications in the schema languages XML Schema 1.0 (W3C) and Relax NG (OASIS) are available.

The present scope of QuakeML 1.2 covers a basic description of seismic events including picks, arrivals, amplitudes, magnitudes, origins, focal mechanisms, and moment tensors. Work on additional packages (macroseismic information, seismic inventory, and resource metadata) has been started, but is at an early stage. Contributions from the community that help to widen the thematic coverage of QuakeML are highly welcome.

Online resources: http://www.quakeml.org, http://www.quakepy.org

SD8/P7/ID14 - QWIDS: A NEW AND STANDARD OPEN-SOURCE TOOL FOR EARTHQUAKE PRODUCTS MESSAGE DISTRIBUTION IN THE UNITED STATES

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Earthquake monitoring networks in the U.S. have relied on the Quake Data Distribution System (QDDS) forinteragency messaging of Earthquake notifications and products since it was rolled out in the late 1990s. Since that time, higher demands on seismic network operators have shown the limitations of QDDS. To improve reliability of delivery, the QuakeWatch Information Distribution System (QWIDS), a push technology based on CORBA was designed and implemented by ISTI. This open source platform leverages

the CORBA programming framework along with message tracking and a file-based archive to guarantee successful delivery of messages across network connections. Furthermore, QWIDS is a message neutral software tool for providing publisher and subscriber services in a reliable and secure mode. QWIDS was originally designed to meet the needs of the CISN Display, Emergency Management Console application and has grown into a complete push solution for publishers and subscribers. EMSC and ORFEUS, in conjunction with the NEIC, are using QWIDS for earthquake hypocenter notification. This presentation will focus on explaining the technology and some examples of its use in the US.

SD8/P8/ID15 - A REVIEW OF SEISMIC NETWORK PROCEDURES IN SWITZERLAND

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The Swiss Seismological Service (SED) is responsible for seismic monitoring in Switzerland, a country with a low background seismicity but where a large ~M6 earthquake is expected in the next decades. With over 30 stations and station spacing of ~25km, the SED operate one of the densest broadband networks in the world, which is complimented by a similar number of realtime strong motion stations. This network is expected to grow with an additional ~100 strong motion stations in the next few years. The backbone broadband network was established over 10years ago, with only 30 realtime stations feeding into software developed at the SED. The hardware has recently been overhauled and replaced by fully redundant high performance machines. The software is being transitioned to SeisComp3, an emerging community standard, which is capable of scaling up with our network densifications. As we make the transition to the new system, we have had to overhaul our archives, metadata, and redesign our realtime acquisition and data access procedures. In this presentation we discuss the major issues and solutions from our perspective, from gaps and data latency, to alert software sharing across networks.

SD12 - INFORMATION TECHNOLOGY APPLICATIONS IN SEISMOLOGY

SD12/P1/ID16 - THE ARRAY NETWORK FACILITY: AN OPEN-SOURCE WEB-BASED TOOLKIT FOR MANAGING THE USARRAY BROADBAND SEISMIC NETWORK

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Since April 2004 the EarthScope USArray broadband seismic network has grown to over 900 broadband stations. Multi-channel data transmits in near real-time to the Array Network Facility (ANF) at the Scripps Institution of Oceanography, UC San Diego. Managing such a large and dynamic network requires a robust, extensible, accessible, and easy to deploy software architecture. The ANF has developed a series of platform agnostic low-latency web-based tools that provide secure, yet open, access to real-time and archived data for a broad range of audiences including seismic network operators, geoscience researchers, funding agencies and the general public. The toolset acts as a publicly accessible interactive front-end to the Antelope Environmental Monitoring System (data acquisition, processing, and archival software middleware from Boulder Real Time Technologies, Inc.), and can be deployed by any network operator that uses Antelope. Tools range from network-wide to station-specific metadata, monitoring state-of-health metrics, event detection rates, monthly event downloads, dynamic station report generation, and an interactive waveform server that allows users to directly query high density waveform data. These tools have helped the network to achieve a data return rate of over 90% for the last 6 years. Much of the software is already freely available from the Antelope contributed code Git repository (http://www.antelopeusersgroup.org).

SD12/P2/ID17 - WEB-GIS TECHNOLOGY FOR SEISMIC HAZARD RESEARCH

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We present network geoinformation technologies for seismic hazard research, which are incorporated into two web-GIS's: GeoProcessor and GeoTime. Free online access to them and to a set of regional GIS-Projects is available at http://www.geo.iitp.ru/GeoProcessor-2/new/index.htm and http://www.geo.iitp.ru/geotime/index.htm. These technologies encompass the following major features: (1) network access to geographical data, which may be distributed over network servers as well as stored on the user PC, (2) modern methods of knowledge acquisition from spatial and spatio-temporal data, (3) high interactivity and clarity of visualization boosting the decision-making efficiency.The main application of web-GIS GeoProcessor is the interactive spatial data analysis. The system is implemented as a Java-applet. It supports operations with grid-based data, raster images and vector-based data. Two case studies will be presented: evaluation of the damage after a strong earthquake and delineation of the potential earthquake source zones.Web-GIS GeoTime is oriented on analysis of spatio-temporal processes. It is implemented as a Java application. GeoTime can jointly handle 2D, 3D and 4D multitype spatial and spatio-temporal data: 2D and 3D polygons, 2D lines, 4D earthquake catalogues, 2D, 3D and 4D grid-based layers, 2D and 3D vector fields, the time sequences localized geographically, and WMS images. The system supports parallel multithreaded data processing on the multiprocessor/multicore user computers.Visualization of 3D and 4D layers employs an animated representation of images. A set of analytical transformations allows GeoTime to extract new properties of

spatial and spatio-temporal data. The current version of GeoTime is basically oriented on analysis of earthquake precursors. Therefore the system includes the following three groups of methods related to the problem's domain. The first group supports computing operations on 2D, 3D and 4D layers representing the major characteristics of a seismic process in space and in time. The second group of operations comprises methods of anomaly detection. The third group of methods is used to estimate the parameters of an expected catastrophe (earthquake): the centre of the preparation zone attributed to a seismic source, its depth, spread, and the degree of confidence in anomaly existence.Two case studies will be presented: (1) spatio-temporal analysis of the noise in earthquake catalogue and (2) detection of earthquake precursors.Nowadays we face a challenging problem of building a multiuser computer environment for on-line integrated processing of heterogeneous spatio-temporal geodata. A modern approach to the solution of this problem consists in embedding the analytical toolkit of geoinformational network systems into a GRID-infrastructure. The research is supported by RFBR projects 09-07-12077, 10-07-00204-a.

SD12/P3/ID18 - FROM MACROSEISMIC INTENSITY DATA TO THE EARTHQUAKE PARAMETERS

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Two tools have been developed within the European Archive of Historical EArthquake Data (AHEAD) in order to process and analyse roughly 270.000 Macroseismic Intensity Data-points (MDPs) related to circa 7000 earthquakes European-wise and spanning more than a 1000 years.

The first addressed task was to investigate interactively on a map such data, to better evaluate the quality and differences between datasets describing the same earthquake. A tool called MIDOP (Macroseismic Data Online Publisher) has been created: by simply choosing a list of earthquakes and their corresponding MDPs, a complete self-sustained website can be created, ready to be published on the web. It offers an intuitive control panel for maps and tables customisation and it offers the possibility to generate places seismic histories. No external data-sources are required while presenting maps and the resulting websites can be browsed also locally. A series of problems related to the AHEAD environment have been taken into account while designing the tool: 1) macroseismic intensity data standardisation of formats among European institutions, 2) support the growth of locally developed macroseismic data-centres and 3) help publishing the earthquake data on the web with a specifically designed web-mapping tool.

The second task to be addressed was to process such amount of MDPs in order to obtain earthquake parameters (epicentral location and magnitude) according to available and published methods. Three parameterization methods were identified: Boxer, Bakun & Wentworth and MEEP, each coming with its Windows pre-compiled line command executable. The tool, called "Parametrizator", is able to batch process the input MDPs and present the result on maps using MIDOP.

SD12/P4/ID19 - THE IT FRAMEWORK OF THE EUROPEAN ARCHIVE OF HISTORICAL EARTHQUAKE DATA (AHEAD)

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The European Archive of Historical EArthquake Data (AHEAD) has been developed in the frame of the EC project NERIES and maintained in the frame of the EC project SHARE.

AHEAD makes available on the web the result of a networked historical earthquake data research, formalised in terms of studies (papers, reports, macroseismic data points, etc). It provides an updated wealth of data that are unique for many European events in the time-window 1000-1963.

A series of IT solutions have been developed in order to support both the research and the networking activities carried out within the building process of AHEAD. The resulting framework is an equally balanced effort in both the back-end and front-end design and implementation, a key feature in a research approach very much human-centred, where the quantity of data is small if compared to terabytes of instrumental data.

AHEAD is composed of five mutually dependent data-components: 1) the "Digital Library", where all the historical earthquake studies are stored and described by bibliographical metadata, 2) the "Consensus Earthquake Inventory", where the relevant macroseismic data (event date, epicentral area, number of macroseismic data-point, maximum observed intensity) are extrapolated, the best available information are selected and fake earthquakes are highlighted, 3) the "European Macroseismic Database", where all the available macroseismic data-points (MDPs) are stored, 4) the "Parameters Laboratory", where earthquakes parameterisation methods are applied to MDPs in order to obtain epicentral locations and magnitudes and 5) the "European Earthquake Catalogue".

The presentation will demonstrate the adopted IT solutions separately for the back-end and the front-end, both for the access-restricted website and the general-purpose implementation designed to be included in the "Earthquake Data Portal", developed within the EC project NERIES, which targets a much broader scientific community.

SD12/P5/ID20 - THE NERIES WEB INFRASTRUCTURE: SERVICES AND TOOLS FOR SEISMOLOGY

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Within the NERIES EC project a service oriented infrastructure has been implemented and deployed, providing an integrated solution for accessing diverse and distributed data sources. A new set of services has been developed and made accessible using standard mechanisms and well known technologies such as HTTP, SOAP, XML, JSON, WSDL. Each service provides a specific type of data, following the paradigm of "Resource- Oriented-Architecture" each resource is uniquely identified by an URI, and eventually could be linked and stored into digital libraries. The adoption of a web data service approach can be seen as a first step towards the next generation of distributed scientific research infrastructures, enabling virtual research communities and cross-domain data-integration. In this regards a particular attention is given to international initiatives such as GEOSS, EPOS and INSPIRE.

Examples of available web services include: Seimolink WS, build on top of the Arclink middleware, provides access to station and network inventory and broadband waveform data coming from the EIDA (European Integrated Data Archive). QuakeML WS provides parametric seismic event information with a number of different searching criteria. Taup WS is an utility service to compute theoretical phases and arrival times given a configurable velocity model SMI WS gives access to RDF-based metadata information These services constitute the data backbone of the Earthquake Data Portal (http://www.seismicportal.eu), but they can also be accessed by external applications and clients.

Examples of stand alone applications publicly available as part of the NERIES framework are: JOQUE (Java Orfeus Quake Explorer) is an event based data retrieval tool PORSCHE (Perl ORfeus Seed Control and Harvest Engine) searches and retrieves waveform data based on time windows Moreover a number of tools have been independently implemented within external collaborations including: SeismoWeb Toolbox is a collection of Matlab and Java tools developed at TU Vienna NERIES-CLIENT developed within the SEE-GRID-SCI project

SD12/P6/ID21 - USAGE OF SEISMON WITHIN THE WEBNET SEISMIC NETWORK

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Fairly new software SEISMON (project started in 2003) for processing of seismic data is presented here in use. SEISMON is an open source software project with its main goal to facilitate the scientific work of seismic research projects using new- or non-standard processing methods. It is written in Matlab and recently available online for public use (http://seismon.sourceforge.net). The MySQL database is used for storing of the data parameters which enables fast and effective access also from others programming environments, e.g. PHP for internet applications. SEISMON is a modular software which allows implementing new code for specific use easily.The software is planned to be used for routine data processing of a local seismic network (WEBNET) situated in the West Bohemia region, the most seismically active area in the Czech Republic. This region is continuously monitored for more than 20 years and the activity is represented mainly by earthquake swarms. The insight into the

SEISMON software use, its main properties and the possibility to customize the software for specific needs is demonstrated on data from this area.

SD12/P7/ID22 - OPENGEM – TOWARDS AN IT FRAMEWORK TO HOST, RUN, AND PUBLISH THE EARTHQUAKE HAZARD AND RISK MODELS OF GEM

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OpenGEM is an open source platform developed to provide the GEM (Global Earthquake Model) public-private partnership and its regional initiatives SHARE, EMME, and others with the capability to host their probabilistic earthquake hazard, risk, and socio-economic impact models following the «living model» paradigm. Modelling input data such as e.g. seismogenic sources catalogs and exposure, earthquake hazard, and risk model definitions, and their results, all stored in potentially distributed backend databases, are exposed in community based XML formats (QuakeML, shaML) over public web services. The GEM hazard, risk, and socioeconomic impact calculators (but also any calculator application implementing the public interfaces) pick up the input data and calculation definitions from these web services, and provide back calculation results. Frontends to configure model calculations, and to explore hazard and risk input data and results are implemented as portlets following the JSR 286 and mounted to the relevant seismic data portals.

OpenGEM is following the same design patterns as the NERIES and NERA portal applications, and shall be kept in line with the upcoming EPOS e-science initiative. While the openGEM codes are intended to be open source, the platform is capable to handle private data, allowing e.g. to apply community loss models to non-public building portfolio data.

First test applications and proofs of concept have been developed 2009/2010 within the GEM1 pilot project; further development towards a fully-featured, publicly available suite was started in spring 2010 carried out by the GEM modelling facility hosted at the Swiss Seismological Service.

SW1 - THE CENTENNIAL OF THE MOHOROVICIC DISCONTINUITY

SW1/P1/ID23 - THE LITHOSPHERIC STRUCTURE OF THE WESTERN TURKEY FROM RECEIVER FUNCTION PROFILE

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A broad-scale seismological experiment, SIMBAAD (Seismic Imaging Beneath the Aegean-Anatolia Domain), is performed in the Aegean-Anatolia region. The objective of the project is to investigate the crustal and mantle structure beneath Western Turkey, the Aegean Sea, and continental Greece. This tectonically very active region has experienced a variety of geodynamic processes and its geology and kinematics have been extensively studied. It is thus a good place to test competing hypotheses on how the surface kinematics is related to mantle structure and dynamics. In the spring of 2007, we installed a temporary network of 33 broadband stations in Turkey, Greece, and S-Bulgaria for 2- year duration. It complemented the permanent broadband networks (▫90 stations) with an inter-station spacing of ▫100 km in the region. The experiment also included 2 north-south profiles of more densely-spaced stations (▫15 km) crossing Western Anatolia at 18°E and 31.5°E.

We performed receiver function analysis on the western transect of 430km in length including 26 stations. Over 60 teleseisms (30° to 95° distance) were used in the analysis and more than 2000 receiver functions were computed. We determined Vp/Vs ratios using H-κ stacking method and applied common conversion point stacking to receiver functions of the NS linear array. The results indicate an average Moho depth of 30km with negligible variations under the major grabens and core complexes (e.g.Menderes Massif)

SW1/P2/ID24 - FIRST RESULTS ON MOHO'S STRUCTURE FROM RECEIVER FUNCTION ANALYSIS FOR BUGARIA

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Bulgarian seismological network was modernized in 2005 and equipped with broad-band sensors and digital acquisition systems. It enabled application of modern techniques of analysis of the velocity structure in Bulgaria. This study presents first results from application of the receiver function technique. For calculation of receiver functions was used the Seismic Handler program. Two stations of the network Vitosha (VTS) and Krupnik (KKB) were chosen for the beginning of the study. These sites are located in areas of complex tectonic structures manifesting high seismic activity during recent years. As a starting models we used shear wave velocity models for the territory of Bulgaria, obtained in Raykova, 2004. From the seismic survey and gravimetric measurements is determined that Moho depth varies between 30 km and 50 km. The obtained results for the both stations show ticker than expected Earth crust. This can be an effect of reflections/refractions on the object close to the station. Further detailization of the structure of the Moho boundary could be done after estimation of receiver functions for other stations of the network. Bulgarian seismological network was modernized in 2005 and equipped with broad-band sensors and digital acquisition systems. It enabled application of modern techniques of analysis of the velocity structure in Bulgaria. This study presents first results from application of the receiver function technique. For calculation of receiver functions usSeismic Handler program. Two stations of the network Vitosha (VTS) and Krupnik (KKB) were chosen for the beginning of the study. These sites are located in areas of complex tectonic structures manifesting high seismic activity during recent years. As a starting models we used shear wave velocity models for the territory of Bulgaria, obtained in Raykova, 2004. From the seismic survey and gravimetric measurements is determined that Moho depth varies between 30 km and 50 km. The obtained results for the both stations show ticker than expected Earth crust. This can be an effect of reflections/refractions on the object close to the station. Further detailization of the structure of the Moho boundary could be done after estimation of receiver functions for other stations of the network.

SW1/P3/ID25 - CODA ATTENUATION IN THE CROATIAN COASTAL REGION (EXTERNAL DINARIDES)

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The tectonics of the coastal region of Croatia are driven by the convergent motion of the Adriatic microplate and the Dinarides. The greater Adriatic area is geologically and tectonically considered to be one of the most complicated regions in Europe. The seismicity of the area varies from low and moderate (in the NW and central parts) to high in the SE. In the past decade the Croatian seismological network was enlarged and modernised by addition of several digital broadband stations. This enabled formation of high quality local earthquake seismograms dataset.

In order to determine seismic attenuation in the coastal region of Croatia, we analysed attenuation of coda waves for nine seismic stations. The coda quality factor Q_c was estimated using the single backscattering model for up to seven central frequencies (f = 1.5, 3, 6, 9, 12, 18 and 24 Hz). To explore the lapse-time dependence of Q_c, its values were estimated for a series of 30 s sliding time-windows. Observed Q_c displays pronounced frequency dependence according to $Q_c = Q_0 f^n$, as well as considerable spatial variability. In addition, both Q_0 and n exhibit notable lapse-time dependence. In general Q_0 increases with the lapse-time (indicating decrease of attenuation with the depth), whereas n decreases. The results also indicate a correlation of observed attenuation with the seismotectonic activity – the areas of high activity are characterized by lower Q_0 and higher values of n, than seismically less active regions.

SW1/P4/ID26 - THE MOHO DEPTH MAP OF THE ANTARCTICA BASED ON SEISMIC DATA

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Different tectonic units cover the Antarctic territory: platform, orogen and depression structures. This structural variability is reflected both in thickness and physical properties of the crust. Previous crustal model (CRUST 2.0.Bassin et al. 2000) have 2x2 degree resolution and don't meet present-day requirements. A lot of new seismic data and regional compilations became available

during last several years. We used data of deep seismic reflection, refraction and receiver functions studies as well as existing regional models (e.g. for Maud Land region, Hoffmann et al., 2003) from published papers and integrate them at a uniform grid with resolution of 1x1 degree. A new Moho map for the crust of Western and Eastern Antarctica and surroundings have been built. The existing data were verified and cross-checked. We present new Moho data within the main tectonic units: West Antarctica rift system (WARS), the Transantarctic Mountains (TAMs), and East Antarctica (EA). The new Moho map demonstrates the large differences with previous models. It turns out that many regions are more heterogeneous than it was demonstrated by the previous compilations. The West Antarctic rift system is one of the largest zones of continental extension on the Earth. The seismic data show a thin extended continental crust. Crustal thickness of WARS is variable from 21 km in the Bentley subglacial trench, to 32 km in the southern flank of the Marie Byrd Land. Transantarctic Mountains: 4000 km long, peaks 4 km above Sea Level, 200-300 km wide. TAMs are characterized by the rather strong variations of the Moho depth (28-40km). Further inland, beneath the TAM, the estimated Moho depths range from 30–33 km (30 km from the coast) to 36–40 km (85 km from the coast), deepening away from the coast beneath the TAM. Crustal thickness of EA is variable from 30 km in the Wilkes basin, to 50 km in the Western Maud Land Region and to 52 km under Gamburtzev Mountains. This Moho data in future should be used in the gravity modeling and in the modeling of the upper mantle.

SW1/P5/ID27 - THE FINNISH PART OF ARCHEAN KARELIAN CRATON: SEISMOGENIC LAYER, CRUSTAL STRUCTURE, MOHO MAP, AND TECTONIC IMPLICATIONS

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Two-dimensional seismic velocity models are derived from passive seismic observations for the Finnish part of Archean Karelian craton (~64°-68°N, 24°-30°E). Based on the models, an updated Moho depth map has been constructed for the area by integrating the results of this study with previous observations from surrounding regions. The seismogenic layer in the Kuusamo seismicity zone is defined with the help of dense local seismic network, new velocity models and synthetic waveform modelling.The structural models image a typical three-layer Archean crust with thickness varying between 40 and 52 km. In the 10-22 km thick upper and middle crust, P wave velocities range from 6.1 to 6.4 km/s and from 6.5 to 6.8 km/s. The relatively high P wave velocities observed in the upper crust are related to layered mafic intrusive and volcanic rocks. The middle crust – lower crust boundary is located to depths between 28 and 38 km. The thickness of lower crust varies from 5-15 km in the Archean part to 15-22 km in the Archean-Proterozoic transition zone. The lower crust and uppermost mantle are associated with P wave velocities of 6.9-7.3 km/s and 7.9-8.2 km/s. The upper, middle and lower crust has an average Vp/Vs ratio of 1.71, 1.74 and 1.76, respectively. The crust attains its maximum thickness (50-52 km) in the Archean-Proterozoic transition zone, where the Archean crust is both over- and underthrust by the Proterozoic crust. A crustal depression bulging out from that zone towards the Kuusamo region in north-eastern Finland is most likely linked to a collision zone between Archean blocks. Crustal thickening under the Salla and Kittilä greenstone belts is tentatively associated with a NW-SE-oriented collision zone or major shear zone. The crust is thinnest (40-42 km) beneath the Pudasjärvi block bordering the Bothnian Bay. This Archean block has experienced significant extension in the early Paleoproterozoic, but it is not significantly affected by the later Paleoproterozoic orogenic events. In the Kuusamo region, lack of seismic activity within the high-velocity body in the uppermost 7 km of crust and occurrence of mid-crustal (20-30 km deep) earthquakes are characteristic features to the area. In other parts of the study area, the uppermost crust is also seismically active. The focal depth distribution supports the "jelly-sandwich" rheological model of eastern Finland, which predicts that the middle crust is close to the transition from brittle to (semi-)ductile behaviour at about 30 km depth.

SW1/P6/ID28 - A VISUALIZATION OF THE COMPLEX 3D CRUSTAL BLOCK STRUCTURE OF THE CENTRAL FENNOSCANDIAN SHIELD

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The complex 3D crustal structure of the central Fennoscandian Shield was formed in several tectonic processes in the Precambrian. The crust is composed of varying size and shapes of blocks composed of accreting terranes and intervening basins. These blocks can be visualized by the seismic travel time tomography.The data set consisted of first P-wave and S-wave arrival data recorded during controlled source refraction and reflection experiments and during passive SVEKALAPKO seismic tomography project. In addition, P- and S-wave arrivals measured from chemical explosions registered at permanent stations were included. The number of receivers added up to 2895 and seismic sources up to 565. A large number of first P-wave arrivals (19180) and S-wave crustal arrivals (15146) were used in the inversion. The inversion produced smooth P- and S-wave velocity models with highest optimal lateral resolution of 50 km. The non-controlled events were relocated using grid search technique in the semi-final tomography model. The final model comprises the crust to the depth of 40 km.The distribution of the P-wave and S-wave velocities and the velocity ratio, Vp/Vs, has local variations throughout crust. Especially, in the upper 10 km of the crust, the velocity ratio distribution depicts a complex mosaic of alternating minima and maxima. The anomalies reveal several distinct blocks and belts, which can be associated with the main geological terranes. The Archean-Proterozoic boundary zone is characterized by an upper crustal low velocity zone (LVZ). The upper crust of the schist belts is associated with velocity minima, Vp <6.1 km/s, Vs <3.6 km/s and Vp/Vs <1.70, whereas the rapakivi granitoid batholiths are associated with high velocity ratio anomalies (Vp/Vs >1.76). The lower crust beneath the granitoid complexes are also associated with high velocity ratios Vp/Vs >1.74. Two high velocity ratio bodies (Vp/Vs >1.76) embedded in low ratio material (Vp/Vs <1.72) suggest hidden mafic blocks in the lower crust below Central Finland Granitoid Complex.

SW1/P7/ID29 - INCORPORATION OF MOHO VARIATIONS FROM RECEIVER FUNCTIONS INTO A JOINT INVERSION OF SEISMOLOGICAL AND GRAVIMETRIC DATA.

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We propose to take into account information on Moho variations from receiver function analysis to better constrain a joint inversion of teleseismic and gravimetric data. This new inversion scheme allows to better image 3-D crustal and lithospheric structures, and strengthens our understanding of lithosphere-asthenosphere interaction. We test our scheme on synthetic examples, and apply the method in a continental rifting region where deformation processes are complex and badly known. In our scheme, receiver functions are first inverted and then the resulting Moho depths are interpolated and incorporated as *a priori* information into the joint inversion of teleseismic delay times and gravity anomalies process. Those two data sets are commonly jointly inverted because they are sensitive to the same parameters, and because they present good complementarity in terms of resolution. Our stochastic approach uses the Neighbourhood Algorithm to concentrate the search within the good data fit regions without discarding exploration of the whole parameter model space. The introduction of Moho variations leads to better distinguish between crustal sources and mantle contributions. This joint inversion thus provides more constraints on the inverted parameters, and allows us to better image lithosphere-asthenosphere interactions in the case of the Mongolia-Baikal region. Indeed in this area, we expect an asthenospheric upwelling to dynamically support the topography, but its geometry and depth extent is still under debate.

SW1/P8/ID30 - SHALLOW STRUCTURE FROM THE PS AND SP CONVERSIONS DETECTED IN THE WAVEFORMS OF MICRO-EARTHQUAKES IN THE WEST BOHEMIA/VOGTLAND SEISMOACTIVE AREA

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The western part of the Bohemian Massif, the West Bohemia/Vogtland region, is the area of the increased geodynamic activity. Knowledge of a detailed crustal structure is essential for all advanced studies of seismicity and focal parameters of the micro-earthquake swarms that occur in this region. In our present study we concentrate on the velocity distribution in the upper crust. The upper crustal structure is studied using waveforms of local micro-earthquakes observed at selected stations of the WEBNET seismic network. The waveforms typically display dominant direct P and S waves, fol-

lowed by coda waves secondarily generated at a shallow subsurface structure. Using the cross-correlation analysis of the waveforms of the multiplets (i.e. the events with similar waveforms and focal mechanisms) we calculate the accurate time shifts and stack the seismograms to extract arrival times of the converted SP and PS waves and reflected PP waves. The arrival times are inverted for the depth of the subsurface layers. The correctness of the retrieved model is further checked by modelling of the full waveforms using the reflectivity method. The approach is applied to different stations of the WEBNET seismic network to get a detailed image of lateral variations of the crustal structure in the target area.

SW1/P9/ID31 - CRUSTAL STRUCTURE AND MOHOROVICIC DISCONTINUITY AT THE CONTACT OF THE ADRIATIC MICROPLATE AND PANNONIAN SEGMENT

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Structure of the crust and surface of the Mohorovicic discontinuity at the contact of the Pannonian basin and Dinarides were determined on the basis of the data acquired in last decade in framework of new research projects (ALP2002, ALPASS-DIPS). Results based on three data sets were combined to solving structural and tectonic relations at this contact as a relation between the Adriatic microplate and the Pannonian segment. The basic exploration was carried out on the profile Alp07, which was a part of the active seismic experiment ALP2002. This profile stretched in Croatia from Istra to the Drava River in a WSW–ENE direction. Gravity modelling on the Alp07 profile enabled a definition of calibrated rock densities that were applied on other profiles set up in the study area, covering the area of Croatia and Bosnia-Herzegovina, for the purpose of determining the structural relations. This significantly improved the resolution of the gravity modelling. Passive seismic data, acquired in ALPASS-DIPS project using temporary seismic stations, provided for additional contribution in solving the crustal structure. The basic model was defined on the Alp07 profile by means of seismic and gravity modelling. The Moho is the deepest in the area of the Dinarides (40 km), and is shallowest in the Pannonian basin area (20 km). The structural units determined on the Alp07 profile (Dinaridic and Pannonian crusts and Transition zone) can be easily followed on all other gravity profiles in the survey area. Wide transition zone corresponds with the ophiolite zones in more recent tectonic maps. The Tisia block can be compared with the Pannonian crust, whereas the Dinaridic crust would relate to the structural units of the Dinarides. The obtained results enabled the development of a 3-D structural map of the Mohorovicic discontinuity. Types of the receiver functions of the passive seismic data approved that different types of crust exist. Modelling of characteristic Pannonian receiver functions affirmed the thesis of the seismic and gravity modelling that the Pannonian crust can be considered as one-layered. On the basis of all data sets a geological model was constructed, which contributes in solving the most interesting tasks in the area. The subduction area, namely the contact of the microplates at the level of the upper mantle, is located on the NE flank of the Dinarides. The NE boundary of the Transition zone is located much further north than the boundary of the Tisia block in published tectonic maps.

SW1/P10/ID32 - MOHOROVICIC'S DISCOVERY AND THE FIRST CENTURY OF STUDIES OF THE CRUST AND UPPER MANTLE IN CROATIA

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Seismological studies of the earth's interior began in Croatia 100 years ago, by the seminal paper in which A. Mohorovičić proved the existence of the crust-mantle boundary. In the subsequent years, Mohorovičić devoted much of his energy to improving travel-time curves of crustal phases. Large-scale seismic profiling carried out in the 1980-ies and interpretation of deep seismic profiles running across the country, yielded the first map of the Moho topography. In the 1990-ies several papers appeared which dealt with determination of velocities and attenuation (coda-Q) in the greater circum-Adriatic region. A more thorough investigation of the coda attenuation is under way. More recently, a large database of Pg-phase arrival times was used to assess the azimuthal anisotropy of the P-wave velocity within the crust in the NW Croatia and in parts of the External Dinarides. An ongoing study of the shear-wave splitting is expected to give additional constraints on the anisotropic properties of the crust and mantle beneath Croatian seismic network. The interpretation of data obtained within a large international seismic experiment (ALP2002) lead to new constraints on the crustal structure in western Croatia. Lithospheric structure beneath coastal and continental Croatia is being studied also by broadband teleseismic waveform modeling using receiver functions. The results indicate that the Mohorovicic discontinuity in Dalmatia may lie considerably deeper than presented on recent maps of the Moho topography in Europe.

SW1/P11/ID33 - SHEAR-WAVE SPLITTING AND VELOCITY ANISOTROPY IN THE CRUST BENEATH THE STATIONS OF THE CROATIAN SEISMOLOGICAL NETWORK

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We present observations of the shear-wave splitting from small local events at a number of stations of the Croatian seismological network. The preliminary results indicate that anisotropy is rather weak, with the fast axis pointing in the general direction of predominant tectonic stress. This indicates that anisotropy is most likely caused by alignment and opening of cracks under the local tectonic pressure filed.

SW1/P12/ID34 - 1-D VELOCITY MODEL AND HIGH PRECISION EARTHQUAKE LOCATION IN NORTHERN EGYPT

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The interpretation of Earthquake data, especially for seismotectonic purposes, strongly depend on accurate locations, so 1D velocity model for P and S waves is calculated in order to improve the location accuracy and to serve as an initial reference velocity model in local earthquake tomography under The Egyptian National Seismological Network in northern Egypt (ENSN). Local earthquakes Data (LED) of northern Egypt are precisely relocated, hypocentral parameters and travel times of P and S waves are used in the calculation of the model following the simultaneous technique and the hypocentral coupling velocity model solution using the routine procedures as defined in the VELEST USERS Guide (Kissling, 1995). Travel time hypocentral distance curve is constructed for P,S phases identification and minimum picking errors. Vp/Vs for all data used are calculated using Wadati diagram. Several trial and error procedures are performed for different initial velocity models, initial hypocentral locations and damping control parameters for the coupled inverse problem to assess the model stability and hypocentral uncertainties. The performance test for the resulted velocity model is done through the relocation of quarry blasts with known parameters as a controlled source, master event too. The new model exhibited reduction in both residuals and estimated location errors.

ES10 - APPLYING SEISMOLOGY TO MONITORING FOR NUCLEAR EXPLOSIONS

ES10/P1/ID35 - IMS SEISMIC STATIONS INSTRUMENTATION CHALLENGES

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The IMS seismic network is a set of monitoring facilities where the primary network has worldwide distributed 50 stations and the auxiliary seismic network consists of 120 stations. Besides the difference in the mode of data transmission to the IDC the technical specifications for seismographic equipment to be installed at both primary and auxiliary stations are essentially the same. In context of technical specifications for IMS seismic stations it was stressed that verification seismology is concerned with searching of reliable methods of signal detections at high frequencies. In the meantime M_s/M_b screening criteria between earthquakes and explosions relies on reliable detection of surface waves. The IMS requirements for instrumental noise and operational range of data acquisition system are defined as certain dB level below minimum seismic noise within the required frequency band from 0.02 to 16Hz. The type of sensors response is requested to be flat either in velocity or

acceleration. The compliance with IMS specifications may therefore introduce a challenging task when low-noise conditions have been recorded at the site. It means that as a station noise power spectrum approaches the NLNM it may require a high sensitive sensor connected to a quiet digitizer which may cause a quick system clip and waste of the available dynamic range. The experience has shown that hybrid frequency response of seismic sensors where combination of flat in velocity and flat in acceleration portions of the sensor frequency response may provide an optimal solution for utilization of available dynamic range and low digitizer noise floor. In addition to the above IMS stations need to meet specific requirements such as data authentication, central facility data buffering, precise relative timing accuracy between data samples coming from array elements as well as more than 97% of data with less than 5 min delay in transmission to IDC.

ES10/P2/ID36 – NEW DIGITIZER FOR INTERNATIONAL MONITORING SYSTEM (IMS) WAVEFORMS TECHNOLOGY STATIONS

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An independent testing of the Guralp Systems CMG-DM24S3AM, a low power 24-bit authenticating digitizer has been carried out by joint team of representatives from CTBTO, Guralp Ltd. UK and RPKromer Professional/Technical Services LLC, USA.

This digitizer is aimed to be used for the International Monitoring System (IMS) waveform technologies stations for CTBT verification purposes. One of the main concepts at the base of requirements for development/procurement of the new IMS digitizer was modular station design, where station components from different suppliers are integrated by the CTBTO. Indeed, the new digitizer (as one of the main components of the station) can be easily integrated with any of the sensors used in the IMS and with the Standard Station Interface (SSI) software of IMS. Optional set up of sampling rates and output data formats (including CD1.1) as well as compliance with IMS minimum technical specifications expands the range of potential applications of the new digitizer to be used for single 3C seismic, T-phase hydroacoustic stations as well as for existing and new IMS seismic and infrasound arrays in combinations with other high resolution digitizers previously installed there. Flexibility in setting up the front-end gaining allows for matching system calibration factors without hardware changes and without significant impact on the digitizer noise floor. The unit was tested and all parameters were checked under extreme temperature conditions over the entire temperature range relevant for IMS stations. In addition to compliant performance within IMS specifications for generic tests like DC accuracy, input terminated noise, harmonic distortion, timing accuracy and channels cross-talk the new digitizer has approximately 3.7W power consumption measured with embedded authentication card. The digitizer has a 2Gb CD1.1 data buffer and the cylindrical casing allows for installation inside boreholes, if necessary. The digitizer is fully IP compliant, allowing for communication via the Ethernet or via the RS232 port; in the latter case both serial and IPoS (PPP) protocols are supported.

ES10/P3/ID37 – NORSAR ACTIVITIES RELATED TO CTBT MONITORING

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NORSAR has over 40 years experience in operating and analyzing data from seismic arrays, which has resulted in significant developments in both processing techniques and instrumentation. NORSAR has recently established a test facility for both seismic and infrasound instruments. The site is co-located with the station NC602 of the large NOA seismic array. The infrastructure consists of a central building with living quarters, an office room, power, internet connection and a spacious nearby concrete subsurface vault. The site has been used for comparing the performance of several seismometers and a brief overview of the capabilities of different broadband sensors will be given.

NORSAR has long experience in the development of operational software for the processing of array data. Recent developments include multi-channel waveform correlation techniques which can lower detection thresholds significantly for source regions where previous events have been observed. Given a signal template from an event of interest, seismic data for periods of many years can be searched rapidly for the occurrence of similar signals. The method has been applied on several arrays to monitor for events close to the DPRK test-site using the signals from the known events as templates. Most recently, correlation detectors were used to identify signals likely to be related to the NPE 2009 event and resulted in extensive lists of events which can with confidence be attributed to the same source region.

ES10/P4/ID38 – BALA, TURKEY EARTHQUAKE AND ITS AFTERSHOCKS ANALYSIS USING ARRAY-BASED WAVEFORM CORRELATION AND STANDARD ARRAY PROCESSING (STA/LTA) METHODS

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Belbasi Seismic Array (BRTR-PS43) in Turkey, originally Belbasi Research Center six decades ago, composed as two arrays. One is a medium period array distributed close to the Ankara city, and the other one is a short period Keskin array. Keskin array was installed in year 2000 as a new array because of the necessity of the silent site to increase data quality and detection capability of BRTR. It array consists of seven elements, located in boreholes and short period vertical instruments (Geotech 23900) installed at depth 30 meters from the surface. Bala earthquake occurred on December 20, 2007 had produced many aftershocks that were monitored properly by the Keskin-BRTR array. In this study Keskin array detection capability of the local earthquakes occurred in middle part of Anatolia has been analyzed using this data. We have applied the standard array processing and array based waveform correlation methods. When we compare these two methods it is clearly revealed that the numbers of detected events are considerably higher when we apply the array based waveform correlation methods.

ES10/P5/ID39 – CONTRIBUTION OF THE BURAR (ROMANIA) SEISMIC ARRAY TO MONITORING SEISMICITY IN THE REGION OF BALKANS AND MIDDLE ASIA

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The Aegean Sea, Greece, Turkey, Caucasus and Iran alongside the Hellenic Arc are the most seismic active regions in the Balkans and Middle Asia. The high seismicity of these zones is reflected in many destructive earthquakes that have occurred in the past.The scope of the present study is to emphasize the importance of BURAR (Bucovina) array from the point of view of seismicity monitoring at the national and international level. Thanks to the cooperation between Air Force Technical Application Center (AFTAC) of the United States of America and National Institute for Earth Physics (NIEP) of Romania, since 2002 the array system transmits data in real time to the National Data Center of Romania (RNDC), in Bucharest and to the National Data Center of USA (US NDC), in Florida. After the waveforms are analyzed, RNDC provides various parameters like travel times, backazimuths to the National and International Seismological Data Centers. In order to evaluate the contribution of the BURAR to seismic activity monitoring in the Balkans and Middle Asia regions, we create a database with events occurred in 2004 - 2009 time interval. Specific array techniques, like wave number-frequency analysis and beamforming, are applied in order to determine the ray parameter and backazimuth values. Then, correction factors are determined for each of the selected seismic region. Inserting the obtained corrections, we relocate the events from the database and compare the new locations with the solutions provided by the IDC catalog.

ES10/P6/ID40 – LOW-LEVEL SEISMIC ANALYSIS OF DEAD SEA CRISIS, FEBRUARY 2004

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The Dead Sea has been subject to strong seismic sequence triggered by mb5.2 mainshock on 11th February 2004 at 08:15. This earthquake sequence took place over a period of 15 days.

The PMCC method (Progressive Multi-Channels Correlation; Cansi, 1995) has been applied to the Mount Meiron array (MMAI station

code) in order to detect the most complete set of aftershocks. The PMCC technique is based on a progressive study of the inter-station correlation functions, which leads to a consistent set of time-delays in case of a seismic phase. For this study PMCC is associated with a single-array location module which allows the production of an automatic regional seismic bulletin.

The results obtained by this automatic tool for the Dead Sea sequence show that the detection capability of MMAI array is significantly enhanced. Automatic bulletin includes weak signal-to-noise ratio events (hidden by background seismic noise or by the seismic coda of previous events) not listed in Geophysical Institute of Israel catalogue. We notice especially that detection of S-wave is well achieved on MMAI array providing a good epicentral distance estimation.

ES10/P7/ID41 **- PROVISIONAL TECHNICAL SECRETARIAT (PTS) PORTABLE INFRASOUND ARRAY**

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The array processing techniques used at the International Data Centre (IDC) of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) for infrasound processing have demonstrated the exceptional capability of the International Monitoring System (IMS) network for detecting signals from a wide variety of natural or man-made sources (e.g. microbaroms, storms, volcanoes, meteorites, mine blasts, accidental explosions, industrial activity). Unlike earthquakes for seismic technology, sources of infrasound signals are rarely energetic enough to be detected on a global scale by the IMS network. The cross-correlation technique used at the IDC is well adapted for infrasound technology as it offers optimum detection capability even in cases of very weak signals. One consequence of the method is that each IMS infrasound station produces a large amount of genuine signal detections from diverse origins that are not all of interest for CTBT verification purpose. The IMS infrasound network is comprised of 60 stations, 42 of which have been built and certified. While the mission of the IDC is to look for large infrasound sources, it is important to understand and categorize the large number of signals observed at IMS stations, including local and regional background noise sources. In order to identify and catalog infrasound signals observed near an IMS station, the PTS has acquired a portable infrasound IMS-type array that can temporarily be deployed in a region of interest. The portable array consists of 4 microbarometer sensors that are sensitive to acoustic pressure variations in the atmosphere in the frequency band between 0.02 to 4Hz, equipped with wind noise reduction system (porous hoses) and deployed with an aperture of about 1 kilometer. The data are collected manually from each of the sites on a regular basis, and can be processed and analyzed on a field laptop computer using the same software as that used in the IDC. Currently the infrasound array is deployed in Japan, where it has helped to characterize sources near the IMS infrasound array IS30. The deployment is a joint collaboration with the Japanese National Data Centre, which has been instrumental in making the experiment a success, through their efforts in securing the location, operating the equipment, and collecting and analyzing the data. The PTS is looking forward to broadening such experiments in different regions of the globe, and pursuing scientific collaborations with other institutes to better understand infrasound signals, atmospheric propagation, and infragenic sources.

ES10/P8/ID42 **- A TOOL FOR AUTOMATIC REAL-TIME SEISMIC BULLETIN CONSTITUTION**

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We present an automatic algorithm applied to seismic arrays and designed for automatic detection and location of regional events. The detection is achieved using PMCC method (Progressive Multi-Channel Correlation). PMCC algorithm is based on a study of the cross-correlation functions between each stations of the array, which leads to a consistent set of time-delays when a seismic phase is present. The set of time-delays allows calculation of horizontal velocity and azimuth of arrival wavefront. This algorithm allows a very low level of detection even for poor signal to noise ratios. A first identification of regional seismic waves nature is obtained using those propagation parameters, providing the estimation of a pre-location. The second step consists in the integration of additional data from regional seismic stations, in order to build a consolidated location. The identification of the nature of seismic phases is based on a direct method using a large search-grid covering PMCC pre-location area. This algorithm has been applied to Songino seismic array in Mongolia, completed by Ulan Bator seismic network data. The results constitute an automatic seismic bulletin characterized by a low completeness magnitude.

ES10/P9/ID43 **- THE CTBTO LINK TO THE ISC DATABASE**

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The CTBTO Link to the International Seismological Centre (ISC) Database is a collection of interactive tools for manipulating seismological data sets provided by the ISC. The Link is open to National Data Centres (NDC) and the Provisional Technical Secretariat (PTS). By means of a graphical interface and queries tailored for the monitoring community, the users are given access to a multitude of products. These include historical seismicity since 1904, nuclear and chemical explosions, Engdahl, van der Hilst and Buland (EHB) bulletins, Ground Truth (GT) events and the IDC Reviewed Event Bulletin (REB). The searches are divided into three main categories: The *Area Based Search (*a spatio-temporal search based on the ISC Bulletin), the *REB search* (a spatio-temporal search based on specific events in the REB*)* and the IMS *Station Based Search* (a search for historical patterns in the reports of seismic stations close to a particular IMS seismic station). The outputs are HTML based web-pages with a simplified version of the ISC Bulletin showing the most relevant parameters with access to ISC, GT, EHB and REB Bulletins in IMS1.0 format for single or multiple events. This is a user friendly interface which we hope will help NDCs to put REB events in context within the historical seismicity.

ES4 - METHODS AND DATA FOR THE STUDY OF EVENTS RECORDED ON PRE-WWSSN HISTORICAL SEISMOGRAMS

ES4/P1/ID44 **- SISMOS PROJECT: NEW PERSPECTIVE IN THE RESEARCH, RECOVERY AND SCIENTIFIC AND CULTURAL VALORIZATION OF DATA OF EURO-MEDITERRANEAN SEISMOLOGY (1895-1980)**

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Italy can boast a long as well as prestigious tradition in instrumental seismology and for the past 20 years INGV has promoted two important projects for research, recovery, reproduction, conservation and valorisation of this outstanding historical and scientific heritage: the TROMOS Project (1988 - 2007) and the SISMOS Project (1999 -). A recent reorganisation of SISMOS integrates the «philosophies» of the two projects in a single multidisciplinary and multicultural and consequently multi-user approach. Hence, today, attention is drawn to the historical assets of Italian seismology both as scientific data and as cultural heritage.

A major effort is currently being made to intervene in the different sectors (scientific, historical, cultural and popular dissemination) with the disciplinary rigour of the different disciplines and synergies at play as compared with analogous initiatives at the national and the international level. With the EuroSeismos project which started in 2002, in the framework of the activity of the WG *History and data of instrumental seismology* of ESC, the experience and the technologies of SISMOS have allowed us to broaden the «user base» of the project to the whole Euro-Mediterranean area (>30,000 seismograms recovered and scanned).

The systematic approach to research, recovery, restoration, cataloguing, reproduction, dissemination and study of the instrumental and documentary historical assets of Italian and Euro-Mediterranean seismology makes available a huge quantity of data and experiences usable by numerous and diverse disciplinary fields.

The main SISMOS products available from its new portal (http://sismos.rm.ingv.it) or upon request are: high resolution digital images of the paper seismograms (180,000) and of the

historical seismic bulletins (120,000pp) from 1895 to 1980; software for the raster analysis of the seismograms; alphanumeric data from the historical seismic bulletins.

Demands for greater efficiency and specialisation have suggested an articulation into some activity sectors: research, recovery, cataloguing, and high resolution scanning of the historical recordings and complementary documentation; vectorization of digital images of seismograms and use of the waveforms for the study of the more energetic earthquakes of the Italian region. Two laboratories for restoration of seismograms and of seismographs have also been set up. Finally a powerful Information System (IS) with web and webGIS interface has been released. This IS is addressed to the collection and management of the historical information related to seismology. Ranging from the instrumental and non-instrumental data to the sources and studies of disciplinary history this particular sector of the earth sciences.

ES4/P2/ID45 - VECTORIZATION ISSUES ON HISTORICAL RECORDS OF THE TSUNAMIGENIC SOURCES IN MARMARA REGION

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The historical earthquakes in the Marmara Sea have led to tsunamis for years. Understanding of these earthquakes provide insights that enable us to interpret seismotectonic characteristics of the region. For this reason, KOERI has taken part in Eurosismos project for the constitution of the digital historical earthquake database. Many geological field surveys and geophysical studies to date indicated that 1912, Şarköy-Mürefte event, which occured on the Ganos fault zone, was one of the largest earthquake in the western Marmara Sea and caused tsunami (Altınok, Alpar, Yaltırak, 2003). The same is also valid for 1935, M=6.4 Marmara (Erdek)-Istanbul, 1963, M=6.3 Çınarcık-Yalova events. The purpose of this study is to examine these earthquakes and reevaluate source parameters of these shocks by digitizing original seismograms.Vectorization process requires considerable amount effort due to many problems that arise from quality of trace on the paper and the mechanism of traditional seismometers. Examples are pen slipping on the paper and little oscillations that are interpreted as noise on the trace because of instrumentation. Correct identification of the earthquake to be studied can also be troublesome and it is also difficult to vectorize old seismograms when a part of trace is erased on the paper. Time marks should be counted very carefully. Yet, some of the historical records don't have well-marked timemarks, therefore it is essential to obtain some bulletins for stations and regard delay times of the first motion polarities in relation to station distances. Another problem with the vectorization of old seismograms arises when a part of the trace is erased on the paper. If the missing part is small, interpolation methods can be utilized, however, they do not provide a reliable basis when large parts are missing from the records. Baseline changes on the records may lead us to disrupt the waveform that is so important for vectorisation. It is also a considerable challenge to vectorize traces in mesh on record , which is a result of the drum mechanism. Besides, the needle mechanism leads to curvatures of the traces. Another difficulty during digitization process is that some records have thick traces that make difficult to vectorize correctly the frequency path on record. This situation may cause missing of the true trace since it is difficult to distinguish the frequency paths. On top of all these difficulties, historical earthquake records are hard to obtain. Therefore, the records of many big earthquakes are insufficient to analyze and decipher. In this study, we have records mostly from western countires for three earthquakes. For this reason, we have azimuthal gaps and need seismograms from eastern countries and southern countries in order to make a reasonable interpretation for these earthquakes.

T/SD1 - ACTIVE DEFORMATION IN WESTERN GREECE: LINKING RIFTING, STRIKE-SLIP AND SUBDUCTION

T/SD1/P1/ID46 - SEISMIC HAZARD ASSESSMENT FOR THE BROADER PYLOS REGION

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The SEAHELLARC project, supported by the European Commission, aimed at evaluating and computing seismic hazard and risk, as well as modelling tsunamis for the town of Pylos, in the western Peloponnese. For this purpose, a new seismogenic zonation has been developed for the Pylos area, and broader region, and the most updated seismic hazard assessment has been provided. Concerning the seismogenic zonation, we started from the zonations available in the literature and refined the sources closer to Pylos town and, consequently, expected to contribute most to the Pylos hazard. This refinement was based on all the results obtained during the project, mainly from seismic exploration. This final seismogenic model is notably different from the national model for the Pylos broader area, while the national model, with marginal modifications, was accepted for the seismic sources far away from the study region. A contribution to the seismogenic zonation was given also by the analysis of the hypocentral probability: in details, the errors in the hypocentral locations were considered and some vertical cross-sections were produced. It was possible, in such a way, to identify some hypocentre alignments that could represent seismic faults. A notable work of data preparation was developed before the actual seismic hazard assessment. In particular, the earthquake catalogue was accurately investigated and important considerations were done on magnitude: new magnitudes were added and the moment magnitude was reevaluated. Some preliminary computations of the seismic hazard led to a refinement of all the parameters used in the calculation and special attention was paid to the scaling laws applied. The probabilistic seismic hazard assessment for the Pylos broader region has been done according to the standard approach of Cornell by using the computer formulation of Ordaz et al. In the present study, a logic tree with 24 branches has been constructed for the rock, stiff, and soft soil hazard maps: it consists of two zonations, two approaches for the seismicity model definition, two methods for maximum magnitude assessment, and four attenuation relations for peak ground acceleration. Two of the attenuation relations refer to surficial earthquakes and the other two are suitable for intermediate and deep events. The final seismic hazard assessment benefits of all the topics previously cited and, being based on a logic tree, which accounts for all the uncertainties identified during the project, represent a robust final result.

T/SD1/P2/ID47 - RELOCATION OF SEISMICITY IN THE SOUTH WESTERN HELLENIC ARC USING A 3D VELOCITY MODEL DEVELOPED FROM ACTIVE SEISMIC AND GRAVITY DATA

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In order to delineate the tectonic elements and active faults at the most seismically active part of the Hellenic arc we conducted a microseismicity study using a local seismic array. This consisted of 17 land and 17 marine seismic stations. In a two months period we recorded 3504 seismic events that were located by the Geiger's classical method based on 1D velocity model. A 3D velocity model was then developed using 2D active seismic lines that constrained 2D and 3D gravity modeling. The density model developed by this procedure was converted into a 3D velocity model applying empirical relationships between velocity and density. Seismic events were relocated using this 3D velocity model and tomographic inversion based on the SIMULP algorithm. This procedure significantly improved the relocation accuracy of the seismic events. RMS values of nearly all recoded seismicity are less than 0.2s, with a maximum concentration of relocated events at 0.07s.Most of the shallow seismicity is located within structures of reverse faulting. Deeper crustal seismicity is found either along the main strike slip faults or the lower part of the crust, which is involved in the subduction process of the Ionian oceanic lithosphere below western Greece. Finally deep seismicity extending to a depth of 90 km and confined in a very narrow zone of the Kiparissiakos basin, is probably associated with a fracturing procedure of the subducted oceanic lithosphere. This occurs due to the variable thickness of the continental crust of the western Hellenides forcing the oceanic slab to deform accordingly.

T/SD1/P3/ID48 - 3D GEOMETRY AND HISTORY OF AN ACTIVE NORMAL FAULT NETWORK, CORINTH RIFT, GREECE

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The Gulf of Corinth is one of the most active

rifts in the world, extending N-S at a rate of up to 1.6 cm/yr. The early rift (Plio-Pleistocene) is today uplifted and spectacularly exposed along the southern coast of the Gulf. The western Gulf is characterised by intense and ongoing micro-seismicity, which describes a gently north dipping zone between depths of 5 and 10 km. Outstanding problems include (1) the nature of the zone of micro-seismicity (detachment or zone of high fluid pressure?) and (2) the geometry of the active fault network in the upper crust. Outcropping normal faults dip dominantly north (40-65°), with an average trend of 110°EN. Kinematic field data show that extension has been consistently N-S since initiation of rifting around 4 Ma. Rift evolution can be reconstructed using syn-rift stratigraphy which records a northward migration of fault activity, and a stepwise acceleration of extension rate accommodated on fewer, larger faults. Active faults are concentrated along the south coast of, and below, the currently subsiding gulf. The largest active fault is the Helike fault (east and west), which initiated around 700-800 ka and has accommodated at least 3 km throw with over 800m footwall uplift. Using the surface trace of the 8 principal normal faults in the Corinth Rift Laboratory area in the western gulf and the focal mechanisms of major earthquakes, several possible models for the 3D geometry of the active fault network are constructed. These are examined in terms of their coherence with available data and with faulting models (connectivity, distribution of displacement, cross cutting relations) and their implications for the relationship between the microseismicity and major faults and the distribution of active deformation in the upper crust. The models indicate that the Pirgaki-Mamoussia fault may still be active, that the East Helike fault or a northern splay was responsible for the 1995 Aegion earthquake, that there is little connectivity between the major faults.

T/SD1/P4/ID49 - MICROSEISMIC ACTIVITY AND MULTIPLETS IN THE WESTERN PART OF THE CORINTH RIFT (GREECE)

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The Corinth Rift, in central Greece, is one of the most seismically active areas in Europe: 5 earthquakes of magnitude greater than 5.8 in the last 35 years, an opening rate of 1-1.5cm/year in a north-south direction, and tens of destructive historical earthquakes. Since the spring 2000 in the framework of the CRL European project, a seismic network CRLNET has been installed in the western part of the Corinth Rift around the city of Aigion. 7 years of seismicity are now available; the seismicity is characterized by frequent seismic swarms and a significant background seismicity rate. Having these 7 years of data (about 60 000 events), we search for all existing multiplets (events with similar waveforms) and relocate precisely the whole database of earthquakes using a double-difference location approach to study the spatio-temporal patterns of the seismicity and to constrain the geometry of active structures at depth. The seismicity is mainly located beneath the Gulf concentrated at depth of 6-10 km deepening towards the north, with no activity in the upper 4 km of the crust. A clear difference of seismicity is observed between the eastern and western part of this area: to the East, we observed a low seismic activity mainly structured along a low-dip angle plan (~25-30°), probably in relationship with the Aigion rupture (15/06/1995, Ms = 6.2). To the West, the seismicity is much more significant with complex patterns, and is located within a low-dip angle structure (2-4 km thick) with several levels of fragmentation. The absence of events shallower than 4 km makes it difficult to identify the links with the faults observed at the surface, but some of the shallower events clearly outline the Aigion fault at depth up to 4.5-5 km. Several hundreds of large multiplets (more than 25 events) have been identified and precisely studied; we will present their geometry, their mechanism, their size, and their relationship with the observed structures at the surface, and we will discuss the implication for the active deformation of the rift. The 1995 earthquake rupture occurred in an area of low microseismicity (before and after the rupture). We will discuss the links between the rupture of this event and the active faults observed on the southern coast (especially Helike fault), and the implication in term of seismic risk.

T/SD1/P5/ID50 - SHEAR-WAVE SPLITTING AND TEMPORAL VARIATION OF TIME DELAY IN NW PELOPONNESUS (GREECE)

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The Gulf of Corinth, located in Central Greece, is one of the faster expanding and most seismically active continental rifts around the world and is characterized by normal faulting in an approximate E-W direction. In NW Peloponnesus, in the area between the Corinth Rift and the Hellenic Arc, there is a transition zone characterised by dextral strike-slip faulting. On 4 February 2008 a seismic swarm, characterized by two moderate-size earthquakes (Mw=4.6, 4.5), occurred in this area. The analysis of earthquakes of the sequence revealed the existence of shear-wave splitting, which is related to the existence of anisotropic medium. All the events that were selected for the anisotropy study are located within the shear-wave window, having incident angles smaller than the critical, as well as clear and impulsive S wave arrival phases on the horizontal components. In addition, the amplitude of the S wave phase on the vertical component was smaller than on the horizontal ones. The methods used to determine the splitting parameters, which are the polarization direction of the S_{fast} wave, the time delay between the two split shear waves and the source polarization direction, are the polarigram and the hodogram. The S_{fast} polarization directions of the fast shear wave vary between N81° and N129°. The coherence of the fast shear wave polarizations, irrespective of the azimuth of each event, is consistent with shear-wave splitting due to seismic wave propagation through an anisotropic medium. These observations are consistent with the general NNE-SSW direction of extension in the Gulf of Corinth and, therefore, in agreement with the extensive dilatancy anisotropy (EDA) model. Time delays are sensitive to small changes in microcrack geometry, since changes in shear wave splitting can be used to monitor the small-scale stress-induced deformation of microcracks throughout the rock mass. This process occurs before a level of microcracking, known as fracture criticality, is reached when rocks are expected to fracture. Temporal variations in shear-wave time-delays have been observed before several earthquakes worldwide. The obtained values of time delays vary between 0.020sec and 0.090sec. Nevertheless, a decrease of the time delay values was observed after the occurrence of the first moderate earthquake, implying changes of the medium's properties.

T/SD1/P6/ID51 - THE JANUARY-FEBRUARY 2010 PYRGOS SEISMIC SWARM: A POSSIBLE ACTIVATION OF THE DEEP PSATHOPYRGOS NORMAL FAULT (WESTERN CORINTH RIFT) ?

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An important seismic swarm started on 18 january 2010, in the western rift of Corinth, close to the city of Nafpaktos. It consisted of 2 events of magnitude larger than 5 (Mw=5.3 for the first and mb=5.3 for the second), 4 days apart, with more than 130 earthquakes of magnitude spanning from 2.5 to 5.3 in less than 5 days. The swarm kept quite active over about 2 months. Located at the northwestern border of the CRL network (http://crlab.eu) , on the northern side of the gulf, it was well recorded by the CRL permanent seismological and strong motion stations, as well as by 3 temporary stations installed just after the first event. It was also recorded by the borehole dilatometer of the Trizonia island, located15 km to the East, and within the array of continuous GPS of CRL, close to the EFP site.. We will present a detailed analysis of the first week of the swarm activity, combining all available observations from CRL, including high precision relocations, fault location and mechanisms of the largest events, and spatio-temporal evolution of the swarm. Preliminary results show that the first mainshock epicenter is located on the western edge of the activated area, implying an eastward propagation of the main rupture. The north dipping nodal plane of its focal mechanisms better fits the micro-seismicity hypocenters which were recorded before the second mainshock, and clustered around 7 to 8 km in depth. This suggests that this plane, corresponding to the root of the Psathopyrgos fault, was the active one. GPS data and modelling of the broadband waveforms of the closest stations will be analyzed and presented to further test this hypothesis. The epicenter of the second event was located about 2 km ENE of the first one. The two main events had a ra-

ther low amplitude start for the first second, suggesting a slow nucleation or precusory phase in both cases. The relationship of this swarm with the background seismicity relocated by CRL will be investigated, within the general scheme of deformation and faulting in this area.

T/SD1/P7/ID52 **– THE 8 JUNE 2008 ANDRAVIDA EARTHQUAKE, MS=6.3 AND ITS KINEMATICS AND TECTONIC SETTING**

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The 2008 Ms=6.3 Andravida ruptured 30 km of a NNE right lateral strike slip fault south of the city of Patras. Although some strike slip activity of minor faults was known, there was no tectonic evidence of large scale NS striking fault: such a large event was not anticipated . Following the event a network of 10 stations was installed for 3 months in the epicentral area in order to monitor aftershocks and in particular the northern part of the rupture area near the city of Patras.

We combine these new aftershock observations with already published source studies, GPS measurements of an already existing geodetic network in the area that have been performed just after the earthquake, as well as interpretation of interferometric images from INSAR, to refine already proposed models of this event. The combined data set allows to define more accurately the lateral and vertical limits of the fault. The absence of seismicity in the upper 10 km of the crust is a puzzling observation which we interpret as a result of either the recent growth of this strike slip fault system within the lower crust or as the effect of shallow salt layers of thrust sheet which may empeed the upward strain propagation – or both.

The northward propagation of the microseismicity reaching the gulf of Corinth may reveal the continuation of this structure towards the north, connected to the western limit of the rift.

T/SD1/P8/ID53 **– THE PELOPONNESUS CONTINENTAL MARGIN FROM THE ISLAND OF ZAKYNTHOS TO PYLOS. PART 2: GEOLOGICAL STRUCTURE AND TECTONIC PROCESSES**

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The Western Peloponnesus is an area repeatedly affected by large magnitude earthquakes occurring as a consequence of the convergence and ongoing collision between the Western continental border of the Aegean sub-plate and the deep Ionian Sea and Apulia domains. Among the objectives of the Sixth Framework Program of the European Commission project SeaHellArc (SEismic and tsunami risk Assessment and mitigation scenarios in the western HELLenic ARC) was to provide a detailed geological and tectonic framework of this continental margin. This segment represents the western border of the Hellenic subduction zone. MCS seismic lines recorded in the eighties for the Hellenic National Oil Company that cut across the study area were made available and integrated with earlier MCS data recorded by OGS in the seventies for geological interpretation, after modern reprocessing performed by the OGS processing group. The MCS data were of different vintages and recorded with different source and receiver configurations thus requiring a detailed processing sequence included migration to ensure the homogeneity of the output and to facilitate their integration and interpretation. The complex thrust and fold geological structure of the margin, as deducted from MCS data, is clearly strongly imprinted by the "Alpine" structural heritage that includes from East to West the Pindo, Gavrovo, Ionian, pre-Apulian zones. They represent structural highs (pre-Apulia and Gavrovo shallow water carbonate platforms) and depressions, such as Ionian and Pindo zones. The Ionian zone thrusts are represented by Triassic to Eocene pelagic carbonates and by late Eocene-early Oligocene flysches, mainly originated by turbidites from the on land Pindo units. The Triassic salt is responsible of the diapirism and thrust movements from East to West after the superposition of Gavrovo carbonates on the Ionian zone. The Ionian zone thrusts, believed to have been active until Early Pliocene, are still well expressed on the margin morpho-structure particularly at the level of the Strofades/Zakinthos acoustic basement ridge along which Triassic salt intrusions are detected. We believe that the two deep, tectonically active, basins extending S-E of Zakinthos and Strofades islands, are "pull apart" type depressions created as a consequence of a general NNE-SSW directed shear motion generated by an ongoing collision between the extending Hellenic border and the Western rigid pre-Apulian platform. Such NNE-SSW strike slip motion appears to be in a good agreement with the focal mechanism of a significant earthquake that occurred in the area of Patras in June 2008.

T/SD1/P9/ID54 **– EMBEDDED TIME SCALES OF SLIP TRANSIENTS ON THE PSATHOPYRGOS NORMAL FAULT SYSTEM, WESTERN RIFT OF CORINTH, GREECE.**

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The western rift of Corinth displays a fast opening rate (1.5 cm/year from GPS) and a strongly fluctuating microseismic activity. We focus here on the activity of the Psathopyrgos fault system, the westernmost one in the rift, about 15 km long. This fault did not rupture in historical times (more than 300 years), despite its clear morphological slip activity, which raises the question of possible creep on this fault.We report several observations, at different time scales, of the transient instabilities on this fault zone. For the last 2000 years, Palyvos et al. (2008), studying paleo-shorelines, identified 5 episodes of rapid uplift in the eastern segment. Each can be modelled with a typical 2 m slip, seismic or aseismic, with a mean return period of 400 years, corresponding to a slip rate of 5 mm/yr, and an opening rate of 2 to 3 mm/yr. On the other hand, repeated GPS since 1990 show a mean opening rate of 15 mm/yr , related to aseismic slip on a low angle detachment zone (e.g. Avallone et al., 2004). The large discrepancy between these figures shows that this region is in a state of transient, accelerated extension, since at least several decades. This zone may thus be on a new stage of rapid, mostly aseismic extension, which may last several decades – or herald a large rupture. At shorter time scales, for a few sites around the Psathopyrgos fault, the repeated GPS measurements provide evidence for non stationary displacements, lasting less a few years. Furthermore, intense seismic swarms have occurred in 2002 and 2009, lasting several weeks, and activating the whole fault structure. The transient deformation seen by GPS is consistent with an episode of creep coinciding with the 2002 swarm, with some 10 cm of slip. The propagation of the micro-seismicity during the 2002 swarm activated successively fault segments of a few kilometres in size, within a few hours or days. When migrating from west to east, it triggered a slow slip event lasting 30 minutes, which culminated in a shallow M=3.5 earthquake (Bernard et al., 2008). The average migration of this seismicity is of the order of 1 km/day, suggesting a possible role of pore pressure migration. The role of these seismic and aseismic transients in the global strain budget in not clear, whether it impedes stress accumulation for large earthquakes, or marks the start of a large seismic destabilization.

T - THE BIRTH AND DEATH OF SUBDUCTION ZONES: CASE STUDIES FROM THE MEDITERRANEAN

T/P1/ID55 **– GEODYNAMIC RECONSTRUCTION OF SOUTHERN ITALY: IMPLICATIONS FROM TOMOGRAPHIC IMAGING OF THE IONIAN SLAB AND PETROLOGICAL INFERENCES.**

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The present-day tectonic setting of the Tyrrhenian-Apennine system is the result of a complex and slow convergence between Eurasian and African plates. The detailed reconstruction of the shape and inner structure of the Ionian lithosphere subducting beneath the Tyrrhenian basin is important to understand the geologic history of Western-Central Mediterranean. In the last decades, many tomographic studies have been performed to define the seismic velocity field in the crust and upper mantle beneath the Tyrrhenian-Apennine system in order to provide cons-

traints on the geodynamic evolution of the Western Mediterranean Sea. Nevertheless, the resolution of the existing tomographies of the region result inadequate to investigate within the subducting lithosphere and the absolute values of the velocity field are not sufficiently reliable to derive petrological inferences about the mineral phases existing at high pressure and temperature in this geodynamic context. Here we present the seismic velocity models of the Ionian slab obtained with a high-resolution seismic tomography based on local earthquake data and furthermore optimized applying the Weighted Average Model (WAM) method (Calò et al., 2009). The obtained velocity models illustrate the tridimensional features of the subducting slab giving evidence on the presence of vertical and lateral tears. Our models show also low velocity anomalies in the inner portion of the slab. Thanks the reliability of the WAM reconstructions, we interpreted the resulting velocity anomalies in the light of mineral phase equilibria governing the progressive dehydration of silicates in the ultramafic portion of the subducted lithosphere. These observations provide relevant insights on the possible influence of intra-slab mineralogy with the H2O-release/retention. The petrological interpretation of the velocity anomalies give new details on the magmatism of the volcanic Aeolian arc and on the large seismically active strike slip system Tindari-Letojanni. Furthermore the obtained models allow inferences on mantle circulation which affects the geodynamical evolution of the area.

T/P2/ID56 - DETERMINATION OF UPPER MANTLE HETEROGENEITY BENEATH AEGEAN-ANATOLIAN REGION FROM TRAVEL TIME TOMOGRAPHY

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Movement and the deformation of the continental lithosphere are not clear completely. In the first end-member model, the lithosphere consists of essentially rigid blocks (with most of the strength located in the upper crust) that float on the asthenosphere, are separated by lithospheric faults, and move because of forces applied to their edges. The second model holds that the lithosphere (including the upper mantle) deforms as a continuum, and that the upper crust moves in response to tractions applied to its base. Most elements of the debate are related to deformation at the surface or within the shallow crust (fault kinematics, geodetic displacements, or earthquake mechanisms). The Aegean Sea, the surrounding Greek coasts and the western Turkey, along with the Hellenic Arc, are the most active seismic areas of the Mediterranean Basin and of the whole Alpine-Himalayan chain. The catalogues of seismicity are certainly incomplete for low magnitude events (M<4.5), but the map permits to identify the active seismogenic zones in a broad scale. Several earthquakes with magnitudes greater than 6 occurred during the instrumental period. The earthquake depths are generally normal (<15 km), with exception for the subduction zones where the events occur at intermediate and high depths (>30 km). This happens along the Hellenic Arc and in the Antalya Gulf (southern Turkey). In the whole area, the frequency of events with magnitude greater than 4, is evident, but there are many events with lower magnitudes. Teleseismic tomography is a powerful tool used to obtain about the deep velocity perturbations in the Earth, using travel times recorded by a regional network from distant sources (usually at distances of more than 20°). This method has been developed since the seventies and has been successfully used for the investigation of different regions. The images of seismic anomalies are then used for the estimation of the distribution of temperature, density and other parameters, which then can be used for geodynamic modeling, gravity inversion and other applications. We will obtain a 3D image of the velocity structure of the Hellenic Arc Zone beneath Greece and Aegean region to a depth of about 300 km. The results might provide better constrains on the evolution of the slab beneath Anatolia and the Aegean. We will compare our results with previous works and regional data.

T/P3/ID57 - THE GROSMARIN EXPERIMENT : 3D CRUSTAL STRUCTURE OF THE NORTH-LIGURIAN MARGIN

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The North-Ligurian rifted margin, south-east France, is singular in that it lies immediately next to the Alpine orogenic arc. The region is seismically active and can experience rare destructive earthquakes such as in 1887 in the region of Imperia—an event that resulted in a tsunami and several casualties in spite of a coastal area that was much less densely populated than today. On a regular basis, the area undergoes a limited and diffuse seismic activity that can remain undetected and is generally poorly located. This leads to a poor knowledge of active structures, especially at sea. Such knowledge is required to quantify seismic hazard along the French Riviera and the Ligurian region. The GROSMarin project was undertaken with a dual objective: (1) to characterize the North-Ligurian margin from a structural standpoint—mode and degree of crustal stretching prior to oceanic accretion, segmentation along strike, subsequent evolution in an orogenic context— and (2) to identify zones of active crustal deformation at sea that are likely to generate earthquakes. It took place from April to October 2008 and consisted in the deployment of 21 ocean-bottom seismometers (OBS) on a grid ranging from mid-slope to the deep basin, located between Nice (France) and Imperia (Italy). This array was extended on land by the permanent stations of the French and Italian regional networks, temporarily densified by 13 portable stations. These instruments recorded the shots of a marine seismic source towed from R/V l'Atalante and were left for more than 5 months for passive surveying. The active part of the programme aims at characterizing the main structures of the margin through crustal 3D tomography; the objective of the passive part is to decrease the detection threshold of marine microseismicity and to reach a precise location of events in order to map active faults. We present some results of this experiment with a 3D tomographic model obtained with travel times derived from our recording of active seismic shots by the OBS and the land stations. These results provide insight into the variability of the crustal structure on the margin and in the transition zone to the oceanic domain.

T/P4/ID58 - SEISMIC EVIDENCE FOR THE PRESENCE OF MESOZOIC OCEANIC CRUST IN THE CENTRAL GULF OF CADIZ AND GEODYNAMIC IMPLICATIONS

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In the Gulf of Cadiz (offshore SW Iberia and NW Morocco) the Africa and Eurasia plate boundary is complex and marked by a broad region of deformation spanning about 200 km in a north–south direction. Earlier seismic surveys had difficulty penetrating the large accumulation of deformed sediments (ranging from 10-15 km in thickness), interpreted as an accretionary wedge formed by the SW migration of the Rif-Betic block.

During the NEAREST-SEIS cruise onboard B/O Hesperides (Nov. 2008), two wide-angle seismic lines were acquired. We report here on profile P2, trending NNE-SSW, from the South Portuguese margin and crossing the frontal portion of the accretionary wedge. It was recorded by 15 OBS and 7 land stations (total profile length = 342km). The main purpose was to determine the crustal structure offshore SW Iberia. The data generally show clear sedimentary refracted and reflected phases, deeper intracrustal phases, some arrivals refracted in the upper mantle and reflections at the boundary between the crust and the mantle (PmP).

A layer-stripping modelling of the corresponding data is performed using a joint refraction/reflection travel-time tomography approach. Information given by coincident MCS data is used to discuss and validate our velocity reconstructions. The Southern part of the model (south of 36.25° N) is characterized by thin crust, ▫7 km thick, and a nearly flat Moho around 16 km depth. This crust is interpreted as oceanic, based on its thickness and velocities. Preliminary modelling indicates a poorly constrained velocity of 7.5 km/s below the Moho, increasing to 8 km/s in a 4 km thick transition layer. The northern part of the model shows a clear and abrupt transition to a thick continental crust, Moho depth at ▫28 km at 36.36° N, comparable to thicknesses obtained by land-based refraction seismics. The average crustal velocity here is ▫6.5 km/s over a ▫23 km maximum thickness and the velocity gradient is smooth, consistent with continental crust. The oceanic to continental transition occurs over a ▫30 km distance. The presence of Tethyan age oceanic crust beneath the accretionary wedge lends support to the east-dipping subduction tectonic model and contradicts previous interpretations proposed by some workers of a Variscan continental crust underlying the central Gulf of Cadiz. The current degree of activity of the subduction zone is still a matter of scientific

debate.

T/P5/ID59 **- MICROSEISMICITY IN THE SE AEGEAN USING DATA OF THE TEMPORARY EGELADOS NETWORK**

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The Hellenic Subduction Zone (HSZ) is the seismically most active zone in Europe. The Aegean and the Anatolian plates are rotated counterclockwise due to the northwards drift of the Arabian plate and the slab pull of the subducting African plate. The relative velocity of the subduction is about 4cm/year.

The temporary broadband EGELADOS network covered the whole HSZ from October 2005 to April 2007 and was part of the CRC 526 ('Rheology of the earth – from upper crust to the subduction zone'). The network consisted of 85 land and 23 ocean bottom stations.

Seismic events are detected and identified by an STA/LTA-trigger and a grid-search algorithm, where relative travel times of pre-defined master events are compared to observed differential trigger times. Because of the high seismicity, we focus on the SE part of the HSZ including the forearc around Rhodes, Karpathos and Kassos and the volcanic arc around Nisyros. In addition, the considered region covers the transition zone from the Aegean to the Anatolian microplates at the west coast of Turkey. More than 3680 earthquakes has been located within 13 months. Microseismicity down to a magnitude of about ML 2 is detected completely. Most earthquakes occured in depths less than 40 km. This shallow microseismicity is observed in the fore-arc with clusters SE of Crete, S of Karpathos (Ptolemy and Pliny trench) and the Karpathos graben (NW of Karpathos and Kassos). Also, high seismic activity is observed along the Santorini-Amorgos graben in the central volcanic arc. A continuous seismically active zone strikes along the EW trending rift of the Gulf of Gökova to western Kos and changes its direction to NS by crossing the volcanic island Nisyros and extruding into the forearc near Kassos. Almost no seismicity at depths less than 40 km has been detected in the forearc around Rhodes. Intermediate depth seismicity of the subducting slab is located in the volcanic arc between Astypalea, Nisyros and Tilos down to 170 km. The strong attenuation of the S-waves of intermediate depth events points to low Q in the mantel wedge above the subducting African lithosphere.

T/P6/ID60 **- CENOZOIC TECTONIC EVOLUTION OF THE ALGERIAN MARGIN AND THE TELL DOMAIN: A SCENARIO OF SLAB ROLLBACK, COLLISION, SLAB BREAKOFF AND INCIPIENT SUBDUCTION**

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Recent studies have highlighted that inversion processes and subduction inception may occur along part of the Algerian margin. The aims of this study are to characterize the parameters that control the inversion of the Algerian margin and to discuss the general timing of the inversion in relationship with the Tell-Atlas orogenic evolution. The Algerian margin has originated from the opening of the Algerian basin about 25 Ma ago. It is now well accepted that such an opening occurs in a backarc position and as a consequence of the retreat of the tethyan slab. Collision processes and the breakoff of the slab are dated at around 19-16 Ma. In the central part of the Algerian margin, a set of NW-SE oriented dextral transform faults was active during basin opening and divided the 600 km long central margin into segments of ~120-150 km. The upper Miocene, Plio-Quaternary, and present-day tectonic setting is, however, compressional and supports the occurrence of a margin inversion.

Using multibeam bathymetry and multichannel seismic reflection sections from the MARADJA 2003 and 2005 cruises, we evidence Plio-Pleistocene shortening with contrasting styles along the margin between west (Khayr Al Din bank) and east (Boumerdès-Dellys margin) of Algiers. Pre-Miocene structures such as basement highs and transform faults appear to control changes of the deformation pattern along this part of the margin, resulting into different widths, geometries, and relative positions of folds and faults. Plio-Quaternary and active blind thrust faults do not reuse Oligo-Miocene normal and transform faults during inversion, but instead grow within the continental margin (as testified for instance by the 21 May 2003 Mw 6.8 Boumerdès-Zemmouri earthquake), at the foot of the continental slope and at the northern sides of basement highs interpreted as stretched continental blocks of the rifted margin. The inherited structures of the margin appear, therefore, to determine this deformation pattern and ultimately the earthquake and tsunami sizes offshore. We show evidence for the activity of blind thrust faults offshore during the Plio-Quaternary i.e. since the last 5 Ma. As collision processes and the breakoff of the tethyan slab are dated at around 19-16 Myr, we discuss possible geodynamic scenarii for northern Algeria implying an evolution from a Tethyan subduction rollback and closure to a passive margin reactivation in the Miocene-Quaternary time span.

SD4 - COMPILING THE EARTHQUAKE HISTORY OF THE EUROPEAN MEDITERRANEAN AREA

SD4/P1/ID61 **- AN UPDATED EARTHQUAKE CATALOGUE FOR GREECE AND ADJACENT AREAS SINCE 1800**

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An earthquake catalogue for Greece and adjacent areas is presented, i.e. the updated version of several published catalogues and individual studies, covering the period 1800-2006. The catalogue of Makropoulos, Drakopoulos & Latoussakis (1989) covering the time span 1900-1985 was updated for the period 1986-2006, using instrumental parameters from the bulletin of the ISC, except for magnitude. For Ms the same procedure as before was applied, that is using the ISC body wave magnitude (mb) and a regression equation. In the present update, Mw is also included for the whole period 1900-2006, calculated from Scordilis (2006) formula. Maximum intensity, when available, was also inserted in the catalogue, with reference to its source and scale used. It is worthnoting that in the 20th century, at least three different macroseismic scales have been published. The catalogue was also extended backwards in time, including the 19th century historical earthquakes and transparent techniques were applied, when the data allowed, for determining their parameters. A completeness test was finally applied to the updated catalogue. Events with magnitude above 4 are complete during the last 30 years of the catalogue (1976-2006). Earthquakes with half a magnitude unit larger are complete for the last 56 years. The analysis also shows that the present catalogue contains almost all the events with magnitude equal to or greater than 5.0 and 5.5 after 1940 and 1911, respectively. Finally, no earthquake with magnitude 6 or greater seems to have been omitted in the whole instrumental period.

SD4/P2/ID62 **- TSUNAMI CATALOGUES FOR THE EASTERN MEDITERRANEAN - REVISITED**

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We critically examine examine tsunami catalogues of tsunamis in the Eastern Mediterranean published in the last decade, by reference to the original sources, see Ambraseys (2008). Such catalogues have been widely used in the aftermath of the 2004 Boxing Day tsunami (Synolakis and Bernard, 2006) for probabilistic hazard analysis, even to make projections for a ten year time frame. On occasion, such predictions have caused media panic. (Ethnos, 2007, Proodos, 2007). We correct classification and other spurious errors in earlier catalogues and posit a new list. We conclude that for some historic events, any assignment of magnitude, even on a six point intensity scale is inappropriate due to lack of information. Further we assert that any tsunami catalogue, including ours, can only be used in conjunction with sedimentologic evidence to quantitatively infer the return period of larger events. Statistical analyses correlating numbers of tsunami events derived solely from catalogues with their inferred intensities are meaningless, at least when focusing on specific locales where only a handful of tsunamis are known to have been historically reported. Quanti-

tative hazard assessments based on scenario events of historic tsunamis for which -at best- only the size and approximate location of the parent earthquake is known should be undertaken with extreme caution and only with benefit of geologic studies to enhance the understanding of the local tectonics.

Tsunami warning systems have been announced for the eastern Mediterranean since 1998, but none are currently operational; if they ever were, there have been no published warnings. The question remains whether local warning systems can be effective in an island archipelago such as the Aegean, or within the Ionian or the Aeolian Islands. Beginning in 2005, a subcommittee of UNESCO's Intergovernmental Oceanographic Commission has been contemplating such a system. To the date of writing, the Mediterranean remains without any tsunami warning system (Synolakis, 2008). It is here that tsunami catalogs also play a role, in that they assist bolstering the decision-making process (based on seismic, GPS, tide and sea-level measurements), if, for example, a tsunami has been documented in the past in the same source region as the event under current scrutiny. Tsunami catalogs can also be used to help educate populations at risk.

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Ambraseys N. and Synolakis C.E., [2010] Tsunami Catalogs in the Eastern Mediterranean - revisited, Journal of Earthquake Engineering, Vol 14 (3), 303-330.

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SD4/P3/ID63 - HISTORICAL EARTHQUAKES IN LOWER AUSTRIA

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A recently concluded investigation of historical earthquakes of Lower Austria led to new information regarding already known earthquakes of this territory and so far unknown tremors. This project permitted the first comprehensive study of earthquakes of this region.Actually in every century – with the exemption of the 20th century, from which just data points were collected – new information of earthquakes could be gathered. After being transcribed, most of those data indicated actual earthquakes, and a large number of them could even be analyzed and parameterized.Altogether 10.370 messages related to 322 earthquakes were analyzed, of which 204 earthquakes occurred prior to 1900. In 106 cases, the earthquakes could not be finally parameterized in terms of location and epicentral intensity as additional information would be required to do so. The whole data set included also 21 fake quakes, all of which referred to storms and other causes before 1900. The most prominent earthquake of this category was the event from 1668 near Wiener Neustadt, formerly known as an earthquake of intensity 7.The famous earthquake of 1590 - known as the "Neulengbach earthquake" - was also studied in great detail. Numerous new sources were found during the course of this investigation. The epicentre appears more to the East – closer to Vienna near Reichersberg, a small village west of the Riedersberg - of the pervious assumed location in Neulengbach. This new epicentral location explains the damage to the capital of Austria and the lack of damage to the provincial capital of St. Poelten

SD4/P4/ID64 - HISTORICAL EARTHQUAKES IN THE VALAIS: PRIMARY AND SECONDARY EFFECTS.

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In recent years the Valais has been one of the most intensively investigated regions in Switzerland. The Swiss Seismological Service performed a series of research projects, and significantly increased the density of the seismic network in this area. Due to the relatively high seismic activity, the region presents many starting-points for research in the seismological field. One main focus was set on historical seismology. During the last 10 years, investigations covered for the first time systematically the whole traceable time using historical methodology. The base for these investigations was a search through all relevant archives and documents. The oldest preserved documents with respect to major earthquakes in the Valais with magnitudes around 6 are those mentioning the aftermath of the 1524 and 1584 events. Earlier events of similar dimension are not traceable in historical sources originating from the Valais region. We present the state of the art of our historical research by giving an overview of the investigated earthquakes with EMS intensity larger than VII. This includes the presentation of historical sources as well as explanation of the used methodology. Damaging earthquakes have much higher recurrence rates in the Valais region than in the rest of Switzerland. For the last half millennium a magnitude 6 event is known to have occurred every century (Aigle 1584, Brig 1755, Visp 1855, and Sierre 1946). Beside building damage we identified numerous secondary effects of various types for all mentioned earthquakes, among them landslides, rock-falls and liquefaction. Remarkable of all these phenomena is the disastrous landslide of 1584 destroying two villages and killing more than 300 people. Others are a rockfall of 4-5 million m^3 near the Rawylhorn triggered by an aftershock of the 1946 event, and widespread liquefaction in the Rhone valley during the 1855 earthquake.

SD4/P5/ID65 - A PRELIMINARY INVESTIGATION OF SOME MAJOR VRANCEA (ROMANIA) HISTORICAL EARTHQUAKES: NEW SOURCES

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During centuries, the Romanian territory has been shaken by strong earthquakes, most of them being centered within Vrancea Zone, which is situated at the bending area of the South-Eastern Carpathians. Powerful earthquakes occurred during the 19th century, on October 26, 1802 and January 23, 1838, having as a result numerous victims, as well as material damages as it comes out of the contemporary people's notes. Recently, there have been discovered new sources that contain information referring to the above mentioned earthquakes. In this study, we used such data coming from 26 historical records, which were obtained after the research of the old books of some monasteries and museums. New elements regarding the research of these earthquakes were obtained after reevaluating the information from certain areas (especially from the epicentral zone), concerning the environmental effects. Within the present study, the information referring to these earthquakes which were identified, as a result of investigating the historical sources, are interpreted and evaluated with the purpose of assigning some macroseismic intensities for elaborating the preliminary macroseismic maps.

SD4/P6/ID66 - ESTIMATING MAGNITUDE AND LOCATION OF ROMANIAN CRUSTAL EARTHQUAKES USING INTENSIY DATA

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Macroseismic intensities (EMS98), instrumental moment magnitude, Mw and hypocenter locations of eleven crustal earthquakes ($4.0 \le Mw \le 5.6$) were used to calibrate a new macroseismic intensity attenuation model for the western part of Romania. Using data obtained for seven earthquakes ($4.0 \le Mw \le 5.4$) the attenuation relationship were tested and validated: Ii = 1.94 + 1.96Mw + 0.004Dih – 4.58 logDih, where Dih is the hypocentral distance in kilometers from epicenter to each observation point. We applied the well known Bakun and Wenthworth (1997) procedure to (re)locate the most important historical events occurred in the region ($M \ge 5.0$) and to estimate Mw magnitude. Focal depths of the new located events were computed using the Kovesligethy's (1906) and Blake's (1941) methods, having attenuation coefficients computed on instrumental well located earthquakes and macroseismic high quality data.

SD4/P7/ID67 - NEW EARTHQUAKED PARAMETER DETERMINATION FROM MACROSEISMIC DATA IN THE IBERIAN PENINSULA USIG PROCEDURES DEVELOPED UNDER NERIES NA4

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Earthquake location and size are important data to characterize seismic hazard. It is known that source parametrization from macroseismic data poses specific questions without easy solution and the obtained results show large uncertainties. Even so, obtaining source parameters from macro-

seismic data is an important topic because it allows expanding the time period of the available series of earthquake data from 100 to 1000, or even more, years.One of the objectives of the NA4 module (Distributed Archive of Historical Earthquake Data) of the European project NERIES recently finished has been to compile a unified macroseismic catalogue for the whole Europe with great emphasis on the standardization and repeatability of the epicentral parameter determination. Among the different tested approaches, a new program to perform such calculations, MEEP (Macroseismic Estimation of Earthquake Parameters, Musson & Jimenez, 2008), has been developed. This program uses different regional calibrations that are obtained throught the use of calibration sets.The "MEEP" approach has been tested thoroughly under NA4 action for different areas in Europe. Here we present the results of the test of this approach specifically for the Iberian Peninsula. Different calibration sets (from the Iberian Peninsula and other regions) have been used and compared. Some of the problems, adopted solutions and results of the calibration and testing of MEEP for the Iberian Peninsula are shown and discussed. Also, preliminary results on location and Moment Magnitude of selected earthquakes are presented.

SD4/P8/ID68 - LIGHT SPOTS THROUGH THE 'DARK AGE' IN SWITZERLAND. RE-ASSESSMENT OF THE SEISMICITY DURING THE PERIOD 1964-1974

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The period 1964-1974 in Switzerland, referred as 'dark age', is a transition time between a period dominated by the historical seismicity and the actual one covered by instrumental seismicity. The data are incomplete and very inhomogeneous.

A detailed report on the situation of the earthquake service and the seismicity of Switzerland and surroundings in these years has been done together with a detailed review of all the events of this period. We are presenting some difficulties and questions, which occur when putting the catalogue together. Looking at the entire period, the data are rather inhomogeneous. The data come not only from different networks but also from very different type of stations (the older one were operating since 1911). The intensity scale used changed from the Rossi-Forel scale to the MSK scale, which was systematically applied since 1972.

Many dams having been constructed during these years and some seismicity might be related to induced events. The most notable events are the Sarnen swarm in 1964 with he two main episodes reached an intensity of VII and the intensty VI Glarus earthquake in 1971. Different methods, macroseismic (Bakun) as well as instrumental (NonlinLoc), have been applied to obtain a probability distribution of the locations. The different magnitude and location re-evaluations are compared and discussed. This information sheds some light on the uncertainty attached to the parameters of the historical events.

Although events with magnitude of the order of two have been recorded for the period until 1971, we consider complete only the events with a magnitude of 3.5 and larger. The magnitude and location uncertainties have been reviewed for the purpose of seismic hazard determination.

SD4/P9/ID69 - COMPILING A CATALOGUE OF MOUNT ETNA EARTHQUAKES FROM 1600 TO 1831

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Mount Etna (Sicily), together with Mount Vesuvius, probably is the volcano with the longest and more detailed historical record in the world. Ten years ago, the most recent portion of this huge historical data set was used to compile a specific catalogue of earthquakes occurring in the Etna region from 1832 to date (CMTE, Azzaro et al., 2000). Now, by maintaining the same criteria of analysis and compilation, the catalogue has been extended backwards to cover the previous two centuries.

A relatively small number of earthquakes are listed in the existing repertories for the time-span 1600-1831: 6 events in the parametric catalogue of Italian earthquakes CPTI04 (CPTI Working Group, 2004), 26 in the PFG catalogue (Postpischl, 1985) and 3 in the CFTI catalogue (Guidoboni et al., 2007). It seems scarcely believable that during this period there had been so few earthquakes, all the more so as in that same time-span there were many relevant volcanic eruptions.

The likeliest explanation was that the available historical record had not been exploited to its full extent. Having tapped this huge reservoir of often only partly "known" data, we then started to hunt for possibly overlooked earthquakes in other "data repositories". The search systematically extended to more than 200 original historical sources - diaries, chronicles, histories, archive records, travellers' journals, newspapers - written between 1600 and 1850 and preserved in 33 libraries or archives in Italy and abroad.

As a result, we have identified 138 earthquakes occurring in the period from 1600 to 1831, 112 of which had resulted unknown to any seismological study. Depending on the collected information, for 72 events we have estimated the parametres (epicentre, magnitude, max and epicentral intensities) while for the other 76 ones it has been possible only to report generic information about location (affected areas) and type of macroseismic effects (felt, damage).

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SD4/P10/ID70 - COMPILATION OF THE EARTHQUAKE HISTORY OF CRETE IS., HELLENIC ARC AND TRENCH

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One of the most active seismotectonic structures in the western Eurasia is the Hellenic Arc and Trench (H-AT) system. The island of Crete occupies the central segment of H-AT just to the north of the front where the lithospheric plates of Africa and Eurasia converge and the former bends and subducts beneath the later. Therefore, the shallow and intermediate-depth seismicity in the area of Crete is very high. In addition, these processes produce volcanic eruptions along the South Aegean Sea island arc as well as tsunamis. The civilization in Crete was developed long ago, and because of this the record of earthquakes goes also very back in the past. Three very important, key-events have taken place in the area of Crete: the LBA or Minoan eruption of Thera and its associated tsunami, and the mega tsunamigenic earthquakes of AD 365 and 1303. The repeat of such extreme events in the future would have dramatic consequences for a large part of the Mediterranean basin. Therefore, their study by all available means is a scientific challenge of high-priority. The rich seismic history of Crete has been documented so far in historical sources and instrumental records. However, the historical documentation is not complete and several earthquake events remained unknown so far. In addition, some strong events of the instrumental era of seismicity are not well-studied. Therefore, there is need to review and complete further the historical seismicity of Crete. In addition, new knowledge about historical earthquakes and tsunamis in the area of Crete was accumulated from geological and archaeological observations as well as from analytical laboratory results, e.g. for dating purposes, which are not integrated so far into a unified methodological approach as a supplement to historical and instrumental documentation. About 200 earthquake events are documented and described with the support of documentary sources, in original and in English translation. Field geological and archaeological observations as well as pictorial material supplement the documentation. Cultural items, such as folk songs, poems etc., when related to the earthquake activity are also inserted along with the rest documentary material. Earthquake focal parameters are evaluated and reliability scales are introduced. Associated phenomena, such as volcanic eruptions, tsunamis, sea-quakes, liquefaction in soil, rockfalls and landslides, earthquake precursors and

the similar are also discussed. Each one of the main historical periods of Crete, from the Minoan era up to the modern one, are examined separately.

SD4/P11/ID71 - RELOCATION OF THE HISTORICAL EARTHQUAKES OCCURRED ON THE ROMANIAN TERRITORY

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The high seismicity of the Vrancea Seismogenic Region and the potential for large earthquakes, require to have accurate locations and source parameters for as many previous events as possible. With this purpose, we have relocated some historical earthquakes occurred in the north-east Vrancea Seismogenic region. In this zone there is complicated fault system, very active, capable of tectonic earthquakes mostly with moderate intensity, but occasionally with bigger ones. On August 17,1893, September 10, 1893 and August 31, 1894 (by the Gregorian calendar), in this area, occurred three significant historical earthquakes. These events are considered significant for hazard mitigation planning. For these historical earthquakes, isoseismal maps indicate intensity VI to VII (MSK). Generally, the relocations require only a small change in location or larger adjustment for the events. However, the August 17,1893, September 10, 1893 and August 31, 1894 earthquakes were mislocated.

SD4/P12/ID72 - HISTORY REPEATING ITSELF: THE RECURRENT SEISMIC DAMAGE OF L'AQUILA LANDMARKS

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The 6 April 2009 earthquake is the last of many strong earthquakes that hit L'Aquila (central Italy) in its less than 800 years of life. Local and non local earthquakes caused severe damage (I≥7 MCS) to what was then the entire town of Aquila (now the «old town» or «centro storico» of L'Aquila municipality) in 1315 (MW 6.0; site intensity 8 MCS, CPTI Working Group, 2009), 1349 (MW 6.4; site intensity 9 MCS), 1461 (MW 6.4; site intensity 9 MCS), February 1703 (MW 6.6; site intensity 9 MCS) and finally 1915 (MW 6.9; site intensity 7-8 MCS). Each episode left a trail of historical records from which we can derive not only the distribution of damage in the urban area but also information on several affected urban landmarks. In the case of the medieval earthquakes, this information is also more detailed than is usually available for Italian earthquakes of that period, with the only exception of the December 1456 earthquake (MW 6.9) effects in Naples (site intensity 8 MCS). L'Aquila old town does still occupy the same site where it was first built in the 1250's AD. The town's historical landmark buildings do likewise still stand (with only a few exceptions), in the same spots which medieval builders chose for them, even if not quite looking the same as they originally did. Piecing together the individual seismic histories of L'Aquila landmarks, it is possible to higlight recurrent damage (or lack of damage) patterns. The resulting set of data, cross-checked with the results of a systematic damage assessment survey carried out according to the EMS scale by Tertulliani et al. (2009) and implemented in a GIS, can contribute useful information to a characterization of the seismic ground response in the «old town» and to a detailed microzonation of the site. References

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SD4/P13/ID73 - THE 25 JANUARY 1348 EARTHQUAKE: INTERPRETATION PROBLEMS AND POSSIBLE SOLUTIONS

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On the 25 January 1348 earthquake, there are several recent historico-seismological studies. Though relying – at least partly – more or less on the same data set, each of these studies reaches widely diverging conclusions particularly for what concerns the seismological interpretation of the available information. The different interpretations proposed by the available studies lead to the definition of contrasting effects scenarios, with strong consequences on the definition of the parameters of the earthquake.

The difficulties experienced by the researchers who have tried to interpret the historical data set available for the 1348 earthquake are a direct consequence of the complexities of the historical background within which the studied event took place. The 1348 earthquake occurred at a difficult time (during the "Black Death" pandemic) and affected a "multinational" and "multilingual" area (the border zone between Austria, Italy and Slovenia) that, in following centuries, would undergo many political changes. This means, for instance, that many localities mentioned by medieval sources in connection with the 1348 earthquake are likely to have changed names, at least once and probably even more often, in the following centuries. This makes it quite difficult to to associate the information provided by historical sources to a specific local context with any degree of certainty.

This paper highlights the problems connected to the interpretation of key historical sources (such as Mathias von Nuvenburg, Giovanni Villani and others), particularly for what concerns the identification and correct location of place names, and proposes how an alternative interpretation of these sources could help reaching a better understanding of the 1348 earthquake.

SD4/P14/ID74 - CONTRIBUTION TO INTENSITY DATA BASE AND CATALOGUE COMPILING FOR EARTHQUAKES IN ROMANIA AND NEIGHBORING COUNTRIES

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The state of the art of the recent investigations obtained in the framework of NERIES (http://www.orfeus-eu.org/neries/neries.htm) and SHARE (www.share-eu.org) projects related to re-evaluation of the earthquake catalog data in the Balkan region are presented. New historical information especially for famous Vrancea earthquakes have been collected also from other Balkan countries like Bulgaria and Turkey and analyzed. It is clear that there are a lot of uncertainties when interpreting and integrating the macroseismic information from different countries. Despite of this the discovered new information contributes to reassessment of the catalog parameters, mainly in Romania and neighboring countries. A few case histories are discussed in detail and parameterization - calibration procedures for historical events are critically reviewed.

SD4/P15/ID75 - COMPARISON OF DIFFERENT COMPLETENESS CHECKS FOR NEW AUSTRIAN EARTHQUAKE CATALOGUE INCLUDING SURROUNDING AREAS

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In regions with long historical earthquake records, seismic hazard assessments are challenged by the uncertainties of the available data. A major source of uncertainty is the lack of completeness of those historical earthquake records. However, earthquake catalogues are fundamental for seismic hazard assessment since they are relevant for determination of a and b parameters of the Gutenberg-Richter relation. Therefore, an important step in seismic hazard assessment is the check of completeness for different intensity levels and the removal of aftershock sequences. We created a new composite catalogue for Austria, Vienna Basin outside of Austria and 100-km wide area outside the boundary of Austria. The dataset is based on four different earthquake catalogues (ZAMG, 2009; ACORN, 2004; Van Gils & Leydecker, 1991; Shebalin et al., 1998). The earthquake catalogues cover different record length from 1048 AD to 2009 AD. In a first step, we declustered the composite catalogue by using magnitude-dependent time and space windows. We used this new data base to compare different approaches to check for completeness: The first method is based on the temporal course of earthquake frequencies (TCEF) and is generally used for completeness checks in Europe (e.g. Grünthal et al., 1998). The second method is based on statistical analysis of mean earthquake recurrence intervals for varying time windows (STEPP, 1972). It investigates (I) the minimum observation required to reach a reliable estimate of mean recurrence periods, (II) the time period from which the catalogue may be regarded complete. Both intervals are function of intensity class. Since the

data includes both historical and instrumental events, these computations are made for intensity. For both methods, we determined the completeness periods for each intensity class and derived the a and b parameters for the Gutenberg-Richter relation. We can show that those parameters depend on the completeness correction method. The TCEF includes always the highest intensity class (I=X), independently on whether the observation period is long enough to determine its completeness. Therefore, it tends to underestimate the a and b parameters. The Stepp (1972) method, on the other hand, excludes the highest intensity class (I=X) in our case because the observation period is too short for constraining a stable recurrence interval. Based on these results, we prefer the Stepp (1972) method. For the remaining intensity classes, the new composite catalogue fulfils the critical minimum observation period and is therefore suitable for hazard assessment for Austria.

ES1 - TRIGGERED AND INDUCED SEISMICITY

ES1/P1/ID76 - A NOTE ON NEAR-SOURCE ESTIMATES OF LOCAL MAGNITUDE FOR THE SHAHRIAR DAM SITE

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Since 2007, one 4 stations network of sensitive regional array has been installed in Shahriar dam preparation for the regional seismic monitoring network.This regional network has provided a detection capability for Dam experts to record microearthquakes around the dam district to compare these data with microearthquakes after loading in the reservouir. 80 events have been detected and located during this period, as discussed in this article. These data, plus similar data from the 6 permanent stations of ISTN (Iranian Short period Telemety Network) digital seismic network comprises three component seismic stations installed near to this area are used to investigate the near-field determinations of M_L: this investigation has relevance for uses of distances in determining seismic design criteria. We have calculated *n* and *k* parameters related to the geometrical spreading and anelastic attenuation. The obtained attenuation curves by using horizontal and vertical data were compared. The average estimates of M_L based on this alternative relation for several well-recorded events are not similar to those obtained on the basis of Richter's standard definition. Using station corrections were investigated and we found that in some stations the local site effect has a strong influence on recorded amplitude. Also a duration magnitude formula is determined which is using signal duration. Comparison M_L values and duration magnitude values for recorded events have been done. Empirical relations were derived between the established $M_L$scale and the Nuttli magnitude scale which is presently is used in the ISTN networks and duration magnitudes. Finally, we find that the source lithology, local site effects, and large-scale geologic features control most of the variability in the amplitude measurements.

ES1/P2/ID77 - POSSIBLE RESERVOIR TRIGGERED SEISMICITY ASSOCIATED WITH ARMENIAN LARGE RESERVOIRS

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The problem of triggered seismicity related with exploitation of reservoirs is essential in geophysics and earthquake engineering, especially for the reservoirs constructed in seismically active regions. Armenia is characterized as a high seismic active region. A review of reservoir triggered seismicity in Armenia shows that it mainly occurs in areas of large dams which are located near active faults.In this paper it is presented seismic activity around Azat reservoir before and after its operation. Azat reservoir is situated on Azat-Sevan and Garni-Elpin active faults conjunction zone. It is shown that the number of microearthquakes increase after reservoirs operation, causing changes of seismic regime in observed region, calculated b values are higher after operation of reservoir as well. Characteristics of seismicity observed from 1962 to 2009 along the active faults and the correlation between the temporal variation of seismicity and the water level changes in the Azat reservoir are analyzed. The number of shallow earthquakes along the active faults are correlated with the water level changes. In general, it is clear that there is a relationship between reservoir water level, which probably modifies the pre-existing tectonic stress field, and pore fluid pressures. Keywords: Reservoir triggered seismicity, Azat dam, microearthquakes

ES1/P3/ID78 - SEVAN LAKE WATER LEVEL CHANGES AND SEISMISITY OF LAKE'S BASIN

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In this work we attempt to reveal possible correlation between Sevan lake water level changes and observed seismicity. Lake Sevan is situated in the central part of the Republic of Armenia, inside the Gegharkunik province, at the altitude of 1900m above sea level. The use of lake waters for irrigation started in 19th century, and from the beginning of 20th century its water were also used for energy production, to address the country's energy deficit. Drawdown of the water level in the lake began in the 1930s.Lake Sevan suffered extenssive withdrawal of water between 1945-1967 and 1992-1995 . It water level has decreased by 19 m. Within the period of intense water emission in 1949-1962 the level of water in Sevan dropped for about 1 meter per year. This study shows that earthquakes with $4 \leq M \leq 5$ are associated with the above mentioned time periods. 6 events occurred in 1933 - 1954 time period, and another 6 for 1991-2005 time period.

ES1/P4/ID79 - DYNAMICS OF LOCAL EARTH CRUST TILTS UNDER INFLUENCE OF HIGH DAM CONSTRUCTION AND LARGE WATER RESERVOIR FILLING

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We aimed to investigate influence of located in West Georgia, Enguri high dam construction and reservoir initial water level variation on dynamics of local earth crust tilts. High arch dam (271.5m high, 728m long) was built in the canyon of the Enguri river in 1978, as the part of Enguri Hydroelectric Power Plant. In present study time series of hourly measured tiltmeter data sequences for 13 years (1971-1983) and water level daily measurements in reservoir, behind the dam, since beginning of its filling by water in 1978, were investigated. Several tiltmeters have been installed in high dam foundation. We considered the following time windows for our data sets: 1) long before water reservoir filling, 2) immediately before and 3) just after beginning of water reservoir filling, 4) after second, 5) third and 6) fourth stage of water reservoir filling and 7) long after completion of water reservoir filling. Thus considered time period of observations included 8 years before and 5 years after the start of filling of the large water reservoir of Enguri power plant. Time series recorded for the first 8 years comprised tiltmeter measurements at the very beginning of high dam construction process, when anthropogenic influence could be considered as practically negligible, but last 5 year included period when high dam was already constructed and tilt process of Earth crust was influenced by increased amount of water in the reservoir. All available water level variation and tiltmeter data sets have been handled by modern methods of time series linear and nonlinear analysis.By our analysis it was shown, that with or without man-made influence or water level variation, Earth tilt dynamics is characterized by linear and nonlinear patterns, which are typical for the low dimensional dynamics. It was quite logical that such type of dynamics of Earth tilts behaviour, according to its recurrence properties, revealed presence of detectable and quantifiable dynamical structure.According to our results the general nonlinear characteristics of dam foundation tilts has not changed qualitatively during dam construction as well as reservoir filling conditions. At the same time some transient quantitative changes in dynamics of Earth tilts have bean detected which have been restored after accomplishment of high dam construction and reservoir filling.

ES1/P5/ID80 - SOME RESULTS COMPLEX ASSESSMENT OF SEISMIC HAZARD AT APATITE MINES IN THE KOLA PENINSULA

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One of the forms of man-made catastrophes is mining-induced seismicity resulted from large-scale mining operations. In order to forecast mining-induced catastrophes, calculations of spatial co-ordinates of the increased seismic hazard zones.

Many parameters of geodynamic processes in a rock mass or even the measuring results obtained by local methods can serve as precursors. At present, the following precursors have been used at apatite ore mines, Apatit JSC:

1) Fractal dimension of spatial distribution of seismic events;
2) Repeatability slope;
3) Concentration criterion;
4) Average length of fractures.

Calculations were made for statistical parameters for seismicity catalogues according to the records from three subsystems of the computer-aided rock mass seismicity monitoring applied at Geophysical Monitoring Centre (GMC), Apatit JSC.

At present, the GMC seismic events parameters catalogues have been retrospectively analysed to get the best prognostic precursors values. It will allow the perspective forecast to be made and the zones of increased seismic hazard to be revealed.

Seismicity catalogues are analysed by each prognostic precursor and by several precursors simultaneously by method complex assessment.

A complex assessment permits the area under control to be in detail differentiated on probabilities of seismic hazard.

For different seismic catalogue it is necessary to correct the values of hazardous levels depending on the considered time periods, coordinates of spatial window, specific mining operation and geology.

As results, we obtained spatial distribution of increased seismic hazard zones for fixed time period. As usual, strong seismic events were registrated of the GMC in these zones.

ES1/P6/ID81 - ROCK MASS WATERING IMPACT ON INDUCED SEISMICITY IN JUNCTION ZONE BETWEEN UNDERGROUND MINE AND OPEN-PIT MINE

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There are cases that have come to notice when the sharp changes of meteorological situation due to frontal passage coincided with local earthquakes. During several decades there was a constant technogenic impact on the apatite-nepheline deposit “Apatitovy Zirk” and “Rasvumchorr Plato” managed by Apatit JSC resulting in separate blocks and fractures formation that are filling with water. The most important seismic events have been analyzed for selected database. These events are mass blasting, natural events and events beyond the registration zone but with necessary information in time and positions. Seismicity increase has been taken into account only during the rain and next three days after.

Season increase of water inflows result in water saturation of weakened zones where water flows in rock mass depthward. Underground mining of this deposit needs to provide drainage because of the water that prevents technological processes. If it is an open-pit mine on the rock mass surface but with the underground mining works it is necessary to take into account intensification of the water inflows due to oxidated zone square growth as these zones are the natural water catchments areas opened by surface workings of the open-pit mine. Besides, it is necessary to take into account the change in stress state of the rock mass both under technological (mining regimes) and natural (hydrological regime) factors. Seismicity in this region is mainly determined by redistribution of gravitational-tectonic stresses in the rock mass as a result of excavation and movement of the large rock and ore masses with open-pit mining in Zentralny mine and underground mining in Rasvumchorr mine. Seismicity activation during this period is initiated by strength properties decreasing of the rock mass fault contacts that are determined by intense rock mass watering as a result of long and heavy rainfalls. Mining-induced earthquake and the rock pressure dynamic occurrences in the workings adjoining ore pass №6 are initiated shifting along the fault filled with oxidated rocks as well as aftershock series of events after the main shock.

ES1/P7/ID82 - MINING INDUCED SEISMIC TREMORS LOCATION USING EXTENDED DOUBLE - DIFFERENCE METHOD.

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Seismic events location is very important issue in seismological observations and interpretations both in natural and induced seismicity. Nowadays, using the relative double – difference (DD) location technique gives more realistic results than another methods because of weak sensibility of location results for unknown velocity model. This presentation deals with mining induced tremors location problems. The double – difference technique is extended to a very specific mining conditions. We propose to release the restriction of the DD approach which requires the waves from each sources to be recorded by all sensors. We did it by combining of the DD schemata with the classical Single Event (SE) technique applied simultaneously for all sources in the cluster. This way we reached more stables results, especially in depths and origin time although by larger dependence on velocity to the original DD technique. The inverse problem is solved using probabilistic Monte Carlo approach which provides the full location error estimation.

ES1/P8/ID83 - TIME AND SPACE VARIABILITY OF THE FOCAL MECHANISMS AND STATE OF STRESS IN THE UPPER SILESIAN COAL BASIN

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The focal mechanisms of seismic events induced in various parts of the Upper Silesian Coal Basin (USCB) (southern Poland) were studied. All the seismic events were related to underground longwall hard coal exploitation. The seismic events were registered by local seismological networks consisting of vertical seismometers (approximately 16 seismometers in one network). The focal mechanisms were determined using seismic moment tensor inversion method in time domain for P-wave first arrivals. Spatial orientation of nodal planes, P and T axes and rake angle were calculated. Various focal mechanisms such as normal, reversed, strike slip or non double-couple were revealed. Assuming that the seismic events occurring in the same area during short time interval are induced by similar stress conditions, the mean local stress tensors for groups of tremors were calculated and the spatial orientations of main stress axes were found. The time and space variability of focal mechanism and state of stress in USCB were discussed.

ES1/P9/ID84 - INFLUENCE OF GEOLOGICAL CONDITIONS ON MAXIMUM VIBRATION VALUES GENERATED BY MINING INDUCED SEISMIC EVENTS IN STONAVA REGION (UPPER SILESIAN COAL BASIN)

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Main goal of this paper is to contribute to study of seismic effects generated by mining induced seismicity on buildings at the surface. Measured data originate from permanent seismic stations working in triggered regime and from short-time experimental continuous seismological recordings. Geological, hydrogeological and other conditions were taken into account using so-called maps of potential conflict of interests between residential area using and mining effects; special methodologies were developed.Experimental and numerical activities were concentrated in Stonava area. Using set of 50 mining induced seismic events, two subsets were realized. One set represents far distance events from evaluated area; second sub-set concludes events induced during exploitation of coalface below village in depth 900 m. This second sub-set includes 12 events with seismic energy $2*10^3$ – $6.4*10^4$ J; depths of events were in range 400 - 600 m. Obtained results represented by maximum values of induced component vibration are summarized in graphs. It was derived for this area (about 2 x 2 km) that in horizontal variable geological, hydrogeological and other conditions, at least two seismic stations are necessary to use for monitoring. One station has to be placed in optimum or favourable foundation conditions and alternative station has to be placed in critical or unfavourable conditions. Only one station is evidently sufficient in areas with simple geological conditions, if it is possible to determine vibration attenuation depending on epicentre distance. Significant parameter, that is necessary to take into account, is level of underground water.

ES1/P10/ID85 - SOURCE MECHANISMS OF MINING INDUCED SEISMIC EVENTS IN HAMM, EASTERN RUHR AREA, GERMANY

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Seismicity in the tectonically inactive Ruhr area is induced by deep coal mining. Since 1983 the seismicity has continuously been monitored by the Ruhr-University Bochum. About 1000 seismic events with 0.7<Ml<1.2 and can be recognized by people living close

to the mining activity. This results in considerable public interest in mining induced seismicity.

Between June 2006 and July 2007 seismicity of a single longwall in Hamm was continuously monitored by a dense seismic network. About 7500 seismic events with -1.7<Ml<2.0 are located. Epicenters cluster in the region of active mining with sharp boundaries that trace the borders of the longwall. Hypocentral depths mainly are up to 100m below and 200m above the active mining. This pattern implies that the observed seismicity is a direct answer to stresses induced by the ongoing mining. This is supported by the migration of epicenters with the advance of mining at about 100 m/month from southwest to northeast. For 90% of the epicenters the horizontal distance to the longwall face is less than 60m.

Furthermore, spatial clusters of seismic activity are observed within distances up to 500m to the longwall. Here, the layout of former longwalls may have led to areas of enhanced stresses. Where rocks at higher levels have been untouched by previous mining the gravitational load is increased compared to regions where mined areas lie on top of each other.

Fault mechanisms of selected events are analyzed. A total of 105 fault plane solutions is determined from the polarities of P-onsets and polarization of S-waves. In general, two types of fault mechanisms are observed and interpreted as, firstly, the mechanisms accompanying mining activity at the longwall face and, secondly, the failure of load-bearing structures. The first type is characterised by steeply dipping, near vertical fault planes that strike parallel to the longwall face. These events occur close to the ongoing mining. Displacement is in direction towards the goaf. P-axes are oriented at an azimuth of 60°, which is equal to the direction of face advance, and a plunge, which predominantly is between 10 and 45°. The second type of events mainly occurs at clusters at larger distances up to 500m. These events can be described by vertical P-axes corresponding to gravitational load and variable azimuths of the T-axes. Here, load-bearing structures may fail when additional stresses are induced by active mining.

ES1/P11/ID86 - CLUSTERING PROPERTIES OF MINING INDUCED SEISMIC EVENTS IN EQUIVALENT DIMENSIONS

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Detection of spatio-temporal dependencies between mining induced seismic events from Rudna mine with use of equivalent dimension metric is the main aim of this study. Equivalent dimension technique transforms events location as well as energy and origin time of event into a multidimensional space of uniformly distributed parameters. Dependencies of events considered in this technique indicate properties of clustering in mining environment. Distances between events in equivalent dimensions of chosen parameters were estimated. The smaller distance indicates the stronger link between events. According to this feature, families of the most connected events were identified. Within those families earlier event has some closely related descendants in considered space, therefore the evolution of clustering in mining seismicity with growth of event families in time was also investigated.

ES1/P12/ID87 - PREDICTION OF COALMINES STRATA INSTABILITY USING INDUCED MICROSEISMICITY

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In the underground coalmines roof falls cause considerable damage to men and machinery in particular the problem is severe in hard roof coalmines. During extraction of coal the strata accumulates high stress energy for some period of time and releases in a particular form of microseismic events. Real time detection of these microseismic events and process them in online to obtain source parameters using advanced 24 bit digital microseismic system will provide the strata failure pattern before an impending roof fall. The changes in source parameter characteristics during the failure process will provide impending roof fall location and time of occurrence. These induced microseismic events source parameters variations were studied and observed in coal mines at Churcha west coal mine and Rajendra underground longwall coal mines, India. In this paper few case studies of precursory pattern obtained for roof falls are discussed and presented. The results of microseismic investigations of a series of roof falls leading to goaf pack during longwall mining are also described.

ES1/P13/ID88 - TRIGGERED AND INDUCED SEISMISITY OF THE CENTRAL PARTS OF EAST EUROPIAN PLATFORM (VORONEZH CRYSTALLINE MASSIF)

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Voronezh Crystalline Massif (VCM) is one of the largest segments of East European platform. By it's origin VCM is a buried ledge of metamorphic and magmatic rocks, covered from above with a sedimentary rocks layer from 100 up to 800 m. thick. Administratively this region corresponds to Central-Chernozemny economic district, with well-developed industry and high density of population. The place considered be passive, with very low seismisity. But lately obtained seismic data shows that seismisity of the region has increased. And the danger grows up every year with the intensification of human economical activity which disturbes the lithosphere more and more. A central role plays the mining activity. At present time more than 20 industrial pits are working on the territory of VCM. The mining works are of open type and proceeded by using short-delay blasting method with the blast power equivalent to 300 and more tons TNT. The blasting creates complicated wave fields which the non-homogenous geological medium perturb propagating through it. Analyzing the data on local earthquakes before and after the blast we can notice a consequence of low-magnitude earthquakes happened within the margins of the Losevsky suture zone 8 hours later the blast. The earthquakes follow each other with the small time span of less than 4 hours. The aftershock earthquakes mostly happen at the Losevsky suture zone at the point where the attenuation ratio reaches its largest values. This may be the evidence of accumulating and further relaxation of the seismic energy through the local seismic events. The effects observed correspond well to the hysteresis model of the geological medium. The heavy use of blasting technologies in mining industry has substantial influence on the increasing seismisity of the region. The local seismic activity grows up and makes the short-delay blasting problem one of the important points at the estimating the seismic state of the industrial region.

ES1/P14/ID89 - THE INFLUENCE OF GAS AND OIL PRODUCTION ON GEOHYDRODINAMIC AND SEISMISITY IN THE SOUTH URAL

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Geological technogeneous changes of oil and gas extraction areas in South Ural are considered. Oil and gas extraction leads to reduce of formational pressure and change of water level. Interaction of seismic activity, hydrogeodinamic and technogeneous changes is detected The increasing gas and oil production, especially in the last forty years than was found large oil and gas deposits in the South Ural (there are Orenburg oil and gas deposit in Sault-Ilecs Vault, oil deposits group in Busuluk Depression and others), results to extract great hydrocarbon and formation water volume from Earth's interior. The extracted substance volume from most of deposits becomes comparable with volumes of water-pressure system of deposits. As a result the hydrogeodinamic balance of geological environment is upset. The Orenburg oil and gas deposit (OOGD) disposes in Ural river valley on south-west from Orenburg, the length of it from west to east is 120 km long and about 20 km wide. OOGD is exploited from 1974. As a result of gas production during 35 years is reducing of strata pressure more than 100 kgc/cm^2 in the central part of OOGD and equals about 60 kgc/cm^2 now. The technogeneous hydrodynamic depression cone is formed on over 3000 km^2 square, it changed hydrodynamic processes in deep aquiferous stratum. The intensive gas production leads to drowning in OOGD and formation of flooding zones. The water-pressure system of deposits was formed during several tens million years with water cycle period equals over million years. But production rate of hydrocarbon is several tens years that is jump in balance in water-pressure system and jump in properly of deflected mode of Earth's crust. The seismic monitoring in South Ural is carried out from 2004 and enables to resume: 1. The seismological net registers in average 2-3 earthquakes in a month with magnitude over 1-2 on exploited deposits. Most of earthquakes are registered on a small deep under 10 km. 2. Concentrations of earthquakes correlates with technogeneous faulted blocks of rock (oil and gas deposits in South Ural.

ES1/P15/ID90 - A STRATEGY FOR AUTOMA-

TED ANALYSIS OF PASSIVE MICROSEISMIC DATA TO IMAGE SEISMIC ANISOTROPY AND FRACTURE CHARACTERISTICS

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Monitoring of induced seismicity is gaining importance in industrial operations ranging from hydrocarbon reservoirs to mining to geothermal fields. It aims at characterising the physical parameters of the rock and deduce the degree and orientation of fractures. By analysing shear-wave splitting it is possible to determine the anisotropy of the rock, which may be caused by sedimentary layering and/or aligned fractures, which in turn offers insight into the state of stress at depth. At reservoir scale this is of interest for safety and productivity reasons. Furthermore, volcanic regions show evidence for characteristic changes is shear-wave splitting parameters ahead of an eruption. We present a workflow strategy for automatic and effective processing of passive microseismic data sets, which are ever increasing in size. Such automation allows for quasi-realtime processing of the data.

The automation provides an objective quality control of the shear-wave splitting measurements and is based on characteristic differences between two independent splitting techniques. We use an automated inversion scheme using rock physics theory to test for best correlation of the data with various combinations of fracture density, its strike and the background anisotropy. We show in several real data sets, how this workflow can help to obtain information about the in-situ rock.

ES1/P16/ID91 **– NON-LINEAR ANALYSIS OF SEISMICITY CHANGE UNDER ELECTROMAGNETIC ACTION**

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A possibility to change seismic regime characteristics by strong electromagnetic field excitation in rocks was previously studied by several researches. The experimental research works, which were conducted at Garm, Tadzhikistan, and Bishkek, Kyrgyzstan, test sites showed short-time increase in the daily number of minor earthquakes, a concentration of the earthquake epicenters near the electromagnetic field source and some others aftereffects of the EM-field excitation. Meanwhile both physical mechanism of EM action on seismic processes and confident detection of EM seismic effects as well as their spatial-temporal limits are not resolved yet definitely.In the presented paper, a study of strong EM pulse actions on seismic regime in the region of Bishkek test site is made with the help of non-linear dynamics methods. A catalog of earthquakes obtained by KNET seismic network was used for the analysis. The catalog included data on 6623 earthquakes with magnitudes from 0.5 to 6 registered since 01.06,1994 to 30.12.2008.The study of the seismic activity variations were made by means of phase portrait reconstructions and calculations of the portrait parameters (an embedding space dimensionality and correlation dimension of an attractor, if that one exists). The considered area of possible EM excitation influence was 200x200 km in size with center coincident with EM source position. The earthquake catalog was divided into two parts of the same durations: before EM excitations and during the excitations. Seismic activity was calculated as sum of cubic roots from energies of seismic events occurred during a week (3 days overlap of the time intervals was used). The obtained time series were analyzed with the help of Grassberger-Procaccia method of correlation integral calculation for different embedding space dimensions. Parameters of time delay were chosen on the base of autocorrelation functions.The obtained results show an increase of seismic regime regularity after beginning of EM pulses action: before EM excitation, the correlation dimensionality of the possible attractor was not less than 8 with corresponding embedded space dimension 14. After start of EM excitations, the attractor correlation dimensionality diminished to 4.6, embedded space dimension – to 6.The model of possible reaction of the geomechanical system governed by rate-and-state friction law on perturbations due to EM actions is considered numerically. It was found, that small change of fault and fracture strengths under EM action leads to diminishing of attractor and embedded space dimensions.

ES1/P17/ID92 **– KINETICS OF THE DEFORMATION AND FAILURE UNDER THE IMPACT BY THE ELASTIC AND THE ELECTROMAGNETIC FIELDS (TO REDUCE THE STRUCTURAL STRESS LEVEL)**

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KINETICS OF THE DEFORMATION & FAILURE UNDER THE IMPACT BY THE ELASTIC AND THE ELECTROMAGNETIC FIELDS(TO REDUCE THE STRUCTURE STRESS LEVEL)*Avagimov, A.A., Okunev, V.I., and Zeigarnik, V.A.*Joint Institute for High Temperatures, RAS, Moscow, Russiazeigarnik@ihed.ras.ruThe surplus local stress discharge is equally urgent in the regions with both natural and man-caused seismicity. The experiments on the stimulated destruction of the model samples are aimed at search for the correlations between the impact energy and the deformation and failure parameters. The goal of the study is to discover the stage of the mechanical instability, k_p, development when the impact is proved to be correct and what the impact energy value will be to promote the discharge of the local (structure) stresses.Here presented are the results of the experiments on the model samples obtained under the successive alternating of the discrete intervals of the elastic loading and the stages of quasi-static deformation mode (QSM); during these QSM stages, the electromagnetic (EM) impact is applied.The estimates are made of the relaxation energy during the QSM stages under the various energy saturation levels; the energy dissipation coefficient is calculated depending on the k_p level. These data make it possible to calculate the ratio, K_{tr}, of the minimal energy of the triggering impact to the stored potential energy. This ratio reflects the threshold properties of the triggering impact and corresponds to the background level of the relaxation process.The relaxation process activation is shown to cause, under the variation of the threshold impact level, the principally different kinetics of the material state. Over the linear interval of the K_{tr} distribution, under the impact energy below the threshold level, the relaxation process activation causes the local structure stress discharging. After the sample reaches its critical strengthening, the pulsed EM impact induces the uncontrolled non-linear process of the elastic energy relaxation resulting in irreversible macro-destruction. The relaxation processes considered are adequately reflected in the failure kinetics parameters. The analysis is performed of the failure kinetics against the acoustic emission intensity within the intervals of loading and of the EM impact; the electromechanical conversion coefficient, K_{em}, is estimated.The external EM energy impact plays the role of the additional energy transfer component and thus may be referred to as the factor influencing the stress level. The K_{tr} data can be used to calculate the external impact needed to trigger the stored energy discharge.The model of the reduction of the structure stress level by the EM impact is discussed.

ES1/P18/ID93 **– EXPERIMENTAL STUDY OF COMBINED ELECTROMAGNETIC AND DYNAMIC EARTHQUAKE TRIGGERING AT THE SPRING-BLOCK FACILITY**

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Based on analysis of dynamic events in the Earth crust, as well as experimental data obtained during the last years, which earnestly demonstrate that the crust earthquakes are rather the slip over existing surface of the fault than propagation of new crack in the brittle material, the special spring-block system was developed, manufactured, and tested for laboratory investigation of electromagnetic and mechanical triggering impacts on the fault area. Dimensions of test specimens are of 50x50x50 mm to 200x100x50 mm. Normal load is up to 50 kg. Drag force of electric drive is up to 100 kg, velocity of movement of running block is 0.010 to 500 mm/min. The system allows to study an influence of weak vibrations, dynamic impacts, heating, and electromagnetic actions as the separate and combined triggering factors on the granular layer simulating the fault zone. Preliminary experimental results of behaviour of seimic cycle under combined dynamic and electromagnetic actions are presented and discussed.

ES1/P19/ID94 **– ROTATIONAL SEISMOMETER AND ITS POSSIBLE USAGE FOR OSCILLATION MEASUREMENT OF HIGH TOWERS OF HISTORICAL BUILDINGS**

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Rotational movement belongs among emerging parts of seismology. Classic methods for studying depend on indirect measurement and careful in-situ planning – arrays, laser gyros etc. Our approach is based on direct

measuring of rotations using sophisticated mechanical transmission of ground movement into change of capacitance between plates of capacitor. It enables to construct quite small, portable, sensor for field measurement. Changes are followed by monolithic capacity-to-digital (C/D) converter with 24-bit resolution. We would like to present the basic ideas, dynamic characteristics – theoretical and measured. Some examples of measured signals will be shown. This sensor is portable and is designed to easy in-situ installation. That is it's the best advantage – it can be deployed almost anywhere. We are going to discuss measuring within our last project – Stability of Historical Buildings, especially high tower vibrations at Prague Castle.

SD10 - INTERNET MACROSEISMOLOGY

SD10/P1/ID95 - ONLINE MACROSEISMIC QUESTIONNAIRES AT EMSC

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EMSC proposes since 2007 on its website a macroseismic questionnaire, in which witnesses may give their testimony whenever they feel an earthquake. This questionnaire is now available in 28 different languages, and we are working toward usage of automatic translation for languages we do not yet cover. Beside an obvious larger audience, language information may be used to guess whether earthquakes were felt by local inhabitants or by foreigners. Others indirect data as the delay elapsed after the earthquake are also studied at EMSC. Our questionnaire may be used to compute both EMS 98 and MMI intensities, provided respectively by an algorithm developed by R.M.W. Musson (BGS) and by David Wald and Vincent Quitoriano (USGS). We contributed to an ESC working group led by R.M.W. Musson to establish a new questionnaire which would smooth even further differences between both algorithms. With our dataset growing (more than 10,500 questionnaires so far), we may be able to step toward intercalibration of these scales. For the EMSC mobile site, currently under development, macroseismic questionnaires are not really an option as it is not convenient to answer a bunch of questions on the relatively small screen of a smartphone. We will therefore follow BCSF tracks and implement thumbnails describing the different EMS 98 intensities; a witness will then choose which thumbnail matches more what he felt.

SD10/P2/ID96 - LINKING GROUND MOTION MEASUREMENTS AND NEARBY INDIVIDUAL TESTIMONIES IN FRANCE A CASE STUDY BASED ON THE RAP – (ACCELEROMETRIC) AND BCSF (MACROSEISMIC) DATABASES

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Earthquake ground motion may be quantified either from instrumental measurements or from macroseismic intensities, inferred from observations of their effects, by using a macroseismic intensity scale (EMS-98 here). The aim of our study is to link the two kinds of data in order to better understand the physical meaning of macroseismic data and quantify the spatial variability of the seismic motion. In the literature, comparison between macroseismic and instrumental data are commonly made by plotting macroseismic intensities statistically estimated within areas of the size of a small city (communal district in France) versus instrumental data recorded at the locations of the sensors. Since 2000, the «Bureau Central Sismologique Français» (BCSF) collects individual testimonies thanks to an online INTERNET macroseismic questionnaire (www.franceseisme.fr). Numerous testimonies are localized near accelerometric sensors of the French «Réseau Accélérométrique Permanent» (RAP). This allows us to look at relationships between accelerometric and macroseismic data with a better control on the spatial significance of the macroseismic observations. It is also a way to test if individual «pseudo-intensities» associated with each questionnaire can be used, instead of communal intensities, to study the ground motion variability. In the east of France, three ML>5 earthquakes occurred between 2003 and 2004 (Rambervillers (ML = 5.4, 2003), Roulans (ML = 5.1, 2004) and Waldkirch (ML = 5.3; 2004)). They have been recorded by at least nine stations of the RAP's Network; six of them are localized near the city of Mulhouse, either in valleys of the Vosges massif or within the Rhine graben. For these events, 21,362 testimonies were gathered and 3,397 of them are located at distances less than 10 km from the accelerometric stations. In a first step, simple instrumental parameters have been compared with pseudo-intensities estimated from the testimonies gathered around each RAP station. Our set of data clearly shows pseudo-intensities are better correlated with the Peak Ground Velocities than Peak Ground Accelerations. Comparison with other instrumental parameters (Arias intensity, Cumulative Absolute Velocity (CAV), signal duration) will be presented at the meeting. In a second step, in order to better investigate the physical content of macroseismic data, the 50 items of each macroseismic questionnaire have been encoded. A correlation analysis shows these items can be merged into six thematic fields. The answers to the questionnaire follow a coherent evolution with epicentral distance and we will present a comparison between the encoded answers and the spectral content of the accelerometric signals.

SD10/P3/ID97 - SISMAP: A NEW SEISMIC SOCIAL WEB FOR THE ALICANTE PROVINCE (SOUTHEAST SPAIN)

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In this paper, a new mashup (SISMAP) that combines Google maps technology and the local seismic information of the Alicante province (southeast of Spain) has been developed. This new application permits to visualize in satellite maps all the information about the seismic events occured in Alicante area. The seismic information (date, hour, latitude, longitude, magnitude, etc) is geopositioned in satellite maps and is provided by the local seismic network of the Alicante province.

The aim of this project is not only to provide a scientific web with the local seismological information, but also a social Web where people can participate with new information, comments, photografies and videos of the earthquake effects. This interactivity becomes our application in a Web 2.0 system.

The application is free and can be used from any platform (PC, smartphone, PDA, etc) through any standard Web browser. Our mashup has been developed using the open source Google Maps (API) with PHP and Ajax as programming language. The software architecture minimizes the resources required for the system, without having to install any additional software by the user. The application provides root access or webmaster to introduce the seismological information in the system. The webmaster controls the comments, pictures and videos of the users. People does not need register to use the application, although they can do it to receive updating information of the seismic events.

The Web application is focused on the local seismic information of the Alicante province (setting the initial satellite map in this region), but it would be very easy and inmediate to extend it to other regions. The accesibility of the seismic information on a social Web contributes to approach the science to the general public.

SD10/P4/ID98 - EARTHQUAKE RESPONSE AND GEOLOGY IN ROME EVIDENCED BY WEB-BASED MACROSEISMIC INTENSITY SURVEY OF MAIN EARTHQUAKES OF L'AQUILA SEQUENCE, APRIL 2009.

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During L'Aquila earthquake sequence, a detailed macroseismic analysis was conducted in Rome, where a large amount of data was collected from web-compiled questionnaires (3695 reliable questionnaires). We consider people and buildings as instruments recording seismic effects such as shaking intensity, movements of objects, human reactions and damage: all these information were collected in real time via our web site *www.haisentitoilterremoto.it* .

Although Rome is settled in a relatively low-seismicity area, in the past, it suffered damage produced by earthquakes occurring mainly in the Alban Hills and in the central Apennines. We expect that local site amplification of the analysed earthquakes will be the same for a larger event occurring in that area.

Data regard low intensity degrees, characterised mostly by transient effects recorded by people all over the urban area located at a distance ranging from 75 to 110 km from the epicenters. All intensity data were normalised for each event by subtracting the mean

intensity for Rome city and by compensating the attenuation effect with distance from the hypocentre. Stacking and spatial filtering procedures were applied to intensities of all events, obtaining a filtered and interpolated residual map. Intensity residuals were compared with detailed geological reconstructions. Good agreement is found between amplification areas of Rome urban territory and geology. We also put in evidence the deep geology role as important as near surface geology for the definition of some amplifications areas. Moreover we reveal some amplification areas unknown by historical macroseismic observations in Rome, due to intense recent urban expansion.

SD10/P5/ID99 - REAL-TIME ESTIMATION OF MACROSEISMIC INTENSITY IN ROMANIA

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Earthquakes that are unambiguously sensed by humans or even destructive are often happening natural phenomena in Romania. Earthquakes risk management is a very important topic today because earthquakes are a rapid on-set hazard (the strong shaking that causes damage during an earthquake usually lasts for less than 1 one minute), although the effects can last for decades. The MACROSEIS application is an automated tool for collecting information from volunteers that felt the effects of an earthquake. Based on this interactive system, data can be collected and macroseimic maps can be obtained. The MACROSEIS application collects reports from volunteers that were sent via Internet shortly after an event is produced. Electronic reports are sent to the National Institute for Earth Physics. This information is transformed in CII Community Internet Intensity Maps by means of a modified version of the Dengler and Dewey algorithm. The algorithm requires that the geographic position of the macroseismic effect is based on the GPS coordinates of the observer during the earthquake. While the information is recorded on the website by the volunteers it is processed by dedicated software and a local map of the seismic intensity is generated on the Internet. Instrumental intensity value obtained from the review of accelerograms (I = f (PGA), PGA = peak ground acceleration) and the intensity value obtained from existing attenuation relationships are considered as a confirmation for the results obtained after processing the macroseismic questionnaire. As a final result a map is generated where every observation point is associated with different colors, according to the seismic intensity in that location and they are compared with instrumental values obtained at seismic stations.

SD10/P6/ID100 - REVISITING THE AUTOMATIC ASSESSMENT OF MACROSEISMIC INTENSITY BY THE FUZZY SETS APPROACH

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Seismic intensity assessment usually consists in the subjective judgment, made by an "expert", of which degree of the scale better corresponds to the macroseismic effects observed at a site. To make this decisional process more objective, verifiable and backward traceable, we already developed a procedure, based on the Fuzzy Set Theory, which formalize it into three main steps: i) the collection and the encoding of effects, ii) the association of effects with the intensity degrees, iii) the final intensity assessment. All of the steps are performed using computer codes that help the user to encode the qualitative information found on documentary source, to georeferencing the sites, to compute the membership functions (that is the level of belonging of a given effect to each degree of the macroseismic scale) used to associate the effects to the degrees of the scale, and finally to assess the intensity.

In this work we describe two improvements of the method. The first one consists in the introduction of more reliable criteria to determine the membership functions. The second one concerns the introduction of multi attribute decision making (MADM) algorithms other than the one (minimax) used in previous works.

These changes improve the ability of the automatic method to reproduce expert intensities particularly for high degrees (IX and larger) that were generally underestimated in previous works. The automatically reassessed intensities result more homogeneous with respect to those made by an expert and the entire procedure is fully traceable and reproducible, hence inconsistencies and mistakes in expert assessments may be evidenced and corrected. This approach might also be used to test the correspondence among different effects observed at the same site in order to improve the macroseismic scale basing on objective criteria.

SD1 - SEISMIC CENTERS DATA ACQUISITION

SD1/P1/ID101 - ACQUIRING, ARCHIVING, ANALYZING AND EXCHANGING SEISMIC DATA IN REAL TIME AT THE SEISMOLOGICAL RESEARCH CENTER OF THE OGS IN ITALY: AN UPDATED VIEW

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The Centro di Ricerche Sismologiche (CRS, Seismological Research Center) of the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS, Italian National Institute for Oceanography and Experimental Geophysics) in Udine (Italy) after the strong earthquake (magnitude M=6.4) occurred in 1976 in the Italian Friuli-Venezia Giulia region, started to operate the North-east Italy (NI) seismic network: it currently consists of 11 very sensitive broad band and 22 more simple short period seismic stations, all telemetered to and acquired in real time at the OGS-CRS data center in Udine. Real time data exchange agreements in place with other Italian, Slovenian, Austrian and Swiss seismological institutes lead to a total number of 90 seismic stations acquired in real time, which makes the OGS the reference institute for seismic monitoring of Northeastern Italy.

Since 2002 OGS-CRS is using the Antelope software suite as the main tool for collecting, analyzing, archiving and exchanging seismic data in the framework of the EU Interreg IIIA project "Trans-national seismological networks in the South-Eastern Alps". SeisComP is also used as a real time data exchange server tool. At OGS-CRS we then adapted existing programs and created new ones like: a customized web-accessible server to manually relocate earthquakes, a script for automatic moment tensor determination, scripts for web publishing of earthquake parametric data, waveforms, state of health parameters and shaking maps, noise characterization by means of automatic spectra analysis, plus scripts for mail/SMS/fax alerting. A new OGS-CRS real time web site has also been recently designed and made operative in the framework of the Italian PC-INGV S3 Project.

SD1/P2/ID102 - THE ALGERIAN NATIONAL NETWORK OF ACCELEROGRAPHS

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The Algerian national network of accelerographs is born following the earthquake that ravaged the region of chlef (El Asnam) October 1, 1980. Currently, it is composed of 217 accelerographs of which 115 of numeric type and the network of seismographs that are composed of a mobile network of 10 stations of K2 type and a broad band network (STS2) of 5 stations in phase of installation. Data acquisition:Accelerograms are acquired after each significant seismic event by CGS team operators. We schedule to acquire the data of the national accelerograph network by an automatic acquisition system by using a telephone lines. The difficulties reencountered are in the availability of telephone lines which is costly. Data analysis, storage, archiving and availability:The data acquired are stored by two different ways. The first concerns analogue data recorded on films. These recordings are classified in a traditional way and stored in a dry environment with constant temperature. The second concerns the digital accelerograms and seismograms which are stored on PC with copy on CD-ROM.The analogue data are digitalized with SCANVIEW software using a step sampling of 200 sps. The digital data acquired with the SSA-1 stations are analysed with SWS software. The ETNA digital data are read with QUICKLOOK software and analysed with the SMA software. All theses softwares are Kinemetric's inc. product.

SD1/P3/ID103 - RAIS: A REAL-TIME STRONG-MOTION NETWORK IN NORTHERN ITALY

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RAIS arose in the 2004-2006 agreement between the Italian Civil Protection (DPC) and Italian National Institute for Geophysics and Volcanology (INGV). The necessity of a dense strong-motion network in Northern Italy was due to the lack of available near-field data after the occurrence of the 24th November 2004, M_L 5.2, Salò earthquake. In fact, due to the saturation phenomena the nearest available waveforms were recorded at an epicentral distance of about 90 km. It is worth noting that, even this event didn't cause losses, it was one of the most energetic earthquake occurred in Northern Italy in the last 20 years. In order to improve the strong-motion monitoring of Northern Italy region, the INGV, department of Milano-Pavia, in June 2006 installed the first strong-motion station of RAIS. The first two years were so dedicated to the installation phase while from 2008 many efforts (founded by the DPC-INGV S3 project) were made in order to improve both automatic data acquisition and processing. At present RAIS include 22 strong-motion stations, 14 of which transmit data in real time through TCT/IP protocol or wi-fi link. The others 8 stations send data by modem gsm. The stations are equipped with Kinemetrics Episensor FBA ES-T coupled with 11 Reftek 130-01 and 11 Gaia-2 seismic recorders (both 24-bits). Both data acquisition and data-sharing of the 14 real time stations is assured by the last release of Seiscomp. The data, in MiniSEED format, are automatically downloaded after each new event thank to a detection procedure based on synthetic spectra calculated following the Brune model. After the acquisition, the data are automatically processed in order to assure the most interesting ground-motion parameters (e.g. PGA, PGV, PSA, PSV, Rd, Ia, Ih). For each event with M_L higher than 3.0 the data are sent to a dedicated ftp-server managed by INGV CNT-Rome with the aim to improve the ShakeMap calculation. Now the RAIS database includes about 70 event with M_L ranging from 2.5 to 5.1 for a total of about 1.500 3-component strong-motion waveforms. For each recorded earthquake the matadata dissemination is achieved through the website http://rais.mi.ingv.it, while the waveforms are downloadable at http://itaca.mi.ingv.it

SD1/P4/ID104 - ADVANCES IN THE CONSTRUCTION OF THE ANTARCTIC SEISMOGRAPHIC ARGENTINEAN ITALIAN NETWORK - ASAIN

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Several seismological research groups have been working in the Scotia sea region and in the neighbouring areas since the beginning of the nineties. Spanish, Italian, Argentinean, USA, British researcher and groups from other countries have operated temporary stations to investigate the characteristics and the origin of the seismicity in specific areas like the South Shetland Is, the Bransfield Strait and the tip of South America both on the Chilean and Argentinean sides of Tierra del Fuego. Both on land and sea experiments lasting some months or some years were performed to collect data on the tectonics and the geodynamics of the Scotia Sea. During the nineties and the past ten years this kind of activity was performed in parallel with the construction of a regional seismographic network composed of several permanent observatories equipped with three component broad-band seismographs distributed around the Scotia sea and in neighbouring areas. Three stations were installed by the IRIS consortium (PMSA, EFI and HOPE), between 1993 and 2006, while the main effort in the construction of the Scotia Sea network was conducted by the Italian PNRA and the Argentinean DNA which realized between 1992 and 2002 the ASAIN network composed of five instrumented sites located in Tierra del Fuego (DSPA,USHU) and in the Argentinean permanent Antarctic bases in the Antarctic Peninsula and nearby islands (ESPZ, ORCD, JUBA). During the IPY (March 2007- March 2009) two more stations (SMAI and BELA), installed at higher latitudes over the Antarctic circle were added to the ASAIN at the Argentinean bases San Martín and Belgrano II which is located on a rocky outcrop emerging from the ice at the south east corner of the Weddell Sea at only 1300 km from the South Pole. During the 2010-2011 Antarctic campaign a polar seismometer which can properly operate at temperatures reaching -50° C. will be installed at Belgrano II. All the data management comprising local storage at the stations, real time remote transmission of the data to the OGS, the Instituto Antrtico Argentino and the ORFEUS Data Centre, and archiving in the ASAIN database at the OGS are performed using mainly SCREAM and some OGS software. The scientific results obtained using the ASAIN data suggest the extension to the east of the network. Even if this appears to be a difficult enterprise the OGS is already preparing a feasible project.

SD1/P5/ID105 - SEISMOMETER CMG-3ESPC CHARACTERISTICS EVALUATION

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The Seismology and Geology Office of the Environmental Agency of the Republic of Slovenia is responsible for the Seismic Network of Slovenia which consists of 26 seismic stations. The typical seismic station is combined by the seismic shaft with the seismometer (CMG-40T, STS2 or CMG-3ESPC) and the data acquisition system (Quanterra Q730) and the service shaft with communication equipment and power supply with a battery box. Seismic station´s performance and data quality is characterized by properties of micro location and by properties of seismological instruments. Before the installation it is worth to evaluate quality and performance of seismic measuring equipment. In a case of seismometers a few parameters such as self-noise and generator constant are prefered to be evaluated at least.

In the year 2009 three new Guralp CMG-3ESPC seismometers with frequency range from 50Hz to 0.0083Hz were purchased. They were tested at the Conrad Observatory in the Central Institute for Meteorology and Geodynamics (ZAMG, Austria) which provides all the necessary equipment and micro location to perform tests to evaluated this two parameters. To evaluate seismometers self-noise all three Guralp CMG-3ESPC seismometers were installed together with a STS-2 seismometer side by side with the same orientation. Seismometers were covered with additional temperature chamber. Acquisition units were two «low self noise» 6 channels EatrhData PR6 datalogers and data were sampled by 200sps. Generator constants of these seismometers were evaluated by the CALTAB-1 shaking table, also installed at Conrad observatory. In the presentation, procedure of tests and outputs will be presented.

SD1/P6/ID106 - THE VIRTUAL EUROPEAN BROADBAND SEISMIC NETWORK (VEBSN)

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The VEBSN is a pool of broadband seismograph stations, the data of which is shared in (near) real-time by European seismological observatories. The data is shared on the basis of the VEBSN statement of operation and is an efficient vehicle to gather and archive data for scientific research. Consequently, the data is secured in the European Integrated Data Archive (EIDA), pragmatically the European regional FDSN archive. The VEBNS has been initialised within the EC-project MEREDIAN. Within the NERIES project the VEBSN has been extended and the EIDA is being created. Data within the EIDA is shared by the ArcLink protocol and made available to the user through well established services like breqfast and NetDC, and more advanced techniques (JOQUE, PORSCHE, Seismic Data Portal - www.seismicportal.eu) based on webservices.

SD1/P7/ID107 - THE GEOAZUR-OCA SEISMIC NETWORK (SOUTHEASTERN FRANCE): IMPLEMENTATION OF REAL TIME SEISMIC DATA SURVEY AND PROCESSING

T. Geoazur seismological observatory[1], J. presented by Salichon[2]
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The Geoazur seismic observatory, as part of the french national network RESIF, is presently in charge of about 20 sites located in Provence, southern Alps, Corsica and Monaco areas and collect data flows from northern Alps and Pyrenees. These data are exploited by institutions such as the french national seismological survey (Rénass), the french accelerometer network (RAP), the french broad band network (RLBP), or the geophysics laboratory of Grenoble (LGIT). In addition, realtime data are distributed to ORFEUS, IRIS, GFZ, and CEA (Cratanem project). The seismic survey is performed using different types of instrumentation: short period velocimeters, broadband velocimeters, and accelerometers, since the region is one of the most seismically active in France. Indeed, the region covered by this network experienced historically large earthquakes (M > 6) such as the 23/02/1887 Ligurian or the 11/06/1909 Lambesc earthquakes. With the development of real time data acquisition systems in the southeastern France during

the past few years, the detection and the observation of the low to moderate seismic activity in southeastern France gained in potential to be accurately monitored. The Geoazur laboratory is brought to manage and process these real time data flows within different projects related to tsunami alert (RATCOM, CRATANEM), improvement of national network (RESIF), transnational real time data exchange (RISE). Consequently, we firstly implement different public domain software suites in order to improve the station survey using performance evaluation tools such PQLX, developped by the USGS, secondly, we set up event detection and location software suites: earthworm V7.3 (maintained by ISTI), and seiscomp3 (maintained by gempa gmbh). Thirdly, we carry out home made softwares in order to perform real time earthquake source estimation using rapid moment magnitude, focal mechanism computation routines. Putting in place all these procedures, we address several questions about the real time data management, storage, and exchange. We also aim at improving the rate of automatically locatable real earthquakes, and address the question of magnitude completeness. Finally, we intend to share metadata with different seismic survey centers, and address the way of managing meta data exchange and event multilocalization issues.

SD1/P8/ID108 - QUANTERRA Q730 LOCAL DATA STORAGE EXTENSION

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The Slovenian National Seismic Network consists of 26 seismic stations all equipped with data acquisition systems Quanterra Q730. Seismic data from all stations are transmittED in real-time to the Data Center in Ljubljana (DC), where the Seismology Office is located. The main disadvantage of Quanterra Q730 data loggers is LOW local memory storage. They are equipped with just 16 Mb (or 8 Mb) RAM module, used for program operations and temporary data storage. In case of larger failure on the communication lines to the data center, data is lost. The length of «allowed» communication breakdowns depend on compression, number of acquisition channels (3 or 6) and the size of installed RAM, but it could only be 1 hour. For this reason, small low cost industrial PC using LINUX OS, with 12 VDC power supply and low consumption (6W), was installed next to the Quanterra Q730 datalogger and connected to Quanterra Q730 by two RS232 ports. First port is used for data acquisition and second port is used for State of Health (SOH) acquisition. SeisComP installed at this computer is used for data acquisition, and some local scripts are used for SOH acquisition, watchdog and UTC time synchronization. While Quanterra Q730 is still sending data, also data from industrial PC is sent to the secondary Data Centre located also in Ljubljana. Local memory storage at seismic station is extended for at least 2 year period. In case of larger failure on the communication lines, data is automatically resended, if breakdown is less than 4.5 days.

SD1/P9/ID109 - MONTANA REGIONAL SEISMIC NETWORK PERFORMANCE: AN EVALUATION THROUGH SNES METHOD

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A properly organized seismic network is a valuable tool for monitoring seismic zones and evaluating seismic hazard. In this paper we analyze the location performance of the Montana Regional Seismic Network by SNES method (Seismic Network Evaluation through Simulation, D'Alessandro et al., 2010). This method permits us to construct, as a function of magnitude, hypocentral depth and confidence level, maps of the number of active stations in the location procedure and the relative azimuthal gaps and confidence intervals in hypocentral parameters regarding both the geometry of the seismic network and the use of an inadequate velocity model. The Montana Regional Seismograph Network is comprised of 38 stations deployed over an area of approximately 50,000 km^2. Montana and immediately surrounding regions have a high level of seismicity that includes approximately 1500 locatable earthquakes annually, most of which occur along the Intermountain Seismic Belt and Centennial Tectonic Belt in the northern Rocky Mountains. Through application of the SNES method, we show that the Montana Regional Seismic Network provides the best monitoring coverage in the Flathead Valley of northwestern Montana and it provides a threshold of completeness down to magnitude 1.8 for most of western Montana. We delineate some seismogenic areas of western Montana, including the central portion of the Centennial Tectonic Belt in extreme southwestern Montana, that are not adequately covered by the existing network. The SNES technique provides guidance for optimal upgrades to the network to provide adequate monitoring coverage for the seismogenic parts of the Northern Rocky Mountains.

SD1/P10/ID110 - REF TEK'S ADVANCED SEISMIC NETWORRKS

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REF TEK's advanced seismic networks are built around the 3rd Generation Broadband Seismic Recorder, Model 130-01. The 130-01 Recorder equipped with Ethernet controller, asynchronous serial communication, and a point-to-point (PPP) serial port make up the primary remote field station components for data telemetry over IP networks. A typical REF TEK network topology is shown in the picture below. Either configuration provides full duplex data transmission between the central recording station and the field stations. Any combination of these Recorder configurations can co-exist in a network. In addition, the 130-01 Broadband Seismic Recorder is designed for backward compatibility with existing networks. Optionally, a Compact Flash drive can be attached to the REF TEK station to provide emergency data backup at the field site in the event telemetry is lost during large earthquakes. A typical central station consists of an online computer used for configuring the remote station DAS, monitoring DAS and communication status, acquire error free, and archiving remote station data. An advanced REF TEK Interface (RTI) with graphical user interface (GUI) is available, providing an intuitive command and control application for the operator. In addition, either REF TEK Seismic Network Data Processor (SNDP) or public domain advanced processing and meta-data management software package SeisComP3, developed by GFZ and servicing by Gempa) can be used by the end-user for real-time event detection, data processing and information exchange. Ethernet controller and PPP serial port supports full duplex data transmission that is compatible with all forms of digital telemetry. This offers the distinct advantage of identical digitizers at field sites and the ability to utilize the most appropriate means of telemetry. For example, remote 130-01 Recorders can be connected to the central station by any combination of spread spectrum radio, VSAT, dialup networking, LAN/WAN, GSM network or the Internet. The 130-01 Recorder utilizes the REF TEK Protocol (RTP) to achieve this flexibility along with a corresponding RTP server application residing on the host computer at the central station. RTP provides a full duplex, packet-oriented, and reliable transport over the point-to-point protocol (PPP) via a serial port and Ethernet port running Transmission Control Protocol (TCP) over Internet protocol (IP), thus providing a conduit to the various types of IP networks mentioned above. Several factors are considered when choosing the type of telemetry that will be employed including initial budget, recurring costs, topography, and existing infrastructure. REF TEK's advanced seismic networks allow the scientist to choose the best telemetry method for a given set of circumstances without a complicated mix of hardware and without sacrificing the timeliness and quality of data.

SD1/P11/ID111 - LOCATION PERFORMANCE OF THE GREEK NATIONAL SEISMIC NETWORK: AN EVALUATION BY THE SNES METHOD

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Seismic networks are powerful tools for understanding the state of seismo-tectonic processes taking place in a region. Their numerous applications, from monitoring seismicity to characterizing seismogenic volumes, make seismic networks essential tools for the seismic risk assessment. Appropriately structured seismic network may also be a valuable tool for the study of deep geological structures through seismic tomography. The ability to detect small and medium sized events requires a seismic network with sufficient number of low noise stations that are optimally distributed. It is, therefore, important to assess existing capabilities of a seismic network, to identify seismic areas that are not adequately covered, and to further ascertain measures for the network improvement. Greece, is the most seismically active region in the whole Mediterranean and in the whole West Eurasia. Seismicity

is associated with the collision between the Eurasian and the African lithospheric plates. Regional seismicity in Greece is monitored by the Greek National Seismic Network that composed by about 120 seismic stations. In this poster we will evaluate earthquake location performance of the Greece National Seismic Network though SNES (Seismic Networks Evaluation through Simulation) method. The SNES method gives, as function of magnitude, hypocentral depth and confidence level, the spatial distribution of: number of active stations in the earthquake location, azimuthal gaps and confidence intervals in hypocentral parameters regarding both the geometry and noisiness of the seismic network and the use of an inadequate velocity model. In particular, through SNES we have identified high and low seismic noise areas of Greece National Seismic Network. Through statistical analysis of P and S residual times we have assessed validity of velocity models used in earthquake location routines and estimate an empirical law that link travel time residual time variance to the hypocentral distance. Finally, from analysis of produced SNES maps, we will identify regions in Greece where it may be opportune to improve the existing seismic network.

SD1/P12/ID112 - SEISMOLOGICAL NETWORK STRUCTURE OF KOSOVO

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The experience from the last earthquake that took place in the surrounding of Gjilan in April 2002 has shown that a network for detailed monitoring of the local seismic activity needs to be installed in Kosovo. For that purpose, a proper distribution and selection of sites/locations for installation of the seismological stations will be necessary. According to the spatial configuration and the relatively high seismic activity originating from the seismic foci in Kosovo and the neighboring countries, a network consisting of 8 seismological stations distributed over the entire territory is proposed to be installed.This network of seismological stations will enhance the accuracy of definition of earthquake parameters necessary for the study of the seismicity of the Kosovo territory. The selected locations of seismological stations are compatible and would fit into the seismological networks of the neighboring countries. Anticipated is a real time online transfer of data to the main centre, i.e., the Institute of Seismology in Prishtina where the data will be processed.The seismological stations are located in the following places: Prizren, Zatriq, Zatra-Peje, Llapushnik, Leposaviq, Smrekonic, Germia-Prishtina and Gjilan. Their micro locations have been defined based on geological, geophysical and seismological investigations. Also, the selection of the locations complies with the requirements set by the producer of the seismological and the accessory equipment regarding communication, power supply and physical protection of the structures in which the equipment will be installed.

SD1/P13/ID113 - STRONG-MOTION OBSERVATION NETWORK IN TURKEY

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It is well known that seismicity of Turkey is very high, and strong-motion shaking primarily causes earthquake damages. Ground shaking is the most significant hazard in the country because of the resulting potentially widespread destruction. Hence, strong-motion seismology became as a significant application starting from the 1970s. As a result of attempts to understand, predict, and mitigate this hazard, National Strong Motion Network of Turkey (TKYHG) was established in 1973 by Earthquake Department under the Disaster and Emergency Management Presidency belongs to Prime Ministry. The first strong ground motion had been recorded in 1976 by analog accelerometers. Nowadays, most analogue, non-communicating instruments have been replaced with modern digital instruments that provide information in real-time. During the past 34 years, nearly 5000 three-component accelerograms have been recorded across Turkey. The collected waveform records of all stations are stored in the strong-motion database at the Data Management Center of TKYHG and all data are provided to researchers, engineers and general public through the Internet under fully open policy. Users can select specific events or stations to download the waveform data. They can also browse, select, and retrieve various information such as distribution map of acceleration, station maps, site information including seismic velocity profiles and soil condition, and so on. Stations are generally abundant on the North Anatolian Fault Zone (NAFZ), East Anatolian Fault Zone (EAFZ), and Aegean Graben System, where destructives earthquakes occurred over there. Instruments are installed as free fields in cities and towns. The TKYHG consists of 300 strong-motion observation stations. Dense networks are being deployed in the urban centres, where 83 instruments installed in major 7 cities throughout Turkey. Those are, the local Network of Bursa-Yalova (BYTNet - 14 inst.), Aydın-Denizli (DATNet - 6 inst.), Hatay-K.Maraş (MATNet – 18 inst.), Eskişehir Province (ANANet- 12 inst.), Duzce province (DUZNet – 7 inst.), Antalya province (ANTNet- 10 inst.) and 16 instrument were installed in Izmir province (IZMIRNet). The URL of TKYHG is http://kyh.deprem.gov.tr.

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SD1/P14/ID114 - REAL-TIME AUTOMATIC EVENT DETECTION AND PICKING OF P-WAVE ARRIVALS IN LOCALLY STATIONARY NOISE USING CROSS CORRELATION

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Automatic onset picking is of great importance in event Location. It also has the advantage of working on very large databases. The increasing of computers power allows the development of more efficient algorithms. All these algorithms are either based on amplitude, envelope, or power of the seismic signal in time or frequency domains. But, they have often ignored conditions and source kind of seismic noise at each record site. The aim of this study is to propose a method for detecting and picking the first arrival P in locally stationary noise seismic. In fact, through the analysis of a large quantity of seismic waves, we have found that the background noises have some regularities. Therefore, if the background noise is stationary and regular, we can anticipate that the seismic noise stationarity will be broken when a first arrival of an event seismic arrives. This seems useful to detect the arrival of P-wave. We can know whether the background noise is truly stationary and when the stationarity is being broken by using the correlation coefficient. By applying the correlation analysis to seismic records at quiet site, we got the result that the correlation is usually satisfied in the background noises, so, we can use the method to automatic determination for P-wave arrival. The application of this algorithm to some seismic records made a good result. In contrast to other algorithms, this method can detect changes in frequency, amplitude and phase. Therefore, if the background noise is stationary, we could detect the arrivals so clearly even if the amplitudes of background noises are large.

SD1/P15/ID115 - REAL TIME SEISMIC WEB MONITORING OF ALGERIAN DIGITAL SEISMIC NETWORK (ADSN)

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A New Digital Seismic Network with 52 stations was recently installed in Algeria. The network, using real time transmission, is managed by the Antelope software for Acquisition, processing, archiving and exchanging data. This new platform allows leading many aspects of real time seismology: seismic monitoring, rapid determination of earthquake, sending alert, moment tensor estimation, seismic source determination, shakemaps calculation, etc.

To improve management of the seismic network, we present an online seismic monitoring tool web-based developed recently at CRAAG. This tool can directly display site description, state-of Health of stations, events map, data quality using PQLX Web Interface and generate seismic catalog. It will help us to maintain the Network in operation and will provide scientists with many useful information to make decision in case of seismic crisis.

SD1/P16/ID116 - THE RISE PROJECT: INTEGRATING WESTERN ALPS SEISMIC SURVEY

NETWORK CAPABILITIES

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An effective management of the seismic survey and earthquake crises requires the integration of the seismic networks and their abilities to exchange information, more specifically when areas of concern are shared between different neighbour countries. The RISE project intends to federate different stakeholders involved in the seismic survey and alert in the western Alps according to the fact that the seismicity of the area is distributed between southwestern France, northeastern Italy and southern Switzerland. In order to implement a robust alpine seismic network and improve the earthquake detection, it is necessary (i) to be able to share real time seismic data over the borders (ii) to quickly exchange observatories analyses, (iii) to quickly exchange the required information during post-seismic intervention (structure of the ground, information on the neighbouring towns, maps, ...), and finally, (iv) to coordinate post-seismic intervention and the deployment of temporary seismic networks, during aftershocks survey.

SD1/P17/ID117 **- IMPROVEMENT OF THE REAL-TIME CATALAN SEISMIC NETWORK (NE SPAIN)**

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Since 1999 the objectives of the Seismic Network of the *Institut Geològic de Catalunya* (IGC) are, on the one hand, providing rapid information for Civil Defence Services and society in general and, on the other hand, to obtain systematically high quality data for the scientific community. In 2010, 16 stations are operative: 15 broad- band on land and one broad band OBS. All the network stations are based on VSAT platforms that are transmitting continuously almost real time seismic data via satellite to the IGC hub. Once at seismic data reception centre data are continuously archived. A real time automatic processing system has been implemented using Earthworm and specific developed tools. When an event is detected and located, an alert system sends a warning message to a distribution list. This information is disseminated in different ways (via web, e-mail, and fax). For events with magnitude greater than 4.5 a seismic risk scenario based on vulnerability assessment methodologies using GIS techniques is also included. The flexibility and modularity of the Catalan Seismic Network allow data exchange between different institutions (ORFEUS, *Instituto Geográfico Nacional* (IGN), *Bureau de Recherches Géologiques et Minières* (BRGM), etc.) and guarantee the interoperability between the different networks. Three accelerometric stations from the BRGM situated in the South of France were incorporated to the VSAT network in 2007 and in 2008 a real time exchange of data was initiated with the IGN. In the frame of SISPYR Project (described in session OS3) the exchange of real time stations is increasing. In consequence the number of stations used in the automatic and manual routines of seismic location at the IGC is increased with 5 stations from IGN, 3 stations from BRGM and 2 stations from the *Observatoire Midi Pyrenées* (OMP).

SD1/P18/ID118 **- A NOISE MODEL FOR HIGH-QUALITY ACCELEROMETERS: THE CASE OF THE MODERN STRONG-MOTION NETWORK OF SWITZERLAND.**

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The Swiss Seismological Service (SED) at the ETH Zürich is responsible for monitoring the seismicity of Switzerland and surrounding areas and the archival / dissemination of high-quality data for seismological and earthquake engineering research studies. In addition to a broadband/short period network and a dial-up strong motion network, the SED operates a modern strong-motion network, consisting of accelerometer stations continuously monitored in real time with high dynamic range instruments (2g ~155dB Epi-Sensors with flat frequency response from 200 Hz to DC) at high sampling rates (250 Hz). Currently, sensors are installed at ~20 free-field urban soil sites and an additional 12 sensors are co-located with broadband sensors at quiet rock sites. Dataloggers are 24-bit Nanometrics Taurus. Waveform state-of-health are available using PQLX software, a standard health-monitoring tool for broadband seismic networks. PQLX allows analysis, and in particular temporal tracking, of background station noise across the relevant frequency spectrum, by means of calculating the power spectral densities (PSD) from short durations and providing the likelihood a station will exhibit a given PSD over each frequency as a probability density function (PDF). Crucial to the understanding of the station quality is comparison of the PDF with the Peterson (1993) low and high noise models derived for high quality low-gain broadband installations. A broadband high and low noise model for modern high-quality strong-motion installations is proposed based on the continuous accelerometer data acquired at the SED since 2006. The proposed model is compared to the Peterson (1993) low and high noise models, existing Swiss strong motions stations, and to typical earthquake signals recorded in Switzerland and worldwide. A new 'low noise model' for accelerometric stations is dominated by the dynamic range of modern sensors and dataloggers. A 'high noise model' reflects 1) at high frequencies acceptable site conditions in urban areas where strong motion sensor are typically placed, 2) at mid-periods the peak microseismal energy and 3) at long periods the noise of the sensor / datalogger system for a well placed insulated station. The results of the present study derived from a new dataset of accelerometer waveform spectra provide a reference for high-quality strong-motion station installations and are of general interest to those who use earthquake and noise recordings obtained from modern-strong motion sensors.

SD1/P19/ID119 **- THE USAGE OF ANTELOPE FOR ACQUIRING END EXCHANGING DATA IN SOUTH-EASTERN ALPS: PRESENT CONFIGURATION AND FUTURE PERSPECTIVES**

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Since 2002 the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) in Udine (Italy), the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Vienna (Austria), the Dipartimento di Scienze della Terra (DST) of the Trieste University in Trieste (Italy), the Agencija Republike Slovenije Za Okolje (ARSO) in Ljubljana (Slovenia) and the Protezione Civile della Regione Autonoma Friuli Venezia Giulia (PCFVG) in Palmanova (Italy) are involved in the EU INTERREG IIIA project "Trans-national seismological networks in the South-Eastern Alps". The commercial Antelope software suite from BRTT has been chosen as the common basis for real time data exchange, rapid location of earthquakes and alerting. Each institute contributes to the seismological monitoring in South-Eastern Alps by sharing data from its seismic network. Antelope is a powerful software suite that easily allows sharing data in real time among several institutions by means of its module'orb2orb'. The current Antelope setup of all institutions involved for data acquisition, sharing and archiving will be described, together with the future evolution of the project.

SD1/P20/ID120 **- BULGARIAN SEISMOLOGICAL NETWORK AND DATA CENTRE - CURRENT STATUS**

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In 2005, the Geophysical Institute performed overall modernization of the National Seismological Network (BNDSN). The upgraded network consists of a National Data Center (NDC), 13 stations equipped with RefTek High Resolution Broadband Seismic Recorders – model DAS 130-01/3, 1 station equipped with Quanterra 380 and broadband sensors. Real-time data transfer was realized via Virtual Private Network (VPN) of the Bulgarian Telecommunication Company (BTC). The data acquisition and processing hardware redundancy at the National Data Center was achieved by two clustered SUN Fire V240 servers and two Blade 1500 Workstations. To secure the acquisition, processing and data storage processes a three layer network was designed at the NDC. Real-time data acquisition was performed using REFTEK's full duplex error-correction protocol RTPD. Data from the Quanterra recorder and foreign stations were fed into RTPD in real-time via *SeisComP/SeedLink* protocol and *sl2rtpd demon* running on Server1. Data processing was performed by the Seismic Network Data Processor (SNDP) software package running on both Servers. SNDP includes two subsystems:

· *Real-time subsystem (RTS)* – for signal detection; evaluation of the signal parameters; phase identification and association; source estimation.
· *Seismic analysis subsystem (SAS)*

- for interactive data processing. The signal detection process is performed by traditional STA/LTA detection algorithm. The filter parameters of the detectors are defined on the base of previously evaluated ambient noise at the seismic stations. Some extra modules for network command/control and monitoring and data archiving are running as well. Three types of archive are produced in NDC - two continuous - *miniSEED* format and *RefTek PASSCAl* format; and one event oriented in format of CSS3.0 scheme. Modern digital equipment and broad-band seismometers installed at Bulgarian seismic stations, careful selection of the software packages for automatic and interactive data processing in the data centre proved to be suitable choice for the purposes of BNDSN and NDC. Currently, the BNDC and BNDSN allow reliable automatic localization of low magnitude events ML>=1.5 within the network, and ML>=2.5 at regional distances. Recently, an evaluation of seismic station performance using the ambient seismic noise was done. Furthermore, the influence of the ambient seismic noise on the hypocenter determination and magnitude estimations was studied.

SD1/P21/ID121 **- THE USE OF ANTELOPE AND SEISCOMP PACKAGES AT DATA CENTER OF THE INSTITUTE OF GEOPHYSICS, PRAGUE**

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Czech Regional Seismic Network consists of nine seismological stations operated by the Institute of Geophysics of the Academy of Sciences CR, Prague (IG-ASCR), four stations run by the Institute of Physics of the Earth, Masaryk University, Brno (IPE), and stations Praha and Pecný operated by Charles University, Prague. Regional Data Center at IG-ASCR closely cooperates with the Data Center at IPE Brno and with numerous European national data centers (e.g. GI-SAS Bratislava, ZAMG Vienna, INGV Rome, GFZ Potsdam, SZGRF Erlangen, IG-PAS Warsaw, ETH Curych, GSS Ljubljana, NIEP Bucharest, GI BAS Sofia). Virtual network of IG-ASCR consists of about 75 stations in the European-Mediterranean region. SeisComP 2.5 and Antelope 4.11 packages are used for real-time data acquisition and exchange. Local, regional and global grids of the Antelope system perform automated detection and earthquake location. Alert messages for seismic events which fulfill selected criteria are distributed by Antelope on request. Digital archive of the IG-ASCR contains continuous data from 2000 to present and is based on the Antelope file structure. Waveforms are copied to the data server with the storage capacity of 50 TB. Data portal for data mining is planned to be installed there. At present homemade scripts are used for retrieval of large amounts of data. Digital data are exchanged both on-line by seedlink and Antelope and off-line (web request form, AutoDRM). Program SeismicHandler (K. Stammler) is used for the routine analysis of digital seismograms of the Czech Regional Seismic Network and other stations of the virtual network of the IG-ASCR.

SD1/P22/ID122 **- THE FRENCH ACCELEROMETRIC NETWORK (RAP) AND THE NATIONAL DATA CENTER (RAP-NDC): FUTURE PLANS AND UPGRADINGS**

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France is a country of low-to-moderate seismic hazard that has, in the past, suffered strong earthquakes that have caused damage and casualties. Since 1980 and the creation of the French national seismological network (RéNaSS, http://renass.u-strasbg.fr), more than 27,000 events have been recorded in the M_L 1-5 magnitude range, corresponding to approximately 20 M_L>3.5 earthquakes per year, which are located in four main tectonic regions: the Pyrenees in the southwest, the Alps in the southeast, the Rhine Graben zone in the northeast, and the Massif Central and Brittany in the central and western regions. Moreover, France's overseas territories include Mayotte in the Indian Ocean, New Caledonia in the Pacific Ocean close to the Vanuatu subduction zone, and especially the French Antilles islands, which belong to the West Indies in the Caribbean Sea.

Since 1995, the mission of the French accelerometric network programme (RAP, Réseau Accelerometrique Permanent) is to expand and modernize significantly the acquisition and application of French accelerometric data (both strong and weak motion) in order to improve earthquake related research and public safety from earthquakes. This network is the result of co-operative efforts including academic institutions (INSU-CNRS, Universities of Grenoble, Nice, Strasbourg, Toulouse, Clermont-Ferrand, IPG Paris) and several state agencies (BRGM, CEA, IRSN, LCPC, IRD). Since 1995, around 140 stations have been installed in seismic areas of France. All the stations are 24-bit digitizer coupled to broad-band accelerometric sensor. This network also includes specific research actions (site effects, building monitoring, deep borehole...). All data are archived and freely distributed in SAC, ASCII and MiniSEED format through the data explorer of the RAP-NDC (http://www-rap.obs.ujf-grenoble.fr).

While the first stations were triggered, new perspectives are planned in the future:

(1) integrating and processing the continuous and real-time accelerometric data in the database. Actually, 40 real-time stations are installed with a seedlink node at the RAP-NDC. Arclink node is actually implementing at the RAP-NDC for improving the data management and data exchange.

(2) real-time processing for accelerometric parameters. Moment magnitude and ground motion parameters are actually extracted from the continuous recordings for improving the earthquake information transmitted to national agency. The ground motion parameters are those defined by the NA5-NERIES group and RAP-NDC participates to the European accelerometric database hosted by EMSC/CSEM.

(3) automatic and manual quality control procedures. Specific tools are actually developped for controlling the quality of the accelerometric data (amplitude, instrument and site response, ...) coupled to the monitoring of the seismological quality control (e.g., PQLX).

SD1/P23/ID123 **- UPGRADING THE OBSERVATOIRE DE GRENOBLE PERMANENT SEISMIC AND GPS NETWORKS IN NORTHERN FRENCH ALPS, A RESIF AND INTERREG-RISE INITIATIVE**

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The Observatoire de Grenoble (OSUG), one of the French academic observatories, is in charge of several permanent networks in the northern Alps. The OSUG presently operates 33 accelerometric, 40 short period, 4 broadband seismic sites and 15 geodesic sites. Since 2008, we have decided to partly reorganize these networks in order to i) share a maximum number of common sites, ii) upgrade the real time monitoring network and iii) improve the broadband sites to conform to a high quality standard defined in the scope of RESIF .

This effort is funded through an INTERREG regional funding, the RISE project, that is conducted under the supervision of the French national networks RESIF.

In this presentation, we present the detail of the new/upgraded sites shared by RLBP, RAP and RENAG networks.

We show the results of differents efforts to improve the quality of data transimission, data noise reduction, lightening protection, etc... and the tools developped in RESIF framework to test and check the data quality .

SD1/P24/ID124 **- ON THE NEW BROAD BAND SEISMIC NETWORK IN TUNISIA**

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Monitoring seismicity in Tunisia is based on telemetred analogic short period seismic stations, installed since 1989 in the frame of PAMERAR project. Analysis of seismograms and dissemination of earthquake parameters are carried in Tunis, at the main centre, the "Institut National de la Météorologie (INM)". A *DOS* desktop computer hosting *IASPEI* software equipped with a *DT2821 A/D PGH* board is used for digitizing waveforms of triggered events. This analogic technology is progressively left, leading the place to digital seismic systems which offer better dynamic range and better tools for seismic processing, rapid dissemination of earthquake parameters and providing data for scientific and engineering purposes. Taking into account above considerations, INM has undergone the upgrading of the existing seismic network with its new project titled

RAST. Partnerships opportunities between Tunisia and the "Principauté de Monaco" and with EMSC have been a suit trigger to start the modernization of the existing seismic network. Monaco requested the scientific and technical support, of the laboratory GeoAzur of Nice - Sophia Antipolis, for site evaluation and for selection of seismic instrumentation. Under this frame, three broad band seismic stations were installed at remote sites, equipped with STS2 sensors and logged to Kephren digitizers' model. To fulfill above objectives, three sites, with acceptable background noise levels, were identified and were managed to host digital broad band seismic stations: Tamra (TAMR) in the north of Tunisia, Thala (THTN) located in the west central part of the territory and Tataouine (TATN) at the extreme south of the country. Data transmissions to the main center at INM were insured through a dedicated digital phone line with at least 64 Kbps of speed with the use of VSAT technology in TAMR and TATN seismic stations. Data are collected in real time from the stations by a SeedLink server installed at INM centre. In case of transmission failure long enough to induce data gaps in the procedure, a complete back up of the data is recovered automatically by ftp. The project included, among complete digital seismic equipments, a server, hosting *earthworm* software, processing of the incoming continuous real time waveforms and dissemination of seismic identified events. This new configuration of the upgraded Tunisian seismic network will lead to more accurate seismicity monitoring locally, regionally and globally and will allow the providing of real time waveforms to neighbor agencies and to prepare, also, an infrastructure for an early warning system for Tsunami in western Mediterranean.

SD1/P25/ID125 **- HELLENIC SEISMOLOGICAL NETWORK OF CRETE (HSNC): A NEW PERMANENT SEISMOLOGICAL NETWORK IN THE SOUTHERN AEGEAN**

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The Aegean region which comprises the Hellenic arc and the adjacent areas of the Greek mainland, the Aegean Sea and western Turkey, is one of the most seismically active zones of the world and the most active in western Eurasia due to the convergence between the African and Eurasian lithospheric plates. The seismicity of South Aegean is extremely high and is characterised by the frequent occurrence of large shallow and intermediate depth earthquakes. Crete marks the forearc high of the modern Hellenic subduction zone in the eastern Mediterranean. In order to provide modern instrumental coverage of seismicity in the South Aegean, as well as some more insight into the stress and deformation fields, tectonics, structure and dynamics of the Hellenic Arc from which will be possible to retrieve information about the rupture process, a seismological network of high dynamic range is installed. It is called HSNC (Hellenic Seismological Network of Crete) and consists of 11 permanent seismological stations equipped with short period and broadband seismographs coupled with 3rd generation 24bit data loggers as well as from 7 accelerographs. Data transmission and telemetry is based on conventional TCP/IP communication using a hybrid network consisting of dedicated wired ADSL links as well as VSAT links by using the private satellite hub located at lab of Geophysics & Seismology (LGS), Chania, Crete. Data centre is equipped with a high performance computing cluster capable of providing real time estimations as well as to support great number experimental investigations using the on line or offline data streams.Prototype software solutions are developed for monitoring and controlling network elements, to automate ordinary procedures, to remote control and reroute data reception as well as to diffuse results in different forms. HSNC is capable to provide estimations in real time by using rapid (<6secs), fast (180secs) and manual procedures.Apart from this, HSNC includes a mobile network called RaDeSeis (Rapid Deployment Seismological network) which is used for real time aftershock studies. RaDeSeis consists of a central station which acts also as the central communication hub since it is equipped with VSAT. Border mobile stations are spread around the area of interest and communicate with central station using WiFi links. By developing dedicate hardware and software solutions in LGS, RaDeSeis has an installation time around 1 hour for each station which means that aftershock studies can be initiated almost immediately

SD1/P26/ID126 **- KOERI TURKISH DIGITAL SEISMIC NETWORK: CURRENT STATUS AND FUTURE CONFIGURATIONS**

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Bogazici University Kandilli Observatory and Earthquake Research Institute (KOERI) National Earthquake Monitoring Centre (NEMC) is operating National Seismic Network in Turkey. Before the year 2000, KOERI's network did consist of mainly short period single component sensors (SP-Z), which were not distributed homegeneously around the Turkey. After Gölcük (Mw=7.4) and Düzce (Mw=7.2) earthquakes in Turkey, priority was given to the installation of BB seismic stations. Satellite communication as the mean of data transmission has been first utilized by KOERI in August 2004. Currently, KOERI's network includes 100 broadband BB stations, where data transmission is performed through satellites for 92 of them. NEMC is capable of rapid and accurate determination of location and magnitudes for earthquakes located in and around Turkey, and for especially earthquakes with M>4.5, we have the capacity of rapid automatic solutions for earthquake parameters and MTIs. Recently, Seiscomp3 system was successfully deployed and is beeing used with zSacWin simultaneously by NEMC. All earthquake information is disseminated automatically to the office of the President, Prime Minister, Minister of Interior and other government offices such the governor and mayor as well as press agencies etc. via internet. KOERI's future plan foresees improvement of the digital network with BB and strong motion instruments. Furthermore, we are in the process of installing 5 Sea Bottom Observation Systems in the Marmara Sea.

SD9 - TRANSPORTABLE BROADBAND ARRAYS IN SOUTHWEST EUROPE: TOWARDS A HOMOGENEOUS COVERAGE OF THE EUROPEAN CONTINENT

SD9/P1/ID127 **- THE PYROPE (PYRENEES OBSERVATIONAL PORTABLE EXPERIMENT) PROJECT: FIRST STAGE OF A «FRANCE-ARRAY» INITIATIVE**

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The «France-Array» initiative aims at complementing the RESIF antenna of permanent seismic stations with a homogeneous and dense coverage of temporary broadband stations. Its main goal is to obtain a reference 3-D model of crust and mantle structure beneath France. The ANR-funded and currently active PYROPE project (http://www.pyrope.fr) is seen as the first stage of «France-Array», and includes the deployment of 50 temporary broadband stations in southwestern France. The PYROPE stations, together with the temporary stations due to be deployed across the Spanish border in early 2011 as the third stage of the Iber-Array project, will form a combined antenna of about 180 broadband stations (150 temporary and 30 permanent stations). Within PYROPE, we are focussing more specifically on high resolution imaging of the deep structures beneath the Bay of Biscay and the Pyrenees. In order to fully exploit the rich dataset that will be collected, we are also developing and implementing fast and practical high resolution imaging methods, relying on finite-frequency kernels and waveform inversion. We shall present the current status and geometry of the PYROPE temporary array, and describe our installation procedure for the broadband stations.

SD9/P2/ID128 **- PROJECT WILAS - WEST IBERIA LITHOSPHERE AND ASTENOSPHERE STRUCTURE: COMPLETING THE COVERAGE ON WESTERN IBERIA**

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The lithosphere of Iberia has been formed through a number of processes of continental collision and extension: in Lower Paleozoic, the collision of three tectonics blocks

produced the Variscan Orogeny, the main event of formation of the lithosphere. The subsequent Mesozoic rifting and breakup of the Pangea had a profound effect on the continental crust of Western Iberia. Since the Miocene, the southern interaction between Africa and Iberia is characterized by a diffuse convergent margin that originates a vast area of deformation. The impact of this complex tectonic in the structure of the Lithosphere remains an incognito, especially in its western part. Which is the relation between surface topography, the observed tectonic units and the deep crustal/lithospheric structure? Similar problems are currently being addressed by programs such US-EarthSCOPE or TOPO-EUROPE. The Iberian Peninsula is covered by two projects, concentrated in its southern collision margin (TOPO-MED) and the central cratonic Massif (TOPO-IBERIA). Within TOPO-IBERIA (Consolider-Ongenio CSD2006-00041), a roughly 50x50 km dense network of BB seismic stations is being deployed in Spain through 2007-2013, sequentially covering southern, central and northern Spain; however, W Iberia will be widely unsampled. Project WILAS (PTDC/CTE-GIX/097946/2008) is a 3 years project funded by FCT in which a temporary network of several BB stations is being be deployed in Portugal. Considering the present BB/VBB network operated by the Portuguese partners IM, IDL, ICIST, CGE and IGUC, to extend to the western border of Iberia the TOPO-IBERIA coverage, several new stations have to be deployed. A set of 20 BB stations, belonging to the GIPP-GFZ-Potsdam, will be temporarily deployed between 2010-2012, and together with new stations to be deployed by the Portuguese and Spanish partners, will create a dense array of Broad-Band (30-60 s) and Very Broad-Band (120 s) seismic stations achieving for the first time full coverage of the Iberian Peninsula. The project aims to image the 3D structure beneath W Iberia. The knowledge of the Crust, Lithosphere and Astenosphere seismic structure must be dealt at different scales, involving different but complementary methods: Local-Earthquake Tomography for fine structure of seismogenic areas, ambient noise tomography for regional crustal structure, Receiver Functions for Lithospheric structure and Surface-wave tomography for large scale Listosphere-Astenosphere structure. Crustal and Mantle seismic anisotropy analysis, coupled with source analysis and correlation with current geodetic measurements will allow establishing a reference 3D anisotropy model of present and past processes.

SD9/P3/ID129 - THE FRENCH NATIONAL POOL OF MOBILE SEISMIC INSTRUMENTS SISMOB AND ITS DATABASE FACILITY SISMOB-BD

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LGIT, Grenoble, is in charge of the management of the French national pool of mobile seismic instruments Sismob. Sismob is the portable component of the RESIF project. The pool is composed of ~130 portable stations covering most of the seismic spectrum, from true broadband (with STS2 sensors) to short periods. ~30 instruments dedicated to high-resolution imaging of structures of kilometric size have 9-component recorders that can be connected to one 3-D and six 1-D short period sensors to build short-aperture arrays. The other ~100 stations are 3-component and can be used with a variety of sensors including accelerometers and short-period to broadband velocimeters. Stations are loaned to French seismologists for temporary experiments of 2-year maximum duration. To complement the service provided to users, we have built in LGIT a database facility that collects raw records and field metadata, prepares, archives and distributes all seismic data recorded from Sismob stations in Seed format. The heterogeneity of instrument responses and the diversity of raw data formats made it a challenge to prepare datasets in the standard exchange format Seed. This is why we had to build a new software suite named BDSis, which is now used both for Sismob and the French permanent accelerometric network RAP. Access to data of temporary experiments is opened within 3 years after the end of the field work, either from the RESIF portal, or from Orfeus data center and IRIS DMC. The Sismob database now includes 4 Tbytes of seismic records in mseed format corresponding to more than 3400 channels recorded during 28 temporary experiments.

SD9/P4/ID130 - TOMOGRAPHIC STUDIES OF THE IBERIAN PENINSULA AND NORTHERN MOROCCO USING BROADBAND DATA FROM THE IBERARRAY EXPERIMENT AND PERMANENT NETWORKS

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We present new tomographic models of the Iberian Peninsula and northern Morocco using broadband data from stations of the permanent national and local networks in the region, complemented by 70 temporary broadband stations from the IberArray portable network. The quality of this combined dataset allows to apply different tomographic methods, including but not limited to: local earthquake travel-time tomography, teleseismic travel-time tomography, surface-wave tomography from regional and distant earthquakes, and surface-wave tomography from correlations of seismic ambient noise. Each of these methods has its strengths and weaknesses, and the combination of all allows to obtain a detailed and consistent picture of the crustal and mantle structure beneath the Iberian Peninsula and Morocco. Using local earthquake and seismic ambient noise tomography we are able to image the shallow crustal structure, also in regions with low seismicity. In particular we have obtained constraints on the lateral and vertical extent of the major sedimentary basins (Gulf of Cadis, west Alboran basin, Valencia trough, and Ebro basin) and the areas of greater than average crustal thickness beneath the mountain ranges of the Rif, Betics, Iberian chain and Pyrenees. Teleseismic travel-time tomography is best suited to investigate the structure of the upper mantle. Using very precise travel-time measurements determined using waveform similarity we have obtained a well resolved image of a high velocity anomaly beneath the Betics and Alboran Sea that extends down to the mantle transition zone and probably corresponds to a subducted slab.

SD9/P5/ID131 - CRUSTAL STRUCTURE OF NORTHERN MOROCCO AND ALBORAN SEA FROM LOCAL EARTHQUAKE TOMOGRAPHY

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We have obtained a new P-wave velocity model of the crust of northern Morocco and the Alboran Sea from tomographic inversion of local earthquake arrival times. The arrival time data used in this study is based on the bulletins of the Instituto Geográfico Nacional (IGN) for the years 2000-2008. This dataset was complemented with arrival times picked by us on all available broadband seismic stations in southern Spain and Portugal and northern Morocco, including permanent stations from national and regional networks and 70 stations from the IberArray transportable network, with 21 of them located in North Africa. Data from these stations in Africa has allowed to improve ray-path coverage in the Alboran Sea and Rif Mountains, which were poorly sampled using IGN data alone. The tomographic method applied uses first arriving P waves (Pg or Pn, depending on the epicentral distance and focal depth), allowing to image Moho variations inside the model volume. We obtain Moho depths greater than average (the initial 1D model has a constant Moho depth of 31 km) beneath the Betics and the Rif, in agreement with existing wide-angle profiles and potential field (gravity) studies. In addition we obtain a detailed image of peridotite bodies that follow the curvature of the Gibraltar arc along the western Alboran Sea.

SD9/P6/ID132 - EXTENDING THE CAPACITY OF THE NATIONAL SEISMOGRAPH NETWORK OF GREECE WITH AN AMPHIBIOUS REAL TIME ARRAY OFFSHORE WESTERN PELOPONNESE

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Seismological networks in Greece are landlocked and bias the definition of the foci parameters, particularly for events located offshore. This can be improved by establishing seismological stations in the marine area capable to transmit data in real time.

In order to extend the National Seismological Network of Greece to the offshore areas and monitor in real time the seismicity in Western Peloponnese, an onshore/offshore array consisting of four land and one submarine seismic station was installed in the Kiparissiakos gulf. Stations were homogeneously distributed over the investigated area. The submarine seismic station was deployed south of the island of Zakynthos. This station was equipped with a 3-component Broad band Sensor (BBS) (30 s to 50 Hz)

compatible to those of the National Network of Greece, and one high sensitivity pressure sensor. The later allows precise observations of sea level changes and it can be used for observing Tsunami waves. The seismic and pressure sensors on the seafloor are connected by cable to a surface buoy where the electronic equipment and energy supply units are housed. The marine station transmits seismic and tsunami data in real time by GPRS connection. Data can also be transmitted by radio link if the distance to the next coast does not exceed 70 Km. On the small island of Strophades, at the south westernmost part of the Hellenic arc, a land seismic station was installed, also equipped with a BBS. Data transmission is accomplished via a satellite connection. Three more land stations were installed at Keri, Zakynthos, and Pirgos and Olympia, western Peloponnese, all transmitting data by GPRS connection.

The seismic array recordings are transmitted to a central station and are available through Internet at any location in real time. The technical solution is economic and can be extended to satellite communication if the marine station has to be places outside the mobile telephony networks.

The amphibious seismic network has successfully extended the capacity of the National Seismograph Network of Greece up to the remote island of Strophades.

SD9/P7/ID133 **- IMPROVING THE DETECTABILITY OF SEISMIC EVENTS IN GREECE: THE RAPID DEPLOYMENT OF NOA'S PORTABLE SEISMOGRAPHIC NETWORK.**

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A increase in the rate of the seismic activity production has been observed since the beginning of 2009 to the south of Zakynthos island, in the Hellenic Arc. Three strong (Ms=6.1, 6.0 and 5.8) crustal earthquakes and thousands of smaller events have been recorded by the Hellenic National Seismographic Network which is coordinated by the Institute of Geodynamics of the National Observatory of Athens (NOA). In addition to these observations, NOA installed a newly acquired portable seismographic network in the region surrounding the seismic activity for a two month period. During this period real time data flow, from the portable seismographic network to NOA's central data base in Athens, was accomplished using GPRS/3G lines.

In this study we show that the rapid employment of NOA's newly acquired portable seismographic network significantly improves the real-time detectability of seismic events and the assessment of seismic hazard in Greece.

SD9/P8/ID134 **- ORIGIN OF CRUSTAL ANISOTROPY: SHEAR WAVE SPLITTING STUDIES IN TURKEY**

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Shear wave splitting manifested as leading shear wave polarization, that is, parallel alignment of leading shear wave particle motions from a variety of sources, has been observed at a number of seismograph stations in the Marmara region and surrounding area. We applied three methods to investigate crustal anisotropy and compare the resolution obtained: (1) Aspect ratio, (2) Cross-correlation, and (3) Systematic analysis of crustal anisotropy, to the events from 2006 to 2009 recorded by three component digital seismometers. The results from the methods are compared in order to acquire acceptable splitting parameters. In order to explain the observed seismic anisotropy in the crust, three phenomena are taken into account: stress-induced microcracks primarily aligned in vertical or subvertical planes; cracks or fractures in the vicinity of active faults having their orientation parallel to the fault planes; and intrinsic rock anisotropy results from preferred orientation of minerals. The polarization of the faster shear waves is dominantly NW-SE and shows a nearly uniform distribution of each part of the study area that separated into four areas in terms of tectonic structure and seismicity. The polarization direction of the fast split shear wave is nearly parallel to the direction of the alignment cracks and hence parallel to the maximum horizontal stress direction in this region. Our analysis indicates that the majority of local events exhibits some degree of splitting and that splitting patterns, while complicated, are coherent. We observed that the results are also consistent with Neotectonic stress in the study area. These results have also important implications for understanding crustal dynamics of the complex regime of the study area.

SD9/P9/ID135 **- SEISMIC ANISOTROPY AND UPPER MANTLE VELOCITY STRUCTURE BENEATH TURKEY AND SURROUNDING REGIONS FROM PN AND SKS MEASUREMENTS**

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We determined P_n velocities and P_n anisotropy of the upper mantle in Turkey and surrounding regions. A database was constructed from the earthquakes occurred between 1999 and 2010 and recorded at more than 800 stations. More than 50,000 phase picks from 700 earthquakes were used in the analysis. We obtained the velocity structure with higher resolutions from previously reported $P_n$velocity distributions. The higher resolution provided greater accuracy and shows better consistency with the main tectonic features of the area. We also obtained shear wave splitting of SKS phases. We compare the results from two different data sets. $P_n$anisotropy better coincides with the direction of the present day plate motions.

SD9/P10/ID136 **- THE LITHOSPHERIC AND UPPER MANTLE STRUCTURE BENEATH THE CENTRAL TURKEY OBTAINED FROM RECEIVER FUNCTION PROFILE**

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A broad-scale seismological experiment, SIMBAAD (Seismic Imaging Beneath the Aegean-Anatolia Domain), was performed in the Aegean-Anatolia region. The objective of the project is to investigate the crustal and mantle structure beneath Western Turkey, the Aegean Sea, and continental Greece. In the spring of 2007, we installed a temporary network of 33 broadband stations in Turkey, Greece, and S-Bulgaria for 2- year duration. It complemented the permanent broadband networks (~90 stations) with an inter-station spacing of ~100 km in the region. The experiment also included two north-south profiles of more densely-spaced stations (~15 km) and one of them crossing Central Anatolia at 30.5°E. We performed receiver function analysis on the central transect of ~500km in length including 27 stations. Over 100 teleseisms (30° to 95° distance) were used in the analysis and more than 1500 receiver functions were selected. We determined Vp/Vs ratios using H-k stacking method and applied common conversion point stacking to receiver functions of the N-S linear array.

SD9/P11/ID137 **- REF TEK BROADBAND SEISMOMETER: ADVANCED FEATURES AND TEST RESULTS**

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The *REF TEK 151 Observer*, a new broadband seismometer, came to the market in January, 2008. The Observer has two frequency response options: 120 sec to 50 Hz and 60 sec to 50 Hz. The *151 Observer* is a rugged force-balance feedback sensor with three independent sensors – one vertical, two horizontal – with built-in electronic feedback and control and power conversion circuits. It features low noise, large dynamic range and ease of installation and use. The *Observer* has built-in leveling and mass lock/unlock facilities. The leveling mechanism includes two bubble levels, three adjustable feet and three locknuts which are located on the chassis. The *Observer* has a built-in mass zero-position automatic adjustment mechanism. When powered on, the seismometer self-checks the zero position of each component's mass and automatically adjusts the zero position if needed. The RT527-B01 Sensor Control Board on the REF TEK 130 High Resolution Recorders can also be used to monitor and adjust mass position. The *Observer* is a low-noise seismometer which makes it ideal for local, regional, and global seismicity studies in different installation configurations including observatory and portable, surface and posthole applications. The results of field evaluation in comparison with other broadband seismometers conducted at Albuquerque Seismological Laboratories and other locations are presented and discussed.

SD7 - IMAGING THE SEISMICITY OF THE EURO-MEDITERRANEAN REGION: FROM SEISMIC NETWORKS TO CATALOGUE PRODUCTION AND INTERPRETATION

SD7/P1/ID138 **- COMPRESSIONAL REGIME IN SEISMOTECTONICS OF THE SOUTHEAST OF SOUTH CASPIAN BASIN, IRAN, BASED ON RECENT REGIONAL AND LOCAL SEISMICITY AND 1985 GORGAN EARTHQUAKE WAVE-FORM MODELING**

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This investigation which conducted at the east of South Caspian Basin is concerned with seismicity and seismotectonics. The area is over the east part of Khazar fault in Alborz range and the northern flat. We used a local temporary seismological network data installed in the studied area for 24 weeks and simultaneously 4 years micro-earthquakes recorded by the permanent seismological network of the Geophysics Institute of University of Tehran and International Institute of Earthquake Engineering and Seismology. Also body waveforms of M=6.0 Gorgan destructive earthquake were modeled. The seismicity of both networks have overlapping with the surface outcrop of Khazar fault and are consistent with NW-SE trending of the South Caspian Basin folds. Processing the data concluded a Vp/Vs ratio about 1.71 and a P wave velocity range, from 5.3 km/s to 6.3 km/s, between the surface and upper than Moho depth. The focal mechanisms of well located events specify 4 pure thrusts and a one normal with T axes correspond with the mentioned trend. The waveform modeling of the 1985 earthquake confirms compressional regime perpendicular to the trend. The depth distribution and the seismic cross section of the micro-earthquakes suggest 10 km for sedimentary cover and also show a concentrated seismicity corresponds with a big dead and collapsed mud volcano in the area.

SD7/P2/ID139 **- GEOPHYSICAL INVESTIGATION FOR BUILDING OF SEISMIC STATION IN TERRITORY OF KOSOVO**

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Kosovo has a great potential for future economic development. It is a fact that, within this economic development, industrial, energetic, traffic and other facilities of capital importance and importance for the social standard are being built. Considering the high seismicity and the frequency of occurrence of earthquakes in this region, these structures are permanently exposed to the risk of being damaged or destroyed.Developed countries and particularly developing countries like Kosovo endeavour to protect these costly structures against catastrophic earthquake effects since it is clear that conservative construction may cause serious economic consequences. To conceive the facts on the economy of development and construction in seismic areas, it is necessary to perform scientific and applicative investigations for assessment of the seismic risk, definition of economically justified and technically consistent criteria for de sign and construction of structures as well as selection of structures and their upgrading for the purpose of sustaining the expected earthquakes. In doing so, one should start from the fact that preventive protection, if harmonized with the level of development and future needs of the society, represents the best way to protect social goods and human lives.For that its need to expansion of seismic station network, therefore geophysical investigations are necessary.

SD7/P3/ID140 **- RELOCATION OF EARTHQUAKE HYPOCENTERS IN THE NORTH-WEST IRAN BY USING DOUBLE-DIFFERENCE METHOD**

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Relocation of earthquake hypocenters in the North-West Iran by using double-difference methodAbstractNorthwest Iran is a part of Alborz – Azerbaijan major seismotectonic province that has experienced numerous earthquakes. The study region is bounded by longitude 44E – 50E and latitude 36N – 40N. No significant earthquake was reported during the past 100 years. Focal mechanism of earthquakes is mainly reverse with significant strike – slip componentsA large set of seismic events recorded in the North-West Iran during 1996-2008 were relocated using the double-difference technique and an appropriate velocity model. The relocated hypocentral locations improve significantly in comparison with those are routinely determined by the Iranian Seismological Center (IRSC). The distribution of 957 relocated events allows delineation of coherent features corresponding to major and some unknown faults. There are new coherent alignments both in depths and epicenters in this region which have not been seen until now. The results show that there is a coherent feature on the south of Tabriz fault with approximately N120 trend which is followed by an alignment on Tabriz fault with trend approximately N115 . Our relocations clearly confirm existence of one tight cluster of activity in the north-west of Iran. This cluster extends approximately parallel to the Tabriz fault. Also, there are probably several faulting systems around the Tabriz fault with different strikes.

SD7/P4/ID141 **- QUALITY IMPROVEMENT OF SEISMIC SIGNALS IN THE SEISMIC NETWORK OF SLOVENIA.**

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Seismic network of Slovenia includes 26 modern digital seismic stations. The records measured by the seismic network are analyzed and used in various seismological studies performed by Seismology and Geology Office. Quality of recorded seismic signals depends on seismic noise level of particular seismic station and on quality of the seismic measurement equipment. Seismic measurement equipment (particular seismometers and data loggers) is subjected to several factors that can lead to increase of the equipment self noise, which can greatly contribute to total seismic noise level of seismic station. Noise level of the location, where the seismic station is situated is another main contributor to the total seismic noise level of seismic station. Therefore, in order to achieve high quality of recorded seismic signals, the site for seismic station must be properly selected and proper conditions for seismic measurement equipment must be assured. In this work the main sources of seismic noise are presented. The seismic noise levels were estimated using power spectral density (PSD) estimates. Methods for minimization of the seismometer self noise are presented and some of them are also realized. Moreover, direct and indirect influence of wind on high frequency seismic noise is investigated in detail. To achieve the optimal performance of seismometers the power supply unit was modernized and the seismometer was additionally thermally isolated. In this way the seismometer self noise was greatly reduced. The increase of high frequency seismic noise levels due to direct influence of the wind was found on all selected seismic stations (they were selected according to the wind type, which is present at their locations). The largest influence of wind on high frequency seismic noise was recorded at a seismic station, where the special wind type called «burja» was present. At the seismic station where seismometer is located in approximate 20 m deep borehole the high frequency seismic noise was not affected by wind. With the implemented modernizations the total seismic noise levels at chosen seismic stations were greatly decreased, quality of recorded seismic signal was improved and the accuracy of seismic studies was assured. Furthermore, we found out that with construction of deeper boreholes the wind influence on high frequency seismic noise could be minimized. KEY WORDS: Seismic noise, seismometer self noise, wind, supply voltage, broad band seismometers, seismic network, power spectral density (PSD).

SD7/P5/ID142 **- A REVIEW OF THE RECENT SEISMIC ACTIVITY IN YEMEN**

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After establishment seismic network (in 1994) of Yemen, seismic revealed some characteristics of the seismic activity in the area. Construction of a seismotectonic map according to the seismicity level and tectonics showed 4 seismic zones. Seismic activity is intense in the Gulf of Aden, along the Red Sea axis and western Yemen area. While the detailed study of western zone showed 8 distinct sub-seismic zones and that the activity is concentrated in and around volcanic fields. The b-value was calculated for each seismic zone; it found that the highest value is in western area zone. A composite focal mechanism solution was prepared for each seismic zone also; it found stresses system coincident with tectonic features. A seismic energy released map of the Yemen was constructed for the period from 1994 to 2009; the map reveals the main active zones with

high energy values. The study gives new insight for a better understanding of the seismic activity in Yemen and helps in the seismic hazard assessment.KEYWORDS: seismicity, Yemen, focal mechanism, seismic energy

SD7/P6/ID143 - THE EGYPTIAN NATIONAL SEISMOLOGICAL NETWORK AND ITS ROLE TO MINIMIZE THE EARTHQUAKE DAMAGES

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Egypt is located in the north eastern part of the African continent and it is bounded by three active tectonic plates, the African tectonic plate, the Red sea tectonic plate and the Levantine transform fault. The majority of seismic activity affecting Egypt coming from these three main sources. It could be concluded that although the damaging earthquakes occurred infrequently, its risky consequences could not be ignored. On 12 October 1992, an earthquake with magnitude (5.9 mb) caught the Egyptian people. This earthquake caused about 600 death, 10000 injured and left a damage of more than 40 million US$. As a result of this damage, the Egyptian government supports the National Research Institute of Astronomy and Geophysics (NRIAG) to install the ENSN and the strong motion network. The main objectives of the network are: Monitoring local and regional activity including the artificial events, assessment seismic hazard, estimating the expected future earthquake and anticipate the future safe development of the strategic projects and archeological sites. Key Words: tectonic plates; earthquake damages and seismic hazard.

SD7/P7/ID144 - STABLE METHOD LOCATION OF THE NEAR EARTHQUAKES

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Traditional methods based on the Geiger's method, minimize the functional residues of theoretical and observed times of seismic waves, which at the same time are proportional to the distance from the hypocenter to seismic stations. In this case the minimum of the functional does not guarantee the minimum distance between of the theoretical and real hypocenters.A method of location of earthquakes based on minimization of a functional of the distance between elements of two multitudes, each of which represents a set of hypocenters; relevant theoretical and actual travel times of seismic waves. The method is more stable to errors in observed data than traditional methods based on the Geiger's method, especially for a small number of recording seismic stations and small hypocentral depth.

SD7/P8/ID145 - SEISMICITY OF UNITED ARAB EMIRATES; ANOTHER LOOK AFTER INSTALLATION OF DUBAI SEISMIC NETWORK

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On June, 2006 Dubai Municipality established a broadband seismological network in Dubai Emirate, United Arab Emirates (UAE). The network consists of four remote seismic stations to observe local and regional seismic activity that may have an affect on Dubai city and its surrounding areas. Each station consists of a 6-channel high resolution, IP-aware digitizer (Q330), a broad-band seismometer (STS-2) and a force balance accelerometer (ES-T). The recorded data was transferred on real time from the remote sites to the Dubai Municipality. ANTELOPE software is used for data acquisition and analysis. The system exchanges real-time data with the National Center of Meteorology and Seismology in Abu Dhabi, the Earthquake Monitoring Center in Oman and few of DSN stations, which increases the aperture of the network.The local seismic activity from June 2006 to March, 2010 reflects low activity. The majority of the recorded earthquakes are located along the boundary between continental collision of the Arabian and Eurasian plates along the Zagros Thrust. Few inland small to moderate earthquake have taking place in the same area of Masafi 2002 earthquake between Dibba-Masafi-Al-Fujairah areas of northern part of UAE. Local seismic activity while generally low constitutes a moderate to strong seismic hazard in Eastern UAE-Northern Oman as was demonstrated by the aftermath of the moderate-sized 2002 Masafi earthquake. The digital records of Dubai and Oman Seismic Networks were used to evaluate the focal mechanisms and source parameters with high accuracy of few well recorded earthquakes in this region. These mechanisms constitute good key for understanding the active tectonics, present-day stress field and evaluation of the ground motions distribution during the earthquake occurrence. The installation of new broad band stations, defining accurate crustal structure and sharing seismic data between Arabian Gulf countries are highly recommended to reduce the earthquake hazard on the region.

SD7/P9/ID146 - SEISMIC DATA MONITORING AND PROCESSING IN NSSP, ARMENIA

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Located in one of the world's most active seismic zone, Armenia frequently experiences earthquakes. Seismic observation and seismic hazard assessment in Armenia are concentrated in National Survey for Seismic Protection of the Republic of Armenia (NSSP). It is a Governmental organization established in 1991, after the catastrophic earthquake of December 7, 1988 with the aim of drastically improves seismic observation system and seismic risk reduction to protect the people against earthquakes.The aim of this paper is to show the present state of the seismic observation (including seismic network and seismic data analysis) and the futures of seismic hazard assessment in Armenia. The existing seismic networks, including the description of equipment used, data flow and processing, the future plans of their development are described as well.For the monitoring of earthquakes NSSP operates an earthquake observation network comprised of about 35 short period seismographs and IRIS GNI station. Recently there was installed mini-array: VAYK, with 5 short period and 1 broadband station (CEA/DASE). The data are received to the Data Center on a near real-time basis from all stations homogeneously distributed in Armenia. When an earthquake occurs, NSSP immediately (for local earthquakes during 20 minutes) issues information on its hypocenter, magnitude and seismic intensity. The information is provided to disaster prevention authorities and reaches the public through local governments and the media. The data are archived at the Seismology Department and stored in database system as waveforms, seismological bulletins and catalogues for research work and other activities.NSSP also provides data to international organizations such as ESMC, ISC est. as near real time information about earthquake and seismological bulletins.Key words: Armenian NSSP, seismic observation, seismic network, seismic data processing

SD7/P10/ID147 - POST SEISMIC ACTIVITY IN ARDABIL-ZANJAN REGION, NW IRAN.

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The study region is bounded by 35N-39N latitudes and 46E-52E longitudes. This region includes a part of Alborz active zone and has experienced the 1990 destructive Rudbar earthquake that has caused extensive destruction and heavy human loss. Both historical evidence and the existance of several active faults indicate that the study region is seismically active. In this study, first, we provided the faults map of the region. Then, we overlapped the epicenters of reported earthquakes on the faults map during 1964-2010. Later, we provided the energy released map of the region by converting the magnitudes of earthquakes to the seismic energy. The results indicate that the region is still seismically active. A great number of earthquakes occurred in southern extension of Rudbar faults suggesting that this area is still active. The epicentral region of the 1962 Buyin-Zahra destructive earthquake in southern part of study area is also seismically active. Considering the results of this study, the occurrence of a destruction earthquake in southern extension of Rudbar fault and around the Buyin-Zahra area in future is expectable.

SD7/P11/ID148 - CRUSTAL MODEL FOR IRAQ

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Iraqi seismological network neerly upgraded with new equipments from kinrmetricCompany . complete system of 6 Streckeisen STS-2 seismometer and 6 Q330 digitizerWere installed in different locations to cover recording area . a preliminary real workWas done to make a crustal model for Iraq . 150 events recorded by the new instrumentsWere analysed using VELEST program which is based on Kisslin algorithim . hypocenterProgram with in seisan system is used to locate earthquakes . it is found that most of eventsLocates in the north and north east of Iraq and there is a considerable activities in the south

SD7/P12/ID149 **- NOISE LEVELS AND DETECTION MAPS FROM THE NORWEGIAN NATIONAL SEISMIC NETWORK**

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The Norwegian National Seismic Network, operated by the University of Bergen (UiB) and NORSAR, comprises of both short-period and broadband seismic stations. The total of seismic stations is 39 of which 35 are operated by UiB and 4 by NORSAR. This presentation will show the noise levels at the UoB stations, and illustatres how those compare to detection maps. The noise levels are presented as power spectral density plots, which have become the standard for displaying microseismic noise. These plots allow for site evaluation, but are also used as tool to identify equipment problems. Based on the recorded earthquake catalogue detection levels were computed, which can help to identify regions where additional stations may be required. Future plans for the network include the installation of additional broadband stations, and completion of the transition to real-time data.

SD7/P13/ID150 **- DETECTION OF QUARRY AND MINE BLAST CONTAMINATION IN EUROPEAN REGIONAL CATALOGUES**

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Seismic catalogues often include man-made contaminations, that range from the changes in seismic networks operating in the region to the different processing of the data and to the inclusion of quarry explosions and marine shots. For example, the installation or closure of seismic stations produce an increase or a decrease in the detection of small events, whilst quarry blasts or mine explosions artificially enrich catalogues. Despite network operators' best efforts to identify quarry blasts, it is easy to find these events in a catalogue, whereas the separation between explosion events and tectonic ones is a difficult task.Detection and removing of artificial events from a seismic catalogue should be the preliminary step in any analysis of statistical seismology. Wiemer and Baer (BSSA, 2000) proposed an algorithm, based on a statistical criterion, to identify and remove quarry explosions from catalogues. It is based on the observation that quarry blasts generally take place during daytime hours: the areas with a high ratio of daytime and night-time events are likely to be regions with quarry activity. In the first part of this work (Gulia, NH, 2010) we have modified the method and then tested it, using both a synthetic and a regional catalogue; in the second part the procedure has been applied to some of the European regional catalogues available on line. The comparison between the results obtained and the location of known quarries and mines for the analyzed catalogues confirms both the presence of non-natural events in seismic catalogue and the reliability of the methodology in identifying mining areas.

SD7/P14/ID151 **- ENRICHMENT OF THE EURO-MEDITERRANEAN BULLETIN WITH LOW MAGNITUDE EVENTS**

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The initial goal of the Euro-Med Bulletin was to include earthquakes of magnitude greater than 3.0. There were several reasons for this choice. Firstly, smaller events have little interest for seismic hazard assessment. Furthermore, by using a lower magnitude threshold, we increase the number of events to merge, leading to complex phase associations. Unassociated arrival times can mathematically merge to several events, identifying the proper association is difficult and time consuming. Today, there is a growing scientific interest to increase the catalogue completeness, especially for earthquake statistics and EMSC members requested to enrich the Euro-Mediterranean Bulletin with all the earthquakes regardless their magnitude. Thus, the magnitude limitation, previously set at 3 has been completely lifted up. The EMB is now produced directly for the full magnitude range as provided by the local networks (i.e. for events occurring after 01/01/2008) and low magnitude events are being integrated to the previously computed period of 1998 to 2007. As a consequence, the magnitude of completeness would exhibit some large geographical variations. For example, the magnitude threshold is set at 3.5 in Iceland while in Slovenia, events of magnitude lower than one are reported.The two main difficulties of integration of events not yet in the EMB are to correctly merge data from several networks corresponding to a single event and to avoid merging data from distinct events. Particularly, earthquakes during a seismic crisis can be very close in space and time. Specific procedures have been developed at the EMSC and tests over a month period (January 2007) were performed. This first attempt took us a week but the automatisation and optimisation of these procedures will help to reduced down to 1 or 2 days the processing of one month of data. Knowing that, as we get 120 months of Euro-Med bulletin, it will require at least a 6-month effort to carry this out. Moreover, from the results obtained for the time period tested, we expect a 3 fold increase of the total number of events in the Euro-Mediterranean Bulletin which then should reach approximately 300 000 for the period January 1998 to December 2007.In this poster, the method used to integrate small magnitude events in the Euro-Med bulletin and results for the year 2007 will be presented.

SD7/P15/ID152 **- THE NATIONAL BELGIAN MONITORING SEISMIC NETWORK**

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The Royal Observatory of Belgium (ROB) has the responsibility of the seismic activity monitoring in Belgium. For this purpose, the ROB operates a network of 24 seismic stations. Stations are a mix of short period and broad-band seismometers, connected to in-house developed PC-based data loggers or commercially available units. In addition, 18 accelerometers have been installed since 2001 in – or close to – the most seismic active zones, taking into account the type of substratum and/or the proximity of important infrastructure. All earthquakes in Belgium or the surrounding regions with magnitude greater or equal to 1.0 are detected and located by the current seismic network. Most of the seismic stations are now sending their data continuously to the Observatory using broadband Internet connections. Among them, 3 broad-band stations are also sending streams to ORFEUS and IRIS data centers. The data from the Belgian superconducting gravimeter are also sent to IRIS. A collaboration including data exchange protocol has been set up with our colleagues from The Netherlands (KNMI) and Germany (Bensberg) to cover border seismic events. In addition, we contribute to catalogues established by the EMSC and ISC by sending data from 7 stations. This is done for both local and teleseismic events. Phase picking and source parameters of local events with magnitude greater than 2.0 are sent manually to EMSC following an emergency procedure. This procedure should very soon be automated thanks to developments made for using SEISCOMP3 for local and regional earthquake detection. The complete ROB seismic catalogue (event location and phase arrival times) for local seismic events is available on the ROB website (http://www.seismology.be).

SD7/P16/ID153 **- EVOLUTION OF THE FRENCH PERMANENT BROADBAND NETWORK (RLBP) IN THE FRAMEWORK OF THE RESIF INFRASTRUCTURE**

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During the past decade a great effort has been carried out in several European countries to install permanent broadband seismic stations, leading now to more than 500 stations available to the community in the VEBSN (Virtual European Broadband Seismograph Network). In order to reach a more homogeneous station distribution in western Europe, a requirement to use the VEBSN as an array for long period records, several French research institutes committed in 2008 to build a homogeneous network of ~ 50 broadband stations in metropolitan France named RLBP (Réseau Large Bande Permanent). Since then, the number of broadband stations installed in France has increased from 17 to 30 and several sites have been modernized. This evolution results from the upgrade of the LDG (Laboratoire de Detection et de Géophysique) network and the involvement of academic institutes, notably through trans-border collaborations in the Alps and the Pyrenees (RISE and SISPyr Interreg project).

The RLBP is now part of the French major research infrastructure RESIF (Réseau Sismologique Français). This important French contribution to EPOS (European Plate Observing system) is intended to build an integrated antenna to observe the solid earth at all time scales using various geophysical instrumentation (seismic, geodetic, gravimetry, ...) deployed permanently or temporarily. In this framework, the RLBP, which is expected

to be completed by 2012, will constitute the backbone of a multi scale seismic array in metropolitan France constituted by ~ 200 permanent velocimetric stations. Some sites will also include strong motion and GPS sensors. The proposed geometry for this array is optimized to allow major advances in the imaging of structures at all depths and in the knowledge of seismicity in and around France.

SD7/P17/ID154 - HOW TO BETTER DISCARD NON TECTONIC EVENTS FROM SEISMICITY CATALOGUES?

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To provide an accurate image of the seismicity useful for seismic hazard assessment, it is crucial to properly identify the different type of events. Not all seismic events are earthquakes. Rock bursts, quarry blasts, explosions are also detected by seismic networks and without proper identification they are reported in seismic catalogues and pollute the image of the seismicity. It can, in turn, affect the computation of seismic hazard assessments. Event type identification relies on the information provided by the local networks. However, data policies are very different. One network may properly identify a non tectonic event and not distribute it while, the neighbouring country was not able to identify it and provide data which will be seen as a seismic event. Moreover, discrimination methodologies are heterogeneous. Specific waveform analysis is pursued in some networks while others institutes are in contact with the mining companies. Last year, the EMSC has contacted the network operators in order to have an image of the current status of their discrimination policy, aiming to discuss and to improve the event identification. We have gathered discrimination methods and policies. We have also collected lists of known quarries location and list of explosions. In this presentation, we review the results and the difference among regions. Based on the Euro-Med Bulletin 1998-2008, we show the uncertainties in some regions and how event type identification can be inconsistent. We also present how, over 10 years, we have been able to improve non tectonic event identification in collaboration with the local networks. While the main goal of this presentation is to review the different problems and inconsistencies encountered, solutions and common procedures still need to be achieved in the seismological community. A dedicated working group could be created and we would like to collect the opinions and ideas of the local networks.

SD7/P18/ID155 - SUMMARY OF THE 2008 REVIEWED ISC BULLETIN

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The ISC Bulletin Editors are currently processing the Reviewed ISC Bulletin for the year 2008, which is expected to be published by the end of 2010. The Preliminary Bulletins (unreviewed) have been available from the ISC website since late 2008. Here we provide an overview of the data in the 2008 Bulletin. The major sources of contributed data are described, and the ISC dataset is compared to those of other global data centres. The importance of re-analysis of events for which hypocentres and phase readings (including unassociated phase readings) are reported by more than one contributing agency is discussed. The overall completeness of the Bulletin as well as the completeness in oceanic and continental areas is discussed, and the differences in location and magnitude computed by the ISC and other global data centres are shown and explained. A summary of «new» events located by the ISC from previously unassociated phase readings is given, and other events of special interest including felt and damaging earthquakes and events caused by human activities (explosions and rockbursts) that were reported to the ISC are shown. The thresholds used for manual review of the ISC Bulletin are discussed.

SD7/P19/ID156 - SEISMICITY OF GEORGIA AND ADJACENT TERRITORY BASED ON CATALOG 2004-2009 YEARS

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A catalog of the felt events in Georgia and adjacent territory for the period from 2004 to 2009 was compiled. Developing of Modern Digital Seismic Network started in Georgia since 2002 year, so it became possible to provide a modern level of seismic monitoring, seismicity analysis and adequate seismic hazard and risk assessment. The earthquakes that occurred or felt at the aforementioned territory were reported in different regional and global catalogs. The Joint Caucasus catalog is the source for our catalog 2004-2009. It is compiled on the basis of data received from stations of operating seismic networks in Caucasus region (Georgia, Armenia, Azerbaijan), as well as Russia (North Caucasus) and Turkey; data of BB stations from IRIS data servers are also used. IASPEI Seismological Software HYPO71PC is the program use for earthquake location. The epicenters were recalculated using refined velocity model. A uniform magnitude scale, local (Richter) magnitude ml was applied through the catalog.For the purpose of seismicity analysis the Ms magnitude scale is used according to the following steps: 1. We consider K=logE (joule) as energy class of earthquake;2. We've obtained correlation relation between K and amplitudes on digital records: 3. For calculating Ms we use formula by Rautian: K=4+1.8Ms.The focal depths of the events were estimated and mean value obtained vary from 5 to 25 km.On the basis of compiled catalog we studied seismicity rate during period 2004-2009, spatial and temporal distribution of seismicity in Georgia, frequency-magnitude distribution of earthquakes (b-value is considered around 1), cumulative seismic strain release.Though some earthquakes of our catalog (especially in earlier period 2004, 2005) have not enough accuracy in their occurrence time, epicentral locations, depths and magnitudes, they remain important for the purposes of seismicity, seismotectonic and seismic hazard studies.

SD7/P20/ID157 - A NEW INSIGHT INTO THE SEISMICITY OF THE SICILY CHANNEL

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The Sicily Channel, bordered by the coasts of Sicily, Tunisia and Libya, Central Mediterranean, is characterized by a generally shallow platform separating the deeper basins of the Eastern and Western Mediterranean, punctuated by the NW-trending Sicily Channel Rift Zone (SCRZ) lying to the south and west of the Maltese islands. The SCRZ features three deep grabens of Miocene-Pliocene age, governed by a system of normal and strike-slip faults that extends throughout the Sicily Channel, and is generally considered to represent divergent tectonics superimposed on the orthogonal convergence of the African foreland on the European plate. The seismic activity on the faults of the SCRZ has so far been poorly monitored and understood, and the region is usually classified as one of low and sparse seismicity. Earthquakes south of the Maltese islands, whose mean magnitude is around 3.0 , are usually recorded only on WDD, a broadband MedNet station on Malta. Mediterranean earthquake bulletins therefore do not give a true picture of this seismicity. The situation has been partially addressed by the design and implementation of an automated, single-station epicentral location algorithm at WDD. The system utilizes the three components on each of three sampling streams (80Hz, 20Hz and 1Hz), with the weighted triggers on all streams acting to discriminate between local/regional and teleseismic events. Automated P and S picking yields the epicentral distance, while polarization analysis on all streams gives a best estimate of the back-azimuth. Since 2006, we have mapped around 170 reliably-located events mainly south of the Maltese islands, more than 60% of which were not reported elsewhere. Moreover, the seismicity is clearly correlated with the grabens and extensions of the SCRZ. During this time period, there appear to be two distinct active regions – the south-eastern extremity of the Malta graben, about 50km south of Malta, and a cluster around latitude 35°N, which corresponds with a right-lateral transform lineament proposed by previous authors. This enhanced picture of the seismicity provides further insight into the complex tectonics of the Sicily Channel, and motivates us to pursue other methods for investigating further aspects of the seismicity, such as depth distribution and focal mechanism.

SD7/P21/ID158 - PERFORMANCE OF ALBANIAN SEISMOLOGICAL NETWORK TOWARDS THE SEISMOLOGICAL BULLETINS COMPILATION.

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Since its beginning, the Albanian Seismological Network had a basic goal to develops and increases its performance on quantity and quality of seismological data collection for Albanian territory and neighbor countries confining it. The real foundation of Albanian seismological network (hereafter

named ASN), is the year 1974, where 13 seismological stations were settled all over the country. After 90-est, developments towards the instrumentations occurred, passing from the analogue to digital records. Actually, ASN consist of 6 BB stations and 6 other SP digital ones, beside TIR which is part of MEDNET, equipped with (VBB) STS-2 sensor. Data are transmitted through VSAT and internet, ensuring central computation at GEO -Sciences Institute of Tirana. The main aim is to collect seismic data and to compile good quality seismological bulletins and permanently update the national seismological catalogue. This serves to the overall interest of scientific community in this field as well as to global contribution in other international and national data centers though data delivery and dissemination. So, compiling good quality seismic bulletins is imperative and interactively related to the development and improves of ASN, in the future. The algorithm used for the hypocenter location of events period 2007-2009 is Hypoinverse and Velocity model is Vel-Albanid 2007. We emphases the role of seismological bulletin and investigate its quality through statistical analysis of data and parameters involved, such as the 60% of located to totally recorded events period 2007-2009; the min and max hypocentral localizing distance are respectively: 5.6 km and 950 km; the lower completeness magnitude ML=1.7; Approximately 78% of events period 2007-2009 have RMS (sec) between 0.12 and 1.0. For events with RMS larger than 1.0 manual review is performed to discharge phases displaying large travel-time residuals. From this point of view, data recorded and collected is enormous and the need for specialize software assistance is crucial to compute them and to ensure the quality of seismological bulletins. All this information of our Bulletins is used to assist disaster management and response efforts; to improve the estimation of seismic hazard, leading to better construction and design standards; and to advance understanding of deep earth structure and seismogenic processes in Albania and its surrounding.

SD7/P22/ID159 - MONITORING OF THE SEISMICITY IN BULGARIA

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The monitoring of the seismicity in Bulgaria is carried out by the Seismological Department of the Geophysical Institute BAS. The main part of the Seismological Department is the National Seismic Network consisting of 28 stations (15 permanent seismic stations and three local networks). The modern digital network became operational in 2005 on the base of 11 RefTek 130 digital acquisition systems, 3 Q330, 1 Quanterra 380 and 8 Guralp 40T, 12 KS2000, and 2 Guralp 3ESP compact BB seismometers and one 3 component S13. Real-time data transmission from field stations to the Operative Center (OC) is accomplished via VPN developed by Bulgarian Telecommunication Company. The real-time acquisition and data processing hardware redundancy at the OC is performed by two clustered SUN servers with software module which re-directs the real-time data flow in case of either server failure. Network control and monitoring are performed by two user interfaces which are running on two SUN Blade 1500 Workstations. Both interfaces serve up html pages that can be displayed in any standard web browser allowing the user to monitor the network status and control the acquisition parameters via Internet. The main task of NOTSSI is to provide reliable detection and precise location of earthquakes that may cause damage or may be felt on the territory of Bulgaria. In the OC the data are also manually interpreted and processed by computer. For the manual focal parameters determination an adaptation of the widespread software HYPO, regional velocity model and regional magnitude formulas are used. The seismologists on duty are also in charge to ensure relevant assessment of the potential dangerous impact on the people or buildings and to inform the responsible governmental bodies. In a case of a strong earthquake on the Balkans, the seismologist sends bulgarian data to the neighboring and international seismological centers. The regular international data exchange is based on some real time exchange and also on later compiled weekly seismological bulletin. An important advantage of the monitor system is the possibility to incorporate real time data flows from other foreign stations and arrays. Recently, the data flows from CTBTO, stations from Greece, Romania and Macedonia seismic networks are incorporated in the real-time data stream in the OC.

SD7/P23/ID160 - RE-PRODUCTION OF THE ISC BULLETIN (1960-2010)

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The International Seismological Centre (ISC) is a non-governmental, non-profit making organization supported by 55 research and operational institutions around the world and charged with production of the ISC Bulletin – the definitive summary of world seismicity based on seismic reports from over 120 institutions. The ISC has a substantial development programme that ensures that the ISC data remain an important requirement for geophysical research. An essential part of this programme is a project to re-produce the entire ISC dataset (1960-2010). Consistency and uniformity of the long period data sets is a major requirement. At the ISC we recently started using the ak135 velocity model instead of Jeffreys-Bullen. We also are preparing to introduce a more advance location algorithm soon. To make sure that newly produced seismic bulletin data are consistent with those in the past we are planning a massive project of re-producing the entire ISC Bulletin since 1960 till 2009. We shall:
· Re-compute ISC hypocentres using new standard earthquake locator, ak135 velocity model and uniform thresholding algorithm, set of defining seismic phases (IASPEI) and error estimates;
· Re-compute event magnitudes using consistent treatment of amplitude measurement outliers, removing magnitude estimates based on too few measurements, providing previously unavailable magnitude error estimates and an account of which stations contributed towards the ISC network magnitude in each case;
· Collect, introduce and process essential additional datasets that have not been available at the time of original ISC Bulletin production;
· Fill known gaps in agency's bulletin reports in the past;
· Rectify known errors, inconsistencies and spurious events, identify and mark data from networks with erroneous time stamp, re-assign event type flags to provide consistency between reports of different agencies. We invite comments, error reports, suggestions and missing bulletin datasets from those who are interested to help the ISC in this vital development.

SD7/P24/ID161 - UPDATE OF THE ITALIAN SEISMIC CATALOG : CATALOGO DELLA SISMICITÀ ITALIANA, CSI V2.0

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Earthquake catalogues are the basic tools that furnish parametric data for seismic hazard evaluation, studies on evolution of seismic sequences and earthquake occurrence. The INGV seismic network covers a large part of the Italian region and it is complemented by several local permanent networks handled by other Italian institutions. The Italian Seismic Catalog (CSI) results from the combination of INGV seismic bulletin with bulletins produced by other institutions. To update CSI from previous release (CSI1.1-1981-2002) to version 2.0 we collected seismic bulletins sent to INGV from, at present, 12 institutions managing local permanent seismic networks during the period 2003-2008. Procedures to convert different file formats to PHS format as input files of Hypoellipse program have been setup also performing preliminary checks on possible errors.

To correctly merge different seismic bulletins it is mandatory to have a strict control on phase associations. To do this, additional procedures to identify earthquakes external to the interest area and wrong associations of different earthquakes based on geographic control network associations and stations' residuals after event location have been produced. Native Ml Magnitudes from 2003 to 2008 are retrieved and then associated to the corresponding event from INGV bulletin. When native Ml is not available, Ml based on regression law, is attributed.

In this study, we have merged all the parametric data collected by the several permanent seismic networks operating in the country (for the period 2003-2008) to create a unified catalog of seismicity that extends observations to the present.

P- and S-wave arrival times are used to relocate the seismicity and compute Ml with an ad hoc scheme developed for optimizing data from local networks. These new locations, integrated with those previously obtained, offer a new image of the seismicity of the region, relying on about 70,000 earthquakes with magnitude between 1.0 and 6.0. The drastic improvement of national and local networks of the past five years yields a consistent improvement of location parameters for a number of events that is almost similar to that acquired in the twenty years before.

The update of CSI catalog offers a more complete image of the Italian seismicity and a new important reference for further

studies on contributing to the understanding of the geodynamics of Italy, inferring insight on the seismotectonic processes and earthquake occurrence.

SD7/P25/ID162 **- EVOLUTION OF THE FRENCH NATIONAL SHORT PERIOD NETWORK (RÉNASS) IN TERMS OF SEISMICITY MONITORING AND BULLETINS**

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The French metropolitan territory is an area of moderate seismic activity compared to the Euro-Mediterranean domain. As shown in historical and instrumental catalogs, the possibility of a major earthquake (M>6) exists. During the last century, the most significant earthquake occurred at Lambesc (1909, Intensity=IX). The recent earthquakes in the Pyrenees (2006/11/17, Ml=4.9), in the Alps (2005/09/08, Ml=4.9) and in the eastern part of France (2004/02/23, Ml=5.1; 2004/12/05, Ml=5.3) remind us that moderate to large events can happen in France. The French National short period network (RéNaSS) is in charge of the metropolitan seismic monitoring. Until 2010/05/31, the RENASS sent seismic alerts in case of earthquake (M>3.5) felt on the French metropolitan territory. Since June, alert activities (implying 24h duty) were transfered to the CEA-LDG (Laboratoire de Détection Géophysique, Bruyères-le-Chatel, France). In this framework, the RENASS alert system and seismic monitoring is currently being restructured in close collaboration with the BCSF (Bureau Central Sismologique Francais, Strasbourg, France) in charge of macroseismic aspects. The RENASS/BCSF activities are refocused on bulletins and seismicity monitoring using both instrumental and macroseismic data for a comprehensive scientific information on earthquakes occurring in the French metropolitan territory (seismotectonic context, historical and instrumental regional seismicity, focal mechanism, felt map, intensities and magnitude, ...). We will present the current state of the French metropolitan seismicity, and the evolution of the RéNaSS activities in close collaboration with BCSF (seismic monitoring, information dissemination, bulletins, ...).

SD7/P26/ID163 **- THE SEISMOLOGICAL CENTRAL OBSERVATORY (SZO) AT THE BGR: THE DATA ARCHIVE OF BROADBAND SEISMIC STATIONS IN GERMANY, DATA ANALYSIS AND SEISMICITY CATALOGUES**

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The Seismological Central Observatory (SZO) is part of the Federal Institute for Geosciences and Resources (BGR) in Hannover. It is the national data centre for seismological broadband data in Germany. The broadband station set consists of the German Regional Seismic Network (GRSN, currently 27 stations) and the Graefenberg array in southeast Germany (GRF, 13 stations). Both station sets are in operation since decades, the Graefenberg-Array since 1976 and the GRSN since 1991. The complete set of continuous waveforms is archived at the SZO and all data are available via a website (http://www.bgr.bund.de), AutoDRM (autodrm@szgrf.bgr.de) or WebDC (http://www.webdc.eu). All detected local, regional and global seismic events are manually analysed every working day. For regional events at the border and outside of Germany waveform data of the stations of the neighbouring countries (including GEOFON stations) are incorporated in the routine data analysis. For local events in Germany and adjacent areas it is discriminated between tectonic events, mining induced events and blasts. Together with the locations and data of local networks, mostly belonging to the geologic surveys of the federal states of Germany, monthly earthquake catalogues are produced. For the teleseismic events we analyse and pick the primary phases as well as depth phases and secondary phases as for example PP, SP, S, SKS etc. A special emphasize is given to PKP-phases of the events in the Fiji-Tonga region which are in a favourable distance range to the stations in Central Europe. Also for the teleseismic events a monthly earthquakes catalogue is produced which is available via our website and distributed to interested parties. Analysed source parameters and significant phases are distributed to international data centres (EMSC, NEIC, ISC).

ES8 - NEW APPROACHES TO EARTHQUAKE PREDICTABILITY AND TIME-DEPENDENT SEISMIC HAZARD AND RISK ASSESSMENT AT LOCAL AND REGIONAL SCALES

ES8/P1/ID164 **- RECOGNITION OF EARTHQUAKE PRONE AREA IN SOUTHWEST PENINSULAR INDIA**

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Kerala state is prejudiced by several natural hazards such as landslides, coastal erosion, floods, lightening and sporadic earthquake activities. Though the earthquakes occurred so far in the region are of moderate size but chances of destructive earthquakes cannot be ruled out in future since an earthquake of M 6 has already rocked the region around Coimbatore and Palakkad in 1900. The region falls in zone III of the Seismic Hazard Zonation Map of India. Occurrence of moderate earthquakes has been reported from various parts of the state since historic times which indicate that the region is reasonably active. The significant earthquakes; Idukki earthquake sequence of 7-8 June 1988 (M 4.5, 4.1 & 3.4); Wadakkancheri earthquake sequence of 02 December 1994 (M 4.3) and the recent Erattupettah earthquakes of 12 December 2000 & 7 January 2001 (M = 5.0 & 4.8) that have occurred in recent times are witness. These earthquakes have occurred in Central Kerala and most of them are associated with NW-SE trending lineaments within 100 km stretch. The series of unusual geological incidents oscillations and rise in water levels, wavy formations and spouting up of water in the open wells, cracks in the buildings, perceptible ground fissures, shaking of trees/bushes and enhanced micro-earthquake activity have occurred throughout the Kerala State (southwest Peninsular India) during the year 2001 mainly in two active phases i.e. February to March, and June to November 2001. The spatio- temporal analysis of incidents data points towards crustal movement leading to uplift and tilt of the ground in Kerala which is visualized as the main cause for triggering these incidents in 2001 and also probably the initiation of dilatancy from the beginning of February 2001. This chain of incidents was preceded by two moderate size earthquakes of M~5 on 12 December 2000 and 7 January 2001 which were not capable to trigger such widespread incidents in the region. The present chain of events, if viewed in terms of the dilatancy diffusion model, can be manifestations of preparatory stage of an earthquake. Using the spatial distribution of these incidents including micro-earthquake activity and past significant earthquakes, an east-west trending potential area (10.7-10.9 oN; 76.0-76.8 oE) is delineated in the central Kerala region as the preparatory zone for the location of future earthquake Hazard.

ES8/P2/ID165 **- CREDIBLE WORST CASE EARTHQUAKE SCENARIOS OF AMMAN MUNICIPALITY, JORDAN**

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Neotectonics, geological and seismological information are the main tools to predict the appropriate credible worst case earthquake scenarios. These tools are mainly involving rupture source, rupture length, location, intensity, and magnitude. In general, for worst case scenarios, the maximum event is adopted. By using the above information, a successful earthquake scenario must define the earthquake of maximum possible magnitude and its specific impacts. In case of Greater Amman Municipality (GAM), which is located about 17 km from the main fault of the Dead Sea Transform Fault (DSTF), all information, including active faults, palaeseismicity, and instrumental seismicity converge to a large earthquake associated with the most potential expected ruptures in the DSTF region. In this study, the approach of credible worst case earthquake scenarios for risk assessment loss estimation of buildings in GAM is introduced.

Keywords: Credible Worst Case Earthquake Scenarios, Neotectonics, Palaeoseismicity, Seismic Risk Assessment.

ES8/P3/ID166 **- SEISMICITY AND HAZARD ESTIMATION IN NORTHWEST OF IRAN**

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Iran is the zone of convergent plate collisions along the Alpine-Himalayan active mountain belt. In order to forecast earthquake activity we need to determine the past history of faults. A fault that was active is likely to move again. Historical background and instrumentally located earthquakes as well as the geological evidences all suggest that northwest Iran is one of the seismically active regions in the Middle East. The destructive Rudbar earthquake of 1990 indicated the need to install a permanent seismological network in the region. In 1995 the Institute of Geophysics of Tehran University deployed a telemetric seismic network in NW Iran to monitor local earthquakes. Relying on the records obtained during this period, several seismically active areas could be recognized. The epicenters of local earthquakes are in agreement with the NW-SE trending major faults. The distributions of earthquakes in east and west parts are consistent with the related major faults (Astara, Rudbar faults in east and Orumiyeh, North Tabriz faults in west). A kind of seismic quiescence exists in central part around Tabriz. There is a probability of a large earthquake occurrence in the North Tabriz Fault (NTF) and the central part of Tabriz to Khoy-Salmas fault. The average recurrence interval is estimated to be 250-300 years. A similar situation could be observed along the Astara fault in the east. The majority of events are shallow indicating that the seismic activity is mainly taking place in upper crust and the seismogenic layer has a thickness of about 20 km. taking into account the background seismicity and present pattern of seismicity, the occurrence of a major earthquake in northwest Iran is expectable. Therefore, as there is a likelihood of large and dangerous earthquakes in northwest of Iran, micro-seismic zonation of this region should be included in future construction planning of the country and it will be effective for the macroeconomic and industrial planning of Iran.

ES8/P4/ID167 - USING EDGE OF CHAOS PECULIARITIES FOR EARTHQUAKE PREDICTION IN SOUTHERN REGIONS OF IRAN

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At the Recent years, many geoscientists have focused on chaos and its relevant subjects for understanding nonlinearity of nature as the main criteria in explaining the dynamic behavior of earthquakes. Mathematically, the multivariate iterative functions have basic fractal expression in the analytical, practical, and computational domains. In this innovative research, a dynamic model of geophysical precursors is presented, using logistic maps, to describe the complexities of seismic events at the edge of chaos. In the proposed model, interpreted geological dataset corresponding to seismic, magnetic, and electromagnetic values are included. According to the historical earthquakes in southern regions of Iran, hazardous area is divided into stable and active prospects nearby Hormozgan fault systems. Determining the μ parameter is used as the average net reproductive rate values. The results show important evidences containing independent variables in eight integrated model cells. Also three forecast cells can be estimated after applying the net values into the regions with higher or lesser potential of future events, in comparison with model cells.

Keywords: Chaos, Earthquake prediction, Geophysical precursors, Nonlinearity.

ES8/P5/ID168 - ON EARTHQUAKE PREDICTION USING PARAMETERS OF NEAR SPACE PLASMA

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We present new results which support idea that variations of near space plasma parameters may be useful for purpose of earthquake prediction. Scientific base for this idea is electrodynamic model of lithosphere-atmosphere-ionosphere-magnetosphere coupling, which suggests that generation mechanism of earthquake precursors in near space plasma is modification of electric field in global electric circuit (GEC) due to earthquake preparation. In modern configuration of GEC, its external boundary is placed on magnetopause, where the electro-motive force generator driven by the solar wind is included. In such configuration of GEC, the role of current wires may play conductive geomagnetic field lines, which are loaned into the earth's crust in magnetically conjugate areas. Taken into account that electrostatic and/or electromagnetic field changes in one part of GEC have to produce practically simultaneous changes in all another parts, one may suggest that not only space plasma parameters will respond to electromagnetic processes occurring in area of earthquake preparation, but and vice versa, the areas of earth's crust will respond to electromagnetic variations of near space plasma up to magnetopause heights. This allows one to suggest that areas of seismic activity may be magnetically conjugate. Our analysis showed that indeed seismic areas along southern part of Mid - Atlantic Ridge are magnetically conjugate to seismic areas along its northern part; seismic areas along southern boundary of Pacific plate are magnetically conjugate to seismic areas along its northern boundary, seismic areas along southern boundary of Nazca plate are magnetically conjugate to seismic areas along northern boundaries of Caribbean and Cocos plates. The area of strong (M_W=7.6) Kocaeli-1999 earthquake (40.75N, 29.86E) is magnetically conjugate to area of strong seismic activity in Africa (25.03S, 34.67E). To our mind, obtained results support a modern idea that earthquake is an element of GEC, and for purpose of earthquake prediction the regular monitoring of electromagnetic parameters along the whole magnetospheric tube loaned into potentially expected source of strong earthquake is desirable.

ES8/P6/ID169 - EARTHQUAKE RISK CLASSES FOR DAMS SITUATED IN THE OLTENIA (ROMANIA) ZONE

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The main goal of this paper is the probabilistic assessment of the seismic hazard in the Oltenia zone due to intemediate-depth and crustal earthquakes and the rating of all dams from the zone into seismic risk classes. Dam owners and regulators must ensure that dams are safely operated and present no risk to the public in case of an earthquake. While most old or new dams in recognized seismic regions have been evaluated and analyzed for seismic loads, dams located in areas of moderate or infrequent seismicity have been given less systematic attention. In such cases, owners of many dams or officials in charge of dam safety programs may consider comparative assessment of the seismic risk associated with their dams and establish priorities, as needed. Risk classes can be used to establish the necessity of detailed assessment of seismic safety of the dams and to establish the priorities of these evaluations. Methodology which is used in this paper offers an easy way to evaluate the most vulnerable hydrotechnical facilities among the multitude of the Romanian dams, that are affected by normal and intermediate-depth Vrancea earthquakes. Generally the risk is expressed as a product between hazard and vulnerability. In particular, seismic risk in the case of hydrotechnical arrangements is computed as a product between seismic hazard (corresponding to the location of the respective hydrotechnical arrangement) and the seismic vulnerability of the respective arrangement. Various risk factors and weighting points can be used to approximately quantify the Total Risk Factor (TRF) of any dam [Bureau and Ballentine, 2002]. The TRF depends on the dam type, age, size, the downstream risk potential, and the dam vulnerability, which depends on the seismic hazard of the site. The dam structure influence is represented by the sum of capacity, height, and age risk factors. The downstream hazard factor is based on population and property at risk.

ES8/P7/ID170 - ANOMALIES OF A STRESS-FORECAST EARTHQUAKE IN SHEAR-WAVE POLARIZATIONS

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A Mb=5.3 Manyas earthquake has been 'stress-forecast' by using variations in time delays of seismic shear wave splitting to evaluate the time and magnitude at which stress-modified microcracking reaches fracture criticality within the stressed volume where strain is relased. Therefore, we processed micro earthquakes recorded by 29 installed in the TURDEP (Multi-Disciplinary Earthquake Research in High Risk Regions of Turkey) project and also 33 from KOERI (Bogazici University, Geophysics Department, Kandilli Observatory and Earthquake Research Institute) stations in the Marmara region by using the methods: the aspect ratio method, cross-correlation method and systematic analysis of crustal anisotropy. The motivation of the study is to measure delay time changes before and after the Manyas earthquake. Remarkably decreases in delay times before the impending event at espe-

cially GEMT are observed. The result is consistent with Anisotropic Poro Elasticity (APE), but we could not observe same changes at other stations surrounding the main event. The logarithms of the duration of the stress-accumulation are proportional (self-similar) to the magnitude of the impending event. It is very hard to conclude that location of the forecast earthquake can be forecasted in terms of variations in splitting parameters before and after the main earthquake, The study gets an example Local investigations indicated the approximate location of the forecast earthquake

ES8/P8/ID171 **- ASPERITY-BASED EARTHQUAKE LIKELIHOOD MODELS FOR ITALY**

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The Asperity Likelihood Model (ALM) was first developed for forecasting earthquakes in California (Wiemer and Schorlemmer, SRL, 2007) and is now being tested for performance in the US testing center of the Collaboratory for the Study of Earthquake Predictability (CSEP). The model hypothesizes that small-scale spatial variations in b-value of the Gutenberg and Richter relationship play a central role in forecasting future seismicity. The physical basis of the model is the concept that the local b-value depends inversely on applied shear stress. Thus, low b-values (b<0.7) characterize locked patches of faults—asperities—from which future main shocks are more likely to nucleate, whereas high b-vaues (b>1.1), found for example in creeping sections of faults, suggest a lower probability of nucleating large events. Here, we calibrate this model for the Italian testing region, the first region in the CSEP European testing center. Italian seismicity is lower, more distributed, and less fault-centric than seismicity in California. Comparison of forecasts of the same model in different regions is a key element in making progress in the study of earthquake forecast models. We also explore two modified versions of this model: in the ALM. IT model, we in addition decluster the input catalog and smooth the node-wise rates of the declustered catalog with a gaussian filter. Completeness values for each node are determined using the probability-based magnitude of completeness method (Schorlemmer and Woessner, BSSA, 2008). In the HALM (Hybrid Asperity Likelihood Model), a 'hybrid' between a grid-based and a zoning model, the Italian territory is divided into 8 distinct regions depending on the main tectonic regime, and the local b-value variabilily is thus mapped using regional b-values for each tectonic zone.

ES8/P9/ID172 **- A HIERARCHICAL MODEL FOR DISTRIBUTED SEISMICITY.**

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A cellular automata model for the interaction between seismic faults in an extended region is presented. It is called Hierarchical Box Model (HBM). Faults are represented by boxes formed by a different number of sites and located in the nodes of a fractal tree. Both the distribution of box sizes and the interaction between them is assumed to be hierarchical. Load particles are randomly added to the system, simulating the action of the external tectonic forces. These particles fill progressively the sites of the boxes. When a box is full it topples and the particles are in part redistributed and in part lost. A box relaxation simulates the occurrence of an earthquake in the region. The particle redistributions mostly occur upwards (to larger faults) and downwards (to smaller faults) in the hierarchy producing new relaxations. This model is consistent with the definition of magnitude, i.e. earthquakes of magnitude *m* take place in boxes with a number of sites ten times bigger than those boxes responsible for earthquakes with a magnitude *m-1* which are placed in the immediate lower level of the hierarchy. The three parameters of the model have a geometrical nature: the height or number of levels of the fractal tree, the coordination of the tree and the ratio of areas between boxes in two consecutive levels. HBM shows a self-organized criticality behavior and is able to reproduce some of the most important statistical regularities of real seismicity such as the Gutenberg-Richter law (both the power law behavior and the value of its exponent), the total percentage of aftershocks in the catalog and the number of aftershocks per mainshocks of a given magnitude. Besides, the HBM describes correctly the observed energy release rate behavior. Two different strategies of forecasting have been analyzed. The first one corresponds to a reference strategy. The second one corresponds to a precursor pattern, called burst of aftershocks, which has been used for real earthquake prediction. In summary, a conceptually simple hierarchical model with a small number of parameters can produce synthetic seismic catalogs that share some of the most important statistical regularities with real ones.

ES8/P10/ID173 **- RETROSPECTIVE EVALUATION OF THE FIVE-YEAR AND TEN-YEAR CSEP-ITALY EARTHQUAKE FORECASTS**

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On 1 August 2009, the global Collaboratory for the Study of Earthquake Predictability (CSEP) launched a prospective and comparative earthquake predictability experiment in Italy. The goal of the CSEP-Italy experiment is to test earthquake occurrence hypotheses that have been formalized as probabilistic earthquake forecasts over temporal scales that range from days to years. In the first round of forecast submissions, members of the CSEP-Italy Working Group presented eighteen five-year and ten-year earthquake forecasts to the European CSEP Testing Center at ETH Zurich. We considered the twelve time-independent earthquake forecasts among this set and evaluated them with respect to past seismicity data from two Italian earthquake catalogs. In this article, we present the results of tests that measure the consistency of the forecasts with the past observations. Besides being an evaluation of the submitted time-independent forecasts, this exercise provided insight into a number of important issues in predictability experiments with regard to the specification of the forecasts, the performance of the tests, and the trade-off between the robustness of results and experiment duration. We conclude with suggestions for the future design of earthquake predictability experiments.

ES8/P11/ID174 **- THE SEISMIC SEQUENCE OF JANUARY 2010 IN CORINTH GULF, GREECE, AND RESULTS ON AN EXPERIMENT OF DAILY SEISMICITY EVALUATION WITH THE ALGORITHM FORMA FOR SHORT-TERM HAZARD ASSESSMENT**

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The strategy proposed for the investigation of significant seismicity changes in the time-space-magnitude domains for the short-term hazard evaluation in real-time was applied during the earthquake sequence of January 2010 in NW Corinth Gulf, Greece. Application was performed with the algorithm FORMA (foreshock-mainshock-aftershock) by updating the earthquake catalogue daily and implementing expert system knowledge on the properties of foreshocks, aftershocks and swarms in Corinth Gulf. On 18.01.2010 and 22.01.2010 two strong normal faulting earthquakes of M_L=5.2 and M_L=5.1 (NOA) occurred. Both were followed by numerous smaller shocks. As soon as the first strong earthquake occurred, the procedure for real-time seismicity evaluation was initiated. The day after the first strong shock the target area was decided from the 1-day activity area while the background seismicity was determined from the long-term catalogue with completeness magnitude cut-off of 2.5. We tested daily the null hypothesis that the activity following the first earthquake was in the state of background seismicity against two alternate hypotheses: (a) foreshocks, (b) aftershocks. The time periods examined were equal to $\tau=(2+i)$ days, *i* ranging from 1 to 10 days. The first period was τ=2 days. In each testing period the significance level of changes of seismicity rate *r* and of *b*-value with respect to *r* and *b* in the background seismicity were investigated. Based on the testing output public evaluation statements were released nearly on a daily basis. Increase in *r* became highly ($z\geq0.99$) significant from the second evaluation period and remained as such until the last period. Parameter *b* increased at highly significant level (p-Utsu$\leq$0.01) since the first period and remained highly significant until the last period. The only exception was on the fourth period when *b* dropped due to the preceding second strong earthquake of M_L=5.1. The combined real-time evaluation of *r* and *b* was critical for the evaluation output which was reflected in the public statements. Until the occurrence of the second strong shock results and statements were against to both, the null hypothesis and the first alternative hypothesis (foreshocks) but in favour of the second alternative, that is of the aftershock case. The occurrence of the second strong shock and the evaluation results of the fourth period caused some temporary skepticism due to the drop of

b-value. However, results favouring the alternate aftershock hypothesis resumed constantly from the fifth evaluation period. The FORMA test proved successful promising new possibilities for operational applications by civil protection.

ES8/P12/ID175 - IMPROVING TIME-VARYING SEISMIC HAZARD ASSESSMENT: ICELAND AS A CSEP TESTING REGION

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Improving our ability to accurately forecast where and when the next damaging earthquake will likely occur is one of the key steps towards improving the earthquake resilience of modern societies. Model testing & validation is a critical next step in implementing time-varying probabilistic seismic hazard assessment (TV-PSHA). Progress in TV-PSHA has been impeded by the lack of an adequate experimental infrastructure, making it difficult to conduct scientific prediction experiments and model development under rigorous, controlled conditions, and even more difficult to evaluate forecasts using accepted criteria specified in advance. To remedy this deficiency, the Collaboratory for the Study of Earthquake Predictability (CSEP, www.cseptesting.org) is promoting a community-supported, geographically distributed laboratory with a computational infrastructure that is adequate to support a global program of research on earthquake predictability.

The CSEP EU Testing Center at ETH Zurich (eu.cseptesting.org) represents the European node of CSEP http://www.cseptesting.org/. It was funded in part through the EU project NERIES (www.neries-eu.org), and it will serve multiple testing regions within Europe. In the first testing region, Italy, fully prospective testing of more than 20 models has started August 1, 2009. Because of the high seismicity and deformation rates, the excellent monitoring network, and the existence of several geophysical models, Iceland is ideally suited as a future testing region within the CSEP EU Testing Center. Applying the wide range of existing models in Iceland should help improve our understanding of the physical processes underlying earthquakes in Iceland, and it may also lead us to generalizations regarding seismicity elsewhere. We have obtained seed funding from the Swiss National Science Foundation for the first phase of such a project. In collaboration with IMO scientists, we have the vision to develop Iceland as a CSEP testing region. This work includes (1) studies of earthquake network homogeneity and catalog magnitude completeness; (2) calibration of a range of existing forecasting models to the seismic regions of Iceland; (3) evaluation of model forecasting ability based on retrospective testing and finally (4) implementation of fully prospective testing of models against a defined authoritative data stream provided by IMO. In this talk, we will present first results of the first three aforementioned topics.

ES8/P13/ID176 - CLUSTERING OF SMALLER SEISMIC EVENTS IN EQUIVALENT DIMENSION HYPERSPACES BEFORE AND AFTER MAIN SHOCKS

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Parameters describing the seismic process: occurrence time, hypocentral coordinates, interevent time and distance, magnitude, seismic energy, stress drop and all other which can be associated with a series of earthquakes are provided in different, in general incomparable scales. In order to study earthquake clustering properties in a multidimensional space, the space must have a properly defined metric. This requirement limits the search for earthquake clustering to trivial cases of only Euclidean spaces or involves speculative equalizations of different scales. An equivalent dimension concept has been worked out to investigate, in a non-speculative way, a short term clustering of events in the spaces built by any combinations of the event parameterizations. It is assumed that the long-term distributions of seismicity parameters are mutually equivalent because they represent the same seismic process. Those intervals of different parameters are assumed to be equivalent, which have the same probabilities of realization in the long term for the considered seismic process. Hence, the transformation into the equivalent dimensions is done by replacing the values of event parameters with the values of their respective cumulative distribution functions. The unknown cumulative distribution function of the parameter under study is assessed by means of the non-parametric, kernel estimator. The background sample for this estimation is composed of parameter values of the long term seismic series. The transformed values of every parameter are in the same linear scale in [0,1] interval, and the distance between points in the transformed space is Euclidean. For every parameter the distribution of background sample values is uniform in [0,1]. Thus, the equivalent dimension values of the long term series of events are distributed uniformly in [0,1]. Short term properties of the seismic process can be investigated by comparing the distribution of locations, in the equivalent dimension space, of events from a shorter time interval to the distribution of locations of events from the long term series. Here, we study clustering of smaller events in the equivalent dimension hyperspaces before and after two earthquakes from Greece. The amount of clustering is measured with the fractal correlation dimension of event locations. Significant reductions of the fractal dimension after but, more interestingly, also before the main shocks point at potential of the equivalent dimension approach to study details of seismic process.

ES8/P14/ID177 - EARTHQUAKE FORECASTING RELATED RESEARCH IN TURKEY: A REVIEW AND OUTLOOK

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Turkey is one of the most seismically active countries in the European – Mediterranean region and, responding to societal needs, the long-term probabilistic seismic hazard analysis using the time dependent and time independent models has been investigated in local (Yarar *et al.*, 1980; Erdik and Oner, 1982; Erdik *et al.*, 1985; Gülkan *et al.*, 1993; Onur, 1997; Erdik et al., 2003) and European scales (GSHAP, 1999, TEFER, 2000; SESAME, 2003; Kayabali and Akin, 2003, Tsapanos *et al.*, 2005) for the probability of exceedence at a specified level of ground shaking over a long time period on the order of 50 years. However, in the last year, a new physics-based and time-dependent "forecasting" approach to hazard assessment in order to respond to changing societal needs and emerging capabilities is required. Based on the short term earthquake probability methods (Gerstenberge et al., 2004), the spatial and temporal seismicity parameters and the related probabilistic aftershock hazard for the aftershock sequence of the 1999 Mw 7.4 Izmit Kocaeli earthquake mainshock by using the ZMAP program (Wiemer, 2001) have been evaluated in a European scale. Spatial variation of b-value across the Izmit earthquake rupture zone, estimated using the maximum likelihood criterion, has been mapped in the studies of Akkar et al., 2004; Bayrak and Ozturk, 2004; Demircioglu et al., 2007; Ethem et al., 2009). As a part of the NERIES project, using the California parameter for generic model and virtual background seismicity , the probability of exceeding MMI level VI for 24 hour have been quantified as a preliminary study for Turkey (Demircioglu et al., 2007). We would like to propose Marmara Region as new CSEP (Collaboratory for the Study of Earthquake Predictability) experiment site, where strategies for testing especially short-term forecasts can be developed and critically evaluated.

ES8/P15/ID178 - THE JANUARY 2010 EFPALIO EARTHQUAKE SEQUENCE IN THE WESTERN PART OF THE GULF OF CORINTH, CENTRAL GREECE.

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The Aegean broader region (Greece) is one of the most active extensional continental regions in the world, located between the two lithospheric plates of Eurasia and Africa, which converge at a rate of about 1 cm/yr. The total extension across the Aegean is about 4-5 cm/yr as deduced from satellite geodesy. The Gulf of Corinth is situated in the inner part of Aegean microplate. The Gulf is the most prominent rift in this region and has experienced several destructive earthquakes in recent decades. The geological evidence of normal faulting and the high level of seismicity, both historical and instrumental, implies a high rate of extension.

On 18 January 2010, 15:56 UTC a Mw=5.1 (NOA) earthquake occurred near the town of Efpalion, about 10 km to the east of Naf-paktos, along the north coast of the Gulf of Corinth. Another strong event occurred on 22 January 2010, 00:46 UTC with Mw= 5.1 (NOA) approximately 3 km to the NE of the first event. This sequence ended a 15-year seismic quiescence in this area of Greece. The last major event was the Aigion (June

1995, Ms=6.2), offshore earthquake about 20 km to the east.

The paper will present an analysis of the seismological data of this sequence and demonstrates a case of dynamic triggering following the 27/2/2010 Chile M=8.8 giant earthquake. Our results include maps of spatiotemporal variations in seismicity rate and implications for the stress state in the western Gulf of Corinth.

ES8/P16/ID179 **– SEISMOTECTONIC DEFORMATION OF THE KURIL-KAMCHATKA REGION AND EVIDENCE FOR STRESS DISTURBANSES IN THE STRONG EARTHQUAKES SOURCE ZONES**

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Seismicity and fault plane solutions in the Kuril-Kamchatka region have been studied to focus attention on the nature of deformation in the northwest boundary of Pacific plate. Predominance of typical earthquake mechanisms with more or less NW--SE pressure axes imply that corresponding compressive deformation is presumed to be the result of collision of north-west moving Pacific plate with the Eurasian plate at the Benioff zone of the Pacific lithosphere subduction in upper mantle. This deformation pattern is subjected however to local short-term variations due to stress state changes in zones of strong earthquakes genesis at preparing stages. These stress state disturbances theoretically are evaluated as a result of reactivation of localised deformation bend or large- scale faults. Statistical study of seismic moment tensors in terms of seismotectonic deformation is performed. Herewith summation of normalised seismic moment tensors for a representative set of seismic events within vicinities of strong earthquakes foci is used. Temporal variations are investigated on the basis of scalar product individual seismic moment tensor and seismic strain rate tensor obtained through this averaging procedure. This simple technique, together with the construction of classification diagrams of fault plane solutions enables us to rapidly examine the stress- field pattern and further discuss the deformation modes of faulting and fracturing, which may take place at a local scale. We have suggested that the local variations of the stress tensor may be considered as an additional tool in solving earthquake prediction problem. . The precursory changes in forshocks source mechanisms were diagnosed retrospectively and in advance by this algorithm of the two recent earthquakes: October 4, 1994, M = 8.3, South Kuril, Shikotan, and December 5, 1997, M = 8.0, Kamchatka. A geodynamic interpretation of the temporal-spatial focal mechanisms variations is proposed to highlight the role played by re-activation of major structural discontinuities in contemporary stress transmission regim.

ES8/P17/ID180 **– A GENERALIZED EARTHQUAKE FREQUENCY-MOMENT DISTRIBUTION: A NON EXTENSIVE STATISTICAL PHYSICS VIEW**

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The statistical properties of earthquakes in time, size (i.e., energy or moment) and space are of crucial importance in any probabilistic seismic hazard estimation (PSHE). One of the laws with fundamental importance in PSHE is the earthquake frequency- moment (or magnitude) distribution. Even if earthquakes are complex phenomena, to final order they followed a power-law distribution called Gutenberg-Richter law (GR), of source parameters such as radiated seismic energy, seismic moment or fault length . The Gutenberg-Richter law is the basic tool used in any earthquake hazard calculation. This power law scaling, hold for moderate and small earthquakes as indicated from the analysis of earthquake catalogues constructed using recordings in digital and analogue seismological era.It is usually asserted that this self similar law could not continue indefinitely to higher magnitudes, due to the physical requirement of finite-energy or equivalently a finite-seismic moment-release rate. Upper bounds to moment-release rates maybe determined from plate tectonic slip rates for interplateearthquakes, or from observed intraplate deformation rates or platemodels .In a number of publications remarked that from small to large earthquakes a modification in Gutenberg –Richter exists and such indicating a change in the scaling properties. Furthermore, a soft cut-off model has advocated according to which the power law is multiplied by an exponential roll-off at large moments(called gamma-law), enabling large moments but with rather small probabilities compared with that of GR power law.In this work we use a current generalization of Boltzmann-Gibbs (BG) statistical mechanics referred as non extensive statistical mechanics [NESM] presented to explore the earthquake frequency –moment distribution and to interpret the scaling law observed. The advantage of considering the NESM distribution is that based on an entropy principle, it can be related to statistical mechanics and reduces to the traditional BG statistical mechanics as a special case. Seismicity is an example of fractality, self-organized criticality and long range interaction. It is precisely such phenomena that constitute the scope of non-extensive statistical mechanic . The non-extensive statistical mechanics offer a consistent theoretical framework, based on a generalization of entropy, to analyze the behavior of systems with fractal or multifractal distribution of their elements. Such systems where long - range interactions or intermittency are important, lead to power law behavior.Consistently, even at phenomenological level, i.e., without specifying any model, the question if seismicity is described by non-extensive statistical physics represents a challenge. This is the problem we address here. Our aim is not to use a precise model but rather to present a simple argument of physical plausibility and to compare the NESM results with earthquake frequency –moment distribution long ago used..

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ES8/P18/ID181 **– TIME-DEPENDENT OCCURRENCE RATES OF LARGE EARTHQUAKES IN THE DEAD SEA FAULT ZONE AND APPLICATIONS TO PROBABILISTIC SEISMIC HAZARD ASSESSMENT**

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The seismicity of the Dead Sea fault zone (DSFZ) during the last two millennia is characterized by a number of damaging and partly devastating earthquakes. These events pose a considerable seismic hazard and seismic risk to Syria, Lebanon, Palestine, Jordan, and Israel. The occurrence rates for large earthquakes along the DSFZ indicate temporal changes in the long-term.

The aim of this thesis is to investigate an approach to test, whether the occurrence rates of large earthquakes in different parts of the DSFZ are time-dependent and how. It means not only to check the time dependency of occurrence rates in the DSFZ, but also to test if the rates follow a temporal change in the long-term. The results for the central part of the DSFZ show that the time-dependent model is not significantly better than the time-independent and the time-independent model is sufficient for the occurrence rate in this part of the DSFZ. The results for the northern part of the DSFZ verify that the earthquake occurrence rate is strongly time-dependent, especially shortly after an earthquake occurrence. The earthquake occurrence rate, corresponding to the selected model, is a smooth function of time and reveals two clusters within the time after an earthquake occurrence. The first cluster begins right after an earthquake occurrence, lasts about 80 years, and is explicitly time-dependent. The occurrence rate of this cluster is considerably lower immediately after an earthquake occurrence, increases strongly during the following ten years and reaches its maximum of about 0.024 events/year, then decreases over the next 70 years to its minimum of about 0.0145 events/year. The second cluster begins 80 years after an earthquake occurrence and lasts until the next earthquake occurs. The earthquake occurrence rate, corresponding to this cluster, increases extremely slowly, so that it can be considered as an almost constant rate about 0.015 events/year. The results are applied to calculate the time-dependent PSHA in the northern part of the DSFZ and neighbouring areas.

T/SD2 - EARTHQUAKE AND TECTONICS: FROM PALEOSEISMICITY TO PLATE TECTONICS

T/SD2/P1/ID182 **– SEISMOTECTONICS CHARACTERISTICS OF KOSOVO**

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The geological-tectonic building of Kosovo is very complication. As the result of this Kosovo is one countries of the highest active seismic in East-South Europe.To detect links between the movements of tectonic movement's neotectonics early, study of Kosovo neotectonics activity is closely linked to early recognition of geological structure. Primary importance is the study of morphology

tectonic severance and their classification in terms of seismic risk assessment.Based on the existing seismic hazard maps of Kosovo for repainting periods of 100, 200, 500, 1000 years, in Kosovo its possible earthquake with maximum magnitude 9. Geological build of building location and seismic hazard is necessary to study the effect which can cause in objects by earthquake. The specific issues that should be studied in Kosovo territory are:
- Separation of area tectonics and their seism-tectonics activity,
- The source of the seismic area,
- The geology properties of seismic area
- Risk assessment of earthquakes. Key words: tectonic, seismotectonic, seismic, risk,

T/SD2/P2/ID183 - SEISMIC VELOCITY STRUCTURE AT THE SOUTHEASTERN MARGIN OF THE ARABIAN PENINSULA

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The lithospheric structure in Oman has been determined by analyzing teleseismic P-receiver functions recorded at broadband and short-period seismic stations of Oman Seismological Network. Lithospheric structure is obtained by jointly inverting receiver functions and Rayleigh wave group velocities derived from continental-scale surface wave tomography of Pasyanos (2005). We observe relatively thick crust (40-48 km) within the ophiolite formed mountains at northern Oman. The crustal thickness is about 35 km within the passive continental margin of the southern Dhofar region. Uppermost (< 5 km) crustal shear wave velocities are faster in the northern ophiolite regions compared to the southern Dhofar region, while shear velocities in the middle crust are faster in the Dhofar region compared to the ophiolite region. This observation coincides well with cretaceous to Eocene marine platform sequences overlying Precambrian to Cambrian basement of the southern part. Joint inversion analysis shows that the Moho depth of Oman varies from 34 km in the southern region to 48 km in the northern part.

T/SD2/P3/ID184 - 1-DETERMINATION OF GRAVITY ANOMALIES OVER THE ARABIAN 2-ON THE ESTIMATION OF A MULTI-RESOLUTION REPRESENTATION OF THE GRAVITY FIELD BASED ON SPHERICAL HARMONICS AND WAVELETS 3-RESEARCHES ON APPLICATION OF GPS TO EARTHQUAKE MONITORING AND PREDICTION

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1-Gravity anomalies derived from satellite altimetry are progressively anomalies-derived from multi-mission satellite altimetry-with gravity anomalies by the EGM96 global geopotential model. The results show some significant differences among these gravity data sources. Ocean satellite altimetry implied free-air gravity anomalies have had the shortest wavelength removed during the processing to generate the optimal solution between multiple radar altimeter missions. Compute gravity anomalies by LSC using along-track, differeced geoidal heights and height slopes. Gravity Anomalies over the Arabian Sea (latitudes: 0-25°N and longitudes: 35 – 70°E) is computed by using along track deflections of vertical and grid along track deflections of vertical using Shepard's method of gridding procedure and finally the gravity anomalies were computed using the inverse Vening-Meinesz formula we used altimeter data from Topex/Poseidon, Jasonl, Geosat, ERSI and ERS2 missions.

2-The gravitational potential of the Earth is usually modeled by means of a series expansion in terms of spherical harmonics. However, the computation of the series coefficients requires preferably homogeneous distributed global data sets. Since one of the most important features of wavelet functions is the ability to localize both in the spatial and in the frequency domain, regional and local structures may be modeled by means of a spherical wavelet expansion. In general, applying wavelet theory a given input data set is decomposed into a certain number of frequency-dependent detail signals, which can be interpreted as the building blocks of a multi-resolution representation. On the other hand, there is no doubt that the low-frequency part of the geopotential can be modeled appropriately by means of spherical harmonics for the low-frequency part and an expansion in spherical wavelets for the remaining medium and high-frequency parts of the gravity field. Furthermore, an appropriate parameter estimation procedure is outlined to solve for the unknown model coefficients.

3-The earliest researches on application of GPS to earthquake monitoring and prediction in China began in 1980s, and it was limited to learn some relative technology from other countries and do some test with a few of equipments. As the improvement of software for data processing and the depreciating of hardware, several local GPS network had been gradually set up till the end of 1990s, and then more systematically GPS monitoring, data processing and its application research have been done gradually. In this paper, 3 research examples of the application of GPS to earthquake monitoring and prediction are presented.

T/SD2/P4/ID185 - DETERMINING THE SLIP RATE AND THE RECURRENCE INTERVALS OF EARTHQUAKES ALONG THE BULNAY FAULT, MONGOLIA.

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The Bulnay earthquake of July 23, 1905 (M_w 8.2-8.5) in north-western Mongolia, is one of the world's largest recorded intracontinental earthquakes and one of four great earthquakes that occurred in the region during the 20th century. The 375 km long surface rupture of the left-lateral, strike-slip Bulnay Fault associated with this earthquake is remarkable for its outstanding expression across the landscape and its complexity. We used differential GPS to survey the geomorphic offsets along the Bulnay Fault. Our field observations suggest that the slip along the fault is characteristic (the different offsets measured at a point are multiple of the 1905 slip at this point), with a mean offset of 8.5 m for the 1905 event. The size and complexity of features produced by one single earthquake are extraordinary in comparison to most other historical strike-slip surfaces ruptures worldwide. We excavated 5 trenches across the fault, and found evidences for two events prior the 1905 rupture at two sites (double pound and pine creek). At pine creek, OSL dates bracket the age of the penultimate event between 2.4 ± 0.10 ka and 3.4 ± 0.12 ka and the pre-penultimate event prior to 5.3 ± 0.4 ka. We surveyed large offsets stream at 4 locations (Genepi, Rainbow, Armoise and Snow Creek sites) and we also sampled deposits using OSL, in-situ ^{10}Be and radiocarbon samples in order to constrain the slip-rate along the fault. Our still-in-progress study indicates that the horizontal slip rate along the Bulnay fault is between 2.6 ± 0.7 mm/yr (Genepi site) and 3.15 ± 0.9 mm/yr (Snow Creek site). Our results for the Bulnay fault, compared with results from studies of the surfaces ruptures associated with the 1957 Gobi-Altay earthquake in south-western Mongolia should allow us understanding whether the 20th century earthquakes cluster in the region repeats a pattern of earlier fault behaviour.

T/SD2/P5/ID186 - INCIPIENT EXTENSION ALONG THE ACTIVE CONVERGENT MARGIN OF NUBIA IN SICILY, ITALY: THE CEFALÙ-ETNA SEISMIC ZONE

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Recent geodetic data are compatible with NNE-SSW tectonic extension at a rate of *c.* 5 mm/y in Sicily, southern Italy, within a broader region of net active compression along the Nubian plate margin (northern Africa). The structures that accommodate such extensional regime and its cause are still unknown. By field structural surveys and seismological analyses, the geometry, kinematics, structural architecture, and seismic potential of an extensional seismic zone linking Cefalù and Mt Etna in central-eastern Sicily are defined. The zone includes high-angle WNW-striking normal and right-lateral strike-slip faults and subordinate N- and NNE-striking strike-slip faults either right- or left-lateral. The occurrence of small discontinuous faults and the absence of related depressions and sedimentary basins suggest that the extensional regime is still in an incipient stage. The ongoing seismic activity possibly reactivates pre-existing faults. Instrumentally- and historically-recorded earthquakes are lower than about 6 in magnitude, and destructive events are historically unknown since at least 1300 A.D. This apparent upper bound of earthquake magnitudes is consistent with the maximum magnitude values estimated from the length of the longest mapped faults and sources of seismic swarms, which all to-

gether suggest a value between 6 and 6.5 as the maximum expected magnitude that can be proposed at the present stage of investigation for earthquakes in the study area. Lateral extension on pre-existing faults and upwelling of melt mantle material beneath Mt Etna are considered viable processes to explain, at least in part, the active extensional tectonics along the Cefalù-Etna seismic zone. Strike-slip seismic faulting beneath Mt Etna may be part of a previously-proposed diffuse transfer zone affecting northeastern Sicily and including the Tindari Fault.

T/SD2/P6/ID187 - CRUSTAL STRUCTURE OF THE DEAD SEA BASIN FROM LOCAL EARTHQUAKE TOMOGRAPHY

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New findings of the structure of the crust across the Dead Sea basin were obtained by applying tomography based on local earthquakes. In the study we use P wave traveltime of 649 earthquakes that occurred in the Dead Sea basin in the period 1983-2008. At shallow depth of 5 km (upper crust) and large depths of 20 and 25 km (lower crust) the Dead Sea basin is characterized by lower velocities relative to both eastern and western sides of the basin. There is a significant seismic activity at depths of 20 and 25 km, mainly in the center and the northern part of the basin. The existence of a number of clusters or earthquakes that spread from shallow depth of a few km up to depths of 27 km and more suggests the existence of several defined faults that traverse the Dead Sea basin. For example, the aftershocks sequence of 2004 earthquake in the northern Dead Sea basin illustrates such activity. The fact that we observe earthquakes at large depths suggests that the upper and the lower crust are relatively cool, as was suggested also by earlier heat flow studies, and the heat flow is significantly below the global average value. The faults on the eastern and the western sides are clearly bordering the Dead Sea basin at depths of up to 20 and 10 km, which are the middle lower crust and lower part of the upper crust, respectively. At greater depths of 15 km or more the western side is partially bounded by a fault. The concentration of earthquakes in the central part of the basin at depth larger than 10 km suggests that the Dead Sea fault at those depths act as a one single fault that is located in or near the middle of the basin.

T/SD2/P7/ID188 - SHERPA: AN ARCHIVING AND SHARING TOOLS FOR FIELD TRIPS PICTURES

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Large crustal earthquakes are the subject of extensive field surveys in order to better understand the rupture process and its tectonic consequences. After the earthquake, pictures of the rupture can easily viewed be on the web. However, once the event gets old, pictures disappear and can no longer be viewed, a heavy loss for researchers looking for information. Even when available, pictures are only linked to a given survey and comparison between different earthquakes of the same phenomenon can not be easily performed.

SHERPA, Sharing of Earthquake Rupture Pictures Archives, a web application developed at EMSC aims to fill this void by making available pictures of past earthquakes and sharing resources while strictly protecting the authors copyright and keeping the authors in charge of the diffusion to avoid unfair or inappropriate use of the photos. Without the author explicit consent, no picture will never be accessible to anyone.

Uploading pictures is quick and easy: once registered, the user can upload pictures that can then be geolocated using GoogleMaps. If the camera is equipped with a GPS, the software automatically retrieves the location from the exif file. Pictures can be linked to an earthquake and be described through a system of tags. This way, they are searchable in the database.

Once uploaded, pictures (in a protected and lower resolution version) become available for browsing for any visitors. Using the tags, visitors can search the database for pictures of a same phenomenon in several events, or extract the ones from a given region, or a certain type of faulting. The selected pictures can be viewed on a map and on a carousel.

With this service we hope to contribute to a better accessibility of the pictures taken during field trips and then improving earthquake documentation.

Finally, the EMSC is currently developing an application named MAPMAG (Mobile Application for Pictures Management, Archiving and Geolocation), which allows seismologists to retrieve, archive and share their pictures directly on field, without an internet connection. This application will provide the following features:
- Search and retrieve pictures from SHERPA database and display them in GoogleEarth
- Create picture projects. i.e. archive, geolocate and tag their pictures directly on field
- Surf through GoogleEarth in an offline mode after having preloaded satellite views of the region of interest
- Back-up picture projects in SHERPA database

http://sherpa.emsc-csem.org

T/SD2/P8/ID189 - SEISMOTECTONIC MAP OF LIBYA

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Abstract (Poster)

The study of seismotectonics is in general concerned with understanding what controls surface deformation, and what controls whether deformation occurs in earthquakes. Plate tectonics are a special form of tectonics, wh

ere surface deformation is concentrated in narrow zones (plate boundaries), while most of the surface (plat cores) does not deform. Earthquake data used in this study are selected from Libyan National Seismological network (LNSN) catalogue, in the period May, 2005 to December, 2009, with magnitudes ≥ 3, and located between 18 – 33.5N and 8 - 26E. The active fault database and Map of active faults in Libya, were compiled according to the ''World Map of Major Active Faults''. In the process of correcting the data and its geographical attribution the «ER Mapper» system is used to represent the coordinates of each point in the map to represent coordinates of the same point in nature. The system of geographical reference "ArcGIS" is used in data analysis and linked using a geographic database and then maps production and printing using the printer hp5500.

T/SD2/P9/ID190 - SIGNIFICANCE AND MICROSCOPIC ANALYZING OF DEFORMATION IN CULTURAL REMAINS OF XIZHOU DYNASTY--LATER PERIOD OF CHUNQIU DYNASTY, DAIJIAYUAN RUINS AT HUOSHAN IN ANHUI PROVINCE ,P.R.CHINA

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Abstract: During excavation surveying to Daijiayuan vestige in Xizhou Dynasty-later period of Chunqiu Dynasty at Huoshan in Western Anhui, ground crack related to tectonic movement was found, which filled in powder fine sand, this phenomena was confirmed initially to seismic liquefaction. A lot of microscopic seismic relics were found during directional microscopic analyze to the deformation. These discovers and cognitions check there are two earthquake events had been taken in Xizhou Dynasty-later period of Chunqiu Dynasty at the area.

Detailed microscopic observation and analysis of the results were given by the thin sections. Then we concluded their microscopic deformation characteristics as follows:

Load flow structure and flow stack structure can be seen in D01, and they are truncated in many places□which were cut by sand veins locally in later period; flow stacked structure can be seen; spherical structure can be seen .

It also can be found that the sample D02 have flow structure, flow deflection structure, flow structure with lens and flow stacked structure. In addition.

The sample D03 have load structure with organic suspended particles; truncated and flamboyancy structure; sand veins surrounded by soil and flow structure.

The sample D04 have deflection veins which have been micro-rupture cut, flow veins that have broken gravel, flamboyancy deflection that has been secondary cut, flamboyancy deflection .

These microscopic sections above were collected from the sand crack in different parts: vertical sand crack (D01), oblique sand crack (D03), and zigzag sand crack (D02, D04). We can see from the microscope that the de-

formation phenomena mainly includes: load structure, flow structure, stacked structure, spherical structure, organic suspended particles, flamboyancy deflection, bending and cutting, cut noodles. These microstructure and deformation phenomena are consistent with the views of the signs of seismic microscopic deformation made by some researchers□Bartholomew M J,etc.2002; Moretti M,etc.,2002)□

By comparing and analyzing to each flake, we find that D01 and D03, D02 and D04 have similar features, and the main difference between them is that, a great deal of flexural phenomenon exist in D02 and D04, which is speculate microscopic evidence of deformation in the two periods.

Overall, the microscopic observation of thin sections not only reveals various states of the natural deformation of relics, and can be assumed the deformation process. The two sets of microscopic fracture system by eyes observed have also been confirmed.

Keywords: Daijiayuan □seismic deformation□ microscopic analysis, significance

T/SD2/P10/ID191 - 2D P-TELESEISMIC TOMOGRAPHY IN SOUTHERN SIBERIA AND MONGOLIA: EVIDENCE FOR UPWELLING MANTLE FLOWS

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We investigate the velocity structure of the Siberian craton and its folded surroundings from teleseismic body-wave data of the permanent Baikal seismological network, the PASSCAL_1992 and MOBAL_2003 profiles which intersect in the southwest of the Baikal region. The structure to 600 km depth has been modeled with the classical 2D *P*-tomography. As shown by graphical tests, a system of teleseismic rays can provide location of velocity anomalies but their predicted intensity is half that of the test model. As result the tomography anomalies are ≤ 3 % relative to the reference IASP91 model of the Earth. According to 2D tomography from the Baikal network, the Baikal rift system centre and its north-east lie over the craton margin with a 100–150 km thick high-velocity lithosphere while the southwestern rift flank corresponds to a zone of low velocity in the crust and uppermost mantle.The low-velocity zone is especially well pronounced along the SE-trending PASSCAL_1992 profile traversing the Siberian craton, Lake Baikal, and Mongolia. The intense anomaly falls within the Khamar-Daban southern foothills, rather than into the Baikal basin. The tomography of the MOBAL_2003 profile along 100 E reveals a complex low-velocity structure with its intensity peak between 0 and 200 km beneath the highest uplift of eastern Hangay. The Hangay anomaly is clearly traceable at least from depth 600 km and is linked with the anomaly of the southwestern rift flank at depths 200–300 km.As geodynamic implications, we suggest that the low-velocity zone in the southwestern flank of the Baikal rift system imaged by the PASSCAL_1992 data to border the steep southern craton edge, may be produced by a mantle flow that rises from beneath the craton.The MOBAL_2003 velocity pattern over the 600-km depth section, with a branching low-velocity structure, fits the plume hypothesis assuming the shallow plume geometry to be controlled by mantle interaction with fluids. Fluids may create conditions for large-scale melting above 200 km (Letnikov, 2006) producing hot buoyant material that impinges on the lithospheric base and isostatically maintains the topographic high of the Hangay. The heat transport associated with the upwelling mantle flows from under the low permeable craton and plume-related fluids rising through the rifted lithosphere may be responsible for the Cenozoic mountain growth and rifting in the area. The study was carried out as part of Integration Project 7.4 of the Earth Science Department of the Russian Academy of Sciences.

T/SD2/P11/ID192 - THE SHEAR-WAVE VELOCITY STRUCTURE OF CRUST AND UPPERMOST MANTLE BENEATH THE BAIKAL RIFT SYSTEM AND THE PROBLEM OF ANIZOTROPY

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We model the shear-wave velocity structure of crust and upper mantle to 70 km depth beneath the Baikal rift using P-to-S receiver function inversion of teleseismic records from the Baikal region and Transbaikalia. The obtained 1D and 2D V_S models across and along the rift show notably different vertical patterns. There is difference in crust thicknesses at the same sites, mostly near the rift axis where the crust is especially strongly deformed and impregnated with fluids. The rift-parallel V_S model of the crust images a complex fault-block pattern. Lower and higher velocities in shallow crust correspond, respectively, to sediment-filled basins and to saddles between them. Thick low-velocity lenses to a depth of 15 km or more may record granitoids. Velocity is the lowest in the upper half of the crust beneath the East Sayan. In the northern flank of the Kumora–Uoyan–Severomuisk profile, the relatively dense permanent seismological network and the directions of seismic rays provide good agreement in details between the models obtained with the teleseismic receiver function method and the local method of DSS. The mantle part of the *Vs* section consists of alternating high- and low-velocity zones against the background of normal mantle velocities (*Vs*=4.45 km/s, *Vp*=8.0 km/s). With this model, we have discovered linear structures in the upper mantle never reported before. This is, namely, a continuous thin (10–15 km) 4.3–4.4 km/s layer along the western and central segments of the rift system. The observed patterns with shear velocities different in rift-parallel and rift-orthogonal directions may be evidence of seismic anisotropy. According to teleseismic data, most of azimuthal anisotropy in the Baikal rift and in Mongolia is known to originate in the upper mantle. Some anisotropy, however, may come from the crust and be associated with S-wave splitting along and across tectonic-induced oriented cracks filled with fluids and with thick mylonite zones related to large pre-Cenozoic thrusts. At this point, shear-wave velocity modeling has provided only fragmentary evidence of anisotropy but we expect to gain more insights into it in future as the issue appears important being one main cause of poor consistency among velocity models based on different data sets and processing techniques. The study was carried out as part of Integration Project 7.4 of the Earth Science Department of the Russian Academy of Sciences.

T/SD2/P12/ID193 - TECTONICS OF THE NORTHERN MARGIN OF GULF OF ADEN (SOUTHERN OMAN)

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Tectonics of the northern margin of Gulf of Aden (Southern Oman) ABSTRACTThe Gulf of Aden is a Tertiary period oceanic basin, located in the southern limb of the Arabian plate. Its orientation (075^{0}E) and its kinematics (about 030^{0}E divergence) are interpreted as the result of an oblique rifting. In this work, the interpretation of seismic profiles from Circle Oil Company and the Encens cruise was used to construct a structural scheme of the study area and therefore, study the structural evolution of the area during the opening of the Gulf of Aden.The direction of the Socotra Fracture Zone could be related to the strike of structures created during the movement of the Indian plate to the northeast direction in the Late Cretaceous. Therefore, it constitutes the well-documented first-order of segmentation of the continental margin. Meanwhile, the second-order of margin segmentation was created during the Tertiary as a consequence of the oblique opening of the Gulf of Aden. In addition, the data allows me to confirm the sequence of the two directions of the extension in the gulf in terms of timing. This is based on the fault orientations and their distribution in the different types of crust, from continental and Ocean continent transition to oceanic crust of different ages. Accordingly, the extension has started during the Late Eocene-Early Oligocene in the direction of about N030^{0}E, then at about 20-17.6 Ma the extension changed to a direction of about N160^{0}E. The oceanic spreading taking place at 17.6 Ma at least. Evidence from the fault orientations has been documented indicating the change of the motion of the Arabian plate, the local stress patterns, back to the original direction (N030^{0}E).

T/SD2/P13/ID194 - ON THE GEODYNAMIC EVOLUTION OF THE SICILIAN-CALABRIAN MARGIN (SOUTHERN ITALY): THE CONTRIBUTION OF GEOPHYSICAL DATA INTEGRATION.

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The Southern Italy is characterised by an intense and heterogeneous seismicity. Deep and shallow active structures contribute to the accommodation of different stress regimes, from compressional to extensional ones, in the same area.

In this work we propose 3D density-velocity models of the area 36°30′-39°N, 11°-15°48′E. These models were obtained by a procedure to jointly invert seismic and gravimetric data with a sequential technique to avoid the problematic optimization of the relative weights to assign to the different type of data.

The seismic velocity models have been obtained using the tomoDD code (Zhang and Thurber, 2003) and further optimized with the Weighted Average Model (WAM) technique (Calò 2009).

The seismic dataset contains 31250 P and 13588 S arrival times related to 1951 events located in the area. The selected events were recorded at least by 10 stations and marked by RMS<0.50 s. The dataset was also integrated with the data picked on seismic profiles relative to high density W.A.R.R. and D.S.S. experiments. The available Bouguer anomaly data were interpolated into the nodes of a 8x8 km regular grid covering the area 36°13′-38°31′ N, 12°-16°01′ E.

A first WAM provides starting Vp and Vs models and a first hypocentral relocation. The implemented code automatically derives, by the empirical Brocher's equations (whose validity range is wider than the Nafe&Drake's relationship ones), two density distributions associated to the Vp and Vs models. These density models, with a rectangular prisms parameterization, are then statistically compared and an average model is determined. The procedure separately computes the correction density values of the shallowest and deepest part of the model through a multiresolution analysis which gives a separation of the residues distribution. The corrections distribution is used both to improve the density-velocity correlation equations and to determine two correction vectors for Vp and Vs. The corrected Vp and Vs distributions are then used as input for a new tomographic inversion: by this procedure the velocity and density models are iteratively upgraded. The applied procedure underlined the necessity of the different data integration although the seismic problem seemed to be a priori well constrained.

In this work we show these reliable and highly resolved models and we suggest a possible scenario of the geodynamic context of Southern Italy that can open new debates on the possible causes of the seismicity occurrence of the region and of the neighbouring areas.

T/SD2/P14/ID195 - HOLOCENE MARINE PALEOSEISMIC RECORD OF THE SW IBERIAN MARGIN REVEALED BY DEEP WATER TURBIDITES

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The SW margin of the Iberian Peninsula hosts the present-day boundary between the Eurasian and African Plates. Convergence (4-5 mm/yr) is accommodated through a wide deformation zone characterized by moderate magnitude seismic activity. This zone has also been the source of the most important seismic events in Western Europe, such as the 1755 Lisbon Earthquake and Tsunami and 1969 Horseshoe Earthquake. Despite efforts to identify active seismogenic structures in the Gulf of Cadiz in the last ten years, little is known about its paleoseismic history. The turbidite paleoseismology approach was applied for the first time in a low-rate convergent margin to determine the recurrence interval of large earthquake events occurred in SW Iberia during the Holocene. A total of 21 sediment cores collected at strategically located basins (i.e. Tagus Abyssal Plain, Infante Don Henrique Basin, Horseshoe and Seine Abyssal Plains) and sediment pathways of the Gulf of Cadiz reveal that these deep-sea basins preserve a record of episodic deposition of turbidites. In the SW Iberian Margin excluding special climatic events, earthquakes are the most likely triggering mechanism for synchronous, widely-spaced distributed turbidites during the Holocene, when the sea level was relatively stable. Age correlation together with textural, mineralogical, physical properties and geochemical signatures of turbidite deposits identified in the new cores complemented by pre-existing multicores and gravity cores reveals a total of 7 widespread turbidite events for the Holocene. Precise dating of the most recent turbidite event (E1) based on ^{210}Pb and ^{137}Cs geochronology provides an age of AD 1971 ± 3. This age corresponds to a high-magnitude instrumental earthquake in the region: the 1969 Horseshoe Earthquake (Mw 8.0). Calibrated ^{14}C ages of subsequent widespread turbidite events (E3 and E5) correlate with the dates of important historical earthquakes and paleotsunami deposits in the Gulf of Cadiz area, such as AD 1755 and 218 BC, respectively. If older synchronous events (E6, E8, and E10) with ages ranging from 4960-5510 yr BP to 8715-9015 yr BP are also taken into account, a great earthquake recurrence interval of about 1800 years is obtained for the Holocene. Our correlations suggest that the turbidite record may be considered as a proxy for paleoseismic activity in low-convergence rate margins, and a valuable complementary tool in earthquake and tsunami hazard assessment along the coasts of the Iberian Peninsula and North Africa.

T/SD2/P15/ID196 - INTEGRATED SEISMOLOGICAL STUDIES OF THE DHARWAR CRATON, INDIA

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Integrated Seismological Studies of the Dharwar Craton, India K.S. Prakasam, S.S. Rai, K. Borah and V. Pavan Kumar We present the preliminary results characterizing the nature of crust and the mantle beneath the Dharwar craton, south India through modeling of the Ambient Noise and teleseismic waveforms recorded over a currently operating network of 50 broadband seismographs since 2009 Feb. Study region comprises of mid-late Archean Western Dharwar Craton (WDC), late Archean Eastern Dharwar Craton (EDC) and late Archaean metamorphic Southern Granulite Terrain (SGT). The Dharwar craton is a unique Archean terrain that exposes progressively the crustal sequence from north to the south. Using correlation of the noise, Group velocity dispersion curve in the period range 5-20 s for each stacked Rayleigh wave Green's function is estimated by using multiple-filter technique (MFT). Using a large number of ray paths Ambient noise tomography of the region is created. At shallower depth (5-16 km), WDC and EDC have similar shear wave velocity except a high in southern part of WDC whereas in the mid- lower crust depth(20- 30 km), WDC depicts a 5% higher velocity than EDC. At 30 km depth, most of the places of WDC have shear wave velocity higher than 4 km/s. The lithospheric mantle anisotropic signatures derived from analysis of SKS, SKKS waveforms indicate the fast direction is subparallel to the current Indian plate motion direction. Shear crustal velocity structure in the region indicate a 45-50 km thick crust under the Archean Western Dharwar craton and Southern Granulite Terrane whereas the Archean Eastern Dharwar Craton is characterised with lower crustal velocities and a thinner crust in the range of 32 to 35 km. The receicer function modeling suggest the uniform mantle transition zone with a thickness of about ~250 km. We discuss implication for these investigations in the framework of Archean crustal evolution and its possible modification due to past and ongoing tectonics.

T/SD2/P16/ID197 - SEISMICITY AND STRESS-TENSOR INVERSION ALONG THE GULF OF AQABA

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Seismicity and stress-tensor inversion along the Gulf of Aqaba *BY Abu Bakr A. Shater and Sallah M. Mahmoud National Research Institute of Astronomy and Geophysics, Aswan seismic Observatory. (abubkr2000@yahoo.com (*

Abstract The Gulf of Aqaba itself is usually described as the succession of three deep pull-apart basins, elongated in the N-S direction. The Gulf of Aqaba earthquakes is mainly concentrated in four zones; the first zone is located between latitude 27.3 – 27.8 and longitude 34.3 - 34.5 degrees in the Hume Basin in the southern entrance of the Gulf. The second zone is located along the Arnona fault between 28.3 – 28.6 and longitude 34.5 - 34.7 degrees; the third zone is located between latitude 28.8 – 29.0 and longitude 34.6 - 34.8 degrees in the Aragonese Basin, the fourth zone is located in the Aqaba Basin between latitude 29.1 – 29.2 and longitude 34.7 - 34.8 degrees. The orientations of fault

planes and slip directions indicated by a population of earthquake focal mechanisms can be used to determine best fit regional principal stress directions and R=(σ2-σ1)/(σ3-σ1), a measure of relative magnitudes, under the assumption of uniform stress in the source region. The technique has been applied to 20 events from the Gulf of Aqaba earthquake sequence for which we have found best fit stresses (plunge and azimuth): σ1=55,60 σ2=34,256 σ3=3,161 and R=0.50. The average misfit between the stress model and all the data is about 5.5°.

T/SD2/P17/ID198 - **SEDIMENTOLOGICAL RECORD OF PAST EARTHQUAKES IN THE ALGERIAN MARGIN FROM TURBIDITE DEPOSITS (MARADJA PROJECT): TOWARDS A PALEOSEISMOLOGICAL APPROACH**

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As shown by the 2003 M 6.9 Boumerdes earthquake, northern Algeria is affected by large seismic activity damaging the Algerian coastal cities. Seismic activity results from the convergence motion between African and European plates. It occurs through large earthquakes, activating fault segments partly located offshore and causing important effects on the stability of the sediments on the Algerian continental slope. Sedimentological and geophysical data acquired offshore Algeria during the MARADJA and PRISME cruises (2003 to 2007) allow to identify possible Quaternary sediment instabilities generated by seismic events. The submarine slope morphology is characterised by deep canyons, indicating highly efficient sediment transport by gravity processes, from the shelf break to the deep basin. Morphological and sedimentological studies of the margin suggest that several types of gravity deposits exist with a possible seismic origin. Large turbidity currents flowing offshore Algeria may well represent the result of sediment destabilisation induced by seismic activity, as testified by direct recording of catastrophic mass flows immediately following some of the most destructive historical earthquakes. During the 1954 Orléansville, the 1980 El-Asnam and the 2003 Bourmerdes earthquakes, numerous deep-sea communication cables were broken by turbidity currents directly triggered by seismic events. Currents, initiated in canyon heads, propagated as far as 100 km and more from the Algerian coast into the basin. These events are recorded as turbidite deposits in the abyssal plain. A detailed sedimentological and morphological study of the margin (especially in the Algiers area) is performed in order to estimate the location of the initial instabilities in the canyons, the paths of active sediment transport and the main flow characteristics of the turbidity currents. Sediment cores, collected in the deepest part of the margin, have been analysed and correlated with Chirp echosounder profiles. A consistent chronostratigraphic framework was established after the detailed stratigraphic study of a reference core located in the Algiers upper slope. The evaluation of recurrence intervals of gravity events is now possible with the detailed correlation of sediment sequences and radiocarbon datations. This approach helps to gain important information on the recurrence of great earthquakes along the Algerian margin in the last 10,000 years and on their actual imprint on the seafloor.

T/SD2/P18/ID199 - **IMPROVING ECUADORIAN INTERSEISMIC SEISMICITY: 3D APPROACH FOR EARTHQUAKE LOCATION**

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In Ecuador, the Nazca plate is subducting beneath the North Andean Block (NAB). This subduction triggered, during the last century, 4 major earthquakes of magnitude greater than 7.7. Between 1994 and 2007, the Geophysical Institute (Escuela National Politecnica, Quito) recorded 40 000 events (Mb 1.5 to 6.9). Unfortunately, local network shows great density discrepancy between the Coastal and Andean regions where numerous stations were installed to survey volcanic activity. Consequently, interplate seismogenic zone (ISZ) seismicity is not well resolved. This study proposed a 3D approach to improve the location of 13 years seismicity occurred during an interseismic period in order to better localize the seismic deformation and gaps. First, we construct a 3D "georealistic" a priori velocity model (3DVM). Because local tomography cannot provide satisfactory model, we combine all local crustal/lithospheric information on the geometry and velocity properties of different geological units. The resulting 3DVM extends from 2°N-6.5°S to 277°E-283°E and 300 km depth. Second, we select an adequate sub-set of stations to correct the effect of station density disequilibrium between coastal and volcanic regions. We thus keep representative volcanic stations in terms of azimuthal coverage, record frequency and signal quality. The data selection (at least 3 proximal stations) provides homogeneous dataset (WRT geographic area). Third, we improve the 3D MAXI technique that is well adapted to perform absolute earthquake location in VM presenting strong lateral Vp heterogeneities. The resulting catalogue improves the location of active deformation in the subduction system. Seismicity previously detected before trench occurs indeed between the trench and the coastal range. Facing the subducting Carnegie Ridge, seismicity aligns along the ISZ between ~8 km and 3~5 km depth. ISZ seismic activity interrupts at depth right beneath a surface topography (coastal range). At these latitudes, diffuse intraplate deformation also affects the subducting plate, probably induced by the locally thickened lithosphere flexure. Between trench and coast, earthquake distribution defines an aseismic zone (ellipse of axes ~55/35 km) comparable in size to the 1942 M7.9 aspirity. The slab seismicity (~25/30° dip) is systematically interrupted between 100-170 km (beneath the volcanic chain). North of 0°, in the megathrust earthquake domain, interseismicity is clearly reduced. The interplate distribution seems to align perpendicular to the trench attesting probably the margin segmentation. The NAB is undergoing active deformation, especially at the location where the Andean Chain strike changes of direction. At these latitudes, no earthquake occurs deeper than 100 km depth.

T/SD2/P19/ID200 - **ONSHORE-OFFSHORE ACTIVE TECTONICS APPROACH: THE CARBONERAS FAULT ZONE EXAMPLE (SE SPAIN)**

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The slow convergence (4-5 mm/yr) between the African and Iberian plates is characterised by a wide zone of low-to-intermediate magnitude seismicity. Shortening is mainly accommodated by a left-lateral strike-slip fault system referred to as Eastern Betics Shear Zone (EBSZ). The NE-SW trending Carboneras Fault Zone (CFZ) with 50 km onshore and more than 100 km offshore is one of the longest structures of the EBSZ. Despite the low seismicity associated to this fault, its morphostructure reveals Quaternary activity, suggesting long recurrence (10^4 years) behaviour. Geomorphologic and trenching analyses along the onshore La Serrata section show faulted Quaternary sedimentary deposits related to paleoearthquakes. Trench walls evidence a minimum of 6 events since the Mid Pleistocene. The 3 younger occurred during the last 41.5 ka, suggesting a mean recurrence period of 13.5 ka. A faulted and buried paleochannel records a minimum of 2 events during the last 30 ka and constrain the last earthquake to AD 772-889. The horizontal maximum displacement observed for the paleochannel is 3 m, suggesting a minimum strike-slip rate of 0.1 mm/a for the last 30 ka, smaller than the 0.6 mm/a strike-slip rate calculated for the last 200 ka by displaced valleys across the NW boundary of La Serrata. Detailed bathymetric data from fault segments offshore show differences in the surface expression, and high resolution multi-channel and single-channel seismic profiles reveal the deep structure. Towards the SW, N45° segment with poor surface expression changes progressively from a 2 km wide positive flower structure, to a single and then double fault traces. Then, this overlaps with the southern N60° segment in a 14 km long zone characterized by prominent pressure ridges and narrow flower structures. The last N45° segment is an 8 km long showing transtensive graben structure. To the south the strain is smoothly transferred to folds and pervasive subvertical NW-SE faults. Offshore geometry is similar to onshore structures indicating a main left-lateral movement with a slight reverse component. Sediment rates obtained from ^{14}C dating of marine cores allow us to calculate dip-slip rates of the CFZ. As observed on seismic profiles, these values range from 0.14 mm/a for the last 165 ka to 0.06 mm/a if considering the whole Quaternary.

T/SD2/P20/ID201 - **OFFSHORE ACTIVE STRUCTURES IN THE BAJO SEGURA FAULT ZONE (WESTERN MEDITERRANEAN SEA): LOOKING FOR THE SOURCE OF THE 1829 TORREVIEJA EARTHQUAKE**

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The present-day convergence between the African and Eurasian plates in the western Mediterranean (4-5 mm/yr in NW-SE direction) is accommodated over a wide deformation zone with significant seismic activity south of the Iberian Peninsula. The Neogene and Quaternary faulting activity in the SE Iberian Margin is dominated by a large left-lateral strike-slip system referred to as the Eastern Betic Shear Zone (EBSZ) and stretching over more than 450 km. The northern terminal splays of the EBSZ correspond to the Bajo Segura fault zone (BSFZ) that extends further into the Mediterranean Sea. The instrumental seismicity around this fault zone is mainly characterized by small to moderate earthquakes. Even though, moderate to large historical earthquakes have affected the zone, being the Torrevieja earthquake (1829; I_{MSK}=X) the largest. The onshore area of the BSFZ has been extensively studied and it is characterized by active structures (faults and folds) displaying a transpressive behavior since the Plio-Pleistocene and resulting in positive relieves and subsiding zones. However, the offshore area shows an almost complete lack of information from the tectonic point of view. To tackle this deficiency the marine geophysical cruise EVENT-SHELF was carried out (September 2008, Spanish RV Garcia del Cid). The main goal was to map the sub-seafloor structures of the offshore area of BSFZ using high-resolution seismics (Spaker GeoSpark 6kJ). A total of 10 regional profiles were acquired along and across the fault zone. The results from the analysis of the acoustic and seismic data show that the main structures observed onshore have their continuation offshore. Moreover, the carefully study and processing of the new data combined with data coming from oil industry allowed us to localize the present active structures and determine the fault geometry, seismic parameters and seismogenic behavior. All this information contributes to recognize some faults that could be responsible of the 1829 Torrevieja earthquake and to a better understanding of the BSFZ and EBSZ kinematics, and the inclusion of these faults in seismic hazard studies will lead to their improvement.

T/SD2/P21/ID202 - ACTIVE FAULTING AT THE EXTERNAL PART OF THE GULF OF CADIZ BASED ON THE SWIM-2006 DATASET

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The Gulf of Cadiz is located at the SW margin of the Iberian Peninsula and hosts the present-day NW-SE plate convergence between the European and African Plates at a rate of 4.5 mm/yr. The region is characterized by an intense seismic activity of moderate magnitude. However, this zone have been the source of some large historical and instrumental events such as the 1755 Lisbon Earthquake (estimated Mw 8.5), the 1969 Horseshoe Earthquake (Mw 8.0), or the recent 17th December 2009 Sao Vicente Earthquake (Mw 5.5). Regional focal mechanisms reveal a combination of thrust and strike-slip fault plane solutions. In June 2006, we carried out the ESF-EuroMargins SWIM marine geophysical cruise with the main objectives of characterizing the shallow geometry, the crustal structure and the timing of deformation of the geological structures recently identified in the swath-bathymetric compilation of the Gulf of Cadiz. The present work is focused in nine multichannel seismic (MCS) processed profiles (SW08 to SW16) showing in detail structures such as the Coral Patch Ridge Fault, the fold and thrust belt in the Seine Abyssal Plain and the SWIM Lineament South. The aim is to understand and quantify the distribution of the deformation, the geometry and present-day activity of these structures, as well as the involvement of basement in the regional tectonics. In addition, a detailed seismo-stratigraphic interpretation of the different depositional units and their associated deformation phases has been carried out. In order to accomplish with these objectives the processing sequence of the MCS data included a velocity model for kirchoff depth migration using the SIRIUS software. This allowed us to obtain neat seismic images with corrected and real depth geometry of the structures, essential to precisely calculate vertical slip-rates and geometrical parameters of individual faults (i.e. fault dip, width, length, etc.) allowing us to estimate their maximum magnitude earthquake based on empirical relationships, fundamental to evaluate the seismic and tsunami hazard in the South Iberian-North African margins.

T/SD2/P22/ID203 - MORPHOTECTONIC EVIDENCE OF THE SAHEL STRUCTURE EVOLUTION FROM PLIOCENE TO QUATERNARY (ALGERIA)

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The Algerian Cenozoic passive margin is presently reactivated in compression along the plate boundary between Africa and Europe. The margin deformation occurs both onshore in the coastal area and offshore along blind reverse faults deforming the seafloor. West to Algiers, between the Chenoua and the Algiers massifs, the Sahel structure forms a ridge parallel to the coast which was interpreted as an elongated anticlinal associated with a blind North-dipping reverse fault. New geological investigations allow to reassess the Sahel structure as a monocline. The study of uplifted marine terraces and morphometric analyses supply significant information on recent morphotectonic evolution of the Sahel structure including the Chenoua and Algiers massifs. The purpose of this work is to determine changes of uplift rate along this part of the Algerian coast related to the fault activity both offshore and onshore.

T/SD2/P23/ID204 - EMBEDDED TIME SCALES FOR SLIP TRANSIENTS ON THE PSATHOPYRGOS NORMAL FAULT SYSTEM, WESTERN RIFT OF CORINTH, GREECE.

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The western rift of Corinth displays a fast opening rate (1.5 cm/year from GPS) and a strongly fluctuating microseismicity. We focus here on the activity of the Psathopyrgos fault system, the westernmost one in the rift, about 15 km long. It did not rupture in historical times (more than 300 years), despite its clear morphological slip activity, which raises the question of possible creep on this fault. We report here observations at different time scales, depicting transient instabilities on this fault zone. For the last 2000 years, Palyvos et al. (2008), studying paleo-shorelines, identified 5 episodes of rapid uplift in the eastern segment. Each can be modelled with a typical 2 m slip, seismic or aseismic, with a mean return period of 400 years, corresponding to a slip rate of 5 mm/yr, and an opening rate of 2 to 3 mm/yr. On the other hand, repeated GPS since 1990 shows a mean opening rate of 15 mm/yr, related to aseismic slip on a low angle detachment zone (e.g. Avallone et al., 2004). The large discrepancy between these figures shows that this region is in a state of transient, accelerated extension, since at least several decades. This zone may thus be on a new stage of rapid, mostly aseismic extension, which may last several decades – or in the failure stage for a large rupture. At shorter time scales, for a few sites around the Psathopyrgos fault, the repeated GPS measurements provide evidence for non stationary displacements, at time scales less than a few years. Furthermore, intense seismic swarms have occurred in 2002 and 2009, lasting several weeks, and activating the whole fault structure. The transient deformation seen by GPS is consistent with an episode of creep coinciding with the 2002 swarm, with some 10 cm of slip. The propagation of the micro-seismicity during the 2002 swarm activated successively fault segments of a few kilometres in size, each within a few hours or days. When migrating from west to east, it triggered a slow slip event which culminated in a shallow M=3.5 earthquake (Bernard et al., 2008). The average migration of this seismicity was of the order of 1 km/day, suggesting a possible role of pore pressure migration. The role of these seismic and aseismic transients in the global strain budget in not clear, whether it impedes stress accumulation for large earthquakes, or marks the starts of a large seismic destabilization.

OS3 - TRANSNATIONAL RESEARCH AND INFRASTRUCTURE COLLABORATION ACTIVITIES IN EURO-MED

OS3/P1/ID205 - SETTING UP ACCELEROMETRIC DATA EXCHANGE AT THE EUROPEAN SCALE

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In contrast to the seismological community, there are currently few consortiadealing with strong motion data exchange, especially cross-border. For this reason, a specific working group of the European project NERIES has been dedicated to the development of strong motion data exchange in Europe. Six accelerometric network operators (LGIT, IGC, IST, ITSAK, ETH, KOERI) and the EMSC have defined common protocols for data processing, archival and exchange relevant for both the scientific and engineering communities. The resulting strong motion data search tool is accessible through the European Earthquake Data Portal (www.seismicportal.eu). Data can be selected and retrievedusing search parameters based on the characteristics of the recorded data, the earthquake or the station site and metadata. In practise, we had four main objectives. A dedicated accelerometric station database was created to store the full technical description of the installed instruments providing full dataless Seed metadata for the entire set of shared stations. Software to parameterise the accelerograms has been developed (IGC) and distributed to each participating network so a homogenous set of search criteria is produced. A processing tool was developed (LGIT) to provide the waveforms and parameters in several formats to the end-users. Finally, in order to provide a unique search upon earthquake parameters from the distributed data contributors, a reference catalogue has been created by the EMSC to provide a continuous earthquake history from 1998 to today. The implementation of the data exchange has been successful, with 400 stations currently accessible on the web from the original participants, corresponding to more than 18,000 records from 650 events. Moreover, the Italian accelerometric network (ITDPC) has joined the data exchange providing data from 130 stations and 230 events. All the infrastructure has been developed with the intention to provide a long term data exchange mechanism, with a view to including as many as possible of the approx. 3,700 strong motion stations currently installed in 39 countries of the Euro-Med region.

OS3/P2/ID206 - EARTHQUAKE INFORMATION SYSTEM IN THE PYRENEES- SISPYR PROJECT

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The main objective of the SISPYR project is the improvement of the Earthquake Survey in the Pyrenees, at both sides of the France-Spain border. In fact the present cover of the stations distribution is not adapted to the cross-border survey. Thus, the installation of new infrastructures, covering present shadow zones and the real-time exchange of waveforms will answer a strong demand of different network operators to improve the Earthquake Alert Systems. The precision of results and rapidity in their diffusion are crucial for the Civil Protection intervention. This project will optimize the adequacy of scientific resources to improve the preparedness of the earthquake crisis in the Pyrenean region. Several actions are planned:- Installation of 7 new broad-band real-time stations and updating 22 existing accelerometric stations with real-time transmission. Post-seismic trans-border intervention protocols will be defined. - Exchange of real time waveforms between different networks and automatic post-processing in near real time after the automatic detection of an event of approximately 50 accelerometric and broad-band waveforms archived in real time in a temporary common data server. - Improvement of seismological knowledge as the inversion of moment tensor, 3D lithospheric model and attenuation of coda waves under Pyrenees.- Development of a cross-border Shake Map for the whole Pyrenees area, integrating near real time peak ground motions from the common data server, macroseismic observations and adapted predictive equations for peak ground motion and macroseimic intensity.- Development of damage scenarios for different cross-border pilot zones, with local hazard analysis with detailed studies of seismic microzonation and the vulnerability assessment of dwelling buildings performed at different levels of detail. - A feasibility study of an Early Warning System will be performed based on the new Earthquake Survey and existing operational Earthworm tools. - Valorization of results will be done through a dedicated web site, information sessions in order to maintain civil protection agencies, local actors of the risk management and population well informed about the seismic risk and scientific diffusion by means of congress and peer review publications. SISPYR project is financed by INTERREG IVa France-Andorra-Spain 2007-2013 program for 3 years duration: 2009-2012. SISPYR-*Working Group** M. Albó, F. Bellmunt, S. Figueras, J. Fleta, T. Frontera, X. Goula, A. LLadós, A. Macau, E. Nus, C. Olivera, T. Susagna, *IGC, Barcelona, Spain*S. Auclair, D. Bertil, B. Colas, P. Dominique, A. Lemoine, D. Monfort, C. Negulescu, *BRGM, Orleáns and Montpellier, France*M. Calvet, S. Chevrot, M. Sylvander, *OMP, Toulouse, France*R. Antón, L.Cabañas, E. Carreño, *IGN, Madrid, Spain* A. Barbat, N. Lantada, LL. Pugades, *UPC, Barcelona, Spain*

OS3/P3/ID207 - THE NERIES DATA PORTAL : INTEGRATED ACCESS TO DISTRIBUTED EURO-MED DATA CENTERS AND TO HETEROGENEOUS DATA AND PRODUCTS

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The Earthquake Data Portal (http://www.seismicportal.eu), originally developed under the EC-funded NERIES project (NEtwork of Research Infrastructures for European Seismology), provides a single integrated point of access to a broad range of distributed, seismology-related data sets available from several participating Euro-Med data centers and research institutions. The data portal aggregates data search and access tools from several NERIES participants within a single web-based application. These tools operate in a coordinated manner to provide a cohesive distributed search environment, linking data search and access across multiple data providers. In addition, the portal provides a platform from which to integrate access to external tools and processing centers. The portal provides a set of interactive, map-based interfaces to discover, explore, and download available data sets. With distributed tools operating in concert, the user is able to make coordinated searches across different data sets. For example, the user can make selections from the EMSC event database, adding selections to a private Event Cart, and then search the ORFEUS data center archives for available data for the selected events. Data requests are then packaged and made available for download. Packaged data sets can also be made available for external processing services, such as through the RapidSeis system. The Earthquake Data Portal is architected as a collection of web portlets operating at the respective data centers, supported by a distributed collection of web services. The portlets access both local and remote web data services. The data services are exposed through standard HTTP access mechanisms and are thus available for direct access by other external clients. This allows the creation of independent external applications that can access the data center holdings directly through these exposed web data services, such as the SeismoLink web service client which provides a single point of access to the ArcLink-connected European seismological data centers. While the portal development followed an iterative design process involving coordination between all participating institutions, the architecture allowed the independent development of the component tools. These models, both process and development, will be continued in the ongoing development and extension of the portal and architecture in subsequent EU projects, including the NERIES follow-on project NERA, an EC-funded Seventh Framework Programme project including 27 European partners.

OS3/P4/ID208 - EARTHQUAKE MODEL OF THE MIDDLE EAST (EMME) PROJECT ACTIVE FAULTS AND SEISMIC SOURCE ZONES (WP-2)

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The Earthquake Model of the Middle East (EMME) Project is a regional project of the umbrella GEM (Global Earthquake Model) project. EMME project region includes Turkey, Georgia, Armenia, Azerbaijan, Syria, Lebanon, Jordan, Iran, Pakistan, and Afghanistan. Both EMME and SHARE projects overlap and Turkey becomes a bridge connecting the two projects. The Middle East region is tectonically and seismically very active part of the Alpine-Himalayan orogenic belt. Many major earthquakes have occurred in this region over the years causing casualties in the millions. Similar to the previous seismic hazard studies of the Middle East region the EMME project will use PSHA approach and the existing source models will be revised or modified by the incorporation of newly acquired data. More importantly the most distinguishing aspect of the EMME project from the previous ones will be its dynamic character. This very important characteristic will be accomplished by the design of a flexible and scalable database that will permit

continuous update, refinement, and analysis. A digital active fault map of the Middle East region is under construction in ArcGIS format. We are developing a database of fault parameters for active faults that are capable of generating earthquakes above a threshold magnitude of Mw≥5.5. Similar to the WGCEP-2007 and UCERF-2 projects, the EMME project database includes information on the geometry and rates of movement of faults in a "Fault Section Database". The "Fault Section" concept has a physical significance, in that if one or more fault parameters change, a new fault section is defined along a fault zone. A separate "PaleoSites Database" includes information on the timing and amounts of fault displacement for major fault zones. A digital reference library, that includes the pdf files of the relevant papers, reports is also being prepared. Another task of the WP-2 of the EMME project is to prepare a strain and slip rate map of the Middle East region by basically compiling already published data. The third task is to calculate b-values, Mmax and determine the activity rates. New data and evidences will be interpreted to revise or modify the existing seismic source models. A logic tree approach will be utilized for areas where there is no consensus to encompass different interpretations. Finally, seismic source zones in the Middle East region will be delineated using all available data.

OS3/P5/ID209 **- BALKAN SEISMO-HYDROGEOLOGICAL STUDIES AND THEIR APPLICATION**

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The earthquakes provoke significant changes in characteristics of the atmosphere, the hydrosphere, the lithosphere, the biosphere and the life of the population. The seismic influence in the hydrosphere is the accent of Balkan studies.

The seismic-hydrogeological phenomena are numerous. Mainly moderate and strong earthquakes provoke them. The phenomena include manifestations of liquefaction, landslides, land subsidence and earthflows, also significant corrections of groundwater characteristics. All events are of importance for the geoenvironment, the evolution of the biosphere and for the life of the population. In the Balkan countries the seismic-hydrogeological phenomena are widely distributed. They occurred in the past, they occur in recent days and they will occur in the future. The 1977 Vrancea intermediate depth earthquakes (Mw 7.5) cause numerous seismic-hydrogeological events in the Balkan countries. The 1928 South Bulgarian crustal earthquakes (Mmax 7.0) are related to consequences in Bulgaria. The studied phenomena are mainly with negative influence on the society and the geoenvironment. They are very often manifested and widely distributed. The seismic-hydrogeological phenomena are similar in both cited cases. The phenomena with positive seismic-hydrogeological effects are very rare. They are generally illustrated by the appearance of new mineral water sources. During the 1928 South Bulgarian earthquakes in the village of Pesnopoy (Plovdiv area) 3 new thermal water sources were noted. The seismically appeared sources have a potential capacity to help the enlargement of the Balkan spa tourism.

The studies of seismic-hydrogeological phenomena represent subjects of UNESCO-BAS Project. The studies have theoretic and practical importance. The Project's research permits to receive deeper knowledge for not well documented seismic-hydrogeological manifestations. The research summarizes past and recent data of these phenomena. The next task is mapping of studied phenomena. We try also preliminary prognoses for spaces where seismic-hydrogeological manifestations are possible. The research stimulates geoenvironmental works for protection of the population, settlements, sites of strategic significance and territories with cultural heritage of national and world importance. It is useful for the planning of new constructions in the Balkan countries. The research contributes the economic evolution of the region.The Project investigations support the coordination of the scientific activities in the Peninsula. They contribute to the development of the regional collaboration.

The Project works permit possibilities to contact Balkan decision-makers. The decision-makers are capable to apply our Project conclusions in life.

OS3/P6/ID210 **- CAPACITY BUILDING IN EARTHQUAKE SURVEILLANCE AND RAPID INFORMATION - AN ALGERIAN - SWISS COLLABORATION PROJECT**

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The SED at ETH Zurich and CRAAG, Algiers, entered a collaboration, sponsored by the Swiss Agency for Development and Cooperation, in late 2007 to promote collaboration in the broader fields of earthquake surveillance and rapid information dissemination. This project was planned in conjunction with the significant upgrade and extension of the Algerian National Seismic Network operated by CRAAG, and the requirement to also bring the earthquake alerting and information dissemination to the state-of-the art. In cooperation with WAPMERR, Geneva, also the first more detailed loss-based earthquake risk scenarios for some Algerian cities were developed. Facilitated by this project further bilateral cooperation agreements were signed between CRAAG and ORFEUS, enabling real-time data exchange, and with ZAMG (Austria) for technical collaboration. Furthermore, bilateral meetings in Algiers and Zurich were held to foster technological and scientific exchange, and participation of CRAAG scientists to various international meetings and workshops were sponsored. This first project finished after 2 years and a successor is in preparation. In planning this next project lessons learned in the first 2 years will be applied, most importantly to implement a strictly modular approach with well defined and committed ressources on the side of all project partners. One major goal of the follow-up project will be to support the regional cooperation with the countries of the Maghreb with emphasis on data exchange, the development of joint research projects, and harmonized seismic hazard assessment, the latter providing a direct connection to the EU FP7 SHARE project and the GEM initiative.

ES7 - SEISMIC ANALYSES OF NON EARTHQUAKE RELATED SOURCES

ES7/P1/ID211 **- FORENSIC SEISMOLOGY: THE AZF TOULOUSE EXPLOSION OF SEPTEMBER 21ST 2001 -- AN EXTENSIVE SEISMIC EXPLORATION CAMPAIGN FOR THE DETAILED ANALYSIS OF THE LOCAL AND REGIONAL SEISMIC RECORDS**

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A massive ML~3.4 explosion entirely destroyed the AZF chemical plant in the suburbs of Toulouse in south-western France on September 21st 2001. The acoustic and seismic signatures of this catastrophic event were recorded on a few audio tapes in the Toulouse area and by seismic stations located at regional distances from the city. The explosion was also accidentally recorded by a 1 Hz short-period seismometer temporarily installed in the premises of the Midi-Pyrénées Observatory (MPO) situated at only 4200 m from the explosion crater (Souriau et al., 2002). This unique record, clearly showing the body waves, surface waves and air wave generated by the blast, rapidly drew the attention of the judicial authority as a key element of the inquiry. Indeed, it was rightly considered that the MPO seismogram, together with the other recordings, would be decisive to answer questions such as the exact origin time of the blast and the possible existence of two or more explosions. It was also expected that the seismic records could give clues on the source mechanism of the explosion.In order to answer these questions, an extensive seismic exploration programme was set up from year 2002 onwards to achieve the following objectives: i) perform a time calibration of the 2001 seismic records; ii) determine the full waveform response of the subsurface between the AZF plant and the MPO site and iii) build a structural model of the subsurface along the AZF – MPO stretch via seismic imaging, including the estimation of the seismic wave velocities. This programme was carried out during summer 2004 with the deployment of about 300 three-component sensors and the firing of 34 (1 to 35 kg) dynamite shots. These experiments were complemented by several hundred recordings of a weight-drop source consisting of a 20 ton weight falling from a height of 20 metres, and by Vibroseis PP and PS seismic reflection imaging along the AZF – MPO profile.The analysis of the large amount (~20 Gbyte) of seismic data acquired during this exploration campaign was mostly performed in 2005 for the purposes of the judicial inquiry. The main results derived from the 2001 and 2004 seismic data are presented in companion papers during this meeting. We focus here on the full waveform modelling of the coupled seismic and acoustic wave propagation along the AZF

– MPO profile based on an average flat-layered model inferred from the processing of the Vibroseis data.

ES7/P2/ID212 **– FORENSIC SEISMOLOGY: THE AZF TOULOUSE EXPLOSION OF SEPTEMBER 21ST 2001 -- TEACHINGS OF THE MPO SEISMIC RECORD INFERRED FROM THE 2004 EXPLORATION CAMPAIGN DATA**

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We present an analysis of the vertical and quasi-longitudinal components of the seismogram recorded at the Midi-Pyrénées Observatory (MPO) on September 21st 2001 and propose an interpretation of the successive arrivals of energy observed on that seismogram. This interpretation is supported by previous analyses of similar events reported in the literature.During summer 2004, roughly 300 three-component sensors were deployed at regular intervals along a linear profile spanning the AZF – MPO stretch. A total of 34 (1 to 35 kg) dynamite shots were performed to gather as much information as possible on the seismic response of the subsurface and to interpret the seismic signals observed on September 21st 2001. These experiments were complemented by several hundred recordings of a weight-drop source consisting of a 20 ton weight falling from a height of 20 metres, and by Vibroseis PP and PS seismic reflection imaging along the AZF – MPO profile.Using the large seismic data set obtained during the 2004 exploration program, we show that, the 2004 seismic records allow us to get a reliable characterization of the elastic wave response (or Green's function) of the subsurface in the Toulouse area. We describe the evolution of the successive arrivals forming the body waves as a function of the distance to the AZF crater. We establish the experimental time-distance relationship for these different arrivals.With the help of the coherency function (modulus of the cross-spectral density normalised by the square root of the product of the spectral densities of two records), we further establish the existence of a linear relationship between the 2001 MPO record and the 2004 dynamite shots emitted near the explosion crater and recorded near MPO. We show the similarity between the sequences of arrivals observed on the 2001 MPO vertical component and on the vertical component of the 2004 records emitted near the explosion crater and recorded near MPO. These similarities reveal that the 2001 MPO signal is the signature of the AZF explosion. The longitudinal component of the body waves of the 2001 MPO record and their 2004 counterparts are also presented. However, due to the limitation on admissible explosive charges imposed by the legislation on environment, the longitudinal components of the 2004 data turned out to be rather noisy and were not as useful as the vertical components.

ES7/P3/ID213 **– FORENSIC SEISMOLOGY: THE AZF TOULOUSE EXPLOSION OF SEPTEMBER 21ST 2001 -- PRECISE ESTIMATION OF THE ORIGIN TIME**

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On September 21st 2001, 10:17:55 local time, a huge ML~3.4 explosion shattered the AZF chemical plant in the southern suburbs of the city of Toulouse in the French Midi-Pyrénées region. Permanent seismic networks (such as those operated by CEA/DASE/LDG and ReNaSS) recorded the seismic waves generated by this explosion. In order to determine its origin time with high accuracy and investigate the source mechanism of this explosion, we use additional data from 34 underground dynamite shots (1 to 35kg) which were detonated on the AZF factory site during summer 2004 to calibrate the permanent stations recordings. A detailed analysis allowed us to obtain a very precise estimation of the origin time of the ignition of the explosion. Experiment, data, method of analysis and results are described in this poster.

ES7/P4/ID214 **– FORENSIC SEISMOLOGY: THE AZF TOULOUSE EXPLOSION OF SEPTEMBER 21ST 2001 -- FROM THE 2004 SEISMIC CAMPAIGN DATA SET TO THE 2001 AZF EXPLOSION RECORD**

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On September 21 st 2001, 10:17:55 local time, a huge ML~3.4 explosion shattered the AZF chemical plant in the southern suburbs of the city of Toulouse in the French Midi-Pyrénées region. In order to determine its origin time with high accuracy and investigate the source mechanism of the explosion (ignition point position, detonation velocity, spatial extension), we use additional data from seven 35 kg underground dynamite shots which were detonated on the AZF factory site during summer 2004.We first present a comparison of the waveform corresponding to the 2001 explosion recorded with a short period seismometer at MPO (Midi Pyrénées Observatory), at a distance of 4200 m from the source, with the seismic response of a 30 kg dynamite shot fired near the AZF crater and recorded at the same location. The sequences of arrivals of energy in the two records are synchronous. However, since source mechanisms are different, the dynamite shot record does not exhibit the same waveform as the AZF record. Small dynamite shots must be combined to «reconstruct» the 2001 MPO recording. Indeed, the AZF explosion must be considered as an extended source in space and time (a moving vertical point force applied at the free surface), whereas the dynamite shots are represented as underground explosive point sources. The different steps of the signal reconstruction (time integration, anti-ghosting, crater effect correction) are presented and physically justified. A sensitivity study of the parameters used for the reconstruction has been performed. Based on the maximization of the correlation coefficient, we show that the recovered detonation velocity, direction and length are consistent with the exploding material and crater size. Our analysis favours without ambiguity a westward propagation of the detonation; however, the position of the ignition point is not well resolved. This reconstruction procedure has also been tested on data from two permanent stations MTLF and EPF, operated by LDG at distances of 69 and 107 km. Despite the greater distances, similar conclusions can be made on the efficiency of the reconstruction procedure. The reconstruction step also plays a fundamental role in the ignition time estimation. Another poster is dedicated to that specific aspect. Finally, our main results will be summarized and discussed.

ES7/P5/ID215 **– SEISMIC SIGNATURE OF PIPELINE EXPLOSIONS IN URAL REGION, RUSSIA**

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On 9 and 10 April 2003 two explosions were recorded by broadband seismic station "ARU" in Ural region. Both explosions had occurred on backbone gas pipeline "Urengoy – Petrovsk". Accident sites were close one to other (the distance less than 1 km). The second explosion was observed in 40 hours after the first. The distances from seismic station to explosions were 177 and 178 km accordingly. Due to long distances body waves (P and S) were not observed on seismic traces. Only air-couple Rayleigh (AcR) waves were reliably revealed. The best appearance of AcR waves were observed at vertical components. At horizontal components due to more intensive seismic noises the AcR waves were less clearly visible. Study of character movement of particles in Rayleigh waves allowed evaluating azimuth to explosions. It was estimated as 240°.

In the case of first explosion the extended codalike signal is observed after the main wave. It means the intense fire of gas and acoustic wave generation due to flame tips. In the case of second explosion the intensity of seismic signal decreases promptly that means quick response of gas transmission company staff on accident.

Another remarkable feature of the first explosion is occurrence of two short time signals which were recorded 13 and 6 sec before the main signal. These signals may be interpreted as signals caused by dynamic processes of pipe rupture.

Comparison of the main signal amplitudes had revealed that the second explosion was more than 2 times intensive. Using the ratio of similarity for shock air waves from theory of explosions (M. Sadovsky, 1994), we had evaluated that in the second case the volume of exploded gas was 10 times as large.

ES7/P6/ID216 **– THE KAMBARATA 2 DAM, KYRGYZ REPUBLIC: THE DECEMBER 2009 SURVEY OF A 2500 TON BLAST**

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We will first present an overview of major ongoing dam projects in the Tien Shan and Pamir Mountains Central Asia. HPP cascades are located along the Naryn River in the Kyrgyz Republic and the Vakhsh-Surkhob valley fault zone in Tajikistan. The latter is hosting, in particular, the presently tallest manmade dam of the world (Nurek dam, height of 300 m) as well as the construction site of the future tallest dam of the world (Rogun dam, height of 335 m). The very high seismic hazard of the future Rogun reservoir region is exemplified by the occurrence of the disastrous Ms=7.4 Khait earthquake in 1949, which had triggered a series of catastrophic mass movements, killing more than 10000 people. Our seismic hazard computations applied to the Tien Shan cover the northern part of the region – for which more than 0.5 g had been predicted considering a return period of 475 years. The future filling of the Rogun reservoir will also be of interest from another seismological point of view since it is expected that it will generate thousands of M=0-6 earthquakes, just as the filling of the Nurek reservoir did in the 70s.

Focus is on the Kambarata HPP-chain project located along the Central Tien Shan tectonic zone (Naryn Valley, Kyrgyz Republic). It includes the Kambarata 2 dam under construction and the future Kambarata 1 dam site. This region is marked by the presence of ancient rockslides and a dense network of seismically active faults. In December 2009, Kyrgyz, Russian, Slovak and Belgian teams have collaborated to monitor the blasting of a slope on the Kambarata 2 site. This work is part of a NATO Science for Peace and Security project on landslide dam hazards in the Tien Shan. The blast had produced a 35m-high blockage on the Naryn River, the main part of the final dam (design height of 50-60 m). Seismic ground motions and slope movements have been recorded on adjacent slopes. At closest sites, the ground shaking exceeded 1 g and a series of shallow slope failures could be observed. Those had also been monitored by extensometer measurements. The neighboring slopes are still being surveyed to detect possible post-blast instabilities. First results of the seismological and geotechnical monitoring will be shown.

ES7/P7/ID217 - ANALYSIS OF THE AMBIENT SEISMIC NOISE AT BULGARIAN SEISMIC STATIONS

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Modernization of Bulgarian National Seismological Network has been performed during a month in 2005. Broadband seismometers and 24-bits digital acquisition systems type DAS130-01 produced by RefTek Inc. were installed at the existing analog seismic stations. In the present study the ambient seismic noise at Bulgarian National Digital Seismological Network (BNDSN) stations is evaluated. The method of McNamara and Bulland was applied and the software code PDFSA was used to determine power spectral density function (PSD) of the noise and to evaluate the probability density function (PDF). The levels of the seismic noise were estimated and the full range of the influencing factors was analyzed. The estimated PSD functions were compared against the high (NHNM) and low (NLNM) noise models widely used in seismological practice for seismic station quality assessment. The mode PDF are used to prepare annual, seasonal, diurnal and frequency analyses of the noise. The annual analysis shows that the noise levels at the Northern stations are higher than the ones at Central and Southern stations for the microseisms' periods (1sec -7sec). It is well observable at PRV and PSN stations located near Black Sea. For the periods of "cultural" noise the power distribution depends on the type of noise sources and related to human activities at or near the Earth surface. The seasonal variations are seen in the microseism band. The noise levels increase during the winter and autumn months and decrease in summer and spring seasons. These variations are due increased intensity of Black Sea storms and heavy atmospheric conditions during the autumn and winter. The diurnal variations, visible for the periods shorted then 1s, are produced by increased human activities during the daylight working hours and lower ones during the night. The frequency analysis estimates the noise variations as a function of geographic location of the stations into three sub-intervals: 0.02s - 0.14s, 0.16s - 0.76s, 1.8s - 8s. The analysis shows that in the period interval of the microseisms the noise levels are as higher as the station are close situated to Black Sea. In the other two sub-intervals the values of the noise levels are higher if the noises sources are near the stations. The performed analyses show that the estimated PSD fall within NLNM and NHNM for all of the BNDSN stations. The seismic noise analysis is useful tool for evaluation performance of the stations as well as for the future site selection.

SW5 - RANDOM WAVEFIELDS IN SEISMOLOGY: NOVEL METHODS AND APPLICATIONS

SW5/P1/ID218 - CRUSTAL TOMOGRAPHY USING BB NOISE RECORDED IN JORDAN AND ISRAEL

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Ambient noise tomography is a rapidly emerging field of seismological research. The method is based on computing the cross-correlations of the long-term continuous broadband (BB) recordings at pairs of stations to estimate 3D seismic velocity structure of the region. The method was applied to the continuous (6-12 months) BB recordings of the 30 stations of the DESERT2000 experiment distributed across the Arava Fault (South of the Dead Sea basin) as well as the 6 permanent (several years data) BB stations of ISN spread throughout the country. The data have been band-passed filtered in the 2-50 sec range and pre-processed to eliminate influence of earthquakes and explosions according to the methodology developed at Colorado University, Boulder. The cross-correlograms of the processed data for each pair of stations have been used to compute group and phase velocity dispersion curves of Rayleigh waves, which have been used in turn to compute tomography images of the region in terms of the Rayleigh waves group and phase velocity determined at the coordinate grid points for fixed periods (8-20 sec). Then the set of tomography images have been converted into a 3D table of S and P velocities, combined of the 1D velocity profiles at each grid point. The tomography image at fixed periods and the obtained 3D velocity models fit well with the existing tectonic elements in the study area. A narrow low velocity anomaly in the crust coincides with the Dead Sea transform that is interpreted as sediments in the shallow layer and a zone of fractured and deformed rocks in the middle and lower crust. The zone of high velocities on the eastern bank of the DST fit well with the previous reporting based on body wave tomography, seismic refraction studies and field observations of exposed crystalline basement in the South-Western Jordan. A number of verification and quality control procedures have been performed to confirm reliability of the results obtained as well as the level of the resolution power.

SW5/P2/ID219 - RECONSTRUCTION OF GREEN'S FUNCTION FROM RANDOM NOISE SOURCES IN A MULTIPLE SCATTERING MEDIUM

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Imagining a medium composed of an arbitrary distribution of point-like heterogeneities, we study the reconstruction of the Green's function from the cross-correlation of waves excited by stationary random noise sources. We show that the reconstruction process is intimately related to generalized forms of the optical theorem, which stipulates energy conservation in the scattering process. The role of absorption in the formulation of the theorem is discussed. The relation between the cross-correlation of two wavefields and the imaginary part of the Green's function is demonstrated to all orders of scattering for the simple case of two point scatterers, through application of the optical theorem for a single scatterer. In the case of N point scatterers, the cross-correlation of two Green's functions is expressed in the form of Feynman-like diagrams. A simple diagrammatic rule is formulated that demonstrates the cancellation of spurious arrivals in the multiple scattering case.

SW5/P3/ID220 - DEPTH-DEPENDENT CRUSTAL Q-MODELS IN THE VRANCEA REGION AND SURROUNDINGS BY HIGH FREQUENCY WAVEFORM MODELLING

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A method based on high frequency waveform modelling is proposed to estimate depth-dependent models for the quality factor of the medium along selected ray paths located at the bending of the Eastern Carpathians. The algorithm is a non-linear inversion in which the normalised amplitude spectra of the records of low magnitude earthquakes are compared with those of the synthetic signals, generated as response of the structure to instantaneous point sources with the same mechanism as the observed event. The technique applied to compute the synthetic seismograms is the multimodal summation, a method which allows to synthesize the complete wavefield in preassigned intervals of frequencies and phase velocities. The maximum frequency considered is 5 Hz, and calculated spectra of both theoretical waveforms and records are smoothed by averaging the amplitudes for a band width of 1 Hz. The models for the elastic parameters of the medium along the focus - recording station paths (velocities of the seismic waves, and density) are 1D approximations representing the structure beneath the seismic stations; they are constructed as realistically as possible on the basis of the most recent information available, and consist of several homogeneous layers for the sedimentary cover and two layers for the crystalline crust (the upper and the lower crust). For the quality factor a set of about 50 models, differing each other by at least 20% of the Q-value in at least one layer, is a priori proposed. The best fitting Q-model is selected by minimizing the sum of squares of logarithmic residuals between theoretical and observed normalised amplitude spectra.The time window selected for the analysis is focused on the most energetic part of the signals (data and synthetics) -- between 10 and 20 seconds, including the S-wave and surface-wave trains. To avoid the effect of the data noise, the misfit function is evaluated only for the frequency range displaying signal-to-noise spectral amplitude ratio greater than 2.The procedure has been tested by theoretical experiments regarding the effect of the seismic source duration, and approximation of the seismic moment tensor by its double couple component, on the estimated best-fitting Q model.The effect of the uncertainty of the structural models considered for the elastic parameters, as well as the effect of the source depth on the resolution of the best-fitting Q structures were also investigated.

SW5/P4/ID221 - COMPUTING GREEN FUNCTIONS BY SIMULATING SEISMIC NOISE USING THE SPECTRAL ELEMENT METHOD

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The long term goal of this work is to improve tomographic images resulting from noise correlations. More specifically we address two questions that relate to each other : 1) Is it possible to compute noise correlation by simulating ambiant noise using the Spectral Element Method and 2) is it possible to «denoise» noise correlations using auto adaptive filters.

Indeed seismic ambient noise correlations have been successfully used to develop tomographic models of the crust. However this method is still limited since correlations are inverted 1) using ray theory and 2) assuming that the noise sources are evenly distributed in the medium so that the correlations contain the Green function of the medium which is not true in practice.

To go beyond this two limitations we investigate the possbility to simulate seismic ambient noise in a 3D medium using the Spectral Element Method. This would be useful to 1) compute synthetic correlations in a 3D starting model and 2) to take into account the uneven distribution of noise sources when inverting the correlations.

To that end we use RegSEM to simulate seismic noise sources and to compute synthetic correlations at the regional scale in the 20-50s period band. We study the convergence time of the correlation towards the Green function and the best way to denoise noise correlations.

SW5/P5/ID222 - AMBIENT SEISMIC NOISE ANALYSIS IN SOUTHERN NORWAY

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Within the TopoScandiaDeep project, which aims to investigate the relation between surface topography and lithosphere-asthenosphere structure in southern Norway, we process broadband seismic noise data from the temporary MAGNUS network and from permanent stations in that region (NORSAR, GSN). We analyze a continuous record of 20 months between September 2006 and June 2008. After usual preprocessing steps, we compute cross-correlation functions from all 41 receivers for three month time windows. Evaluation of the azimuthal and temporal variation of signal to noise ratios and f-k analysis of NORSAR array data shows that the dominant propagation direction of seismic noise is south-west to north, corresponding well to the Norwegian coast line. During summer months, the signal to noise ratios decrease and the azimuthal distribution becomes more uniform. This observations implies that the conditions to obtain reliable Greens function estimates are best fulfilled in that time period. Time-frequency analysis is applied to measure Rayleigh and Love wave group velocity dispersion curves between each station pair. After rejection of low-quality data using various selection criteria, we obtain reliable velocity estimates for periods between 3 and 30 seconds, which we invert for group velocity maps at respective periods. At all inverted periods, most velocity anomalies are consistent with the surface geology. However, the interpretation of low velocity anomalies in the western part of southern Norway is uncertain. At short wavelengths, the effect of large topography contrasts might bias the velocities towards lower values in that area. We analyze synthetic data, which we computed using spectral elements, to investigate whether this phenomenon is responsible for the low velocity anomalies. We also show that the spatial autocorrelation (SPAC) method of Aki (1956) can be used to extract phase velocities from a regional network without using the Greens function estimates.

SW5/P6/ID223 - LOCATING A SMALL CHANGE IN A MULTIPLE SCATTERING ENVIRONMENT (LOCADIF) : APPLICATION TO MONITORING CONCRETE.

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Most conventional imaging techniques are operated in single scattering media where the Born approximation is found relevant. In the multiple scattering regime where this approximation does not hold, the wave forgets its initial direction after a few scattering events and we can not have access to the precise trajectory of the wave. All waves are mixed together in phase, amplitude, wavevector… which defines the diffuse regime.

This paper presents an imaging technique to locate a weak perturbation in a multiple scattering environment. We derive a formula to predict the spatio-temporal decorrelation of diffuse coda waves induced by an extra-scatterer. Locating this new defect is then formulated as an inverse problem which is solved by a maximum likelihood approach. Using elastic waves in the 100-350 KHz frequency band, we show that the position of a millimetric hole drilled in a heterogeneous concrete sample can be retrieved with a precision of a few cm. By analogy, this technique could be applied to monitoring changes in dynamic geophysical media like volcanoes, where seismic waves are multiply scattered in the strongly heterogeneous internal structure.

SW5/P7/ID224 - TWO-LAYER EARTH MODEL CORRECTIONS TO THE MLTWA ESTIMATES OF INTRINSIC- AND SCATTERING-ATTENUATION OBTAINED IN A UNIFORM HALF SPACE.

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Following the numerical scheme of Yoshimoto we synthesized seismogram envelopes in the multiple scattering framework. We supposed the earth model constituted by a inhomogeneous crust overlying a transparent mantle. In this model velocity is assumed depth-dependent through a continuous function of the depth, v=v(h); Moho discontinuity is approximated by a sharp increase of the velocity around the crust-mantle boundary; inhomogeneity in the crust is parametrized through a depth dependent scattering coefficient (the inverse of mean free path) $g=g_0 f(h)$, with f(h) function of depth, and g_0 the scattering coefficient at zero depth; intrinsic attenuation is parametrized in terms of the intrinsic attenuation coefficient,η_i that is assumed independent of depth. Generating a suite of energy envelopes as a function of lapse time and distance, for reasonable values of B_0 , the seismic albedo, and Le^{-1} , the extinction length inverse (which

are functions of g_0 and η_i, we span a wide range including most of the measurements done through the world. Then, we apply the ordinary MLTWA technique to these synthetic envelopes. In this application we assume a constant g and a constant velocity, v=

SW5/P8/ID225 **- SEASONAL VARIATIONS OF OBSERVED NOISE AMPLITUDES AT 2-18 HZ IN SOUTHERN CALIFORNIA**

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We show that noise amplitudes at frequencies above 1 Hz exhibit strong seasonal variations in a broad southern California region. The results are based on 3-component seismic data recorded between 2002 and 2009 by 30 stations. Focusing on continuous 6-hour night-time segments, the seismograms are bandpass-filtered in 9 frequency bands between 2-18 Hz. Squared amplitudes are median-filtered to reduce the influence of earthquake signals and integrated to yield half-hourly noise energy estimates. The 6-hour minimum energy values are converted back to ground velocity and used as representative daily noise level amplitudes. Notwithstanding various trends, drifts, and other transient complexities, a common feature of the resulting time series in both the horizontal and vertical components are annual and sub-annual amplitude changes at all examined frequencies and all stations. The strength of amplitude variations shows no correlation with distance from the coast and some particularly clear seasonal changes are seen near topographic features in arid uninhabited areas. The results may reflect the ongoing occurrence of multitudinous small-scale failures in the shallow crust, induced by thermoelastic strain generated by interaction of atmospheric temperature field with spatial variations of surface properties.

SW5/P9/ID226 **- BROADBAND SEISMIC NOISE LEVEL ANALYSIS IN GREECE**

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The characteristics of the ambient seismic noise across Greece have been investigated. Power spectral densities (PSDs) are estimated at ~80 broadband seismic stations for frequencies ranging from ~0.01 to 16 Hz. We use 1-hr waveform segments for a 3-yr period, from 2007 to 2010, from continuous data collected by the Hellenic Unified Seismic Network (HUSN) and collaborative stations in Greece. A statistical analysis of PSDs at each station-component yields probability density functions (PDFs) with the method proposed by McNamara and Bulland (2004). In this way, we estimate both overall station quality and the level of earth noise at each site. There is a large variability of power spectra among different sites, due to different cultural, geological and station's installation quality. Wind and water noise due to weather conditions is also affecting the noise levels. This is observed in seasonal variations of the microseismic noise that correlate with oceanic storms in Atlantic Ocean and sea wave heights in the Aegean and Ionian sea. Finally, we map, geographically, the noise levels in different frequency bands across Greece.

SW5/P10/ID227 **- ON THE ORIGIN OF AMBIENT SEISMIC NOISE IN NORTHERN CHILE : INSIGHTS FROM NUMERICAL MODELLING**

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Analysis of one-year correlations of ambient seismic noise recorded by the broadband stations of the IPOC network in northern Chile showed some intriguing features that have motivated the present study. After classical processing of noise traces, stacking one month of correlation signals is enough to clear Green's functions reconstruction down to periods around 1 second (mainly surface waves).

Preliminary analyis of the observed correlations shows that:

1. the cross-correlations show coherent energy reconstruction in the 1-6 s band (secondary microseism band) suggesting near coastal source regions,

2. apart from the well-documented amplitude asymmetry between causal and anticausal portions of the cross-correlations, regarding the orientation of the station pair azimuth with respect to the Pacific coast, a difference in frequency content is clearly observed in some station pairs,

3. the analysis of the full cross-correlation matrix (including horizontal components) gives further information about surface waves polarization, and therefore possible source locations.

In order to understand the physical process(es) that could give rise to these observations, numerical modelling of noise propagation appears to be an adequate tool. We calculate Green's functions from vertical and horizontal point forces applied at the surface of the model. As a first step, we decided to concentrate the source locations to near coastal regions, in order to validate the hypothesis of shallow water noise generation. We used a 1D layered velocity model of the study area issued from previous active seismics and seismological studies. Even with this simplified earth model, we are able to reproduce several features of the observed cross-correlations.

Comparison between synthetic and real correlations help us to discriminate between some hypothesis regarding ambient noise generation. The very first results will be presented and discussed at the Meeting.

SW5/P11/ID228 **- DETAILED ANALYSIS OF REGIONAL SEISMIC PHASES USING ARRAY PROCESSING: EXAMPLE ANOMALOUS OBSERVATIONS IN CENTRAL ASIA**

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The Seismic mini-arrays installed in the framework of the International Data Canter for the Complete Test Ban Treaty Organisation provide a new opportunity for a systematic analysis of regional seismic wave fields on a wide scale. Signal processing techniques dedicated to mini-arrays allow a continuous description of regional seismic wave fields in terms of time-frequency-wavenumber representation. We present preliminary results obtained on the mini-arrays installed in Asia (e.g. Makenchi in Kazakhstan, Zalesovo in Russia). The array analyse technique reveals various behaviour of the main regional seismic phases. At the opposite of Pg and Pn phases which exhibit stable results all along each phase, including their corresponding coda, Lg-phase, as well as his coda, often presents a systematic variation of azimuth, which can reach deviations up to 90° from the expected azimuth. Numerous examples are provided in order to evaluate the stability and a possible regionalization of these results.

SD14 - VOLCANO SEISMOLOGY: NEW PERSPECTIVES AND RESEARCH DIRECTIONS

SD14/P1/ID229 **- INVERSION OF INFRASONIC OBSERVATIONS: APPLICATION TO VANUATU'S VOLCANOES ERUPTIONS**

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In the framework of the verification of the Comprehensive Test Ban Treaty (CTBT), a network of 60 microbarometric stations (IMS) is deployed in order to monitor atmospheric nuclear explosion. Operational arrays record various sources of infrasound, such as ocean swells, meteorites, supersonic aircrafts and volcanoes eruptions at long range.

Several studies have shown the need of a good atmospheric specification in order to well understand the infrasonic observations. Indeed, these studies underline the limits of atmospheric models to explain the large variability observed in infrasound data. Systematic biases are observed between simulations and observations, especially during the seasonal transitions. Moreover, influence of meteorological variability, at different time scale, is observed in infrasound records and poorly simulated with current atmospheric models. From this point of view, volcanoes represent repetitive sources of infrasound at known locations which are of great interest in order to assess and improve atmospheric specifications.

Past eruptions from Vanuatu's volcanoes have been well recorded since 2001 by the microbarometric array ISS22 at Nouméa (New-Caledonia) and more lately by microbarometer set up for near field studies of degassing dynamic. These records constitute a unique way for sounding the upper atmosphere and to complete the understanding of eruptions activities.

We present a method for infrasound data inversion from point source in order to re-

trieve some meteorological parameters of the atmosphere such as wind velocity. The inversion algorithm is then applied to eruptions from Vanuatu's volcanoes.

SD14/P2/ID230 **- PRECISE HYPOCENTRAL RELOCATION OF EARTHQUAKES ALONG THE PERNICANA FAULT (MT. ETNA, SICILY, ITALY): NEW STRUCTURAL INSIGHTS FROM SEISMOLOGICAL DATA**

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The Pernicana Fault represent an important active tectonic structure, of the north-eastern flank of Mt. Etna. This structure, WNW-ESE oriented, together with the NE Rift, play a fundamental role in the eastern flank dynamic of the volcano.

The Pernicana Fault is very active through sinistral, oblique-slip movements and is also characterised by frequent shallow seismicity (depth < 3 km) on the uphill western segment and by remarkable creeping on the downhill eastern one. The Pernicana Fault earthquakes, which can reach magnitude up to 4.3, sometimes with coseismic surface faulting, caused severe damages to tourist resorts and villages along or close this structure.

In the present work, we performed a precise relocation of the seismicity recorded along the Pernicana Fault during the period 1999-2009. The earthquakes, recorded by permanent seismic network of the Istituto Nazionale di Geofisica e Vulcanologia - Sezione di Catania, preliminary have been located with a 1D model using the algorithm Hypoellipse. Subsequently, the same events have been relocated using two different methods of location: NonLinLoc and HypoDD.

The first methodology is based on a process of global research, in 3D space, of the location parameters that can be obtained using different algorithms.

The program HypoDD, is based on the algorithm of double difference that minimizes the residual between observed and calculated traveltime differences for pairs of earthquakes at common stations.

Moreover, the cross-correlation analysis of the waveforms recorded allowed to identify seismic families of earthquakes, and to study their occurrence time and to associate with well-defined parts of the strucure.

These methodologies, highlighted, for the first time, that this structure is composed by several segments characterized by different seismic releases. Finally, the analysis of time-space distribution of Pernicana Fault seismicity related to the eruptive periods, could provide a better understanding of the complex dynamic of the eastern flank of the volcano.

SD14/P3/ID231 **- SEPTEMBER 30TH , 2007 VOLCANIC AND SEISMIC ACTIVITIES IN JABAL AL-TAIR ISLAND**

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The Yemen region had a prolonged history of volcanic activity since the Tertiary (Yemen Volcanic Series), till the Quaternary (Quaternary Volcanics), and still at present on relatively minor scale. Jabal Al-Tair is an oval-shaped volcanic island in the Yemeni offshore, covering area of 3.99km2, located in the mid-axial trough of the Red Sea. Jabal At-Tair represents the youngest activity in the whole region and is the lonely active volcano in the Red Sea. The volcanic formations underlying stratovolcano rises from the 1200 meters below the surface of the Red Sea, continuing for 244 meters above the surface up to the summit of active crater. The volcanic of Holocene age lies in the seismic and tectonic boundary between the Africa and the Arabian plates. Historical eruptions of this volcano were reported in the 18th -19th centuries and 1883, the most recent have been erupted at 7pm local time on September 30th, 2007, throwing lava and ash hundreds of meters, this eruption is rising from new central vents, aligned to the north of the former one. Subsequently, youthful basaltic poheohoe lava flowing from steep-sided central vent and fissures. Pyroclastic cones were located along the NW and southern coast, the fumarolic activity occurred from two eroded scoria cones at the summit. Radial 1.5 meter fissures extended from the summit, some which were the source of lava and gases flows. Volcanic harmonic eruption at the main crater and gases flows of active fissures were observed at October 21th, 2007. Majority of seismic activities is clustered on or near the transform faults of the deep axial trough in the southern Red Sea. Most of the recent earthquakes which were calculated by Yemen Seismological Network concentrated in the Gulf of Aden and the southern part of the Red Sea, The seismically active area between latitude 16.3°N and 17.4° N. is believed to extend southeastwards to the Jabal Al-Tair, the 2006-2007 seismic activities indicated considerable earthquake epicenters that plotted in the southeastern part of the Island. Seismic Characteristics supports the mechanism of sea-floor spreading and believes that the seismic activity in the shield area and the southern Red Sea may be attributed to stresses resulting from subsurface magmatic activity and the spreading centers, respectively.

SD14/P4/ID232 **- SEISMICITY AND VOLCANOLOGY OF THE RIFTED ZONE IN WESTERN SYRIA-A RISK MAP**

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At the northern part of the Dead Sea Fault Zone (DSFZ), and in the continuity with the Red Sea, Syria has a long record of active seismisity and recent volcanism. Field observations, physical effects on ancient building structures and movement analysis show that tectonic is still active at present time. A seismicity map has been established, based on the analysis of historic and recent seismicity, seismic parameters and laboratory odometric experiments. The movement rate along the syrian rift, is estimated at <1 to 2,7 - 3,3 mm/year, with a seismic acceleration coefficient (Z) at 0 to 0.25 cm/S^2 .The whole Syria territory is divided into five decreasing seismic zones, from 1 to 5, respectively. Earthquakes may occur in the whole country, but most epicenters, with the highest magnitude, are located within the first two seismic zones, including the Syrian rift and associated volcanism. A closer comparison with structural-petrological data shows however that recent volcanic activity, issued from a shallower mantle source, tends to distantiate from the rift zone. Major seisms appear to be related either to ancient, extinct volcanoes (Cretaceous age) or to superficial deformation of the sedimentary cover. Their intensity has significantly decreased during the last millenium.Key words: seismicity, volcano-petrology, syrian rift, Syria.

SD14/P5/ID233 **- BRITTLE SEISMIC DAMAGE BEFORE AND AFTER ERUPTIONS, WORLDWIDE STATISTICAL ANALYSES.**

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Recent studies suggested that the seismic events prior and after an eruption follow an Omori's law similar to the one observed for earthquakes with possible different exponent values (e.g., Lemarchand and Grasso, 2007). Given these similarities, we are interested in going further into the analogy between damage triggered by earthquake failure and eruption onset, by studying the damage of the upper crust contemporary to eruptions.

First, using worldwide earthquakes and eruptions databases, we quantified the spatial scale involved in crust damage around eruptions, as a function of the size of volcanic events, i.e. as measured by VEI. Using the distribution of seismic events around the time of eruption onsets, we found that larger volumes are involved in the brittle crust damage for the largest eruption sizes.

Second, we analyzed the analogy between eruptions and earthquakes regarding crust loading and discharge, thanks to patterns of seismicity around event times. For eruptions on a given volcano, evidences for crust loading have been highlighted thanks to seismicity up to ten days prior eruption time (e.g.,Voight, 1988; Kilburn, 2003; Chastin and Main, 2003; Collombet and Grasso, 2003). For worldwide eruptions, average seismicity around eruption time, shows direct and inverse Omori's law, the same way earthquakes do but with different values of exponents (Lemarchand and Grasso, 2007). Contrarily to earthquakes Omori's law, our preliminary analysis suggests that the values of these exponents vary with the eruptions size.

Given that small eruption processes (effusive volcanoes) generally show longer failure times than earthquake rupture propagation, we are interested in the mechanical responses of the brittle crust damages as a function of the forcing rate. It possibly argues for the small eruption process to impact the brittle crust the same way than a slow earthquake.

Implications for prediction of eruptions, regarding the size of events and the time of onset, will be discussed.

SD14/P6/ID234 **- SEISMIC TOMOGRAPHY OF LA SOUFRIERE DE GUADELOUPE VOLCANO, LESSER ANTILLES**

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We present the results of seismic tomographic experiments conducted on La Soufriere de Guadeloupe volcano. La Soufriere is an active geothermal system that has been the source of many instabilities leading to major flank collapses (1 every 8000yrs) and whose last phreatic eruption occured in 1976. Several projects have been devoted to the geophysical characterization of this geothermal system, in order to better constrain the zone of mechanical weakness, and zones of water and gaz circulation. These methods include seismic and EM imaging, gravimetry. In this presentation we show the results obtained from active seimic experiments, noise correlation passive imaging, resistivity profiles and gravity measurements that are analysed together to give more details on the upper volcanic system, above sea level.

SD14/P7/ID235 **- INTRAPLATE SEISMICITY ACROSS THE CAPE VERDE SWELL: INSIGHTS ON VOLCANIC BUILD-UP**

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The Cape Verde archipelago consists of 10 islands and several islets located on the southwest flank of the Cape Verde Rise, 500 to 800 km west of Senegal, off the African coast. This is an elevated region of ocean floor approximately 1200 km wide and encompassing an area greater than 3 x 10^5 km^2. The fact that the islands do not form a linear chain as observed in other hotspots is interpreted as the effect of a mantle plume underlying an almost stationary plate. The CV-PLUME project aims at characterizing the structure beneath the archipelago through an assembly of seismic, magnetic, gravimetric and geochemical observations. The core of this 3-year project was a temporary deployment of 39 VBB seismometers, which were operational from November 2007 to September 2008. We report a preliminary characterization of the recorded regional seismicity recorded by the network. To detect small magnitude events, the continuous data stream was screened using spectrograms. This technique proved to be very robust in the face of the high short-period noise recorded by many of the stations, particularly during daylight time. The recorded background seismic activity in the Archipelago and surrounding area is low, very few events being recorded by the complete network. Besides some dispersed seismicity, two main clusters occur near Brava and Santo Antão Islands. In both cases the clusters trend NE-SW. Unlike Brava, where felt earthquakes are frequent, the cluster around Santo Antão was somewhat unexpected. The Brava cluster marks the alignment of the Secos Islets, Brava Island, Cadamosto submarine volcano. The Santo Antão cluster extends for 110 km, from approximately 50 km SW to 25 km NE of the island; its trend coincides with the island's length and with the direction of the main dike system that fed the shield building phase of Santo Antão. Being an active volcano, with the most recent activity at the SW end (Tope de Coroa volcano), this seismicity can be related to tectono-volcanic structures extending beyond the volcano's limits. The CV-Plume network also detected several T-phase sets of arrivals that were generated by seismic events at the Mid-Atlantic Ridge. The network acts as an antenna allowing the location of earthquakes that were not detected by the Global seismic networks. This study was supported by projects "CV-PLUME: An investigation on the geometry and deep signature of the Cape Verde mantle plume" (PTDC/CTE-GIN/64330/2006) and "COBO: Cape Verdes Origin from Broadband Observations", GDSS, GFZ-Potsdam.

SD14/P8/ID236 **- HYBRID PROBABILISTIC/ DETERMINISTIC SCENARIOS FOR SEISMIC HAZARD ANALYSIS AT CAMPI FLEGREI AND VESUVIUS VOLCANOES, IN CAMPANIA REGION, SOUTHERN ITALY**

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Classic probabilistic seismic hazard analysis (PSHA), proposed by Cornell (1968), is performed by assuming: a uniform space distribution for the seismicity in a given magnitude range and a poissonian time-independent earthquake occurrence model. The effect of each earthquake is estimated by using a proper ground-motion predictive equation (GMPE). The application of classical PSHA is not obvious when a single causative fault and an associated maximum earthquake are considered as the threat for the site of interest. Particularly for volcanic areas and largest earthquakes, two main limitations have to be faced in order to apply classical PSHA. First consists in the estimation of the expected return periods, the second one in the characterization of a strong seismic wave attenuation media.

In this work an extension to time-dependent model of the integrated probabilistic–deterministic method proposed by Convertito et al. (2006) is presented with an application to Campi Flegrei and Vesuvius volcanic areas. This method can be used to overcome some of the limitations of both PSHA and deterministic approaches when applied to a single fault for a scenario-like description of the hazard. The distance and azimuthal distribution of ground motion parameters and their expected ranges of variability, relevant for estimating the earthquake effects, are obtained through a statistical analysis of a synthetic waveforms database. The waveforms have been produced by a hybrid simulation method by Gallovič and Brekesova (2007) for a large number of possible scenarios for M4.0 and M5.5 earthquake. Different nucleation points, rupture velocity, and fault mechanism have been considered. For Campi Flegrei surface fault projection are located on the caldera border, for Vesuvius volcano the fault are located in the center of crater. Peak-ground motion estimates are validated through a comparison with an ad-hoc GMPE retrieved for the area of interest by using the stochastic approach of Boore (1983).

Concerning the time-dependent approach, different renewal models (i.e. log-normal and Brownian passage time) have been considered and applied. The measure of the gain between the time-independent and time-dependent model has been evaluated in order to estimate the better time-dependent approach.

SD14/P9/ID237 **- BELGIAN-INDONESIAN COLLABORATION FOR SEISMIC MONITORING OF VOLCANOES**

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We present the state of the collaboration between Indonesia and Belgium for the volcanic activity monitoring using modern broadband seismic stations deployed on the flanks of active volcanoes. These include Papandayan, Rinjani and Kawah Ijen volcanoes. The seismic activity is correlated with other effects, such as gaz emission or pH and level of crater lake waters.

These three volcanoes are of major interest as they are in very densely populated areas, and addind broadband seismometers in the vicinity of the volcano is of high importance to identify the possible precursor signs of an eruption.

SD14/P10/ID238 **- ERUPTIONS OF EYJAFJALLAJÖKULL VOLCANO, 2010: MONITORING THE FLANK AND THE SUMMIT ERUPTIONS**

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Increased seismic activity and ground deformation was seen periodically for over 15 years befire the 2010 eruption of Eyjafjallajökull (see another presentation in same session). In early March 2010 the seismic activity intensified and on 20 March a flank eruption began at Fimmvörðuháls. In this eruption mainly lava was extruded with very little ash production. It lasted for more than three weeks and ended on 12 April (Gudmundsson et al., 2010). Late on 13 April a new swarm of earthquakes was observed beneath the summit of Eyjafjallajökull, and after midnight it was clear that a new eruption was beginning, close to the summit. Everyone was evacuated from the farms near the volcano as the ~200 m deep summit crater was filled with ice that would melt. The ash plume became visible in the early hours of 14 April and at about 07 UTC floodwater started to flow to the south and north of the volcano.

The summit eruption went through diffe-

rent phases, which all have different seismic characteristics. The first phase, while the crater was still covered by meltwater, was phreatomagmatic. In the second phase, ash production was less intensive and after a while it was clear that lava was flowing out of the crater. In the first week of May, after an intense swarm of earthquakes at considerable depth, the eruption revived with heavy ashfall that lasted for over two weeks. On 21 May the activity had almost died down, but still there were occational ash explosions. At the end of May no magma was coming from the crater, but it was still degassing and steam was rising. This presentation will focus on the monitoring of the two eruptions.

References:

Gudmundsson, M. T., R. Pedersen, K. S. Vogfjörð, K. S., B. S. Thorbjarnardóttir, S. S. Jakobsdóttir, and M. J. Roberts 2010. Eruption og Eyjafjallajökull Volcano, Iceland. EOS, Vol. 91, No. 21, 190-191.

SD14/P11/ID239 - SIMULATED VOLCANIC SEISMICITY SCALES ACCORDING TO BRITTLE-FAILURE IN THE ABSENCE OF FLUID FLOW

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Here we present a new analysis of experimental data meant to simulate the types of seismic signals seen in a volcanic environment. Two rock deformation experiments performed under both water saturated and unsaturated conditions produce acoustic emission events which resemble hybrid earthquakes commonly observed in a volcanic environment. We obtain the source spectra of events occurring in both the unsaturated experiment and during the decompression phase of the saturated experiment using an empirical Green's function method, and estimate their spectral corner frequencies, which are inversely proportional to event duration. Spectral fits indicate that the acoustic emission events occurring under dry conditions follow the expected scaling of moment and corner frequency for standard brittle failure in an elastic medium with constant stress drop, namely $M_0 = f_c^{-3}$. The events occurring during the fluid decompression phase of the saturated experiment have estimated corner frequencies which are not easily described by any simple scaling relationship with seismic moment. The observed scaling for the events under dry conditions suggest that that the event durations change in a predictable way with increasing moment. Conversely, the lack of any obvious scaling between corner frequency and moment for the wet events suggests that the durations do not change in any particular way with increasing size.

A comparison of the moment-corner frequency scaling between experiments suggests an observation of $M_0 = f_c^{-3}$ scaling must result from a standard stick-slip (i.e. brittle failure) source. Furthermore, such scaling should rule out fluid flow as a source of the observed waveforms, as there is no plausible reason for the driving pressure for fluid flow to be dependent on duration in any specific way. If such a $M_0 = f_c^{-3}$ is observed for low-frequency events in a field environment, it would require such a similar brittle-failure source to explain such source parameter scaling. The implications of our work are that hybrid seismic signals observed in a volcanic environment do not always require fluid flow to explain their signal, and therefore are not necessarily indicative of sub-surface fluids.

TS - TSUNAMIS: NEW EFFORTS IN TSUNAMIGENIC EARTHQUAKES MONITORING AND ESTABLISHMENT OF WARNING SYSTEMS IN THE EURO-MEDITERRANEAN REGION

TS/P1/ID240 - THE USE OF PROBABILISTIC TSUNAMI HAZARD ASSESSMENT IN EARLY WARNING SYSTEM DESIGN

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Installing a tsunami warning system in the Mediterranean region is crucial for reducing the risk related to large tsunamis. To assure a cost-effective design of such a system, the relative contributions of potential source zones to the hazard and the associated tsunami travel times must be evaluated. Probabilistic tsunami hazard assessment provides a useful framework for such evaluation. Estimating the occurrence probability of tsunami events is furthermore critical for setting construction standards and, more generally, prioritizing risk mitigation efforts. Tsunami hazard in the Mediterranean region has traditionally been estimated by considering scenarios of tsunami impact for limited geographical regions, but little attention has been paid to the probability of any given scenario. We present the first probabilistic estimate of earthquake generated tsunami hazard for the entire Mediterranean, and we estimate the annual probability of exceeding a given runup height at any coastal location in the region. The highest hazard is in the Eastern Mediterranean owing to earthquakes along the Hellenic Arc, but most of the Mediterranean coastline is prone to tsunami impact. Our method allows us to identify the main sources of tsunami hazard at any given location, and to investigate the potential for issuing timely tsunami warnings. We find that the probability of a tsunami wave exceeding 1 m somewhere in the Mediterranean in the next 30 years is greater than 95 percent. This underlines the urgent need for a tsunami warning system in the region.

TS/P2/ID241 - PRELIMINARY OUTCOMES OF THE 27 FEBRUARY 2010 CHILE TSUNAMI POST-EVENT FIELD SURVEY BETWEEN LLO-LLEO AND PUERTECILLO (NORTH OF THE VI REGION, CHILE)

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The 27 February 2010 Chile M=8.8 earthquake generated a tsunami that had disastrous effects along a quite long portion of the central Chile coastline and that also propagated across the entire Pacific Ocean with much more moderate consequences. In the hours following the earthquake the attention was very much concentrated on the trans-Pacific propagation of the tsunami waves and on the response and performance of the Pacific tsunami warning system. But the tsunami had already took only about 20 minutes to attack the Chilean coasts and to produce large destruction, without any local warning or alarm issue. The entity of the effects produced by the tsunami in the near-field was assessed by a number of post-event field surveys carried out by different international teams under the umbrella of the UNESCO-IOC-ITIC. We summarise the results of the survey carried out by the authors of this contribution from 8 to 11 April 2010 in different sectors of the stretch of the VI Region coastline ranging from Llo-lleo in the north to Puertecillo to the south. The places visited were Llo-lleo, La Boca de Rapel, Las Brisas de Navidad, Matanzas and Puertecillo. In some places, especially in Llo-lleo, the traces of the tsunami already disappeared, but in the other places the tsunami signature was still evident. Following the ITIC guidelines, a large amount of material was collected, including interviews to eyewitnesses and local people, pictures, videos, flow depth, run-up and inundation measures. The latter were collected by using a kinematic GPS approach. In general, we found that the topography of the sites had strong influence on the tsunami effect pattern. Sand dunes demonstrated to be an excellent protection element against the impact of the incoming waves, while the presence of rivers or even small streams favoured the water waves ingression: for example, the tsunami was able to travel upstream the Rapel river for about 1 km and a very narrow stream in Puertecillo for about 700 m. Run-ups varied significantly even at local scales: the largest value (circa 16 m) was measured in Puertecillo, in correspondence with the largest inundation distance. A final important note regards the awareness of the tsunami hazard that we found in almost all the people we interviewed. In the absence of a local tsunami alarm issue, the knowledge local people have about the tsunami greatly helped in saving lives. The survey has been funded by an Italian project on tsunamis and tsunami early warning system (FIRB- RBAP04EF3A_004).

TS/P3/ID242 - OVERVIEW OF THE REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM FOR AFRICA AND ASIA (RIMES)

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In the aftermath of the 2004 Indian Ocean Tsunami, efforts to establish an early warning system have been initiated. As the devastating impact of this event revealed the absence of a tsunami warning system in the region, a number of Asian and African countries have expressed interest in developing a regional early warning organization. Hence, the Regional Integrated Multi-hazard Early Warning System for Africa and Asia, also known as RIMES, evolved. As an end-to-

end system, it covers the entire spectrum of early warning from hazard detection to community preparedness. Having a multi-hazard framework, the Center incorporates tsunami early warning into existing national warning systems to include other natural hazards such as earthquake, floods, heavy rainfall, etc. In the context of regional cooperation, it employs a participatory system where countries exchange seismic data and information, research results, best practices, technical experiences and expertise towards the development of tsunami-resilient communities. The interrelated components of RIMES involve regional tsunami and earthquake observation, prediction and advisory dissemination to Member States through a distributed network of monitoring stations and data-communication systems in the region, including hydro-meteorological risk information generation and application; capacity building of national institutions in managing disaster risks and emergency response; capacity building of local authorities and communities in disaster preparedness and mitigation; and research in all aspects and elements of an end-to-end early warning system.

TS/P4/ID243 - THE RATCOM PROJECT: IMPLEMENTATION OF A LOCAL TSUNAMI ALERT PROTOTYPE FOR THE LIGURIAN AREA (MEDITERRANEAN SEA).

T. RATCOM Team[1]
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The RATCOM project, funded by the French R&D ministry and local collectivies, is a multi-disciplinary initiative that intends to implement a robust and rapid near-field tsunami alert and a hazards management information system. This prototype aims at supervising the tsunami hazard of the Ligurian coastal area (Southwestern French to northeastern Italian and Corsican coastal areas) generated by either local earthquakes or landslides. The RATCOM system carries out an architecture able to manage a complete tsunami alert extending from the detection of the ongoing event to the population warning. The system relies firstly on real-time offshore and inland seismological and oceanographical data acquisitions that are automatically processed and compared to pre-calculated scenarios in a data center in order to provide in a short time an assessment of the tsunami threat. Secondly, the rapid diffusion of the alert at regional scale is insured by a powerful and secured communication network (Secunet) further linked to mass alert systems including mass media for population warning. This prototype allows for developing acquisition and processing techniques relevant to early tsunami detection and alert when occurring at short distance from the coast.

TS/P5/ID244 - NUMERICAL MODELLING OF THE 1979 NICE LANDSLIDE-GENERATED TSUNAMI

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On the 16th October 1979, a part of the building site of the Nice airport extension intended to become the new Nice harbour collapsed into the Mediterranean Sea during landfilling operations. This submarine slide of initial volume of 10 millions of m3, located near the seashore, generated a turbidity current that propagated along the Var canyon. A few minutes after the landslide, a small tsunami was observed by several witnesses 60 km along the coast, called «Baie des Anges». The most destructive effect occurred near the city of Antibes, 10 km away from the source, which was inundated and where one person died.

In the framework of the RATCOM (Réseau d'Alertes aux Tsunamis et COtiers en Méditerranée) project, this event is numerically simulated with the goal of establishing the appropriate monitoring network which could have detected this event by means of gauges located offshore. Two additional scenarios of hypothetical sources recently identified by IFREMER in the same area are also computed. A very accurate bathymetric map of the area provided by IFREMER and completed by SHOM data near the coast is used. The dynamics of the slide and the water waves generated are both computed in the shallow water approximation, considering the interaction between the mass of sediments constituting the slide and the water. The landslide is modelled as a Newtonian homogeneous viscous flow sliding under gravity along the bathymetry and the tsunami model is initialized by taking into account the bottom deformation induced by the slide. Incorporation of water in the mass of sediments at the interface between landslide and water can be considered. The equations are solved by a finite difference method based on shock capturing.

Numerical results of tsunami waves amplitudes generated by the landslide during the propagation and along the coast are compared to witnesses observations and available tide gauges signals. Local effects in front of the Nice airport are well reproduced with consistent wave polarity, arrival time and amplitude. However, in the far field, results are not in agreement with observations, in particular, simulated wave amplitudes are too small to inundate Antibes city. Water entrainment inside the slide increases these amplitudes.

Further investigations will involve run up computations in Antibes area with a refined grid including topographic data in order to compare with an inundation map recently established.

TS/P6/ID245 - POTENTIAL TSUNAMI INUNDATION MAPS ALONG THE MEDITERRANEAN COAST OF ISRAEL

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Maps are presented of the potential tsunami inundation along the most densely populated and developed Mediterranean coasts of Israel. These maps may help in areal planning, tsunami hazard mitigation, as well as in identifying vulnerable buildings and infrastructure facilities onshore and offshore the Haifa Bay, Tel-Aviv, Ashdod and Ashqelon areas.A previous investigation (Thio, 2009, Tsunami hazard in Israel, URS Corp.) calculated the expected tsunami scenarios that could result from remote and local tsunamigenic earthquakes in the eastern Mediterranean basin as well as from submarine landslides along the continental slope of Israel, and delineated the zones of potential inundation. The potential sources and their estimated return periods, which seem to contribute significantly to the tsunami hazard in Israel and were thus selected for modeling, are based on earlier seismotectonic and historical studies as well as on the typical behavior of tsunami wave propagation. In order to prepare the maps for public use, the hazard of tsunami inundation was examined in relation to several time windows, namely, 500, 2,500, 10,000 and 100,000 years. Nonetheless, this form of hazard map is still complicated, for there are significant uncertainties in some of the assumptions used for constructing the maps, the contours of return periods overlap in places, and sometimes are not consistent with the shoreline, probably due to the limited resolution of the digital elevation model. It therefore seems that in this stage, the concept of a time-dependent hazard cannot be used as such. Instead, it is suggested to present the public the line of maximal inundation, which is composed of the worst-case scenarios only. Although this is a conservative, time-independent hazard evaluation, it seems to be simpler to explain and easier to understand.

TS/P7/ID246 - DISCUSSION ON THE TSUNAMI TRIGGERED BY THE EL ASNAM (ALGERIA) EARTHQUAKE OF 1980

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On the 10th of October 1980, a Mw=7.1 thrust earthquake destroyed the town of El Asnam (actual Ech Cheliff, Northern Algeria) causing several thousands of casualties and leading to considerable economic losses for Algeria. This is the biggest instrumentally recorded earthquake in Africa. A lot of measurement campaigns have been immediately set up in order to constrain the fault rupture mechanisms, furnishing important information concerning principally the focal mechanisms in this area (aftershocks studies), the length and width of the rupture zone, the depth and the coseismic slip. But although the epicenter has been located about 45 km from the sea, and 15 km east of El Asnam, in the same area of the 1954 Orléansville earthquake (Mw=6.6) and other important events (1928, 1934), it is known to have triggered a small tsunami which was able to reach the south-eastern Spanish Coast in several locations where it has been recorded on tide gages. Thus five maregrams are available from Alicante to Algeciras. Several previous studies present this tsunami as the result of a submarine mass failure as the 1954 event which led to the rupture of submarine phone cables (associated to a turbidity current). Unfortunately, no proof of such failure as landslide scar has been highlighted by bathymetric surveys on the continental slope. In this work we propose a rupture scenario based on previous studies results as geodetic measurements of vertical movements, aftershocks localization, focal mechanisms determination and identification of geological

features among other things. We show that the seismic initial deformation itself, using Okada's formulae, is able to disturb the sea surface near the Algerian Coast by several centimeters, even at this distance from the epicenter, and propagate a tsunami wave toward the Spanish Coast. The results are compared with historical records in terms of arrival times, polarity and wave amplitudes and discussed, especially concerning the integration of such inland earthquake in the catalog of the future Western Mediterranean Tsunami Warning System. This study was partially funded by the European project TRANSFER which aimed at constraining tsunamigenic sources and hazard zones in Mediterranean Sea more particularly, and by the French ANR project MAREMOTI under contract ANR-08-RISKNAT-05-01c which aims to assess the tsunami hazard for the French Territories.

TS/P8/ID247 - MODELLING MODERATE TSUNAMI ON THE FRENCH COASTS

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The 2003 tsunami generated by the Boumerdes-Zemmouri earthquake reminds us of the possibility for intermediate submarine earthquakes to generate moderately damaging tsunamis in the area of interest. A field survey allowed identifying several harbours in the French Riviera where disturbances related to local resonances have been reported during the tsunami. This new database illustrates well which kind of effects a moderate tsunami can imply on coastal infrastructures. To study in more details this effect, the French ANR Maremoti project is focusing on the tide gauge and field tsunami observations, and modelling and vulnerability studies for the Northeast Atlantic and western Mediterranean area. This project is done with ten scientific partners (nine French and one Portuguese). In this study, we discuss the effect of moderate earthquake-generated tsunamis on the French Mediterranean and Atlantic coasts. To this aim, we use real tsunami events like the Boumerdes-Zemmouri tsunami (2003) and the 1969 earthquake off Portugal. Available observed data are synthetised, and are compared to tsunami modeling results. We use a numerical tsunami simulation based on non linear shallow water equations and using imbricated bathymetric grids to simulate tsunami propagation from source to more detailed areas. This allows computing the tsunami effect in some harbours and bays, especially in terms of local resonances. High resolution grids, which are set up for the last grids level, are made from digitized, georeferenced and interpolated nautical bathymetric charts, and bathymetric soundings from SHOM. The objective is also to discuss the tsunami hazard for French coastlines, which is rather poorly known to date, and thus we use different earthquakes sources parameters for the Mediterranean and Atlantic coastline.

TS/P9/ID248 - FORECASTING DATABASE FOR THE TSUNAMI WARNING REGIONAL CENTER FOR NE ATLANTIC AND WESTERN MEDITERRANEAN SEA

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Improvements in the availability of sea-level observations and advances in numerical modeling techniques are increasing the potential for tsunami warnings to be based on numerical model forecasts. Numerical tsunami propagation and inundation models are well developed, but they present a challenge to run in real-time, partly due to computational limitations and also to a lack of detailed knowledge on the earthquake rupture parameters. Through the establishment of the tsunami warning regional center for NE Atlantic and western Mediterranean Sea (CRATANEM), the CEA is especially in charge of providing rapidly a map with uncertainties showing zones in the main axis of energy at the Mediterranean scale. The strategy will be based initially on a pre-computed tsunami scenarios database, as source parameters available a short time after an earthquake occurs are preliminary and may be somewhat inaccurate. Existing numerical models are good enough to provide a useful guidance for warning structures to be quickly disseminated. When an event will occur, an appropriate variety of offshore tsunami propagation scenarios by combining pre-computed propagation solutions (single or multi sources) may be recalled through an automatic interface. This approach would provide quick estimates of tsunami offshore propagation, and aid hazard assessment and evacuation decision-making. As numerical model accuracy is inherently limited by errors in bathymetry and topography, and as inundation maps calculation is more complex and expensive in term of computational time, only tsunami offshore propagation modeling will be included in the forecasting database. Far-field solutions are less sensitive to spatio-temporal details of the source (they depend primarily on the magnitude and location of the epicenter), and allow using a single sparse bathymetric computation grid for the numerical modeling. But a database of pre-computed results cannot contain all possible tsunami events, because of too much variability in the mechanism of tsunamigenic earthquakes. In principle, an infinite number of tsunami propagation scenarios can be constructed by linear combinations of a finite number of pre-computed "basis" scenarios. The current recommendation will be to take a conservative approach, selecting the scenario –or interpolation between several scenarios- with the higher impact. The whole notion of a pre-computed forecasting database also requires a historical earthquake and tsunami database, as well as an up-to-date sismotectonic database including faults geometry and a zonation based on sismotectonic synthesis of source zones and tsunamigenic faults. A discretization of the faults will be done for the scenarios computation.

TS/P10/ID249 - NUMERICAL MODELING OF EARTHQUAKE-GENERATED TSUNAMIS FOR TSUNAMI RISK ASSESSMENT IN BALCHICK, BLACK SEA, BULGARIA

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The Black Sea is characterized by low seismicity and very low tsunami production rate. However, the very few tsunami events reported in the past indicate that the tsunami risk assessment should not be neglected there. Within the frame of the research project SCHEMA, the coastal area of Balchik to the north of Varna in the Bulgarian Black Sea coast was selected as a test-site. From a new tsunami catalogue for the Black Sea compiled by NOA, we selected an earthquake source for tsunami generation offshore Balchik. The earthquake source was selected on the basis of the strong, historical tsunamigenic earthquake of AD 544/545. Documentary sources but also archaeological observations indicate that the coastal zone of Balchik was inundated by that tsunami wave. Tsunami and runup modeling was performed for the region of Balchik. Two alternative earthquake sources with different fault strike but for common earthquake magnitude of M=7.5 were taken into consideration. Bathymetry from GEPCO but also from digitized bathymetry maps were used, while a DEM was constructed by digitizing local topography maps. The wave propagation was simulated with the use of the software package GEOWAVE which is a combination of TOPICS (Tsunami Open and Progressive Initial Conditions System) and FUNWAVE. TOPICS uses a variety of curve fitting techniques and was designed (Grilli and Watts 1999) as an approximate simulation tool that provides surface elevations and water velocities as initial conditions for tsunami propagation. The numerical model FUNWAVE (Wei and Kirby, 1995; Wei et al., 1995) performs wave propagation simulation, based on the fully non-linear Boussinesq theory using a predictor-corrector scheme. Wave runup was calculated from the approximation $R=A^{0.8} \times H^{0.2}$ (Ward and Day, 2008). The tsunami excitation, propagation and inundation was modelled for both regional and local scenarios. Maximum and minimum water elevation and maximum current velocity were calculated for both sources for the regional and local scenarios. The hydrodynamic results were used for the development of the tsunami hazard maps of the test-sites. These results were also used as an input for other SCHEMA partners to perform risk assessment in terms of building damage. This is a contribution to the EU-FP6 research project SCHEMA.

TS/P11/ID250 - NUMERICAL SIMULATIONS OF THE 27 FEBRUARY 2010 CHILE TSUNAMI AND COMPARISON WITH SELECTED INSTRUMENTAL RECORDS AND RUN-UP MEASUREMENTS

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The very strong earthquake with Mw = 8.8 that occurred offshore central Chile on 27 February 2010 was located in the subduction zone originated by the convergence between the Nazca and the South American plate and was characterized by a thrust mechanism fault. The earthquake was followed by a catastrophic tsunami that killed more than 500 people causing severe damage to structures and houses especially in the Juan Fernandez islands and along the Chilean coast between the cities of Valparaiso and

Talcahuano, that are located very close to the source area. This event represents the demonstration that the protection of the coasts near the tsunami sources represents an unresolved and urgent issue in the tsunami early warning field. In this work we try to provide a preliminary reconstruction of the tsunami using the comparison between some of the available observation data (tide gauge records and run-up measurements) and the results obtained by the numerical modelling. The simulations are performed by means of the finite-difference code UBO-TSUFD, developed and maintained by the Tsunami Research Team of the University of Bologna, Italy, that can solve both the linear and non-linear versions of the shallow-water equations on nested grids. After having selected some fault models resulting from studies published online or in the literature, we try to give some suggestions on the probable source by analysing the fit between calculated and observed data via a direct approach, which is split in two parts: 1) a far-field analysis focusing on the offshore propagation of the tsunami to simulate the observed offshore DART buoys recordings and 2) a near-field analysis focusing on propagation and flooding (which implies the use of a system of nested grids with various resolution to zoom on the coastal areas of interst) to try to reproduce the run-up heights that were collected by a joint team of the Universities of Bologna (Italy), of Valparaiso and of Santa Maria (Chile) along the coastline running from Llo-Lleo in the north to Puertecillo in the south

TS/P12/ID251 - THE PROTOTYPE REAL-TIME SCENARIOS COMPONENT OF THE INGV TSUNAMI EARLY WARNING SYSTEM FOR THE COASTS OF ITALY

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In the framework of the agreement between Italian Civil Protection and INGV (DPC-S3 project), we have been studying the feasibility of a Tsunami Early Warning System (TEWS) for the coasts of Italy. We focused in particular on the real time tsunami scenarios to be produced once an earthquake has occurred. The underlying concept is borrowed, as a starting point, from the Japan Meteorological Agency's TEWS. Some differences arise, however, due to the specificity of the Mediterranean context, as well as due to the reduced possibility of fast direct measurements of the tsunami waves eventually generated. The prototype forecast system is based on a set of elementary pre-calculated submarine earthquake sources, plus a set of scaling laws of the tsunami height with respect to source parameters. In case of an earthquake, according to information released by the INGV seismic center (epicenter, depth, and magnitude), the pre-calculated wave heights produced by each elementary source must be interpolated to evaluate where and how a tsunami could hit the coastlines more severely. We start by considering a grid of nine epicenters on a 20x20 km square in front of the Algeria coast, and potentially threatening the southern Sardinia coast. At the moment, the geometry of the faults (strike, dip, rake) is keep fixed, while we consider for each of the epicenters several different depths and magnitudes. The (empirical) scaling laws that serve as a guidance for the interpolation are instead derived numerically for a wider range of earthquake parameters. The performances of the prototype have been evaluated both by means of synthetic earthquakes (by simulating hundreds of earthquakes falling in the prototype grid), and by using an ad-hoc database around the epicenter of a real earthquake, which generated a moderate tsunami in the western Mediterranean (the Mw=6.9 May 2003 Boumerdes-Zemmouri earthquake, Algeria). The synthetic tests also serve to assess the uncertainties that will be attached to the forecasts issued. In the next future, we plan to complete the errors evaluation, with a series of sensitivity tests on parameters not yet investigated, such as fault geometry and earthquake (magnitude to slip) scaling laws. We will also test the performance of the prototype algorithm with several tsunamis outside the Mediterranean, for which more experimental data are available. We will finally extend the database over and around the main potentially tsunamigenic zones in the Mediterranean basin, in order to implement it at the INGV seismic center.

TS/P13/ID252 - POSSIBLE TSUNAMI IN BLACK SEA BASIN: TWO MECHANISMS OF TSUNAMI SOURCE FORMATION

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As known, the eastern part of the Black Sea are mainly located inside the Alpine fold belt, and from analysis of plate kinematics for central part of Alpine-Himalayan fold belt it follows that the Caucasus region is undergoing to strong compression due to convergence between Arabian and East-European plates. The south boundedness of Eastern Black Sea microplate coincides with eastern part of North Anatolian fault and as follows from analysis of active tectonics of Eastern Mediterranean region, the velocity of right-side shift on this fault reaches to 26 mm/year. Though the tsunami danger of Black Sea as well as Marmara, Azof and Caspian Seas of Mediterranean belt is essentially lower as compared with that e.g. in the Pacific, the study of tsunami there is of importance because of densely populated coasts. In present work, it is performed a numerical simulation of possible tsunami in Black Sea basin. There are considered two different mechanisms of formation of tsunami source: landslide and keyboard ones. It is studied a formation of landslide processes in the Novorossiysk city region where due to performed preliminary research it is possible to trigger process of initiation of beach slope sliding where it has been formed landslide body at seismic or mechanic action. With using of numerical code FLAC it is performed numerical simulation of stressed state in each of 7 layers to which the landslide body was divided for each of which there are determined shear strains which permits to determine component of vertical shift for each point of moving landslide mass. The data obtained are used to simulate the process of generation of surface water wave and formation of tsunami source above the moving landslide mass. Using nonlinear shallow water equations and taking into account dissipation on the bottom there were computed the wave characteristics as in near-field zone (Novorossiysk city region) as well as in far-field zones (Sochi city region, Turkey coast). In work it was also considered possibility of appearance of tsunami waves induced by possible earthquakes in the region of Tuapse foredeep and its consequences for Sochi coast (Russia) where in 2014 it is planned to held Olympic Games. In work, there are determined the sections of Black Sea coast most dangerous at possible inundation by tsunami waves. For given mechanisms of formation of tsunami source there is determined maximum tsunami wave height distribution on all perimeter of Black Sea basin.

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TS/P14/ID253 - THE HELLENIC NATIONAL TSUNAMI WATCH CENTRE (HL-NTWC)

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Following the efforts of UNESCO's Intergovernmental Oceanographic Commission-Intergovernmental Coordination Group (IOC-ICG) for the development of tsunami early warning and mitigation systems within the Eastern Meditteranean, Greece has responded by establishing a National Tsunami Watch Centre for the Ionian, Aegean and Eastern Mediteranean Seas. The center is also a candidate Regional TWC for the Eastern Mediteranean.

The Hellenic NTWC (HL-NTWC) is being established at the National Observatory of Athens Institute of Geodynamics (NOA-IG), where the National Unified Seismic Network of Greece is currently operating Real time tide gauge data are provided to the HL-NTWC by the Hellenic Navy Hydrographic Service and seafloor pressure measurements are received from an instrument platform west of SW Peloponnese, operated by the Oceanography Institute of the Hellenic Centre for Marine Research (HCMR). A database of precomputed simulations for tsunami evolution from source to target regions for scenario earthquakes for rapid assessment of the hazard following any real emergency; this is being undertaken by the Institute of Computational and Applied Mathematics (ICAM) of the Foundation of Research Technology (FORTH).

TS/P15/ID254 - TSUNAMIGENIC POTENTIAL OF THE NORTH-GORRINGE ROCK AVALANCHE (GULF OF CADIZ, SW IBERIA)

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Landslides along continental margins represent a significant source for tsunami generation, due to the oversteepened slopes where they are usually located, enhancing mass velocity and then their tsunamigenic potential. Exploring the seafloor in search of evidences

of past slide events is a crucial point in order to understand their entity and to evaluate their impact on the coast through proper modelling. This approach can be useful also for defining scenarios and for assessing future possible threats. One of the possible areas for such landslide generated tsunami, probably related to seismic activity, is located along the Gorringe Bank, in the Gulf of Cadiz. The Gulf of Cadiz is located in the SW margin of the Iberian Peninsula and hosts the present-day convergent boundary between the European and African Plates (plate convergence 4.5- 5.6 mm/yr). In this work we present a morphological characterization of the North-Gorringe rock avalanche and we evaluate its potential tsunami generation. The North Gorringe rock and debris avalanche is located in the south-eastern edge of the Tagus Abyssal Plain, at the north-eastern flank of the Gorringe Bank. This landslide, with a total surface of 378 km2, is composed by a massive rock and debris avalanche, developing for 35 km in a depth range of 2900-5100 m, for a consequent height drop of almost 2200 m. The main source area is a 7 km large 11° steep headwall scar located at a depth range of 2900-4500 m and covering a surface of almost 100 km2. The corresponding depositional area is characterized by a much lower slope (1.5°). It is composed by a proximal rock cluster area and a distal lobe totalizing a surface of 280 km2 and maximum run-out distance of 27km. Based on the interpretation of multichannel seismic profiles and interpolation of bathymetric data we estimated the volume of the North-Gorringe rock avalanche in 70-80 km3. Such landslide, generated in really deep water (at about 3000 m below sea level) and hundreds of km far from the coast, can represent a potential threat for the coastal communities. The landslide motion is simulated through the UBO-BLOCK2 code, from the University of Bologna team. The results are really interesting: the coasts of Portugal are reached by considerable waves, up to 10 m high, in around 30 minutes, and the tsunami reaches the Spanish and African coast after about 60 minutes.

ES12 - NATURAL AND INDUCED SEISMICITY DRIVEN BY FLUIDS: OBSERVATIONS AND MODELLING

ES12/P1/ID255 - LABORATORY STUDY OF TEMPORAL-SPATIAL PECULIARITIES OF MICROSEISMICITY SPREADING DUE TO PORE PRESSURE CHANGE.

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In the presented paper, results of laboratory experiments on study of relation between acoustic emission (which corresponds to microseismic emission in real scale) and change of pore pressure in a model sample under load are considered. Experiments were made with the help of laboratory setup, which consists of long rod (1060 mm in length) with rectangular cross-section (117×82.5 mm). A channel with rectangular cross-section was milled in the rod. The channel was filled by a mixture of pebbles and crushed pine rosin in proportion 1 to 3; then the sample was vertically loaded. A number of pressure and acoustic emission sensors were placed at both lateral and bottom sides of the rod. Assembled setup was vacuumized and filled by distilled water. Valves at both tips of the box were used for fluid injection (through inlet) and pore pressure release (through outlet). The experimental study showed close relation between change of pore pressure with time and variation of mean acoustic event activity. A model is suggested which describes a relation between acoustic events and pore pressure change in time. The model is based on an assumption that the events occurred when pore pressure reaches a critical value, which is distributed under some probability function. As the probability functions, Weibull distribution, Gausian error function and Log-normal distribution were considered. The comparison of AE mean activity change in time with calculation based on considered models showed that Weibull distribution is preferable. In case of pore pressure increase, the value of pore pressure defines the number of AE events; in case of pore pressure decrease, a difference between external load and pore pressure can be considered as a critical value for AE events triggering.The study showed significant change of permeability on non-stationary stage of fluid flow during both pore pressure increase and decrease. Permeability variations were calculated based on data of pore pressure change in time at several points along the sample and with the help of microseismic activity variation data. Results of permeability evaluations based on two above methods are compared with each other. It was found that permeability variation as well as resulting permeability on stationary stage can be estimated by means of microseismic activity registration.

ES12/P2/ID256 - THE RULE OF PORE PRESSURE DIFFUSION IN THE INITIATION OF INDUCED SEISMICITY AT MOSUL DAM'S LAKE

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Mosul reservoir is located in the northern part of Iraq which is characterized by moderate to high seismic activity and which had experienced strong earthquake in the past (Ayar, 1986). The dam height is 100m while the maximum capacity of the reservoir is $11x10^9$ cubic meter. Seismic activity has been noticed in the reservoir after starting filling of the lake in June 1985. Induced seismic activity has been studied at Mosul reservoir for the period March 1986 to December 1987. The earthquakes were located using the HYPO71 program written by Lee and Lahr (1972), and using a crustal velocity model for the area suggested by Al-Saigh and Toffeq (1993). More than 250 micro-earthquakes of magnitude up to 3.1 ML were observed, of which 181 were located. Nearly all earthquake epicenters were located within a radius of less than 25km from the dam site. Clusters of epicenters were observed in the eastern embankment of the lake. Most of the hypocenters were located between the ground-surface and 2km of depth. It has been found that lithology and the presence of faults were the major effecting factors on the spatial distribution of seismic events. Most of the sedimentary succession are consisting of limestone and dolomite rocks (competent strata) which have high strength and capable to sustain high stresses. Therefore it has been expected that the induced earthquakes be located within these limestone beds. Butmah Formation however is expected to make a buffer zone that does not allow pore pressure to penetrate into deeper formations. The formation composed mainly of shales (incompetent strata) which have relatively low permeability and lie at depth ranges between 2730m and 2800m. It persists throughout the area with a thickness of more than 500m. A composite fault plane solution indicates that the mechanisms of seismicity were right-lateral strike-slip faulting along N44°E with a dip of 60° NW in conformity with the local tectonics.

ES12/P3/ID257 - SEISMICITY IN CLOSE VICINITY OF MIROVO SALT DOME

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The Provadia region is located in seismically quite part of Bulgaria. The exploitation of the Mirovo salt dome, near the town of Provadia, started in 1956 using leaching method. Since 1980 several moderate earthquakes (M>4.0) occurred in this region. To improve the monitoring of the regional seismicity a local seismic network (LSN) was deployed in 1993. In 2006 the modernization of LSN Provadia was completed. The four stations of the network are equipped with digital acquisition systems, 3 component geophones and modern radio connections. One more station is working as stand-alone point of observations. In summer of 2009 a small aperture array was installed. The installed equipment and increased number of observation points permitted to screen out large number of quarry blasts and increased the accuracy of the earthquake hypocenter location. For the period 10.2006 - 12.2009 more than 150 microearthquakes close to and inside the salt dome were localized. We could distinguish events clustered along known regional faults from events at the western border of the salt stock. Some events localized inside the salt dome may have technogenic origin. The main concentration of the epicenters is one kilometer to the south-west from the salt dome. The recorded earthquakes around the salt dome are at depths up to 5 km. We observed some changes in the number of the events during the period. This might be linked to the leaching process. Twice a sequence of four events was detected in the local zone. The first event is the strongest and it is followed by weaker events that can be regarded as normal mainshock-aftershock sequence for microearthquakes. We performed an alternative localization for 21 events which are well clustered around the salt dome using HYPODD. Relocalization is done in two steps: first we had to cluster events; the second step was to minimize the travel time's differences for each station and event cluster. We observed a weak migration of the hypocenters to the north-east direction. Some of the earthquakes migrate closer to exploitation area and along the isoline 2000 m of the salt dome. Several microearthquakes were used for tests of location errors of

the small aperture seismic array comparing it with locations from the full network. The existence of the active tectonic structure in the region and the contrast boundary between the salt dome and the surrounding structures is a precondition for the higher seismic activity in the region.

ES12/P4/ID258 **– PASSIVE SEISMIC MONITORING - UNDERSTANDING AND REDUCING EVENT LOCATION UNCERTAINTIES**

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Passive seismic monitoring is now a standard tool to follow the evolution of hydrocarbon, geothermal as well as CO2 geological storage reservoirs. Despite the fact that large volumes of data have already been acquired in one of the contexts just mentioned, our understanding of the relation of the microseismicity to the hydraulic fracture geometry is still very poor. Very precise location of seismicity is the first step to better understand and delineate hydraulic fracture geometry. Among many factors that contribute to microseismic location errors, the largest contribution is due to the lack of knowledge of the wave-propagation medium. In spite of efforts to build the "best" velocity model derived from surface seismic and/or logging data, these models are very often not adapted to the microseismic context and are characterized by numerous uncertainties. Precise location of hypocenters requires a very accurate P and S velocity model, the calibration of this model is a difficult task but cannot be neglected. In addition, this required calibration/inversion of the velocities is a totally non-linear problem; taking into account this difficulty we developed a non-linear (Monte Carlo) tomographic inversion algorithm. This paper presents our non-linear calibration algorithm that updates the P and S velocity model in the context of Passive Seismic Monitoring that is with few receivers and calibration shots. Furthermore the uncertainties associated to the velocity model are computed. Two original features of our algorithm are: A new accurate Eikonal solver to compute synthetic travel times. Numerical errors of current solvers are of the same order of magnitude as the traveltime picking uncertainties, and these same errors prevent taking into account reliably polarization information. Our new forward modeling code based on the factored Eikonal equation overcomes these limitations. Most linear or non-linear tomographic inversion algorithms give a unique maximum likelihood model and no information on the resolution power of the data. Our non-linear inversion algorithm outputs all velocity models that explain the observed data within the traveltime picking uncertainties. All these inverted models are then used to build a reliable uncertainty map of the hypocenter location. The final output is an optimal velocity model to relocate all events, a posteriori uncertainties on the P and S velocity models, and most important of all, a reliable uncertainty map of hypocenter locations.

ES12/P5/ID259 **– SURFACE MICROSEISMIC: HOW DO WE KNOW IF IT WORKS FOR OIL-FIELD APPLICATIONS?**

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The use of surface sensors for the monitoring of oilfield-related microseismic activity has received considerable attention recently, primarily due to their potential for extensive fracture mapping as well as continuous reservoir monitoring. Unlike the more traditional approach of deploying tens of sensors in a borehole close to the region of activity, these surveys use hundreds or even thousands of sensors, and use migration methods to enhance the arrivals from subtle events. However, the use of surface sensors for microseismic monitoring is by no means established. Of chief concern is that signal amplitudes recorded from microearthquakes at the surface are generally much lower than the noise levels in the seismic recordings. This means that standard methods for assessing the detection threshold and accuracy of microseismic surveys, which are based on individual waveform observations, are no longer appropriate and it is necessary to explore new techniques to evaluate the efficacy of surface microseismic monitoring.

Downhole methods of microseismic event location based on arrival-time picking result in error and uncertainty that are functions of the pick errors and the sensor placement. For surface monitoring based on a migration location methodology, the uncertainty and error are functions of the frequency content of the recorded seismic energy and the network geometry. Assessment of the uncertainty is possible by analysis of a point spread operator. With both methods of event location errors in the velocity model will influence the ability of any location procedure to position sources correctly.

Traditionally event detectability is assessed by inspection of noise levels in the raw data. However, in the case of surface based studies where arrivals are generally not visible in individual traces, less direct methods are required. A very useful method of understanding detectability is to model a known source in terms of size and source mechanism then propagate this energy to the surface. The addition of a surface noise sample then allows for an estimation of the influence of noise, network geometry, source mechanism on the imaged source. Such modelling work can take place prior to the deployment of field equipment – so long as one has a reasonable estimate of environmental noise and rock emissivity.

ES12/P6/ID260 **– FEASIBILITY OF JOINT 1-D VELOCITY MODEL AND EVENT LOCATION INVERSION BY THE NEIGHBOURHOOD ALGORITHM**

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Using a set of synthetic P- and S-wave onsets, computed in 1-D medium model from sources that mimic a distribution of microseismic events induced by hydrofrac treatment to a monitoring geophone array(s), we test the possibility to invert back jointly the model and events location. We use the Neighbourhood algorithm for data inversion to account for non-linear effects of velocity model and grid search for event location. The velocity model used is composed by homogeneous layers, derived from the sonic logging. Results for the case of one and two monitoring wells are compared. These results show that the velocity model can be obtained in the case of two monitoring wells, if they have optimal relative position. The use of one monitoring well fails due to the trade-off between the velocity model and event locations.

ES12/P7/ID261 **– COMPARISON OF MICRO-EARTHQUAKE FOCAL MECHANISMS OBTAINED FROM DIFFERENT NETWORK MONITORING CONFIGURATIONS AND INVERSION METHODOLOGIES, APPLICATION TO A FRACTURING JOB**

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For several years now, passive seismic monitoring of hydraulic fracturing operations is routinely carried out to characterize the geometry of the activated zone and possibly to estimate the induced fracture(s) geometry. Such results are intended to be used for optimizing the reservoir development plan. The micro-earthquake hypocentres constitute the main attribute used to provide these results. Despite it is fundamental information, it represents only a small part of the microseismic source description. Efforts are made to deliver more from microseismic processing. The seismic moment tensor determination becomes the obvious next step since it gives additional knowledge on the rupture process and should provide valuable data for integration with geomechanics in particular. We compare the focal mechanisms of micro-earthquakes obtained from two distinct inversion methodologies and applied on a microseismic dataset acquired during a fracturing job in Argentina. Different microseismic networks were simultaneously monitoring this operation. The first technique is based on the inversion of the P-, Sv- and Sh-wave first arrival amplitudes. It is applied on the data acquired by a single vertical string of eight 3C-receivers. This array was deployed in a vertical well 250m southward from the stimulated well. The second technique is an automatic P-waveform inversion technique which is applied on the data acquired by an array of 520 vertical geophones deployed at the surface, about 1600 m above the stimulated zone, and centred on the stimulated well. So, for this specific application, limitations exist, either regarding the number of available observations, for the downhole string, or regarding the very low signal to noise ratio, for the surface array. We have been able to compare about 20 micro-earthquake moment tensors. According to the network configuration, only double-couple moment tensor solutions were considered for the downhole data processing whereas the surface processing provided full moment tensors.

ES12/P8/ID262 **– COMPARISON OF PICKING-BASED AND WAVEFORM-BASED MICRO-EARTHQUAKE LOCATIONS IN A MULTI-NETWORK MONITORING CONFIGURATION, APPLICATION TO A FRACTURING JOB**

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In order to image active faults or fractures using microseismic monitoring, the capability to detect and to correctly locate microearthquake is necessary. This may become a real challenge when the micro-earthquakes are of small magnitude (below -1.5) or/and when the monitoring network design is not optimum. This is especially the case of most fracturing operation monitoring which involves either a single down-hole monitoring string of tens of 3C-receivers or a seismic-type array of typically one thousand sensors deployed at the surface. Therefore, to minimize the effects of these acquisition limitations, an effort in the processing must be undertaken. As a consequence, we developed innovative location techniques. We compare the results of four location methods applied on a microseismic dataset acquired during a fracturing job in Argentina. Several microseismic networks were simultaneously monitoring this operation. The first three location methods are applied on the data acquired by a single vertical string of eight 3C-receivers. This array was deployed in a vertical well 250m southward from the stimulated well. These methods are: (1) the usual method based on the picking of first time arrivals and the P-wave polarization analysis, (2) a second picking based method using the S-wave polarization and (3) a three-component P and S waveform-based method using an automatic pseudo-migration algorithm. The fourth location method is applied on the data acquired by an array of 520 vertical geophones deployed at the surface, about 1600 m above the stimulated zone, and centred on the stimulated well. It is a single component waveform-based method using a waveform inversion. As a result, for the downhole processing, the picking-based method using the S-wave polarization doubled the number of located events compared to the conventional P-wave polarization method; the pseudo-migration method multiplied by ten the size of the located dataset. Hence, the reliability of the result interpretation increased with the number of located events although the fractured zone interpretation remained consistent. The surface waveform inversion processing allowed to locate as many events as the conventional P-wave polarization method, with magnitude around -2, but provided additional information consisting of the full microseismic moment tensor.

ES12/P9/ID263 - THE SWARMS 2000 AND 2008 IN WEST BOHEMIA / VOGTLAND: SEARCH FOR THE DRIVING FORCE

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The West-Bohemia/Vogtland region is well known for frequent occurrence of earthquake swarms. The results of many recent studies indicate that the pressurized crustal fluids participate in triggering and driving of the swarm activity. The recent seismic activity is concentrated in the Nový Kostel area, where a steeply dipping fault segment of an areal extent of about 40 km2 is being reactivated by a number of microearthquake swarms. The recent strongest swarms were those of 2000 and 2008. The 2000 swarm with five M_L 3+ events fade away in 2001 in few microswarms. After a short quiescence period the microswarm activity was continuously increasing and resulted in the 2008 swarm with nine M_L 3+ events. The course of the 2008 swarm resembled that of the 2000 swarm with periods of increased activity (swarm phases) and periods of relative quiescence. However, the 2008 swarm was much faster than the 2000 swarm, which was pronounced both in the shorter duration and in the larger seismic moment released during the 2008 swarm. The hypocenter cluster of the 2008 swarm overlaps by 100% the cluster of the 2000 swarm and the lateral positions of the hypocenters of the two swarms seem identical considering a location error of about 100 m. It thus appears that both swarms have activated identical or very close parallel fault planes. The migration patterns of the swarms differ partially, however both swarms show similar general trend with the first swarm phase at the bottom of the activated fault patch and the last events in the uppermost part. The analysis of the spatial distribution of seismic moment along the fault plane shows that rather than reactivation, the 2008 swarm represents a complementary seismic activity to that of the previous 2000 swarm. We applied the seismostatistics to find the interplay of stress triggering (self-organization) and fluid pressure triggering in the spatiotemporal pattrns of the two swarms. We found that similar to the 2000 swarm, also the 2008 swarm was governed by stress transfer with significant role external force, most likely nonstationary increased fluid pressure.

ES12/P10/ID264 - EARTHQUAKE SWARMS - COMPARISON BETWEEN WEST BOHEMIA AND SOUTHWEST ICELAND

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Earthquake swarm is a specific type of seismic activity during which the deformation energy is released subsequently, in a huge number of weak earthquakes that are clustered in space and time. They occur mainly in volcanic areas. Earthquake swarms without active volcanism are less common and occur mainly in the areas of enhanced crustal fluid activity. One such area is the West Bohemia/Vogtland region (WB) in the Central Europe where the activity has typical intraplate character. The second region of our interest is southwest Iceland (SWI) where some of the worldwide most intensive swarms are observed. This region is located on the Mid-Atlantic Ridge where two tectonic plates are drawing apart so the activity has an interplate character. Despite the different geological setting and evolution of both areas the driving physical processes and triggering mechanisms are assumed to be similar and closely connected to the crustal fluids inherency. Even though the earthquake rate in SWI is about ten times higher, and the maximum magnitudes of swarms one level higher than in WB, we attempt to compare specific swarms which are similar in size and time span. The statistical analysis is based on the catalogues of earthquakes recorded during the last twenty years of continuous monitoring of both areas. As regards the WB, we focus particularly on a large M_{Lmax} = 3.8 swarm of 2008, the catalog of which comprises approximately 20.000 events with the magnitude of completeness M_{Lc} = 0.5. As for the SWI, we aim above all at three swarms: Hengill of 1997, South of Hengill of 1998 and Krisuvik of 2003. The basic statistical characteristics as magnitude-frequency distribution, interevent-time distribution and space-time evolution are used for determining the swarm characteristics that are independent or vice-versa dependent on the tectonic environment.

ES12/P11/ID265 - FAULT REACTIVATION POTENTIAL OF HYDROCARBON RESERVOIRS OVERLAIN BY ROCK SALT.

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Pore pressure changes, caused either by the production of hydrocarbons from faulted reservoirs or by the injection of gas into reservoirs during CO_2-storage or underground gas storage, can be a driving mechanism for fault reactivation and related induced seismicity. Small induced earthquakes related to the production of gas from faulted reservoirs often occur in the Northern part of the Netherlands. Hydrocarbons are predominantly produced from Rotliegend sandstone reservoirs, which are often covered by a Zechstein salt caprock. The mechanical behavior of these salt rocks differs significantly from the mechanical behavior of the Rotliegend sandstone, since salt exhibits time-dependent deformation behaviour, i.e. creep. In order to be able to predict the seismic risk associated with hydrocarbon production, CO_2-storage or underground gas storage, it is crucial to understand the impact of the time-dependent creep behaviour of the salt caprock on fault stability. In this study, a simplified 3D geomechanical numerical model was constructed of a sandstone reservoir, which is intersected by a planar fault. The model was used to investigate fault reactivation potential for a reservoir overlain by rock salt with time-dependent deformation behaviour. A sensitivity analysis was carried out to quantify the effects of uncertainty in rock salt properties on fault reactivation potential. The results were compared with the results from the model for a reservoir overlain by caprock without time-dependent deformation behaviour.

ES12/P12/ID266 - SEISMIC RISK ANALYSIS OF SMALL EARTHQUAKES INDUCED BY HYDROCARBON PRODUCTION IN THE NETHERLANDS

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In the northern parts of The Netherlands, the exploitation of gas fields has induced small earthquakes. These induced earthquakes have occasionally caused damage to buildings. Since 2004, the Dutch mining

legislation requires a seismic risk analysis to be performed for new exploitation licenses. In the last few years, a new workflow to evaluate the seismic risk of the exploitation of hydrocarbon fields was developed by a group of experts, participating in the Technical Committee on Earthquakes. The workflow can be used to quantify the risks of induced earthquakes in the Netherlands. It consists of a probabilistic seismic hazard analysis, a site response analysis, and a damage analysis. Based on the geomechanical parameters and reservoir production parameters of an individual hydrocarbon field, a probability can be assigned that this field will show induced seismicity during production. For those fields that show induced seismicity, probable ground motions can be obtained from the results of the probabilistic seismic hazard analysis and site response analysis. Estimates of ground motions (in terms of peak ground velocity) can then be used to estimate the amount and extend of damage to residential buildings. So far, focus of the risk study has mainly been on ordinary residential buildings. However, part of the workflow can also be used to quantify the risks of induced seismicity for special constructions (such as dikes, power plants, pipelines, sluices).

SW4 - AMBIENT VIBRATION SEISMOLOGY

SW4/P1/ID267 - USING LENNARTZ LE-3D/5S IN HVRS ANALYSES - PRELIMINARY RESULT OF TEST

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The three-component Lennartz LE-3D/5s seismometer is widely used for microtremor measurements. Theoretically, all sensors of this seismometer have a flat response to the velocity from 0.2 Hz. The transfer function of sensors can affect the H/V curve and consecutively also its interpretation, if the parameters of the transfer function change and if these changes are not detected and taken into consideration while performing the microtremor spectral calculations. The applicability of this particular seismometer and the influence of its transfer function in HVRS analyses were verified with side-by-side measurements using two Streckeisen STS-2 broadband seismometers as references units. The investigation shows, that the HVSR curve of the LE-3D/5s system slightly differs from results obtained from both reference systems, but only at low frequencies. The LE-3D/5s seismometer can be therefore used for reliable HVRS measurements beyond 0.25 Hz without any doubt, but below this frequency the instrumental correction for all components is needed. We show that below 0.11 Hz, the self-noise of the LE-3D/5s instrument influences the results of measurements. The difference between the PSD of the instrument's self-noise and of the signal must be evaluated for any particular measurement, especially at the low frequency.

SW4/P2/ID268 - APPLICABILITY OF TROMINO INSTRUMENTS IN HVRS ANALYSES - PRELIMINARY TEST RESULTS

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Micromed TROMINO instruments are widely used for microtremor measurements. The unit includes three orthogonal electrodynamic velocity sensors, a GPS receiver, a digitizer and a recording unit with a flash memory card enclosed in a common case. The applicability of a TROMINO instrument in HVRS analyses is based on an assumption, that the transfer function of sensors does not affect the results. Side-by-side test measurements were performed using five TROMINO instruments where two Streckeisen STS2 seismometers were used as references units. The investigation shows that the HVSR curves of all TROMINO instruments differ between each other and they also differ from the H/V curves obtained from both reference systems. The results of our study also show, that the ratio of transfer function affects the error and all tested TROMINO instruments can not be used without instrumental correction in the frequency interval between 3 Hz and 8 Hz. The self-noise of the TROMINO instrument is critically high at low frequencies, this is below 3 Hz in our experiments. At the frequencies above 8 Hz, just the transduction constants of all components need to be redefined. An additional problem arises from the TROMINO's unstable internal clock when the GPS signal is unavailable: within one hour time span, the internal time differs from the reference UTC by 0.1 second. Additionally, the transfer function of TROMINO instruments need to be frequently checked.

SW4/P3/ID269 - EVALUATION OF THE 1ST AND 2ND MODE OF VIBRATION OF THE MEDIEVAL TOWER OF SONCINO (LOMBARDIA) BY AMBIENT NOISE RECORDING

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Ambient vibration techniques are nowadays a very popular tool to assess dynamic properties of buildings.Due to its non destructive character, this method is particularly valuable, especially for health monitoring of historical monuments.The present ambient vibration experiment consists on the evaluation of vibration modes of a Medieval tower. Situated in Soncino (Lombardia, close to Cremona), the tower of 41.5 meters height has been monitored by seismometers located at different points inside the structure.Spectral ratios of the recorded ambient vibrations clearly identify a fundamental mode at about 1 Hz, with a slight difference in the two horizontal components. A second mode is also evidenced at approx 4-5 Hz, with a moderate degree of uncertainty.We observed that the results obtained by the analysis of the vibration set recorded day-time are different with respect to the ones derived by the signals recorded at night.In particular both the sets allow a precise evaluation of the fundamental mode. In contrast the second mode, evident in the spectral ratios of day-time set, is difficult to assess or could lead to misinterpretation when considering the night-time set.

SW4/P4/ID270 - IMPACT OF WINDSTORMS KYRILL AND EMMA TO MICROSEISMS LEVEL AND ENVIRONMENT

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In mid-January 2007 and at the turn of February and March 2008, two extremely strong windstorms occurred, which were named Kyrill and Emma, respectively. These windstorms hit most central European countries, having brought hurricane-force winds, which caused serious damage, mostly to structures, cars and trees. Moreover, 40 fatalities were documented. For the purpose of seismological evaluation, values of microseisms measured every hour on the hour were used from the Czech seismological observatory Ostrava-Krásné Pole (OKC), where tri-axial broad-band digital seismographs Guralp CMG-3ESP are installed. The output digital data assessment focused on the determination of particle velocities, which were afterwards transposed to displacement amplitudes. Besides predominant periods and/or frequencies of long-period (secondary) microseisms observed during both windstorms were estimated as well. It was documented that the maximum amplitudes corresponding to the windstorms Kyrill and Emma reached the values of A ≈ 2 μm, and A ≈ 1.5 μm, respectively. On the other hand, their predominant periods and/or frequencies were observed almost within the same range of T ≈ 5.4-6.2 s or f ≈ 0.16-018 Hz. The spectral analysis of microseisms revealed two peaks, the first one corresponded with the abovementioned secondary microseisms, while another less distinct peak was connected with primary microseisms having periods (or frequencies) of T ≈ 12.5-16.5 s (f ≈ 0.06-0.08 Hz).As for the meteorological observations during the passage of both windstorms, only the data on wind speed, gusty winds and wind direction was available from the meteorological observatory in Ostrava-Poruba, which is situated about 1.7 km from the OKC seismic station. Other relevant meteorological data and charts for the interpretation (synoptic maps, history of origin, and the development of pressure depressions) were obtained from various professional sources. In accordance with the meteorological observations, it was concluded that the maximum wind gusts coincident with Kyrill and Emma were measured at the top of Giant Mts., namely on the Sněžka mountain, reaching 60 m/s and 47 m/s, respectively. During the passage of Kyrill over the Czech Republic, gusting winds were locally accompanied by rainfalls and, in West Bohemia, even by thunderstorms. At the same time, there were observed some changes in the direction of wind gusts before and after the arrival of both cold fronts. The comparison of windstorm effects showed that the Emma windstorm was less devastating than the Kyrill windstorm.

SW4/P5/ID271 - MICROTREMOR HVSR STUDY OF SITE EFFECTS IN THE ILIRSKA BISTRICA TOWN AREA (S SLOVENIA)

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The region of Ilirska Bistrica is one of the most seismically active areas of Slovenia, where 15 damaging earthquakes with maximum intensity equal or greater than V EMS-98 have occurred in the last one hundred years. These earthquakes have shown that strong site effects are characteristic of the parts of the town that are built on soft Pliocene clay and sand overlain by Quaternary alluvium. Since there is a lack of boreholes and geophysical and earthquake data, the microtremor horizontal-to-vertical spectral ratio (HVSR) method was applied to a 250 m dense grid of free-field measurements over an extended area and to a 200 m dense grid in the town area in order to assess the fundamental frequency of the sediments. Measurements were additionally performed in ten characteristic houses to assess the main building frequencies. The effects of wind and industrial noise on the reliability of the results were analyzed. The map of the fundamental frequencies of sediments shows a distribution in a range of 1-20 Hz. The lower frequency range (below 10 Hz) corresponds to the extent of Pliocene clays and sand overlain by alluvium, which form a small basin, and the higher frequencies to flysch rocks, but variations within short distances are considerable. The measurements inside the buildings of various heights (2-6 storeys) showed main longitudinal and transverse frequencies in the range 3.8-8.8 Hz. Since this range overlaps with the fundamental frequency range for Pliocene and Quaternary sediments (2-10 Hz), the danger of soil-structure resonance is considerable, especially in the northern part of the town. Soil-structure resonance is less probable in the central and southern part of the town, where higher free-field frequencies prevail. These observations are in agreement with the distribution of damage caused by the 1995 earthquake (M_L=4.7, I_{max}=VI EMS-98), for which a detailed damage survey data is available.

SW4/P6/ID272 - ESTIMATION OF THE GROUND COEFFICIENTS IN THE SPANISH SEISMIC CODE BY USING THE REFRACTION MICROTREMOR METHOD

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International seismic codes, as Eurocode (EC8, 2004), International Building Code (IBC, 2006) or Japanese Seismic Design Code (BCJ, 2000) establish regulations for building systems using prescriptive and performance-related provisions. Building design is defined, among other parameters, by the ground motion in the construction site and, often, these codes propose ground classifications according to the soil characteristics. In the case of the Spanish seismic code (NCSR-02), soil is classified in four different types and a ground coefficient averaged to 30 m depth (C) is defined. This factor is subsequently used for obtaining the normalized elastic response spectra.

The C factor can be estimated through the lithological column or the shear-wave velocity profile to 30 m depth. This information is usually obtained from geotechnical analyses. However, techniques based on borehole information and related geotechnical analyses are too expensive and time consuming to estimate Vs profiles in urban areas. This is the main reason why non-destructive methods are increasingly preferred for the estimation of the Vs profiles of a soil structure. Methods based on seismic noise measurements are particularly attractive from an economic point of view, as they can be relatively easily applied in urban areas and they do not require artificial seismic sources.

In this work we have conducted the refraction microtremor method (ReMi) in order to estimate the shear-wave velocity profiles at 15 sites of the province of Alicante (southeast of Spain) and subsequently the associated C values. The different sites were chosen according to the places where some geotechnical information was available, in order to compare the ground coefficient obtained by both techniques. Moreover, we have chosen different types of terrain, covering different ground coefficient values between the maximum (2) and minimum (1) C.

The study shows that the results obtained by both methods are very similar, with a standard deviation of only 0.06 in the C values. Furthemore, applying the ReMi method we can also estimate the Vs profiles, which can be relevant in the site effect analyses. Consequently, the application of the ReMi technique to the soil characterization established by the NCSR-02 code seems to be a reliable alternative.

SW4/P7/ID273 - FEASIBILITY OF VS30 FOR THE ESTIMATION OF SITE EFFECTS IN THE VEGA BAJA BASIN OF THE SEGURA RIVER (ALICANTE, SOUTHEAST SPAIN)

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The experience of recent earthquakes has manifested the importance of local geology in the amplification of ground motion and the subsequent damage effects. There is no full agreement about the most effective parameter indicative of the site amplification effects, although the most common parameter adopted worldwide, according to the National Earthquake Hazards Reduction Program (NEHRP, 1997), is the shear-wave velocity averaged to 30 m depth (Vs30).

In the present work we have applied the ReMi technique and the neighbourhood algorithm for estimating the Vs30 values. The study has been carried out along the province of Alicante (southeast of Spain), in 18 sites where borehole information was available. In this way, the results obtained through both techniques have been compared.

From the analyzed sites, we have shown that Vs30 parameter is not univocally associated with the Vs profiles, which implies that this parameter may not be a good indicator of site amplification effects. Moreover, the combined use of Vs30 with the H/V analysis may even lead to erroneous values of the sediment thickness, especially when depth to bedrock is below the 30 meters.

Therefore, for site amplification studies, we suggest that a more reliable soil classification should be based at least on the Vs profile, as it provides more consistent information about the sedimentary cover. From this information, it is possible to calculate the Vs30 parameter required by NEHRP, but also, the depth to bedrock and the soil resonance frequency. In case that the sediments-bedrock interface is unclear or even not reached by the estimated Vs profile, we furthermore suggest to carry out H/V measurements and combine both results for estimating the depth to bedrock and the soil characteristics.

SW4/P8/ID274 - ESTIMATION OF DEEP SEDIMENT CHARACTERISTICS FOR DIFFERENT URBAN AREAS OF THE ALICANTE PROVINCE (SOUTHEAST SPAIN)

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Southeast part of the Iberian Peninsula is a region of moderate seismicity with occurrence of high magnitude historical events. Bajo Segura Basin is placed in the south of Alicante province and constitutes a Neogene-Quaternary depression developed in the Betic Cordillera. Its basement is composed of limestones and marls of Mesozoic age, while the sedimentary fill comprises soft materials from the Miocene to contemporary age. This region is growing both economically and demographically, as most of coastal areas of Spain. Hence, the presence of soft soils in a seismic region where many towns and villages are placed, shows the importance of site effect studies around this area.

In the present study, we analyze ambient noise meassurements carried out in three urban areas of Bajo Segura Basin during summer of 2007, by using different array configurations with three-component sensors of 1Hz. The recorded data were analyzed by using H/V, frequency-wavenumber (F-K) and extended spatial autocorrelation (ESAC) methods. ESAC method seems to provide more reliable results in the low-frequency range, allowing a deeper sediment investigation. F-K technique let us to check the noise sources distribution, finding a nearby isotropic distribution in most of the tests. The estimation of the Vs profiles was carried out by using a genetic algorithm and the combination of the ESAC and H/V results.

The obtained results show lower resonance frequencies in inner parts of the basin, 0.4-0.5 Hz, and higher values in external areas, 1.8 Hz. Respecting to the estimated Vs profiles, similar velocities appear in all the three studied sites, but at different depth. In fact, deeper sediments are found as we move to the inner parts of the basin.

We also have used the velocity profiles to model the fundamental mode of the Rayleigh wave ellipticity curves and the S-wave site transfer functions, showing a good correlation between these curves and the experimental H/V analysis.

SW4/P9/ID275 **- MICROZONATION STUDY IN THE CITY OF DELHI (INDIA) BY AMBIENT NOISE MEASUREMENTS**

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Local site conditions, especially soft soils, substantially affect the characteristics of seismic waves and its potential to cause earthquake damage. The Delhi region in India, is an example of a region with significant sediment accumulation. From the available geotechnical information and bed rock topography, it was known that some of these sediments were soft soil, but their exact distribution and thickness was unknown.

In this work, we have carried out a microzonation study for the city of Delhi, India, combining different techniques for the characterization of the soil. Ambient noise measurements were taken at 116 sites around the city and the fundamental resonance frequencies were estimated through the H/V technique. At the same time, array measurements were also taken at three different areas of the city, where it is expected that the mean soil thickness may differ. The f-k technique was applied for obtaining the dispersion curves and the neighborhood algorithm was used for estimating the S-wave velocity profiles at each area.

Combining the information provided for both methods, we characterized the soil sediments of the city of Delhi, obtaining different zones of resonance frequency, soil thickness and mean S-wave velocity. The observed resonance frequencies vary from 0.45 to 10 Hz, showing the lower values in three pockets, in Trans Yamuna and in the northern and western regions of Delhi. With respect to the thickness of the sediments, they cover approximately from 25 to 100 m.

SW4/P10/ID276 **- MICROTREMOR HVSR STUDY FOR ASSESSING SITE EFFECTS IN THE URLA, TURKEY RELATED TO 2003 MW5.6 AND 2005 MW5.9 EARTHQUAKES**

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Urla city locates western extremity of the Gulf of Izmir, Turkey. The area is of great archaeological importance, as it contains a number of long-occupied archaeological sites that were inhabited from the prehistoric times to Byzantine era. (i.e. Modern harbour of Iskele-Liman Tepe; Karantina Island, Ionian port city of Clazomenae. Urla is also one of the most populated, tourism and cultural city in the Aegean region, Turkey. Seismically, it is surrounded by dominant strike-slip tectonic features such as Urla, Karaburun and Gulbahce faults. Hence, the region of Urla is one of the most seismically active areas of Turkey, where more than 20 damaging earthquakes with maximum intensity equal or greater than Io>=V (EMS-98) have occurred in the last 100 years. Latest activity of the zone was evidenced by the April 2003 (Mw5.6) and October 2005 (Mw5.9). According to the recent correlation between the active faults and the seismicity near the study area, the EW oriented Izmir Fault across Izmir city is not only responsible for earthquake activity in Urla, but the NS, NE-SW oriented Urla, Gulbahce and Karaburun faults are also responsible for earthquake activity in the last decade, including the 2003 and 2005 earthquakes. These earthquakes have shown that strong site effects are characteristic of the parts of the town that are built on soft sand overlain by Quaternary alluvium. Since there is a lack of boreholes, geophysical and earthquake data, the microtremor horizontal-to-vertical spectral ratio (HVSR) method was applied to a 250 m dense grid of ~200 free-field measurements over an extended area and to a 500m grid in the outer part of the town area in order to assess the fundamental frequency of the sediments. Study was performed in the following way of EU-SESAME Project. All measurements are free-field performed by Guralp CMG-6TD velocity sensor during at least 30 min. The effects of wind and artificial noise on the reliability of the results were also analyzed. The map of the fundamental frequencies of sediments shows a distribution in a range of 0.3-1.2 Hz. The lower frequency range corresponds to the extent of Pliocene clays and Quaternary sediments. The danger of soil-structure resonance is considerable, especially in the northern part of the town.

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SW4/P11/ID277 **- JOINT INVERSION OF RAYLEIGH WAVE ELLIPTICITY AND SPATIAL AUTOCORRELATION MEASUREMENTS**

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The local soil structure (notably the shear wave velocity profile) can be obtained by inversion of dispersion curves defined over a sufficiently large frequency range. However, measurements of such dispersion curves using ambient seismic vibrations require large numbers of seismometers and long measuring times.

As a simple alternative, Rayleigh wave ellipticity curves can be used to characterize the soil structure. The frequency dependence of Rayleigh wave ellipticity is tightly related to the shear wave velocity profile of the soil. Ellipticity curves can be obtained by applying RayDec, a method based on the random decrement technique (Hobiger et al., 2009), to ambient seismic noise measurements.

As different soil structures can result in the same ellipticity curve (e.g. homothetic structures in velocity and thickness), the inversion of ellipticity curves alone is ambiguous. Therefore, additional measurements fixing the shear-wave velocity of the superficial layers have to be included into the inversion process. Spatial autocorrelation curves or MASW measurements can be used for this purpose. In this way, the local soil structure can be characterized by using few sensors and short measuring times.

The method to extract the Rayleigh wave ellipticity curve will be presented and it will be shown which parts of the ellipticity curve have to be included in the inversion process. Then, the benefit of the additional spatial autocorrelation curve measurements will be demonstrated. Finally, the method will be applied to real noise data collected at well-known European accelerometric sites within the framework of the NERIES project and the results will be compared to broadband dispersion curve measurements at the same sites.

SW4/P12/ID278 **- ANALYSE OF AMBIENT NOISE DATA COLLECTED ON SEDIMENTS IN YALOVA, TURKEY**

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Ambient noise is a useful signal for investigating the effect of the subsurface geology on ground motion. The spectral ratio between the horizontal and vertical components (H/V) of noise recordings are generally used to estimate the fundamental resonance frequency of the site. We collected the ambient noise data with Guralp 6T instrument to investigate site effects in Yalova, Turkey, where occurred high damage during the August 17, 1999 Izmit earthquake. The field experiment and parameters of calculation followed the recommendations of the SESAME consortium to verify the reliability of results. The horizontal to vertical ratios have been computed for sites located on sediments with different thickness. 56 per cent of H/V curves show a clear peak, whereas 12 per cent of H/V curves do not show any peak. 32 per cent of H/V curves show unclear peaks with low amplitude. The nonappearance of clear peak on H/V curve in the region is very likely due to the local underground structure, which may not exhibit any sharp velocity contrast at any depth leading to low amplifications. Acknowledgement:This study was supported by TUBITAK under the project Nr. 109M317.

SW4/P13/ID279 **- SEISMIC NOISE IN A GEOLOGICALLY COMPLEX SITE (L'AQUILA, CENTRAL ITALY) TO FINE-TUNE THE SUBSOIL MODEL FOR SEISMIC MICROZONATION MAPPING**

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We present the fine scale investigations of seismic noise carried out in a geologically complex site at Regional Hospital of L'Aquila (central Italy). The investigations were performed within the scope of a seismic microzonazion project carried out in the area following L'Aquila earthquake (6 april 2009,

Mw: 6.3). It was coordinated by the Italian Civil Protection Department for the future urbanistic planning.

We acquired about 250 seismic recordings with a 3-component seismometer featuring a 0.05 Hz to 40 Hz passband (Lennartz LE3D-5s) and the preliminary results show a strong variability of frequencies in the case study area with values ranging between 0.8 Hz and 11 Hz.

The goals of the study are to point out the efficiency of seismic noise technique in geologically complex site by comparing those data with other geophysical investigations (active seismic techniques, gravimetric survey) and geological data (more than 60 well logs and a detailed fine scale geological mapping), to fine-tune the subsoil model (ii) and to locate the geometry of seismic and geological bedrock (iii).

SW4/P14/ID280 **- VALIDATION OF THE LOWER TAGUS VALLEY (LTV, PORTUGAL) VELOCITY MODEL USING MICROTREMOR H/V SPECTRAL RATIO**

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Along his history the Lower Tagus Valley LTV area was shaken by several earthquakes. The largest reported had their origin in the southwestern part of Iberia. These earthquakes were destructive, and some of them were produced in large ruptures of offshore structures located southwest of the Portuguese coastline; other moderates earthquakes were produced by local sources such as the 1344, 1531 and the 1909 (Benavente). In the last years, due to 3D structural model improvement and development in numerical methods and computational capacities, several studies have successful obtained strong-ground motion synthesis for the Lower Tagus region using finite difference method [1]. To confirm the velocity model of the LTV sedimentary basin obtained by geophysical and geological data, we use broad-band microtremor measurements and application of the horizontal to vertical (H/V) spectral ratio method [2]. Some seismic data collected in a profile with azimuth perpendicular to the basin axis reveals a dependence between the thickness of sediments, the frequency and the amplitude of the low frequency peaks (0.15 -1 Hz) of the H/V curve. [1] Grandin R., Borges J.F., Bezzeghoud M., Caldeira B., Carrilho F., 2007. Simulations of strong ground motion in SW Iberia for the 1969 February 28 (MS = 8.0) and the 1755 November 1 (M ~ 8.5) earthquakes – II. Strong ground motion simulations, Geophys. J. Int., Vol. 171, 2, 807-822. [2] Nakamura, Y., 1989, A method for dynamic characteristics estimations of subsurface using microtremors on the ground surface, Quarterly Report, RTRI, Japan, v. 30, p. 25-33.

WEDNESDAY 8, THURSDAY 9

SH1 - GEOLOGICAL INPUT FOR SEISMIC HAZARD ASSESSMENT: A EUROPEAN PERSPECTIVE

SH1/P1/ID1 **- CONTEMPORARY SEISMICITY OF KOSOVO**

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In this work are presented basic characteristics of the seismicity of Kosovo, for the period 1901 to 2008 with emphasis on the most active regions. In terms of seismicity the territory of Kosova is very active, characterized with local seismic sources that has generated strong earthquakes throughout history (1456, Prizren with intensity I= IX MSK-64, 1662, Peja earthquake with intensity I= VIII MSK-64 scale, 1921, earthquake affected region of Gjilan-Viti- Ferizaj with I=IX MSK-64, 1980 earthquake, in Kopaonik I=VIII scale MSK-64, and in 24 April 2002 earthquake with epicenter intensity I=VII +½ MSK-64 heavily damaged area of the Gjilan. Kosovo's. territory is also affected by the earthquakes generated from seismic sources in the border regions of the neighboring countries. The effects of the local and regional seismic activity on territory of Kosovo result in complex seismicity pattern that was studied in detail for the first time in this work. Compilation and updating of earthquake data was made in order to define an earthquake catalog for territory of Kosova, which will provide a basis for determination of the main characteristics of the seismicity of Kosova. Results of the existing investigations were a basis for defining the regional geologic, seismologic, neotectonic and seismotectonic characteristics of the area as well as definition of seismogenic sources. Obtained results will be applied for assessing seismotectonic conditions, seismic macro and micro zonation, seismic risk estimation of territory of Kosovo as well as estimation of the effect of strong earthquakes on the built environment and defining a set of consistent measures for protection and mitigation of the consequences. Also these investigations have great significance from scientific and applied aspect and will provide reliable assessment of Kosovo seismicity. Results can be used as input for further investigations in the field of seismic hazard and risk assessment and engineering seismology as well for physical and urban land use planning and design in seismic prone areas.

SH1/P2/ID2 **- THE MOST ACTIVE SEISMOGENIC ZONES IN ALBANIA DURING 2009**

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Abstract

The Albanian orogen, as the most southwestern part of the Euro-Asiatic plate, in convergence with the Adria microplate, is divided in two areas with different tectonic regimes: the external area with compressive regime, representing its offshore part and the internal area with expanding regime, representing the continental area. Albania is a country of high seismic activity. The earthquake foci during 2009 year are concentrated mostly along the active faults. On Albania and its surrounding territory, 610 earthquakes with magnitude ML >2.0 were located and 37 of them were felt by population of Albania. The epicentral distribution of earthquakes shows that: Elbasani-Dibra, Lezha-Ulqini, Durres-Kepirodonit, Borsh-Kardhiq fault zones are most active. The activity of Elbasani-Dibra transversal zone was culminated with the Earthquake of September 6, 2009, magnitude (ML = 5.4) in Gjorica village, followed from 250 localised aftershocks. This earthquake of intensity of VII degree at the epicentre caused more heavily damage in Gjorica, Qerenec villages and Shupenza municipality in Dibra district. The focal mechanism solutions show that this earthquake has been triggered from the activation of a normal fault with NE-SW direction, in conditions of an extensional tectonic regime, in the northeastern segment of Elbasani-Dibra. The earthquake of August 21, 2009, magnitude (ML = 5.0), occurred in Adriatic Sea express the increased seismic activity of the Lezha-Ulqini seismogenetic zone during 2009 year. From the focal mechanism solution results that the earthquake was triggered from pure thrust fault with an NE-SW compression stress direction. In some cases where seismic energy flux failed to discharge through these lines, the process is accompanied by reverse faults, as is that of Lezha-Ulqini area. Some increasing of seismic activity was registered at the Durresi-Kepirodonit region during 2009 where the strongest earthquake occurred on the 7th of March at 17:51 (UTC), magnitude (ML = 4.5). It is necessary to underline that Durresi-Kepirodonit fault zone is located near the Albanian Orogen front, in convergence with Adria micro plate, and for this reason compress movements here are strongest ones. On the southwestern part of Albania, in the Borshi-Kardhiq fault zone a small increase of seismic activity was presented during 2009. The strongest earthquake occurred on the 25th of March at 11:23 (UTC), magnitude (ML = 4.5).

SH1/P3/ID3 **- SEISMOTECTONIC AND SEISMIC HAZARD OF YEMEN YEMEN IS LOCATED ON THE SOUTH WESTERN CORNER, OF THE ARABIAN PLATE, NAMELY ON THE EASTERN MARGIN OF THE RED SEA AND ON THE NORTHERN MARGIN OF THE GULF OF ADEN, APPOSITE AFAR DEPRESSION . THIS CONTRIBUTION PRESENTS THE EARTHQUAKE HAZARD CALCULATIONS THAT HAVE BEEN REALIZED FOR TERRITORY OF YEMEN AND ADJACENT AREA WHICH BELONG TO AN AREA OF RELATIVELY HIGH SEISMICITY THAT EFFECTED FROM TIME TO TIME BY MODERATE EVENTS IN THE LAND ,AND WITH THE MODERATE TO STRONG EVENTS IN THE SURROUNDING SEISMOGENIC ZONES(THE RED SEA AND THE GULF OF ADEN). THE EARTHQUAKE CATALOGUE FOR YEMEN INCLUDES THREE KINDS OF OBSERVATION METHOD, BASED ON THE PERIOD OF OCCURRENCE, FROM THE HISTORICAL TO RECENT SEISMIC ACTIVITY IN BEHALF THAT WITH THE TECTONIC REGIMES, WE MIGHT DELINEATED SOME SEISMIC AREA ZONES DEPEND ON THE STATISTICAL ANALYZING FOR EACH ZONE IN BEHALF THE RECURRENCE RELATIONSHIP REGRESSION,**

THE MEAN FOCAL DEPTH AND MAXIMUM MAGNITUDE ,THE SEISMIC HAZARD ASSESSMENT WAS ESTABLISH BY USING THE POINT SEISMIC SOURCE MODEL, THE RESULT OF SEISMIC HAZARD ANALYSIS THAT USED, WAS PRESENTED IN THE MAP OF DISTRIBUTION OF THE MAXIMUM PEAK GROUND ACCELERATION AND MAXIMUM INTENSITY VALUE ON ALL YEMEN TERRITORY AND ADJUSTING REGIONS.

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SEISMOTECTONIC AND SEISMIC HAZARD OF YEMEN Abstract: Naji A. S. husain Alhetar , Chief of the geophysical department, Strong motion data analyzing (NSOC) naji_ husain@yahoo.com Yemen is located on the south western corner, of the Arabian plate, namely on the eastern margin of the Red sea and on the northern margin of the Gulf of Aden, apposite afar depression . The relative motion between tow great plates, to the north and north-east direction, in different geological stage had been appear displacement between African continent, and Arabian shield by the rift valley, which considering the weakness Zone. Recent seismic activity is well recognized and maps located after the installation of Yemen seismic stations in 1994, which gave a scientific view about the geological and tectonic phenomena in the area. Seismic hazard in different Yemeni areas still haven't an enhance research enough ; many evidence appear time to time, with new seismic and volcanic activity regions, as we observed a new volcanic eruption ,in the southern part of the red sea (mount island Tair) that would be a significant research project in the future, the present work suggest of the seismcity and seismo-tectonic depend on the investigation through the local observation, special distributions and analyzing the local earthquakes hypocenter, seismic wave travel time and focal mechanism solutions .This brief study tends to present overall assessment of the potential of earthquakes effects on the territory of Yemen and adjacent area. We shall try to introduce the simple and basic definitions for the sake of clarifying of seismicity and seism tectonic activity. ,we use the composite focal mechanism technique, to determine focal mechanism fault plane solution, for moderate and small events, These regions consider the most active seismic and volcanic sources, that due to the presence of various type of active faults systems within the shallow geothermal activity. in behalf we evaluate of possible seismic forces that might effect a structure, also we might follow either the deterministic seismic parameter sources and determine the probabilistic approach to derive the estimations design for seismic ground motion of Yemen hazard. Which depend at amount of data and site information? This contribution presents the earthquake hazard calculations that have been realized for territory of Yemen and adjacent area which belong to an area of relatively high seismicity that effected from time to time by moderate events in the land ,and with the moderate to strong events in the surrounding seismogenic zones(the Red sea and the Gulf of Aden). The earthquake catalogue for Yemen includes three kinds of observation method, based on the period of occurrence, From the historical to recent seismic activity in behalf that with the tectonic regimes, we might delineated some seismic area zones depend on the statistical analyzing for each zone in behalf the recurrence relationship regression, the mean focal depth and maximum magnitude ,The seismic hazard assessment was establish by using the point seismic source model, The result of seismic hazard analysis that used, was presented in the map of distribution of the maximum peak ground acceleration and maximum intensity value on all Yemen territory and adjusting regions.

SH1/P4/ID4 **- SEISMIC HAZARD IN CRITICAL FACILITIES FOR STABLE CONTINENTAL REGIONS OF RUSSIA**

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Some critical facilities in Russia have been investigated during last years. The critical infrastructures of Novovoronezh, Kursk, Smolensk, Kalinin and Leningrad regions are located on the East European craton. Bilibino critical infrastructure is located in the Mesozoic Verkhoyansk-Chukotka fold belt. For capable faults within the investigated territories are carried out microearthquake registration. Automatic phase pickers are designed for seismogram processing based on STA/LTA ratios jointly with polarization analysis. Neotectonic bending strain rate and the seismotectonic strain rate, which depend on the Mmax, and seismicity parameters are determined. Maximum magnitudes for all the above mentioned sites are found to be in the range 4-4.5 The intensity I of strong shaking is less than 5 balls. Three different approaches were applied in estimating target response spectrum. Generalized response spectrum was calculated based on West Europe seismic records. Parametrisation of Eurocode 8 (1998) as well as standart spectrum spectra from Russian Guideline NP-031 (2002) were used. Ground time history acceleration was synthesized on a basis of standard generalized ground spectra.

SH1/P5/ID5 **- THE 1887 EARTHQUAKE AND TSUNAMI ON THE NORTHERN LIGURIAN MARGIN (WESTERN MEDITERRANEAN)**

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Early in the morning, on the febuary 23, 1887 occurred one of the major earthquake that damaged the Italian and the French Riviera. The earthquake was followed by a tsunami wave with a maximum runup of 2 m near Imperia. At least 600 hundred peoples died mainly due to building collapses. The "Ligurian earthquake" occurred at the junction between the Southern French-Italian Alps and the Ligurian Basin which is one of the most seismically active areas among the western European countries. This zone is presently characterized by a continuous low to moderate seismic activity and a high vulnerability due to the 2.500.000 inhabitants who are presently living between Cannes and Genoa and because of the numerous industries that set here. The epicentre and the equivalent magnitude are controversial, and the fault producing the earthquake remains unknown. The recent MALISAR marine geophysical survey along the northern Ligurian margin allows identifying a large system of faults recently activated. A set of N70°E recent scarps is displayed at the foot of the northern Ligurian margin. They correspond to cumulated reverse-strike slip faulting consistent with the present-day kinematics of earthquakes. We propose that the rupture of some segments belonging to this 80 km-long Imperia faults network is the source of the 1887 Ligurian earthquake. We investigate the seismological data from the historical data bases sisfrance2008 and DBIM04 using several models of intensity attenuation and crustal structures. For focal depth of 15 and 18 km, all results are consistent with the location offshore provide an offshore epicentre around 43.70-43.78N and 7.81-8.07E with a magnitude Mw in the range of 6.3-7.5 and a preferred magnitude of 6.5-6.7. Taking into account the complexity of the seismotectonic setting and the few data on the earthquake, several interpretations are plausible. Using the tide gauge record of Genoa harbour and the FUNWAVE tsunami propagation and runup/inundation model, we expect that the hydrodynamic information (here the simulated tsunamis for the different scenarii) may provide us with some information on the 1887 rupture characteristics. The initial wave is computed through Okada (1985)'s dislocation model. Rupture characteristics proposed in our scenarii like the fault geometry, the focal depth, the epicenter location, the amount of slip are input in the model and an initial tsunami wave is generated along with its inner properties (characteristic initial wave length and period, initial trough and peak amplitudes). The results allow us to identify the most coherent scenario.

SH1/P6/ID6 **- UP-DATING MAP OF POTENTIALLY ACTIVE FAULTS IN FRANCE ASSOCIATED WITH A NEW DATABASE**

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The characterization of the earthquake sources and of the ground motions that they may produce are two necessary steps for seismic hazard assessment. Concerning the earthquake sources, it is necessary to define their geometry, their geological history and, if possible, their tectonic strain rate accumulation. This task is particularly important in the vicinity of critical facilities. To this aim, the IRSN launched a project to up-date the seismotectonic map of France performed by Grellet et al. (1993) using the current knowledge of potentially active faults. The new version of the seismotectonic map will include segment line redrawing of each potentially active fault system at a scale of 1/250,000, derived from geological maps, Digital Elevation Models, aerial photographs and specific publications. A GIS structure will be provided, compatible with an easy data share in an interactive environment

such as the widely used software Google Earth. This map will be associated with a relational database describing the state of knowledge on each fault segment. This database is composed of several thematic tables linked together by an identification key (attributed to each cartographic structure):
- The "fault attributes" table contains all the available information on the recent tectonics (i.e. age, kinematics, geometry, neotectonic evidences) as well as the historical and instrumental earthquakes (current tectonics) that might have occurred on the fault system;
- The "bibliographic references" table lists the most relevant publications to characterize the active fault system;
- The "neotectonic and paleo-earthquake evidences" table includes all neotectonic evidences reported in the national NEOPAL database (www.neopal.net);
- The "historical earthquake database" table includes all historical earthquakes parameters according to the national database SISFRANCE (www.sisfrance.net);
- The "fault activity" table provides our evaluation of uncertainty about the fault activity. In addition, each potentially active fault system on the map will be linked to a synthesis detailing its characteristics with complete bibliographic references, the idea being to provide all the information to allow external experts to make their own opinion about fault activity. The first step of this project consisted to define the strategy and database architecture which is now applied to the Provence Alpes-Cote d'Azur and Brittany regions. By the end of 2010, the map should encompass East of France and Brittany.

SH1/P7/ID7 - THE DATABASE OF INDIVIDUAL SEISMOGENIC SOURCES, DISS 3.1.1: NEW TWISTS AND TURNS

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The Database of Individual Seismogenic Sources (DISS) was conceived at the end of the 1990s by a group of scientists at Istituto Nazionale di Geofisica e Vulcanologia. The database was designed to host data about seismogenic source models intended to serve as geological input for ground-shaking SHA applications and was continuously updated since then. In 2005 there was a big turn in this process as we launched a new version of the database (DISS 3) which augmented the database with two innovative categories. The first, now named "Composite Seismogenic Source", was intended to overcome the inherent difficulties in identifying fault segment boundaries. The second, named "Debated Seismogenic Source", was devised to host tectonic information about active faults that have been proposed in the literature as potential seismogenic sources but are not fully parameterized or are considered to be not reliable or have been deprecated by subsequent work. In 2005 the database was first made available to the public through a specifically designed web-based GIS application. This new database is now being widely used in various branches of ground-shaking SHA practice and tsunami hazard. The main strength of this database is that it stores fault parameters in a native 3D and flexible conceptual model. Lately, we also developed strategies to make it testable with independent data under a number of different tectonic and seismic hypotheses.

During the years, DISS brought together a large amount of published and original data on Italian seismogenic sources having a potential for a magnitude 5.5+ earthquake and is now being extended to the rest of the Euro-Mediterranean area.

We present highlights on the identification and characterization of new seismogenic sources in three key-areas in Italy, namely Lombardia/Veneto (Southern Alps), Adriatic Sea, and Abruzzo/Molise (central Apennines). These new sources describe youthful structures of the Alpine south-verging contractional system, the external fold-and-thrust system in the Adriatic offshore, and the extensional domain of the inner central Apennines.

SH4 - SITE EFFECTS AND THEIR EFFECTS ON THE UNCERTAINTIES ON GROUND MOTION PREDICTION EQUATIONS

SH4/P1/ID8 - SITE EFFECT ESTIMATION THROUGH SITE CHARACTERIZATION FROM AMBIENT NOISE RECORDINGS, EUROSEIS-TEST (VOLVI, GREECE)

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Site effect assessment is an important step in seismic risk mitigation. There is therefore a drastic need for cost-effective proxies to site effects estimates. In that context, a new promising approach was proposed, using the time-average velocity over the top z meters with z varying form 5, 10, 20 and 30 meters (Vsz) and the fundamental resonance frequency (f_0) as a two-parameters characterization of a site. Then to assess site effect, a Site Amplification Prediction Equation, SAPE, completely defined by these two parameters was build-up based on Japanese data from the KiK-Net network. Thus it remains to be validated using other dataset. For that aim the EUROSEIS-test data is a suitable one. The EUROSEIS-test is a sedimentary basin in northern-Greece that has been thoroughly investigated through grants from the European Commission, mainly to study site effects. Fourteen accelerometric stations have been installed since 1995, that to date recorded more than 100 events. After a review of the main available information over the EUROSEIS-test, we end up with a poor Vs description for some of the accelerometric stations. Thus eight accelerometric stations were selected for noise array measurements surveys to provide more details information about Vsz and f_0 parameters. The noise array technique has been proposed some decades ago but its development is still in progress, particularly regarding the inversion step. Different approaches (Savvaidis el al. 2009, Renalier et al. 2009) were tested in this study to provide Vsz. These two inversion strategies provide comparable Vsz for z equals to 10, 20 and 30 meters. With the resulting Vsz and f_0 from noise analysis, a validation-test of the so-called SAPE was realized. The results of such a comparison are encouraging and indicate as well limitations of the SAPE approach. It is a promising tool for engineering and seismic risk management.

SH4/P2/ID9 - EXPERIMENAL VALIDATION OF AN IDENTIFICATION PROCEDURE OF SOIL PROFILE CHARACTERESTICS FROM FREE FIELD ACCLEROMETER RECORDS

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We present in this paper, an experimental validation of a new approach for identifying soil profile characteristics by fitting the theoretical amplification functions of sites to those obtained experimentally. The comparison of identified characteristics with those obtained by in situ and laboratory tests shows a very good agreement. The present approach which makes use of system identification and free field records is based, firstly, on a formulation of a theoretical soil amplification function for two sites in terms of the different parameters of the layers constituting the soil profiles (thickness, damping ratio, shear wave velocity and unit weight). Then, this function is smoothed with analogous function obtained from experimental data (spectral ratios) by using the least squares minimization technique. The identification of the parameters is performed by solving, numerically, a non linear optimisation problem. The numerical efficiency and the validity of this procedure have been demonstrated in previous works. In this approach, soil profile characteristics of two sites can be identified, simultaneously, from only a single soil acceleration record at free surface of each site without need of bed rock or outcropping acceleration records. Strong ground motions data recorded during the Boumerdes earthquake of May 21, 2003 are used for validation.

SH4/P3/ID10 - MODELLING 3D SEISMIC WAVE PROPOGATION IN MARMARA REGION

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Modelling seismic wave propagation becomes a progressive tool to investigate the influence of structural properties of the crust with recent advances in development of complex three-dimensional earth models and their requirements in computational power. The main objective of this study is to apply this approach for the investigation of the wave propogation around the Marmara Sea (Turkey) and in particular for Istanbul identified as one of the megacities with the highest seismic risk in the world. The wave propogation is first implimented using a simple crustal model with horizontally layered structure. The frequency-wavenumber method is used at this initial stage to generate this generic model. The model is then refined into a 3D structure using an integrated geologic/seismic model for Marmara Sea and surrounding region. The wave propogation at this stage is implemented using Finite Difference (FD) code, which is called WPP, running on parallel processing

environment. In this framework, we have simulated a small earthquake of mag□4.0 occured in Marmara Sea and recorded at stations nearby. Observed waveforms are compared to synthetic seismograms computed with the frequency-wavenumber and WPP method and differences are interpreted. Additionally, strong ground motion recordings of the same earthquake are studied in order to form a basis for understanding wave propagation in small basins in metropolitan area of Istanbul using 3D velocity model. In this content, we have investigated that if sediment-filled basins significantly amplify the wave amplitude and represented the requirement of the consideration of 3D propogation path and site effects.

SH4/P4/ID11 **- COUPLIG NETWEEN DISCRETE ELEMENT METHOD AND SPECTRAL FINITE ELEMENT METHOD. CONVENTIONAL AND NON-LINEAR TESTS.**

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The code Mka3D [1] is initially a code of mechanics using the Discrete Element Method and taking into account non-linear phenomena, as the rupture under shock and impact. This approach can be also used in other domains, in particular the seismic survey, but the consideration of non-linearity, (which entails an important calculation time) is not necessary generally during the treatment of the wave-propagation. So,we have chosen to couple this Discrete Element Method develeopped in the Mka3D code with a Spectral Element method [2]. This Spectral Element method is often used to simulate waves propagation and is «less» expensive in times of calculation.

For the first validations in 2D in the seismic domain, we have resumed the cases-tests of Lamb and Garvin, which are conventional ones often used to measure the precision of a numerical method un the elastic waves-propagation.

Non-linear tests have also been resumed with the Euro-Seistest located in the epicentral area of June 20th 1978 Thessaloniki earthquake (Ms 6,5).

The valley lies between the lakes of Volvi and Langada.

We present 2D calculations including realistic geometry and rheologic layers and also signals of 3 different amplitudes ollowing to model nin-linear effects.

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SH4/P5/ID12 **- HVSR METHOD SENSITIVITY INVESTIGATION FOR THE CORSSA ARRAY IN W. CORINTH GULF (GREECE)**

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The Aegion area located in the western part of the Gulf of Corinth, one of the most seismically active areas in Greece, was selected as target area for the EU funded project CORSEIS. Within the framework of this project the Corinth Soft Soil Array (CORSSA) an array of surface and down-hole accelerometers was installed in the hanging wall of the Aegion Fault, a normal type tectonic feature crossing the city of Aegion. The array consists of four 3D down-hole accelerometers and an additional one at the surface. The deepest of the sensors is installed in a conglomerate formation at 178m depth while the remaining three sensors are located within fluviodeltaic marine deposits at depths of 60, 30 and 14 meters. Detailed geophysical, geological and geotechnical surveys carried out during the CORSEIS project have provided the necessary parameters for the definition of the geological structure and dynamic soil properties at the installation site. The array remains in operation after the completion of the project providing valuable acceleration records.

The ability of the horizontal-to-vertical spectral ratio (HVSR) method to provide credible estimates of amplification properties of soil layers has been debated ever since its original introduction in 1989, although the method is nowadays widely used in microzonation studies. The issues raised are mainly related to the interpretation of the actual HVSR measurements and in particular whether these can be used only as an indicator of the resonant frequency or the interpretation can be extended so that the amplitudes can be considered as representing amplification spectra at the measured site. In the present study amplification phenomena at the various depths and site characteristics of the CORSSA array are investigated using the horizontal-to-vertical spectral ratio HVSR calculated for the recorded events. In addition, the theoretical HVSR are modeled by taking into account the available geotechnical and geophysical characteristics of the CORSSA site soil profile and compared with the observed ones in order to test the accuracy and sensitivity of the geotechnical model and verify the amplification factors obtained from the analysis of the recorded data.

SH4/P6/ID13 **- COMPARISON OF FREQUENCY AND TIME DOMAIN OBJECTIVE FUNCTIONS FOR THE INVERSION OF THE SOIL STRUCTURE OF A BOREHOLE STATION**

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The assessment of local site effects on seismic ground motions is of great significance in earthquake engineering. With the construction of borehole stations, several inversions techniques and objective functions have been developed in order to determinate the shear-wave velocity and the damping factors from available data. Using a genetic algorithm technique to inverse the problem, this paper compares the use of frequency and time domain objective functions to evaluate the "distance" between observation and theory.A common objective function is the computation of the integrated residuals between an observed spectral ratio taken on the S-wave portion of a seismogram and the one computed theoretically. The shortcoming of this process is not the objective function itself, but the use of a cosine tapered window to smooth to zero both ends of the seismogram in order to compute the Fast Fourier Transform. This paper shows that the length of the window slightly affects the location of the resonant peaks along the frequency axis, and can greatly affect the height of the peaks and consequently can skew the inversion of the S-wave velocity or damping factors.An alternative to this process has been introduced where the objective function is defined as the normalized cross-correlation between observed data and synthetics previously decomposed in the wavelet domain. This process has been proven to perform well; however, the cross-correlation and the wavelet decomposition might increase the computation time of the inversion.Consequently, this paper introduces a simple time domain objective function and compares the results obtained with the common frequency domain objective function.

SH4/P7/ID14 **- DIFFERENCES BETWEEN ANALYTICALLY DEFINED ACCELERATION RESPONSE SPECTRA AND DESIGN SPECTRA INFERRED FROM THE ISRAELI SEISMIC CODE**

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Seismic wave amplification in soft deposits has contributed to damage and loss of life in a number of earthquakes in the recent past. The resonant periods of urban structures are often close to those of the soft layers upon which many towns are built. Thus, reliable assessment of the frequency dependent site amplification effect is very important for safe design of buildings. In most National Building Codes, including the recently updated Israeli Standard (SI 413), amplification factors short period F_a and long period F_v ground motions are defined as a function of the site class which is based solely on geotechnical parameters of the upper 30 m of the soil profile, as quantified by the average shear wave velocity $V_{s,30}$.

Over the years, we have conducted site investigations in thousands of sites across Israel, including more than 30 towns. These investigations demonstrated the usefulness of using the horizontal-to-vertical (H/V) spectral ratios from ambient noise measurements to identify sites with high amplification effects and to determine their resonance frequencies. Sites exhibited H/V peak amplitudes ranging from 2 to 8 in the frequency range 0.3-14 Hz. These results suggested great variations of the thickness and shear wave velocity in the sedimentary column. For many sites, the H/V spectral ratios show two significant peaks appearing at different frequencies. These are associated with two reflection layers formed by high seismic impedance. This empirical information is correlated with other geological, geotechnical and geophysical data to construct

a reliable 1-D multilayer soil column model for each site. Many sites are characterized by having a seismic reflection layer located within a depth of 80 to 300 m. We used the information about the subsurface to calculate the uniform hazard (10% exceedence in 50 years), site specific acceleration response for structures with 5% damping. Computations are made using the SEEH procedure -Stochastic Estimation of the Earthquake Hazard developed by Shapira and van Eck [Natural Hazard 8, 201-215, (1993)]. In addition, accelerograms of earthquakes occurring in Europe and in the USA and recorded on hard-rock sites were used to synthesize site specific time histories and corresponding acceleration response spectra. The amplification factors thus obtained showed that the factors F_a and F_v, which are copied from the US standards and are based on $V_{s,30}$ disagree with analytically obtaind values using either the SEEH or real accelerograms and consequently, should not be implemented in the Israeli building code.

SH4/P8/ID15 **- SITE EFFECT ASSESSMENT IN BISHKEK (KYRGYZSTAN) USING EARTHQUAKE AND NOISE RECORDING DATA**

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Kyrgyzstan, which is located in the collision zone between the Eurasian and Indo-Australian lithosphere plates, is prone to large earthquakes as shown by its historical seismicity. Hence, an increase in knowledge and awareness of local authorities and decision makers of the possible consequence of a large earthquake is mandatory to mitigate the effects of an earthquake and can only be based on improved seismic hazard assessments and realistic earthquake risk scenarios. To this regard, the Cross-Border Natural Disaster Prevention in Central Asia (CASCADE) project financed by the German Federal Foreign Office aimed at the installation of a cross-border seismological and strong motion network in Central Asia and at triggering microzonation activities for the capitals of Kyrgyzstan, Uzbekistan, Kazakhstan, Tajikistan and Turkmenistan. During the first phase of the project, a temporary seismological network of 19 stations was installed in the city of Bishkek, the capital of Kyrgyzstan. Moreover, noise recordings were collected by means of nearly 200 single station noise measurements as well as in array configuration. In this study, we analyse the earthquake and noise data. A broad band amplification (starting at low frequencies) is shown by the Standard spectral ratio (SSR) results of the stations located within the basin. The reliability of the observed low frequency amplification was validated through a time-frequency analysis of the seismograms opportunely de-noised. Discrepancies between Horizontal-to-vertical spectral ratio (HVSR) and SSR results are due to large amplification of the vertical component of ground motion, probably due to the effect of converted waves. The single station noise results, once their reliability was verified by the comparison with the earthquake data, have been used to produce the first fundamental resonance frequency map for Bishkek.

SH4/P9/ID16 **- SOIL HAZARD CHARACTERIZATION FOR ASSESSING SEISMIC RISK OF STRATEGIC BUILDINGS AT A REGIONAL LEVEL**

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In assessments at a territorial level, the estimation of the severity of the ground shaking has a limited usefulness, unless the local conditions of subsoil and the vulnerability of buildings become also known. The identification of the most damageable buildings, taking also into account the effects of local seismic amplification, and of the dynamic behaviour of the site-building system, seems to be the most correct and rational way to follow. In the work the authors present the multidisciplinary approach adopted within the project ASSESS aimed at defining the strategy of intervention for the seismic risk mitigation of the schools of the Friuli Venezia Giulia Region (NE Italy). In particular, an innovative methodology for characterizing the soil hazard, referring to areas with homogeneous amplification factor and spectral shape, is here presented.

SH4/P10/ID17 **- IN SITU BOREHOLE MEASUREMENTS IN BUCHAREST, ROMANIA AS A TOOL FOR ASSESSMENT OF THE SEISMIC SITE EFFECTS**

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Within the NATO Science for Peace Project 981882 *"Site-effect analyses for the earthquake-endangered metropolis Bucharest, Romania"* we obtain a unique, homogeneous dataset of seismic, soil-mechanic and elastodynamic parameters. Ten 50 m deep boreholes are drilled in the metropolitan area of Bucharest in order to obtain cores for dynamic tests and vertical seismic profiles for an updated microzonation map related to earthquake wave amplification. The boreholes are placed near former or existing seismic station sites to allow a direct comparison and calibration of the borehole data with actual seismological measurements. A database is assembled which contains P- and S-wave velocity, density, geotechnical parameters measured at rock samples and geological characteristics for each sedimentary layer. All the V_{s-30} computed values belong to type C of soil after this classification (Romanian Code for the seismic design for buildings - P100-1/2006). Approximately 250 samples were gathered from the 10 drill sites. These samples were mostly not disturbed (samples as they were recovered from the tube of the drilling rig) and partly disturbed (those which had no proper consistency). The geotechnical laboratory analysis consists in the following parts: geological identification of the sample, identification of the sample after the ternary diagram, percentage of clay – dust - fine sand - medium sand - big sand - gravel, density mineral skeleton, particle percent with diameter d<2μm, plastic limit determination, tests of compression - settling, triaxial (dynamic) test and resonant column tests. Results obtained by the downhole method in the 10 boreholes drilled in Bucharest City as well as from laboratory measurements are used as input data in the program SHAKE2000.

SH4/P11/ID18 **- ESTIMATION OF TOPOGRAPHIC AMPLIFICATIONS AND IMPLICATIONS FOR GROUND-MOTION PREDICTION: THE CASE OF NARNI (CENTRAL ITALY)**

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Within the project "Italian Strong Motion Database", promoted in the period 2007-2009 by the Italian Civil Protection (DPC) and National Institute for Geophysics and Vulcanology (INGV), the Narni ridge (central Italy) was selected as site with possible site amplification effects due to topographic irregularities. A dense velocimetric network was installed from March to September 2009 in Narni, a village on the top of a limestone 220-m-high ridge, which is characterized by slopes ranging from 22° to 35°. To investigate amplification without and with a reference site, three stations were installed at the base of the hill and seven on the top. The seismic array recorded 706 earthquakes with M_L 1.5-5.3, was collected. The great amount of data are related to the April 2009 L'Aquila sequence. Site amplifications related to the morphological features were investigated computing Standard Spectral Ratio (SSR) and Horizontal to Vertical spectral ratio (HVSR). With the aim to recognize dependence of amplification on the morphological features, directional spectral analyses were also performed. The results coming from SSR and HVSR allow us to assess seismic amplification for frequencies ranging between 3 and 5 Hz for all stations installed on the crest: in particular, the SSR curves show amplification factors up to 4.5. Moreover the highest amplification (almost double) were observed when the SSRs are computed are computed along direction perpendicular to the main elongation of the ridge. Finally, considering a subset of events with epicentral distance up to 30 km (M_L up to 3.6), test-empirical ground motion prediction equations (EGMPE) were calibrated for maximum horizontal peak ground acceleration (PGA) and acceleration response spectra (SA, 5% damping) up to 1s. These EGMPEs were carried out with the only one scope to evaluate site-corrective coefficients for topographic amplification. The regression analyses show that, for the stations installed on the crest, the corrective coefficients ranging between 0.35 and 0.48 (decimal logharitm) for the SA ordinates between 0.2 s and 0.3 s.

SH4/P12/ID19 **- MULTI-METHOD CHARACTERIZATION OF A FRENCH-PYRENEAN VALLEY NEAR LOURDES: A MIX OF SUCCESSFUL RESULTS AND INCOHERENCES**

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France is considered as a country of moderate seismicity. At the historical time scale however, it experienced destructive events with human fatalities, in particular in Lourdes and Bagnères-de-Bigorre in central Pyrenees. For this reason, a seismological experiment supported by the French Accelerometric Network (RAP) and the «Earthquake Plan» (2005-2010) of the French governement was performed in Bagnères-de-Bigorre, Pyrenees. This choice has been motivated by the proximity to seismic sources, and by the simple geometry of the valley, which is nearly rectilinear. In order to evaluate the response to seismic excitations, a temporary network of 10 accelerometric stations with continuous recording has been set up during two years along and across the valley. The network recorded about 80 events with magnitudes up to 5.0. The data have been processed for classical methods such as H/Href -the spectral ratio between horizontal components measured at a soft site, and at a reference station located on rock, respectively-. In addition the partition ratio between horizontal and vertical kinetic energies (H/V) has been studied. This ratio stabilizes in the coda of the largest events, which is interpreted as a sign of equipartition. The analyses of earthquake data were complemented with H/V measurements in noise records. MASW experiments have been conducted at the sites of the stations. The dispersion curves obtained from phase velocity and ellipticity measurements have been processed to derive 1D velocity profiles down to about 100 m. These profiles have been used for the numerical modelling of the H/V ratio of noise and coda records, based on the calculations of synthetic seismograms excited by random sources. The 3D response of the valley to seismic excitations has also been modelled numerically using the spectral element method, which allows us to evaluate the relative contributions of the topography and sedimentary filling, respectively. This study reveals a good consistency of the results obtained from S-wave analysis and coda analysis, and a satisfactory modelling of the H/V noise ratio from the 1D structure. The 3D- numerical modelling clearly shows amplification effects due to wave interferences at the edges of the valley. The observed variations of spectral ratios across the valley are well explained by taking into account the low-velocity sedimentary fillings. In contrast, the numerical analysis did not reveal any significant effect of the topography.

SH4/P13/ID20 - LOCAL EFFECTS INDUCED BY CRUSTAL SEISMOGENIC ZONE OF FAGARAS-CAMPULUNG, ROMANIA

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Seismic hazard in Romania is believed to be dominated by the Vrancea intermediate-depth events. In the same time, at local scale the hazard generated by the superficial sources can not be neglected especially in Fagaras-Campulung seismic area where at least once per century are reported effects of VIII+ and/or IX MSK. In order to mitigate the seismic risk of the vulnerable man-made structures (bridges, large dams), we are investigating the local effects at certain sites in this mountainous area. The aim of this paper is to evaluate the seismic effects induced in the local structure of the Fagaras-Campulung area. A complex geotectonic and physical-lithological analysis has been carried out for the area of interest, which has the geographical limits between 45.0 – 46.00 North latitude and 24.00 - 25.80 East longitude. Seismicity of the area is presented with a history of seismic activity, majority of events are 2-3 M_W but there are also some greater ones (28 seismic events with magnitude greater than 3.9 M_W took place between years 1517-2008). Also is presented the hypocentral distribution of seismic events function of depths, where the majority of sources (~ 1070) are at depths no more than 20km. We present the epicenters distribution on a topographic surface, together with focal mechanisms of the events. As a consequence, three seismic scenarios are taken into account to evaluate the expected accelerations and local soil response for Fagaras-Campulung zone. There are presented accelerations and response spectra (with 3 damping 5%, 10% and 20%) at Campulung-Muscel bedrock. Nonlinear effects induced by significant deformations need a certain approximated method – linear equivalent - for a multistratified zone as we considered for the Fagaras-Campulung superficial areas. Therefore important nonlinear variations of shear modulus and damping functions with state of strain during earthquakes were evidenced in superficial soils. The obtained response spectra (with 3 different damping values) and the transfer functions of the superficial layers shows important amplifications at the studied sites. All these give us a very complete image of the local effects influence on the seismic hazard in Fagaras-Campulung zone. Therefore, these results could be considered to design large structures in the studied area. Acknowledgements This work has been done in the frame of the National Research Program PNCDI II contract no.31036/2007.

SH4/P14/ID21 - INVESTIGATION OF SITE AMPLIFICATION AT AEGION, GREECE, USING EMPIRICAL SPECTRAL RATIOS ON VARIOUS PARTS OF WEAK MOTION SIGNALS FROM A BOREHOLE ARRAY

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This paper aims at studying site effects on seismic ground response through spectral ratios calculated on an extensive dataset of weak motion records, focusing on the effect of the time windows chosen for the signal analysis. The site chosen is Aegion, which is located on the Southern shore of the Gulf of Corinth, one of the most highly seismic regions in Europe. We study the northern part of the city, where a basin filled with deposits begins, extending across the Gulf to its Northern shore. The CORinth Soft Soil Array, or CORSSA, was installed in 2002 near the edge of this basin. It is a downhole array consisting of 5 accelerometers, one at the surface and four at various depths: 14, 31, 57 and 178 m. The sediments there have a thickness of around 150 m and are underlain by a stiff conglomerate. The deepest station lies within the conglomerate and is used as reference. Between 2002 and 2008, a large number of small earthquakes were recorded by the array. Among these, 473 events were selected; these were well recorded at all stations and identified in earthquake catalogues. This weak motion dataset is used to calculate empirical spectral ratios at all stations installed in soil, using the horizontal-to-vertical (HVSR) technique and the standard (SSR) technique with respect to the station at depth. We investigate the effect of window choice in spectral ratios for specific time windows: the entire signal, an S window, an 'early coda' (mainly surface wave) window and a 'late coda' (mainly coda) window. The coda windows are not chosen in the usual rigorous way, but this does not affect results greatly. As expected from the classic definition of coda waves, the two coda definitions yield similar results for both horizontal components. During the S-window, a striking difference between radial and transverse component takes place over the resonant frequency (for which the coda wave analysis provides an average). The vertical component is also amplified (but obviously at a higher frequency), at a similar level as the horizontals at deep stations and less nearer to the surface; this difference is more prominent for the S-window than for the coda windows. We find that all techniques used can identify the main features of site effects, while the time window chosen affects specific characteristics of the transfer functions. Similar investigations have been made before but rarely with such a large dataset.

SH4/P15/ID22 - NEAR FAULT EARTHQUAKE GROUND MOTION SIMULATIONS IN THE SANTIAGO DE CHILE BASIN BASED ON A SHEAR-WAVE VELOCITY MODEL DERIVED FROM AMBIENT NOISE MEASUREMENTS

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It is well recognized that during a seismic event, soil site effects are generally responsible for a large spatial variability in the ground shaking. This effect is particularly evident in the case of complex three-dimensional alluvial structures, where the coupling between the mechanical properties

contrast and the shape of the bedrock-soft soil interface, tend to amplify the spatial variability of the motion. In this contribution we present the experimental studies and the 3D numerical simulations recently performed within the area of Santiago de Chile to characterize its seismic response. Measurements of seismic noise at 146 sites have been carried out in the Northern part of the town, first to determine the fundamental resonance frequency of the sites and then to invert the horizontal-to-vertical (H/V) spectra individually, considering additional geological and geophysical information as constraints, for estimating local S-wave velocity profiles. The resulting 3D model was derived for a 26 km x 12 km area by interpolation between the single S-wave velocity profiles and shows good agreement with the few existing velocity profiles but images the entire area as well as deeper parts of the basin. Using the highly variable S-wave velocity-depth gradient and including notable high-resolution surface and bedrock topography of the investigated area, we simulated 3D near fault seismic wave propagation by means of a spectral element code GeoELSE. For the scenario events, we focused on the San Ramón fault, a multi-kilometric frontal thrust, crossing the eastern outskirts of the city. A conservative estimate of the rupture with well-constrained hypocenters down to 15 km depth under the Principal Cordillera yields events of magnitude Mw 6.9 to Mw 7.4. Our results indicate that peak ground velocity can vary significantly on small scale due to both site and topographic effects, hence allowing to identify, for seismic hazard assessment studies, areas that are most prone to large amplification of earthquake ground motion.

SH4/P16/ID23 – VS30 AND EARTHQUAKE DAMAGE: SOME COMPARISONS IN YALOVA CITY, TURKEY

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Local amplification caused by soils up to 30 meters is an important factor in destructive earthquake motion. The geology of the sites is characterized by very large Quaternary deposits, Tertiary Yalakdere and Kilic formation. Quaternary deposits consist of stratified materials having varied grain sizes, and derived from the various geological units in the vicinity. From the available records of the boreholes drilled in different locations throughout the study area, it is evident that the groundwater table is generally very shallow. In the first phase of this study, to obtain Vs30 values of soils are carried out by geophysical(MASW and MAM) measurements for 100+ sites. After the dispersion curves obtained, Vs-depth sections for 30 meters are estimates each sites. Vs30 map of the region are constructed. All results are evaluated in integrated form with earthquake damage caused by 1999 Golcuk earthquake. This study are supported by Istanbul University Research Fund (YADOP-4145)

SH4/P17/ID24 – ESTIMATION OF SITE EFFECTS BASED ON GEOLOGICAL AND GEOTECHNICAL INFORMATION – EXAMPLES FROM LISBON

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Due to the importance of local geological conditions on ground motion amplification, several studies have been developed aiming the estimation of site effects in the city of Lisbon. The first published work regarding 1D theoretical approach for the microzonation of Lisbon was based on an empirical evaluation of the physical and geotechnical parameters which were estimated from the few available experimental tests and from specialized literature.In the present days there is a considerable amount of relevant geological and geotechnical studies performed by several private companies and national institutions. However, the information is sparse and these studies are very heterogeneous, regarding methodology and regarding its notation. Furthermore, they present considerable heterogeneity regarding their geographic distribution. In the framework of the project GeoSIS_Lx - A Geoscientific Information System for Lisbon Geotechnical Data Management, the collected data was homogenized and assembled on a geoscientific GIS supported data-base in order to generate a 3D geological model of Lisbon. Based on this model several soil profiles were selected in order to cover the different geological and geotechnical Lisbon's environment. Local site effects were estimated using different approaches (including non-linear 1D theoretical modelling), for the areas where enough information exist. When not available, S-wave velocities were estimated from the correlation with geotechnical data, for the different geological layers. In order to quantify the potential site effects, theoretical simulation was compared with noise measurements analysis performed on different sites inside the town. The results will be used for site classification and for VS30 estimation. Some examples will be presented in this work.

SH4/P18/ID25 – BENEFITS OF A STATISTICAL SPECTRAL RATIO APPROACH FOR 3D TOPOGRAPHIC SITE EFFECT ASSESSMENT

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The amplification of the ground motion due to surface topography is of great concern for the seismic risk characterization of mountainous areas. However the quantitative prediction of an amplification factor in the right waveband is still a challenge to the research community. Despite numerous studies performed on this problematic, no common agreement exists about the method to use and large discrepancies remain between observed and computed cases.The traditional site-to-reference spectral ratio method is widely used to compute the amplification factor. This method is fast and does not require a high number of stations. But it also needs the description of a reference site, considered as not affected by a site effect. As a consequence each study has its own reference point, chosen as adequate as possible in the considered area, but this choice prevents any comparison between different experiments.In order to improve the quantitative evaluation of the topographic site effect, we suggest following the statistical spectral ratio approach presented by Wilson and Pavlis (2000). The reference becomes a generalized ground motion that can be considered as the median ground motion in mountainous areas.We compare the two interpretations of a numerical case issued from the site-to-reference and statistical approaches. We demonstrate the variability of the site-to-reference spectral ratio results due to the variability of the possible choices for a reference site; while results from the statistical method remain stable whatever is the number of stations. This statistical approach also has the benefit to greatly simplify the choice of a reference. As an application, we show the sensitivity of the amplification factor to the 3D aspect of the topography, to the steepness of the hills and to the source location. The source variability is the next statistical dimension we want to add to the topographic site effect assessment: a high amount of calculations with changing sources was processed at the GENCI – IDRIS facilities in order to explore that question.We employ two methods (finite-difference and finite-element) to insure the reliability of the results especially when high frequencies (up to 10 Hz) are considered.Our computations are conducted from the digitalization of the inter-Disciplinary Underground Science and Technology Laboratory (LSBB, France, http://lsbb.oca.eu) real topography. The LSBB facilities help to improve the possibility of comparison between real and calculated seismic data: a permanent seismic array is deployed and a 3D model is currently elaborated from a seismic imaging experiment.

SH4/P19/ID26 – LOCAL SITE INVESTIGATIONS USING AMBIENT NOISE IN NORTH GREAT CAIRO, EGYPT

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LOCAL SITE INVESTIGATIONS USING AMBIENT NOISE IN NORTH GREAT CAIRO, EGYPT H. EL-KHASHAB[1], A. HASSOUP[2], EL-SAYED FERGANY2 AND KHALED OMAR[2] ABSTRACT We evaluated the local site effect and phase velocity structure based on the microtremor measurements at 101 sites in Qalyoub town in north Great Cairo Province. The seismograph recorder, which consists of Trillium 120 seismometer and Taurus Portable recording unit, was operated for about 30 minutes at each site. The observed raw data were subjected to filtering process before calculating the fundamental frequency and amplification of each site based on application of H/V technique. On the mean time the portable seismograph array observation was carried out to determine the phase velocity structure in the area. The array configuration including 4 seismograph stations with 200 m spacing was employed in determination of the phase velocity structure by applying the SPAC method. The results of H/V and The SPAC were correlated with the geology of this area and giving a good agreement. Key

wards: Qalyoub, H/V and SPAC methods, site investigation 1- Geology department, faculty of science, Sohag University, Sohag.2- National research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt.

SH4/P20/ID27 - THE EFFECTS OF GEOLOGICAL IRREGULARITIES ON SITE AMPLIFICATION DURING APRIL 6, 2009 L'AQUILA EARTHQUAKE

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The site response during the L'Aquila (2009) earthquake was investigated using seven acceleration stations in L'Aquila City, Italy. The site amplification function was calculated as a shear wave spectral ratio of the horizontal to the vertical components at each site. The observed amplification functions reveal different peak frequencies and amplification values compared to the theoretical prediction using 1D soil model with S-logging data investigated. There are two peak frequencies with low amplifications that are split around the predicted 1D peak frequencies. The 2D effect of a valley located in the vicinity of L'Aquila City (scales in tens of meters) was examined to find possible explanation for the observed amplification functions. Furthermore, the 2D effect of a small-scale valley was numerically examined using the finite element FLIP program. The results of the numerical analysis indicate that the site amplification characteristics in the high frequency range could be influenced by the 2D effect of a small-scale valley, which is a consequence of the coupling between two shear waves propagating with different velocities in close proximity to the valley and plain boundary. The outcome provides an observed evidence for shear wave coupling due to a small-scale geological irregularities, and shows its influence on site amplification characteristics, especially for the high frequency range (>1 Hz).

SH4/P21/ID28 - SITE EFFECTS PRODUCED BY A BURRIED SOFT LAYER: NATURAL PASSIVE CONTROL OF THE SURFACE GROUND MOTION

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The Belleplaine test site, located in the Guadeloupe island (French Lesser Antilles) is made of a 3 accelerometers vertical array, designed for liquefaction study. The geotechnical characteristics of the Belleplaine test site is made of a mangrove layer overlaid by a sandy stiff deposit. This configuration is widely found at the border-coast of the Caribbean regions, exposed to high seismic hazard. The seismic response of the soil column is computed using three methods: the spectral ratio method from the vertical array data, numerical method using the geotechnical properties of the soil column and operative modal analysis method (Frequency Domain Decomposition). We show that the buried mangrove layer plays the role of an isolation system equivalent to those usually employed in earthquake engineering for reducing the seismic shear forces and by reducing the internal stress within the structure. In our case, the flexibility of the mangrove layer reduces the distortion and the stress in the sandy upper layer, and then the potential of liquefaction of the site,. As for earthquake engineering practice, the variability of the ground motion due to the source and propagation of waves is also reduced by controlling the maximum amplification.

SH4/P22/ID29 - INVESTIGATION THE RELATIONSHIP BETWEEN HORIZONTAL TO VERTICAL SPECTRAL RATIO (H/V) AND SHEAR WAVE VELOCITY (VS30) USING FUZZY CLUSTERING METHOD

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Because site effect has an important role in seismic researches, several methods have been suggested to acquire site parameters. Since the pioneering work of Nakamura in 1989, the single-station technique of horizontal to vertical spectral ratio (H/V) has gained the interest of many researchers because of its simplicity and efficiency in estimating the local site conditions. As there is not a clear quantitative relationship between the physical parameters of site conditions like shear wave velocity and the characteristics of the H/V spectral ratio, high level of uncertainty is the major drawback of this method. In this paper, the existence of such relationship is intended to investigate through studying 1062 strong motion acceleration time histories of earthquakes occurred between 1975 and 2008 in Iranian Plateau. These time histories have been recorded in 86 stations of Iranian Strong Motion Network (ISMN). The records are corrected by the use of wavelet de-noising method, which is capable of cancelling out the non-stationary noise. As a result, it is possible to persuade the relationship between Vs30 of the stations and general characteristics of H/V spectral ratios of the corresponding records. In this paper, the presence of a logical relationship between the characteristic parameters of H/V spectral ratios and Vs30 is examined by the use of fuzzy clustering technique. Cluster analysis is based on partitioning a collection of data points into a number of subgroups, here different site classes, where the objects inside a cluster show a certain degree of closeness or similarity. In fuzzy clustering, the data points can belong to more than one cluster, and associated with each of the points are membership grades which indicate the degree to which the data points belong to the different clusters. As a result, fuzzy clustering methods are more suitable for cases where the boundaries between different classes are not crisp. In the way of examining the relationship between shear wave velocity and spectral parametes in a site, a clustering algorithm is performed among Vs30- amplitude and Vs30-dominant period pairs of the H/V ratios. The results of clustering analysis revealed the high level of uncertainty involved in relationship between Vs30 and spectral parameters.

SH4/P23/ID30 - NEAR-SURFACE TOMOGRAPHY PROTOCOL ESTIMATION TO CHARACTERIZE HETEROGENEITIES AT HECTOMETRIC SCALE IN A FRACTURED-POROUS LIMESTONE FOR COUPLED TOPOGRAPHIC AND GEOLOGICAL SITE EFFECT ASSESSMENT

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Obtaining comparable observed and computed site amplification factors on topographies remains a difficult process, as this effect is high-frequency and can be affected by small scales underground features. Therefore 3D realistic models are more and more necessary. However obtaining high resolution images of the on-shore geological features at hectometric scale is still a major challenge of geophysics because of the extreme variability of the near-surface.A 500 m x 800 m tomographic P-wave velocity image is inferred from a ground level-to-gallery vertical seismic experiment conducted at the inter-Disciplinary Underground Science and Technology Laboratory (LSBB, France, http://lsbb.oca.eu). 94 shots on the surface were recorded by a line of 189 seismometers on the topographic surface and by a line of 150 geophones in the 800 m long, 250-500 m depth gallery.Geological and petrophysical interpretation of rock properties is presented within the fractured-porous carbonate platform surrounding the laboratory. The P-wave velocities obtained after first-arrival travel time inversion display a relatively large set of values in 4000-6000 m/s range. Such seismic velocity variations correlate well with the 5 to 20% porosity variations between the geological units. The main units consist of two sedimentary facies affected by a complex cemented fault zone. The final tomographic image shows local seismic heterogeneities as evidence of perturbations from that fault zone.Taking advantage of the known geology of the site, this study explores the influence of the acquisition geometry and of the near-surface weathered zone onto the shallow tomography resolution ability. Considering the mesoscopic scale of the targeted medium, reliable imaging of hectometric geological features with 10% contrasts in porosities can be achieved only with the simultaneous association of 1) a high density of sources and receivers in the monitoring array geometry, and 2) the consideration of the surface-to-surface first-arrival travel times as an essential constraint to correctly image the underlying structures. We are able to image 50-m wide geological features down to 500 m below the surface at the LSBB. Our imaging also shows the wide range of seismic velocities in such a small space and features that are able to affect the frequency content of the seismic signal. However a higher resolution is necessary for calculating seismic waves crossing this medium up to 20 Hz. Small scale seismic imaging of the on-shore topographic surface is the next step to elaborate high-frequency 3D realistic models for the characterization of coupled topographic and geological site effects.

SH4/P24/ID31 - EXPERIMENTAL VS. THEORETICAL BASEROCK TO SURFACE TRANSFER FUNCTIONS AT DESSEL, BELGIUM

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At a planned site for the disposal of low- and intermediate-level radioactive waste in Dessel, Belgium, the bedrock (Cretaceous and Palaeocene limestone) is covered by 585 m of Tertiary sediments. We determined the transfer function between Cretaceous baserock and the surface with two independent methods. The theoretical transfer function was modelled using a 1-D reflectivity method based on geotechnical parameters measured in a borehole at the site (shear-wave velocity) or extrapolated from other boreholes in northern Belgium (density and shear-wave quality factor). The experimental transfer function was calculated from a combination of different types of well-recorded events including local earthquakes, induced earthquakes and explosions, regional earthquakes and not too distant teleseismic earthquakes, using SH waves recorded at the surface and in a borehole at 702 m depth in Cretaceous limestone (considered here as baserock). Their FFT spectra were smoothed and truncated to the significant frequency range where the earthquake spectra were well above the spectra of the noise before the arrival of the events. The surface-to-borehole ratio of these spectra is the experimental transfer function. The median and 84th percentile over all the events yield significant results between 0.02 and 19 Hz. After correction for the surface noise using the quality factor or the noise spectral ratio, the resulting experimental transfer function was found to be comparable to the theoretical transfer function.

SH4/P25/ID32 - A SEISMIC SITE RESPONSE SURVEY OF THE MALTESE ISLANDS

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The Maltese Islands in the Central Mediterranean are composed of a simple 5-layer sedimentary sequence of Oligocene - Miocene age. The sequence is highly disturbed by syn-sedimentary to recent faulting, and the islands are characterised by a variety of outcropping rock types and underlying lithology. The seismic history of the Maltese islands includes a number of earthquakes in which serious building damage was experienced, the maximum intensity being of EMS98 VII - VIII in 1693. A correspondence is observed between building damage and areas underlain by soft clay layers, for example, but a seismic risk assessment of the islands that takes into account such site effects has never been attempted. Since the last damaging earthquake, the building density has increased dramatically, and the building footprint extended to regions of diverse lithologies, while general building practices have not undergone any upgrade in standards. In this study, an extensive ambient noise survey of the two major islands (Malta and Gozo), utilising the Nakamura method, has been undertaken, covering all outcrop types and major morphological features. Clear correlations between geology, topography and response frequency / amplitude are observed and their implications in the light of building vulnerabilty and seismic risk discussed.The Maltese Islands in theCentral Mediterranean are composed of a simple 5-layer sedimentary sequence of Oligocene - Miocene age. The sequence is highly disturbed by syn-sedimentary to recent faulting, and the islands are characterised by a variety of outcropping rock types and underlying lithology. The seismic history of the Maltese islands includes a number of earthquakes in which serious building damage was experienced, the maximum intensity being of EMS98 VII - VIII in 1693. A correspondence is observed between building damage and areas underlain by soft clay layers, for example, but a seismic risk assessment of the islands that takes into account such site effects has never been attempted. Since the last damaging earthquake, the building density has increased dramatically, and the building footprint extended to regions of diverse lithologies, while general building practices have not undergone any upgrade in standards. In this study, an extensive ambient noise survey of the two major islands (Malta and Gozo), utilising the Nakamura method, has been undertaken, covering all outcrop types and major morphological features. Clear correlations between geology, topography and response frequency / amplitude are observed and their implications in the light of building vulnerabilty and seismic risk discussed.

SH4/P26/ID33 - HVSR USING MICROTREMORS IN THE DETERMINATION OF SURFACE AND SUBSURFACE STRUCTURE OF KASTELLI-KISSAMOU (NORTHWESTERN CRETE, GREECE) AND PALEOHORA BASINS (SOUTHWESTERN CRETE, GREECE)

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HVSR using microtremors is conducted for surface and subsurface seismic ground response characterization of Kastelli-Kissamou and Paleohora basins that possess an important role in seismic hazards assessment estimation of the studied areas. The dense microtremor data set of ninety-six and forty-five recordings is selected with the means of Cityshark-II station connected with a Lennartz (LE-3D/5s). One amplified clear HVSR peak, two amplified HVSR peaks, broad and flat or low amplitude HVSR peaks that attribute the effects of surface and subsurface structure on seismic ground motion are identified. The effects of thick and thin alluvial deposits, fault zones, lateral heterogeneities/discontinuities on seismic ground motion are determined using HVSR technique. The higher ground amplification level is observed in Paleohora (A=5.7) compared to Kastelli (A=3.5). Seismic ground response classification based on the seismic ground vulnerability Greek code (EC8) is presented for the investigated areas. Spatial distribution of similar characteristics delineates large scale fault zones that might be active. HVSR reveals five and four major fault zones crosscutting the densely urban areas in Kastelli-Kissamou and Paleohora basins. HVSR using microtremors perpendicular and parallel to ground truthed fault zones verifies the validity of the applied technique in fault determination. The experimental HVSR research outcomes in fault determination are cross-correlated from ground thruthing geological field survey suggesting the validity of HVSR and microtremors for surface and subsurface characterization. Geological ground truthed field survey revealed a complex tectonic structure characterized of fault system zones crosscutting the populated areas. Geological evidence from the Kastelli-Kissamou region reveals numerous 12-15 active faults, dominantly occupying a sector between NNE and NNW. Geological ground truthed survey in Paleohora suggests that it is the most remarkable peninsula that originates from breaking of the coastline by NNE-SSW-striking left-oblique extensional faults, traced for several kilometres inland. The faults segment the E-W coastline which is itself bounded by a continuous large scale E-W fault which is one of a series of E-W faults that occur at intervals up to several kilometres inland that posses an important role in the earthquake hazards estimation of the area. HVSR using microtremor survey was correlated with geological field investigations and indicated the continuation of previously mapped faults as well as revealing previously unreported faults.

SH4/P27/ID34 - SITE EFFECTS AND GROUND MOTION PREDICTION IN THE MYGDONIAN BASIN – VERIFICATION OF THE 3D NUMERICAL METHODS

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The Mygdonian basin (Greece) has been a subject of extensive geophysical and geotechnical investigations for more than two decades because its structure and regional and local earthquake activity provide a valuable opportunity to investigate site effects of earthquakes and test methods for ground motion prediction.A new detailed 3D model of the basin (5 km wide, 15 km long, with maximum sediment thickness 400 m and minimum S-wave velocity 200 m/s) as well as recordings of local earthquakes by the Euroseistest instruments provide a reasonable basis for the verification and validation of the numerical methods.We present the results of the verification phase of the E2VP project for 3D numerical methods. Numerical-modeling teams from Europe, Japan and USA employ the finite-difference method (FDM), finite-element method (FEM), global pseudospectral method (GPSM), spectral-element method (SEM), discrete-element method (DEM) and discontinuous Galerkin method (DGM).The problem configurations include elastic and viscoelastic rheologies,

basin models built from smooth velocity gradients or composed of three homogeneous layers, one hypothetical event and six local events with magnitude between 3 and 5. Numerical predictions for frequencies up to 4 Hz are compared using quantitative time-frequency envelope and phase goodness-of-fit criteria computed at 288 receivers. Solutions are also compared with respect to rheology, geometry of the interface and source parameters, and their representations in the computational models. In particular, it is shown that the agreement between numerical predictions of ground motion duration strongly depends on the ability of each method to model accurately the surface waves diffracted off the basin edges and propagating within the basin.

SH4/P28/ID35 - VALIDATION TESTS FOR NON LINEAR SITE AMPLIFICATION FACTORS TO BE IMPLEMENTED IN SHAKEMAP®

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A set of non linear relationships between the stratigraphic amplification factor (S_s) and peak ground acceleration (PGA) at bedrock (ar) was produced to be implemented in Shakemap®.

The relationships represent a data-set of pairs (S_s, ar) referred to the sites selected in the Italian accelerometric archive and previously sorted according to the EC8-NTC2008 prescriptions about soil classes. The data-set contains pairs obtained by:comparing the site and reference-site records de-convolution of records at sites where the subsoil is adequately characterized1D seismic response analysis performed on «virtual» stratigraphic profiles, consistent with the EC8-NTC2008 site classification, and subjected to accelerograms recorded at different Italian sites.The relationship between Ss and ar is expressed by a stepwise function obtained by meaning the data included in different range of PGA considered.

A series of test have been performed to validate the results and Shakemap® has been used to generate the PGA distribution associated to the 23.XI.1980 Irpinia earthquake (MW 6.9). The residuals of the generated values have been analyzed.

The 23.XI.1980 event has been chosen due to the detailed characterization of the closer station's sites that allow to back figure the accelerograms at bedrock by a 1D numerical deconvolution of the record. In this way, it has been possible to use two data-set: one containing the observed horizontal PGA (i.e. the surface recorded values), a second made by the deconvolved values, assumed to be the PGA distribution observable in case of bedrock outcropping motion.

Sensitivity analysis had been performed to find the best setup, aiming to isolate the influence of the site corrections.

The test 1a and 1b have been run without site corrections; a distribution of values of PGA have been produced with all stations (1a) and removing one station at time (2a), revealing the capability of the algorithm to generate values of PGA consistent with the real values. The role of the attenuation law and the geographical distribution of the real stations has been underlined plotting the residuals on real values.

The test 2a and 2b repeat the previous ones introducing site corrections. A comparison has been done on the residuals produced by performing the test 2a and 2b with other two sets of amplification factors: the first has been proposed by Barani et al (2008) and the second one is currently used in italian shakemap implementation.

SH4/P29/ID36 - SITE EFFECT CHARACTERIZATION OF THE ULAANBAATAR BASIN: AMPLIFIED FREQUENCIES AND CHANGE IN THE SIGNAL DURATION BASED ON WEAK MOTION RECORDS.

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The hazard of the capital of Mongolia is related to several active faults at less the 20 km that could produce events with magnitude 7 and more and that are associated with microseismicity since 2005 (See Munkhuu and al and Schlupp and al abstract, ESC2010). Moreover, the Ulaanbaatar city, were 1/3 of the population of Mongolia lies, is built on a sedimentary basin of less than 100 thick. The aim of this work is then to quantify the site effect due to the basin. In this analysis, microtremors data recorded at 100 sites have been used. Additionally, we recorded 63 events, weak motion measurements, at 32 sites. We applied 1) horizontal to vertical (H/V) spectral ratio of microtremors and events as well as 2) ratio of site with respect to reference site of the horizontal spectra of earthquake motion. In the analysis we found that HV ratio has amplitude variation due to noise level and it's azimuths. Also we construct a first 3D Ulaanbaatar basin model using available cross-section, borehole and geophysical data. To investigate the velocity structure of the basin, an array measurement has been conducted. . This velocity structure is the first one estimated in the region, which is necessary for numerical simulation of site effect due to basin. 1D and 2D simulation were performed using base on the 3D basin model and compared these results with HV and SSR results. One of less studied field in site effect estimation is the signal duration extension due to a sedimentary basin. Several methods have been applied based on Arias Intensity, time-frequency analysis and group delay time to estimate the signal duration extension in the basin. . We observed up to now, using the weak motion data available in the Ulaanbaatar basin that the main increases of duration motion is due to the amplification factor itself. The extrapolation of these data to strong motion will be discussed.

SH4/P30/ID37 - BUILDING A VS,30 DATABASE FOR ADDRESSING SITE EFFECTS

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The inclusion of site-specific conditions in a regional sense is important to adequately represent the seismic hazard in Seismic Hazard Maps. Measuring and mapping shear-wave velocity (VS), in particular, its average over the first thirty meters (Vs,30) is becoming the standard approach to evaluate near surface site conditions for ground motion amplification and liquefaction. The Vs,30 parameter is used for the identification of ground types in recent building codes and is the main parameter used to take into account the influence of local ground conditions on the seismic action. The project Site Condition Evaluation for National Seismic Hazard Estimation (SCENE) aims at gathering subsurface geophysical, geotechnical, and geological information of the Portuguese territory and at acquiring geotechnical and geophysical data to characterize near-surface-soil conditions and shear-wave velocity profiles where strong-motion instruments are deployed. These data will serve to make the characterization of strong-motion sites and to develop a database relating near-surface lithology and shear-wave profiles for the upper 30 meters that will allow the inclusion of first-order site effects in regional seismic hazard maps. We present the first results towards the construction of a national GIS database of geological units and corresponding shear-wave velocity. This database is being built, in a first stage, by gathering available disperse subsurface geophysical, geotechnical and geological performed for specific purposes. We compare Vs,30 values directly measured, with estimates from commonly used proxies like surface geology from geologic maps, geological analogy, and correlations with topographic slope to evaluate the uncertainty involved in each of these approaches.

SH4/P31/ID38 - DERIVATION OF VS30 FROM DISPERSION CURVE: SKIPPING THE INVERSION STEP?

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In the framework of the EU-NERIES project, 20 sites among all European strong motion sites in Italy, Greece, Turkey and France were selected to be representative of most common soil classes, and for which shear-wave velocities from borehole measurements (cross-hole and down-hole tests) are available. Passive (array noise) and active experiments have been carried out at these sites in order to evaluate the ability of surface waves technique to provide reliable estimates of shear-wave velocity profiles. In order to stay cheap and feasible, active seismic experiments involving 24 geophones and hammer source were carried out at all sites. Data were processed by using the MASW technique and Rayleigh and Love waves dispersion curves were retrieved from 5-10 Hz to 30-50 Hz. Passive array experiments were also performed by using 8 seismological stations linked with wireless connections and monitored with near real-time processing.

Combining up to four different arrays with aperture ranging from 10 m and to 900 m, Rayleigh and Love waves dispersion curves were derived over a broad frequency range (from 0.5 Hz up to 45 Hz) by using the FK and MSPAC techniques. At about 75% sites, dispersion curves from ambient vibration and MASW are in good agreement over the overlapping frequency band. The other 25% sites correspond to complex geometrical site structures. Whatever the site, passive experiments are shown to be very suitable to retrieve accurate estimates of phase velocities at high frequency (over 20-30 Hz). This experiment also clearly outlined the limited penetration depth (comprised between 15 and 25 m) of the MASW technique. Inversion of dispersion curves to derive shear-wave profiles and EC8 site class (which is mainly based on Vs30) is a difficult and highly debated issue. Here we test an alternative to get average shear-wave profiles and especially Vs30 from the dispersion curves only. For these 20 sites, we show that site classes may be estimated directly from the dispersion curves. Theses results are confirmed by an extensive study involving about 800 velocity profiles from real sites.

SH4/P32/ID39 **- VARIABILITY IN SEISMIC SITE EFFECT RESPONSE OF A LANDSLIDE: RESULTS FROM A ONE-YEAR MONITORING OF THE UTIKU LANDSLIDE (NORTH ISLAND, NEW-ZEALAND)**

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A seismic network was installed for 14 months to monitor the re-activated deep-seated landslide of Utiku (North Island, New-Zealand). As since 1964 this landslide caused subsidence to the main Wellington-Auckland highway and more seriously to the railway, it is thoroughly instrumented and monitored nowadays. Boreholes and permanent GPS measurements acquired for surveillance purposes notably showed that its thickness varies from 70 m to less than 20 m, while its velocity can reach more than 2 m /year in the most active zone. All the studies conducted on this landslide also suggest that its dynamics is mainly controlled by rainfall and has not been affected by earthquakes until now, despite being located in a moderate to active seismic zone. Like other similar landslides, it is however important to assess potential seismic site effects generated by the disturbed material. During the seismic monitoring, thousands of earthquakes have been recorded displaying a large variability in magnitude, distance and back-azimuths. It permitted a thorough study on site effect response variability of such 3D objects. The network of five broadband (30s – 40 Hz) seismic stations recorded ambient vibrations as well as thousand of earthquakes over a period of 14 months from November 2008 to January 2010. Here, we present a comparison of spectral amplification analyses derived from the classical ambient seismic noise ratio (H/V), from a near seismic excitation (train) and from a large set of earthquakes measurements (spectral ratio). We study the variability of this amplification along the landslide: from the monitoring stations and also from seismic noise measurements performed along the landslide. A comparison with boreholes inclinometers measurements first show that small scale variations of landslide thickness control spatial variation of seismic site amplification, both in amplitudes (from 6 to 10) and frequency (1D fundamental frequency from 1.6 to 4.3 Hz). We also measured a large anisotropy in amplification of horizontal components, which are not correlated with surface topography.

SD3 - REAL TIME WAVEFORMS AND SHAKEMAPS.

SD3/P1/ID40 **- A NEW GEOSTATISTICAL METHOD TO ESTIMATE THE GROUND MOTION PARAMETERS**

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A rational and rigorous methodology for the interpolation of measured ground motion from discrete array stations is developed. The methodology has the potential of being used in shakemap applications for bias adjustment. Limited number of accelerometers or difficulty of monitoring at unreachable locations often has a negative impact on the generation of the maps of shaking after an earthquake. This gap in information needs to be filled through the estimation provided by the observed records. The presented methodology estimates properly-correlated earthquake ground motion parameters; herein peak ground acceleration (PGA), at an arbitrary set of closely-spaced points, in a way that is statistically compatible with known or prescribed ground motion parameters at other locations. The observed data recorded by strong motion stations of Istanbul Earthquake Rapid Response System are used for the development and validation of the new numerical method.

SD3/P2/ID41 **- MODELLING THE FINITE SOURCE EFFECTS IN SHAKEMAP THROUGH SYNTHETIC SEISMOGRAMS: TESTS ON THE 2009 M=6.3 L'AQUILA EARTHQUAKE**

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On April 6, 2009 a strong earthquake with Mw=6.3 occurred in L'Aquila area (central Italy) causing many human losses and large damages on infrastructures and buildings. ShakeMaps were generated few minutes after the earthquake occurrence but the lack of near field data combined to the ignorance about the finite source parameters took to large uncertainties on ground motion estimates and macroseismic field in area closer to the epicenter. To overcome such situation that could be very common in absence of recorded data in the near field or in case of gaps in data transmission, we aim to generate fast and reliable ShakeMaps integrating the recorded data with synthetic seismograms generated including the main source effects. To be effective the procedure requires a fast estimation of the main features of the finite fault and a quick computation of the synthetic seismograms. In our study we estimate a rough slip model and the directivity of the rupture process by teleseismic body wave inversion. The finite fault parameters are then used to compute synthetic seismograms for near field receivers placed on a grid or on sites of missing stations; peak ground motion parameters (PGA, PGV and SA) are extracted and the ShakeMaps are generated integrating real data and computed ones. The comparison of the ShakeMap computed for L'Aquila earthquake using real and synthetic data with those ones obtained after several hours from the event, when all the recorded data were available, evidences that our approach is promising and that the use of synthetic seismograms can ameliorate the ShakeMaps when near field data are not available.

SD3/P3/ID42 **- AN INVESTIGATION OF VARIOUS DEFINITIONS OF INSTRUMENTAL SEISMIC INTENSITY, WITH APPLICATION TO THE CHARACTERIZATION OF STRONG VRANCEA EARTHQUAKES**

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The paper presents a comparative assessment of a number of definitions of instrumental seismic intensity, based on the analysis of ground motions recorded during the 1977, 1986 and 1990 strong Vrancea seismic events (M_w>=6.4). Two frequency dependent intensities, proposed earlier by Dr. Horea Sandi, are considered. The first, the intensity based on destructiveness spectrum, $i_d(\varphi)$, is calculated basically by the integration of the square values of spectral acceleration and is calibrated to match the values of macroseismic intensity scales. The second, the spectrum-based intensity, $i_s(\varphi)$, is calculated from the product between the absolute spectral acceleration and the absolute spectral velocity. Furthermore, these intensities are averaged on characteristic frequency bands, in order to better account for the frequency contents of analyzed ground motions. In addition, global intensities as I_S (defined as the product between the effective peak ground acceleration and a modified expression of the effective peak ground velocity) and I_A (based on an Arias-type intensity) are calculated. A particular focus is placed upon the spatial variation of seismic intensity for each event. Results are compared and correlated with previous studies on Vrancea earthquakes, with information provided by other ground motion parameters and with data on actual damage caused by the analyzed earthquakes.

SD3/P4/ID43 **- PYRENEAN CROSS-BORDER SHAKE MAP: TECHNICAL AND SCIENTIFIC CHALLENGE**

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One of the main scopes of the SISPyr Interreg

IVa project is to implement a NRT Pyrenean Shake map. Do this cross-border Shakemap presents both technical and scientific challenges.

The technical challenge is having Near Real Time (NRT) Peak Ground Motion (PGM) and macroseismic data from the two border sides and to process them in NRT too.

A sharing agreement was signed and 50 stations continuous waveforms will be shared NRT. This will be done by a server that will storage temporary continuous waveforms, and will allow to extract them NRT. These NRT waveforms will be processed in order to compute the PGM parameters and trigger the Shake map process.

For the macroseismic data, sharing conventions will be proposed during next months, with SISPyr and non-SISPyr agencies, in order to share automatic or non-automatic interpreted data, in a common ftp. This data will allow improving the Shakemaps, especially no-NRT Shakemaps.

An automatic localization by one of the project agencies will trigger the first shake map (NRT). After this first NRT shake map 2 more automatic generated maps will be done 1-3h and 12-24h after the earthquake. This shake map will incorporate all the available PGM data and more macroseismic data (automatic interpreted).

The shake map process will be done by a regional adaptation of the USGS ShakeMap v3.5 software.

The scientific challenge is to define the proper physical parameters relationship for the Pyrenees. Past data have been collected to define the better relationships. For the PGM data around 1.800 M≥3 (3 components) Pyrenean accelerometric records and 120 M≥4 BB Pyrenean records have been collected and the PGM values computed. For the macroseismic data more than 7.000 MDPs from the two border sides are being collected.

With this data proper Intensity Prediction Equation (IPE), Ground Motion Prediction Equation (GMPE) and Intensity versus PGM (IvsPGM) relations have to be defined:

For the M<5.5 IPE, GMPE and IvsPGM definition, different approaches are being investigated. As a first approach, a complete residuals study (including the *Scherbaum, 2004* method) is being done for all the data and a broad list of relationships.

The last main issue for the Shakemap generation is to determine the amplification due to the site effects. For doing this, a geology simplification done for the SISPyr project will be used in order to obtain different soil classes and assign different amplification to each of them using existing Pyrenean data.

SD3/P5/ID44 - TESTING THE IMPROVEMENT OF SHAKEMAPS USING FINITE-FAULT MODELS AND SYNTHETIC SEISMOGRAMS

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ShakeMap package uses empirical ground motion prediction equations (GMPEs) to estimate the ground motion where recorded data are not available. Recorded and estimated values are then interpolated in order to produce a shaking map associated to the considered event. Anyway GMPEs account only for average characteristics of source and wave propagation processes. Within the framework of the DPC-INGV S3 project (2007-09), we evaluate whether the inclusion of directivity effects in GMPEs (companion paper Spagnuolo et al., 2010) or the use of synthetic seismograms from finite-fault rupture models may improve the ShakeMap evaluation. An advantage of using simulated motions from kinematic rupture models is that source effects, as rupture directivity, are directly included in the synthetics. This is particularly interesting in Italy where the regional GMPEs, based on a few number of near-source records for moderate-to-large earthquakes, are not reliable for estimating ground motion in the vicinity of the source.

In this work we investigated how and if the synthetic seismograms generated with finite-fault models can be used in place of (or in addition to) GMPEs within the ShakeMap methodology. We assumed a description of the rupture model with gradually increasing details, from a simple point source to a kinematic rupture history obtained from inversion of strong-motion data. According to the available information synthetic seismograms are calculated with methods that account for the different degree of approximation in source properties.

We chose the M_w 6.9 2008 Iwate-Miyagi (Japan) earthquake as a case study. This earthquake has been recorded by a very large number of stations and the corresponding ShakeMap relies almost totally on the recorded ground motions. Starting from this ideal case, we removed a number of stations in order to evaluate the deviations from the reference map and the sensitivity of the map to the number of stations used.

The removed data are then substituted with synthetic values calculated assuming different source approximations, and the resulting maps are compared to the original ones (containing observed data only). The use of synthetic seismograms computed for finite-fault rupture models produces, in general, an improvement of the calculated ShakeMaps, especially when synthetics are used to integrate real data. When real data are not available and ShakeMap is estimated using GMPEs only, the improvement adding simulated values depends on the considered strong-motion parameters.

SD3/P6/ID45 - SHAKEMAPPLE : TAPPING EMBEDDED MOTION SENSORS TO MAP THE FELT EXTENTS OF AN EARTHQUAKE

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There is a significant pool of untapped sensor resources available in portable devices' embedded motion sensors. As installation of dense accelerometric networks can be costly, these sensors can provide an alternative, ready and available source of accelerometric information in urban areas. Included primarily to detect sudden strong motion in order to park the disk heads to prevent damage to the disks in the event of a fall or other severe motion, these sensors may also be tapped for other uses as well. We have developed a system that takes advantage of these embedded Sudden Motion Sensors to record earthquake strong motion data in order to rapidly build maps of where and to what extent an earthquake has been felt. The ShakeMapple system operates in the background, continuously saving a narrow window of the most recent data from the motion sensors. After an earthquake has occurred, the ShakeMapple client calculates the peak acceleration recorded from within a time window around the expected arrival and submits that to servers operating at the EMSC. Maps representing the shaking intensity based on these submitted values are then plotted and made available. These maps, using data collected locally, may be valuable in assisting local authorities in emergency response planning, and may also be useful in mapping localized site characteristics.

SD3/P7/ID46 - ACCOUNTING FOR RUPTURE DIRECTVITY IN SHAKEMAP

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The rapid and accurate information about the ground shaking following an earthquake is necessary for emergency response planning. A prompt strategy is contouring the real data recorded at the stations. However only few regions, i.e. Japan and Taiwan, have an instrumental coverage as good as needed to produce shaking maps relying almost entirely on real data. ShakeMap has been conceived in order to "fill" the data gap and producing stable contouring using the ground motion predictive equations (GMPEs) and site effect. Thus for regions where the data coverage is sparse, the interpolation plays a crucial role and the choice of the GMPE can affect strongly the goodness of the ground shaking estimation. However the GMPEs derive from an empirical regression describing the averaged behavior of the ground shaking and tend to mask, when present, specific trends due to multidimensional effects like the asymmetry of the rupture process (directivity effect). Thus, ShakeMaps for large events may not reproduce faithfully the ground motion in the near source if determined without the introduction of rupture related parameters. One way to improve the ShakeMap prediction is to modify the ground motion modeling in order to better explain the ground motion variability. To this purpose, the empirical model can be refined with information about the rupture process (Spagnuolo PhD2010), in this case using the directivity term defined by Spudich and Chiou (Earthquake Spectra 2008). The aim of this work is to quantify the effectiveness of refined GMPEs in improving the performance of ShakeMap. We quantify the agreement of this new GMPE with the real recorded data, and make inference about the reliability of this new ShakeMap.

The test is focused on the study of the ShakeMap degradation when the number of the observations is reduced, and on the quantification of the improvements due to the directivity term. In order to conduct properly the test, we investigate two well-recorded events from Japan: the 2008 Iwate-Miyagi (M7) and the 2000 Tottori (M6.6) events. This work is part of the DPC-INGV S3 project (2007-09), as described in the companion abstract Ameri et al. (ESC2010).

SD3/P8/ID47 **– REAL-TIME GENERATION AND PERFORMANCE OF SHAKEMAP® WITH IRPINIA SEISMIC NETWORK (ISNET) IN CAMPANIA REGION, SOUTHERN ITALY**

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Ground-motion shaking maps represent a promising tool to recognize the areas mainly involved in damage and losses after an earthquake. These maps, showing the spatial distribution of some parameters like peak ground acceleration, velocity, spectral acceleration and/or instrumental intensity, play a fundamental role for decision maker to properly direct rescue teams and organize the emergency service operations. Shakemaps could be particularly useful in those areas with high-seismicity risk levels, such as the Campania-Lucania region in southern Italy. In these areas a very dense and wide dynamic seismic network (ISNet) has been recently installed and ShakeMap® is applied to generate ground shaking map during the earthquake occurrence.

ISNet covers an area of approximately 100 km x 70 km along the southern Apennine chain, and it has been deployed to monitor the active fault system that generated the 1980, MS6.9, Irpinia earthquake. The ISNet configuration comprises an extended star topology that has been designed to ensure fast and robust data recording, transmission and analysis. To ensure a high-dynamic range and to avoid signal saturation, each station is equipped with a 3-C strong-motion accelerometer and 3-C velocimeter. The inter-station distances vary from 10 km to 20 km. ISNet has 29 seismic stations that are grouped into six sub-nets.

To evaluate the influence of the station density and the performance of the ShakeMap® implementation, a massive synthetic waveforms data-base has been produced for possible M6.9 earthquakes scenarios located at the center of ISNet. The synthetic waveforms have been computed using a hybrid approach for source modeling, which combines the integral approach (based on the evaluation of the representation theorem) at low frequencies (<1 Hz) and the composite approach at high frequencies (1–20 Hz). Both approaches are based on a common set of sub-sources providing ''k-squared'' slip distribution. The source model is coupled with full-wavefield Green's functions computed, for a 1D layered crustal model, by the discrete wave-number method.

A total of 300 scenarios for the M6.9 earthquake have been computed by combining variable nucleation points in the lower half of the fault, and different final slip and rupture velocity distributions over the fault plane. The scenarios provide relatively large variability of the synthetics. For each scenario event, the ShakeMap has been computed allowing us to analyze the variability of acceleration, velocity and instrumental intensity.

SD3/P9/ID48 **– RAPID DETERMINATION OF MOMENT MAGNITUDE MW FROM THE NEAR-FIELD SPECTRA: APPLICATION TO THE APRIL 6 2009, L'AQUILA SEISMIC SEQUENCE**

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On April 6th 2009, a magnitude Mw=6.1 earthquake struck the Abruzzi region in central Italy. Despite its moderate size, the earthquake caused more than 300 fatalities and partially destroyed the city of L'Aquila and many villages in its surroundings. The main shock was preceded by an earthquake swarm that started at the end of 2008, and, by the end of November 2009, more than 16,000 aftershocks with M> 0.5 have been recorded by the INGV seismic network-Current advances in data transmission and communication yield high quality broadband velocity and strong motion waveforms in near real-time. These data allow for the rapid characterization of earthquake sources in terms of fault geometry, focal depth and seismic moment. Delouis et al. (2009) have developed a methodology for rapid determination of moment magnitude from the near-fields spectra. In this study we test this methodology on the L'Aquila sequence earthquakes for which we have indipendent moment magnitudes values coming from the already computed moment tensor solutions (Scognamiglio et al., 2010).

SD11 - SCIENTIFIC AND TECHNOLOGICAL ADVANCES IN EARTHQUAKE EARLY WARNING AND RAPID RESPONSE

SD11/P1/ID49 **– COLLABORATION AND COMMUNICATION: EFFECTIVE TOOLS FOR RAPID RESPONSE DURING DISASTERS AND SUSTAINABLE DEVELOPMENT**

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Society is often resistant to change even if that will improve their lives. In some societies information diffusion is enhanced by the availability of resources including Internet and thus change is easily accepted. However, this is not easily attainable especially when the communication relates to scientific facts. Proponents are often unwilling to collaborate in programmes that are more scientific and as such the goals of such programmes are either not attained or where they are, they cannot be sustained. Communication is very relevant in our daily lives since lack of it could cause disasters, likewise, the importance of communication and collaboration amongst key players during disaster recovery. The paper, based on the authors research work in The Hague University, examines various communication tools that could be used by the scientific community to improve collaboration and coordination with the view to sustaining development programmes. Data was obtained from a wide range of sources across Asia, Europe and Africa through questionnaires, emails, phone calls, literature and desktop research. Those contacted include the scientific community, NGOs and the general public. In Asia, information was gathered from Male', Maldives from the following NGOs: American Red Cross and the International Federation of Red Cross and Red Crescent. Data from Europe was gleaned from world vision Switzerland and Netherlands general public. Most of the data input came from World Vision (Bongo district) Ghana and also professionals living and working in Ghana. The findings showed that despite the wide range of communication tools available including Internet, intranet, social networking sites etc, scientific knowledge still remains technical and this impedes development programmes. Collaboration in partnership programmes lack support due to technical information not treasured by the non-technical civil society. The level of acceptance is noted to be easily embraced in Holland and Switzerland as compared to Ghana and Maldives. This could be ascribed to lack of resources in the latter countries to determine the best communication tool(s) and how to enhance collaboration and communication in relation to scientific facts and thus sustaining development programmes.

SD11/P2/ID50 **– SPATIAL VARIATION OF STRONG GROUND MOTION: MODELING FROM STOCHASTIC PERSPECTIVE**

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Earthquake ground accelerograms measured at different locations along a large engineered structure could be significantly different. This has led to considerable research in the last decade on the modeling of the spatially varying earthquake ground motion. The spatial variability of strong ground motion incorporates the effects of wave propagation, amplitude variability and phase variability, as well as the local site effects on the motion. This variation of ground motion could have the possibility to cause important effect on the response of linear lifelines such as long bridges, pipelines, communication systems, and should preferably be accounted for in their design.

The objective is to evaluate and improve existing spatial variation quantification relationships by studying data available from different networks; investigate the possibility of employing functional forms for the characterization of spatial variation of ground motion in the assessment of strong ground motion distribution.

In addition, this study concentrates on the stochastic description of the spatial variation, and focuses on spatial coherency. The estimation of coherency from recorded data and its interpretation are presented. Cohe-

rency model for Istanbul for the assessment of simulation of spatially variable ground motion needed for the design of extended structures is derived.

SD11/P3/ID51 - FAST S-PHASE ARRIVAL IDENTIFICATION FOR LOCAL EARTHQUAKES

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In the case of a strong local earthquake, a quick report about the earthquake's location is expected. Such reports are usually produced automatically and the correct identification of the seismic-phase arrival of various seismic waves on the seismogram is the most important task. For this purpose, numerous detecting methods are used for the first P-wave arrival identification and determination. However, in some cases, where the number of seismic stations in a local seismic network is very small, an automatic reading of the S-wave arrival is required. We present an algorithm developed for the automatic picking of the S-wave arrival from three-component seismic data. Three parameters of the signal are calculated from these data and the S-phase arrival is declared when the product of these three parameters increases above a reference level. Such, so-called S-phase picker is used to automatically analyze the data from Slovenia's seismic network.

SD11/P4/ID52 - THE QUAKE-CATCHER NETWORK: A COMMUNITY-LED, STRONG-MOTION NETWORK WITH IMPLICATIONS FOR EARTHQUAKE EARLY WARNING

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The goal of the Quake-Catcher Network (QCN) is to dramatically increase the number of strong-motion observations by exploiting recent advances in sensing technologies and distributed computing techniques. Micro-Electro-Mechanical Systems (MEMS) triaxial accelerometers are very low cost ($30-$100) and interface to any desktop computer via USB cable enabling dense strong motion observations. Shake table tests show the MEMS accelerometers record high-fidelity seismic data and provide linear phase and amplitude response over a wide frequency range. Volunteer sensing using distributed computing techniques provides a mechanism to expand strong-motion seismology with minimal infrastructure costs, while promoting community participation in science. QCN has approximately 2000 participants worldwide that collect seismic data using a variety of MEMS sensors internal and external to computers. Distributed sensing allows for rapid transfer of metadata from participating stations, including data used to rapidly determine the magnitude and location of an earthquake. Trigger metadata are received with average data latencies between 3-5 seconds; the larger data latencies are correlated with greater server-station distances. Trigger times, wave amplitude, and station information are currently uploaded to the server for each trigger. Following the 27 February 2010 M8.8 earthquake in Maule, Chile we initiated a QCN Rapid Aftershock Mobilization Program (RAMP) and installed 100 USB sensors to record aftershocks. The USB accelerators were deployed mainly in regions directly affected by the mainshock and were densely concentrated around Concepción. Using this data, we refined our triggering and event detection algorithms and tested, retrospectively, whether the network can rapidly and accurately identify the location and magnitude of the moderate to large aftershocks (M>4). Our preliminary results suggest that MEMS sensors installed in homes, schools, and offices provide a way to dramatically increase the density of strong motion observations for use in earthquake early warning. In addition, the dense waveform observations will provide higher resolution source imaging of a rupture in near-real-time. These same observations will provide new images of the subsurface, which are used in earthquake hazard scenarios to predict ground motion. QCN has the potential to produce wide-reaching outcomes for: earthquake advanced alert, improved seismic safety, and increased public knowledge of earthquakes.

SD11/P5/ID53 - ADVANCED SYSTEM FOR ANTISEISMIC PROTECTION OF THE CIVIL BUILDINGS AND INDUSTRIAL STRUCTURES IN CASE OF STRONG EARTHQUAKE OCCURRENCE

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Romania is an European country with significant seismicity. So far, the 1977 event had the most catastrophic consequences: about 33,000 residences were totally destroyed or partially deteriorated, 1,571 people dies and another 11,300 were injured. Moreover, 61 natural-gas pipelines were damaged, causing destructive fires. The total losses were estimated at 3 mld. U.S. dollars. During the last 70 years, Romania experienced four strong Vrancea earthquakes: 10 November 1940 (Mw =7.7, 160 km depth), 4 March 1977 (Mw =7.5, 100 km depth), 30 August 1986 (Mw =7.2, 140 km depth), 30 May 30 1990 (Mw =6.9, 80 km depth). The 1977 event was characterized by catastrophic consequences: 1500 casualties and collapsing of 35 high-risk buildings, mostly occurring in Bucharest.

Presently, in Romania safe and efficient accepted solutions for improving the buildings and structures securing, using antiseismic protection of the dangerous installations and equipment are not available. We present an advanced protective system designed to be installed in the civil buildings and industrial structures placed in the high seismic regions, in order to contribute to the mitigation of the strong earthquake effects on human society.

The proposed system for antiseismic protection system is designed for the shutting down of the installations and equipment mounted in the building's infrastructure, which can become extremely dangerous in case of a major earthquake by appearing the possibility of explosions, deflagration, fires, toxic and polluting fluids leakage. The damages are strongly amplified by the fact that, simultaneously, water and electric energy lines distributions are damaged too, making impossible an efficient firemen intervention, for localizing the fire sources. Moreover, the installations of the individual heating stations which operate with open flame increase the risk of explosions inside the buildings during an earthquake.

The system is based on a seismic switch used for activating through weak-electric-currents of the building's safety systems in case of strong earthquake (building's elevators and moving parts of installations which require positioning in safety place areas). The seismic switch device comprises a network of minimum three seismic sensors (accelerometers), which, through a coincidence circuit, endorses the presence of a seismic shock, excluding the accidental triggers caused by local noises and mechanical shocks from neighboring area. When is activated, the system allows to automatically place in safe position the most dangerous installations located in buildings, such as elevators, heating systems using natural gas or high pressure liquid, water pipes, thermal stations, electrical power line etc.

SD11/P6/ID54 - A TOOL FOR AUTOMATIC EARTHQUAKE QUALITATIVE IMPACT ASSESSMENT

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EMSC developed a new methodology to assess earthquake impact named EQIA (Earthquake Qualitative Impact Assessment), based on empirical relationships of Samardjeva and Badal (2002). These relations estimate the number of casualties due to the earthquake itself (and not for instance from a consecutive tsunami) with respect to magnitude and density of population around the epicentre. This work was part of the NERIES-JRA3 project, along with ELER (Earthquake Loss Estimation Routine), developed by KOERI, which is a manual multi-parameter tool that is able to provide level 0, 1 and 2 casualties estimation. EQIA provides an automatic real-time level 0 impact assessment for each crustal earthquake of magnitude greater than 5 reported on EMSC website. It does not intend to estimate the number of casualties but rather to determine a qualitative impact defined from following categories: "none", "light", "moderate", "heavy", "very heavy", "extreme". Some refinements have been applied to raw application of Samardjeva and Badal relationships to better match the data. First of all, thousands of scenarios are played out for a given earthquake to take into account both epicentre location and magnitude uncertainties; results for all of them is then synthesized into an impact range such as "None to moderate". Vulnerability is also taken into account I,n impact assessment; countries have been sort in three categories : low (e.g. Japan), normal (e.g. France) and high (e.g. Iran). For earthquakes with magnitude greater than 7, rupture direction as provided by moment tensors is also taken into account. Finally, Samardjeva and Badal law for low density (< 25 inhab/km^2) population has been adapted to better estimate cases with very low densities, which were very often overestimated. EQIA proved to be quite reliable and gave correct impact assessments in 95 % of our

dataset of 719 events. However, low impact earthquakes may still be tricky to evaluate as for instance one single collapsing building may result in tens of casualties, which can't be predicted. EMSC will soon propose an alert service based on impact assessment of real-time earthquakes.

SD11/P7/ID55 - PERFORMANCES AND RECENT EVOLUTIONS OF EMSC REAL TIME INFORMATION SERVICES

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The European Mediterranean Seismological Centre (http://www.emsc-csem.org) operates rapid earthquake information services which aim to provide fast and reliable information on the seismicity of the Euro-Mediterranean region and on significant earthquakes worldwide. They are based on parametric data rapidly provided by 65 seismological networks, automatically merged and processed at the EMSC. Over the 5 last years, the performances and the success of the different services have improved significantly. The number of events published on EMSC web site has increased by 68% since 2004 (16,818 events in 2009). For the Earthquake Notification Service, the median dissemination time for Euro-Med events decreased from 40 minutes in 2004 to 21 minutes in 2009. The operating rate of EMSC infrastructure reached 99.7%. The EMSC web site audience has carrying on increasing over the last years. As a consequence, the number of traffic surges and plotted *felt maps* continues to increase as well. Today, after widely felt earthquakes, we are able to map the felt area generally in less than 5 minutes after the earthquake when no seismic data is generally yet available. The number of collected questionnaires also keeps on increasing. Within NERIES-JRA3, the EMSC developed an Earthquake Qualitative Impact Assessment Tool (EQIA) in collaboration with KOERI. Its shows remarkable performances (success rate > 95%) to pinpoint damaging earthquakes and qualify their impact. Based on EQIA, an quick alert service based on the expected level of damage will be proposed to EMSC Members in 2010. An authoritative locations procedure will be implemented before the end of 2010 by considering as authoritative the locations that do not need to be relocated by the EMSC and can therefore be directly published on the web site. The new EMSC web site - operational in June 2010 - will provide several features that should allow to collect more questionnaires and pictures. It will also propose new tools to help the users to correctly identify the event they have just felt.

SD11/P8/ID56 - PROPOSED THRESHOLD LEVELS FOR BUILDING AND FACILITIES EARTHQUAKE ALERT SYSTEMS IN MARMARA REGION

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Two recent catastrophic earthquakes that struck the Marmara Region on 17 August 1999 (M_w 7.4) and 12 November 1999 (M_w 7.2) caused major concern about future earthquake occurrences in Istanbul and the Marmara Region. As a result of the preparations for an expected earthquake may occur around Istanbul region, an earthquake early warning system has been established in 2002 with a simple and robust algorithm, based on the exceedance of specified thresholds of time domain amplitudes and the cumulative absolute velocity (CAV) levels. Rational threshold levels related to new bracketed CAV window approach (BCAV-W) are determined, based on dataset of strong ground motion records with fault distances of less than 100 km, as 0.2 m/s, 0.4 m/s and 0.7 m/srelated to three alarm levels which will be incorporated in the Istanbul earthquake early warning system. In addition, a few facility-specific earthquake alert systems have been separetely installed at Isbank Tower (IS KULE), Kanyon Tower & Mall, and Trakya Elektrik & SII Energy Power . In order to develop the triggering levels for structural type alert systems, for a large number of worldwide earthquakes were gathered addition to the existing Marmara region accelerometric records. Using the data set, the rational threshold levels, are determined.

SD11/P9/ID57 - ROMANIAN EARLY WARNING SYSTEM, PART OF SEISMIC RISK MITIGATION MECHANISMS

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The need to use early warning methods to reduce natural risks in modern societies is related to their unprecedented dependence upon technology. The strong seismic events originating from Vrancea(M_w =7.9) can generate the most destructive effects experienced in Romania, and may seriously affect high risk manmade structures located within a wide area from Central Europe to Moscow. NIEP developed an early warning system that is able to evaluate earthquake magnitude in *4-5 seconds* after detection in the epicenter. This system consists of several software modules developed at NIEP that optimize communication, are able to estimate earthquake magnitude and send earthquake alarm very fast.

EWS uses the time interval (28-32 sec.) between the moment when the earthquake is detected by the local seismic network installed in the epicenter area (Vrancea) and the arrival time of the seismic waves in the protected area (Bucharest) to send earthquake warning to users.

SD11/P10/ID58 - ESTABLISHMENT THE FIRST EARTHQUAKE QUICK DAMAGE AND LOSS ESTIMATION SYSTEM IN TEHRAN

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After an earthquake, having a proper and in time estimation about distribution of destructed buildings and the degree of destruction, as well as number and distribution of casualties can considerably facilitate decision-making and planning for disaster managers. Such information can be estimated by having a network of seismometers that are in safe and continuous connection with the Emergency Operation Center (EOC) and having appropriate databases on buildings and populations and necessary software for quick damage and loss estimation.

For the first time in Iran this system has been developed and operated in Tehran by Tehran Disaster Mitigation and Management Organization (TDMMO) with assistance of Japan International Cooperation Agency (JICA). For this purpose at the first stage, 10 accelerometers have been prepared and installed in different parts of Tehran and on-line communication between these stations with main center have been provided using ground MPLS lines (as main connection means) and satellite phones (as back up system) for transferring maximum PGA per second continuously. In addition necessary databases on buildings and population distribution have been updated and a professional software were developed for using these information in order to estimate number and distribution of damages and casualties in Tehran by using native fragility curves and casualty functions. The project has been successfully finalized in March 2010 and the system is operational now at TDMMO. The details of the project will be presented in this paper.

SD11/P11/ID59 - PSINSAR APPLICATIONS IN SEISMOLOGY: PRODUCTS AND SERVICES FOR END USERS MANAGEMENT TOOLS

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The maturity level reached by the PSInSAR (Persistent Scatterers InSAR) technique is allowing us to develop projects aimed at the measurement and monitoring of surface displacements due to active faults. Although standard InSAR has been demonstrated as an effective tool for coseismic deformation retrieval since 1992, the step forward towards the detection of interseismic movements required significant improvements. The PSInSAR approach has demonstrated its capability to detect mm/year movements over large areas. The very high accuracy of such multitemporal InSAR techniques can be exploited to generate reliable products and services to be integrated in the monitoring chain of end users and decision makers. The Tectonics theme of the ESA Terrafirma Project is aimed at exploiting PSInSAR from ERS, Envisat and, for testing issues, TerraSAR-X data, for providing velocity maps of some of the most seismically active regions in Europe; in particular Italy, Turkey and Greece. PSInSAR results are compared, validated and integrated with GPS and ground data with the objective of better understanding the pre-earthquake deformation process and the vulnerability of foundation soils to seismic shaking. This should lead to a more effective and standardised approach to monitoring developing hazard and risk in earthquake-

prone regions.

SD11/P12/ID60 **- SECURE TRANSMISSION OF TUNISIAN BROAD BAND SEISMIC NETWORK FOR A CONTRIBUTION TO A WESTERN MEDITERRANEAN TSUNAMI EARLY WARNING SYSTEM (NEAMTWS)**

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Establishing a Tsunami Early Warning system, based upon a seismological observation, requires efficient detection of the phenomena, robust data transmission and close connection with international agencies involved in this task. There are many examples illustrating the importance of a robust transmission system such as the event of Boumerdès (M6.8) on May 21st 2003 when submarines cables were damaged impeding phone and Internet connection between Maghreb and Europe and the seismic event of Indonesia (M9.0) on December 26th 2004 when the generated Tsunami was not well warned. An upgrade of the seismological network of Tunisia, operated by INM, towards modern instruments with high dynamic broad band seismological observation and digital real time transmission began in 2008. This project started within a partnership opportunity between INM and the department of international cooperation of the "Principauté de Monaco", and EMSC. Geoazur scientists provided scientific and technological assistance mainly in site quality estimation and instrumentation definition. To insure effective, timely and robust system, a server running the Seismological Communication Processor (*SeisComP3*) developed originally for the GEOFON network was installed at the main centre in Tunis. Enhancements to the *SeedLink* protocol supported by the installed *SeisComP3* server, which is, a robust data transmission through internet or devices that support TCP/IP, network and station codes were stored in addition to their locations and channel codes. To fulfill this task, GFZ (Germany) and INM made the Tunisian data available in real-time in the NEAMTWS (North East Atlantic and Mediterranean Region Tsunami Warning System) framework and within the GFZ GITEWS (German Indonesian Tsunami Early Warning System) project, according ORFEUS standards. The data are transmitted from the INM to GFZ through a VSAT system set-up by GFZ for its GEOFON network. In complement, for rapid and robust INM contributions to the EMSC Real Time Earthquake Information services, QWIDS/EIDS was also implemented. The implementation of the *SeisComP3* software and the integration of other stations from neighbouring agencies, especially from Europe, boosted INM capacity for real time automatic earthquake monitoring and offered an efficient role as a virtual monitoring network among its physical one. The next steps will be the replacement of the existing analogic seismic stations with digital one, find the good parameters for regional seismicity automatic location and to insure at INM the robustness of data servers and of the processing.

SD11/P13/ID61 **- EARTHQUAKE EARLY WARNING FOR TEHRAN, IRAN**

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Early warning systems have important role in decreasing fatality and economic loss due to natural and manmade hazards, specifically in densely populated areas. Tehran, the capital of Iran, accommodates nearly 10,000,000 people. It is located in the vicinity of many major faults (Mosha, North Tehran, Kahrizak…) and its historic records indicate the occurrence of many devastating seismic events. Therefore, an earthquake early warning system for Tehran seems to be very essential. However, very few earthquakes of magnitudes more than 5 have taken place in instrumental period in this area. Therefore, the correlation parameters should be extracted from an area of high seismicity, and then be cross checked with data available for Tehran. On the other hand, the available seismic records in Iran are sometimes of poor quality and lack absolute timing. To optimize the use of accessible data, a method should be used which is capable of using both single-station and multi-station data, so that we can make the best use of existing data. Therefore, a combination of Elarms and tau-c Pd methods is chosen for this area. At the end, the results can be used to optimize and modify the existing seismic networks to form an earthquake early warning system for Tehran.

ES13 - FUNDAMENTALS OF MODERATE TO GREAT EARTHQUAKES FORECASTS

ES13/P1/ID62 **- THE VELOCITY RATIO OF VP/VS AND THEIR BEHAVIOR BEFORE THE EARTHQUAKES OF 2000-2008**

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The hypothesis that before strong earthquakes the wave velocity ratio of P and S waves was first suggested by Japanese scientists Sass in 1948 and by Khakiav in 1949. Japanese scientists tried to explain the Vp/Vs correlation change before strong earthquakes by the change of crust tension. But in 1940-1950's this hypothesis didn't get further development in Japan because of the difficulties of precise definition of Vp/Vs correlation. According to Rikitake, investigating temporal changes in seismic velocity as a premonitory phenomenon in earthquake prediction was first attempted by Hayakawa, and his results were negative. In the 1950s, a seismic network was established at Garm, USSR, for earthquake prediction research. In the early 1960s, specific results concerning velocity changes as a diagnostic precursor to earthquake occurrence in the Garm region were published. According N.K. Karapetyan, the use of the value change of Vp/Vs as an indication is applicable in Armenia and it can be one of the most interesting and the most prospective methods.For Vp/Vs velocity ratio value research we have chosen IRIS GNI seismic station which is the most sensitive and precise equipment in Armenia. The investigations in this report are done using the records from GNI seismic station in 2000-2008. In the result of the investigations it became clear that abnormal values of Vp/Vs in the research areas are noticed 12-20 days before the earthquakes and they last for sometime after the earthquake.In the result of some investigations it was found out that Vp/Vs correlation can change before 2.5-3.0 magnitude earthquakes.

ES13/P2/ID63 **- GOLDFISH BEHAVIOUR IN TIME AND PLACE BEFORE THE SMALL AND MIDDLE EARTHQUAKES**

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Analysis of the behavior of goldfish started, when my kids would like some animal. We bought an aquarium, goldfish and a small bookshelf for their books. Children had to be alert to the fish, read something about, observed it and nutrients. The first serious problem is entered with before seismic movements in the Metkovic area (1988, 350 km, Ml = 4). Fish was nervous in a period of fifteen days, especially the last three days. She was placed in the middle of the aquarium and some times tried to escape on the side, several times a day. Those days didn't eat very much, and the children were worried. When EQ came, it was clear that the fish exactly determine movement and positioning. It also responded to the movement of large trucks. At that time, the fish tried to remain in place and turning nervously. Same was when the earthquake occurred in Jablanac (1988, 100 km, Ml = 4.5), except the reaction times were different. The third earthquake was in Bovec (1998, 160 km, MLV = 5.6). Last five days, the fish sometimes jumped out from the aquarium and we put the temporary lid on. After one of a after seismic shocks, the fish jumped out of the aquarium, and die. There were also several other reaction to ground movements in the area. Some of them could be connected with weak earthquakes announced on the public TV, and the origin of else, couldn't be clarified. The fish movement was not danger, and non in clear series, so we didn't watch on it. I can say that the fish move in accordance with their instincts for survival. Movements were the same as in nature, when the fish are in a situation to be caught. There is no doubt that behavior described above is relating to before-earthquake movements, and shock. The movements of the fish show that our today measurements are not entire exact. It is necessary to construct and use some additional measurement equipment.

ES13/P3/ID64 **- METHODICAL FEATURES AND RESULTS OF MONITORING OF KINEMATICS PRECURSOR ON THE DATA OF SEISMIC OBSERVATIONS IN KAMCHATKA**

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Methodical features of algorithms and programs of a kinematics method of long-term, middle-term, and short-term prediction of strong earthquakes (eruptions of volcanoes) are considered. Results of calculations of parameter with revealing of anomalous areas for the Kamchatka seism focal zone are resulted. The method is based upon the idea about directed changes of physical parameters of medium occurring during preparation strong earthquake. Under the influence of increase of stress field, at last stage of preparation earthquake the medium loses stability, and it is reflected in the increase of dispersion of various geophysical parameters, including travel times of seismic P- and S- waves from weak regional earthquakes. Observing variations of travel times P- and S-waves and their relations - Ts/Tp (parameter TAU) in space and time, and carrying out the analysis of fluctuations concerning long-term average value, it is possible to reveal time interval where the values of fluctuations are maximal, and to contour the area of localisation the anomalies. In the short-term variant prognostic curves for separate stations are calculated. On comparison of anomalies on several seismic stations it is possible to estimate probable area and time of strong earthquake occurrence. In long-term aspect the mapping of parameter in the area is made. The consecutive analysis of several maps in time allows to reveal and contour the zone of anomaly and to trace its development. It allows developing the system of monitoring of short-term precursor. The precursor is revealed during preparation of different scale level events, from mine shocks and volcanic eruptions to strong earthquake. Within last 10 years monitoring in operative mode for the Kamchatka seism focal zone, with transmission of calculation results and the conclusions to the prognostic Centres is carried out. At mapping of parameter deviations from average long-term values considerable anomalous areas along focal zone at the coast of Kamchatka are revealed. The increase in anomalies in absolute value from the end of year 2009 to February 2010 is observed. During the observation period since 1995 there was no such situation. The estimation of developed seismic situation and the general geologic-tectonic situation in the region is resulted. Retrospectively the periods of preparation of Petropavlovsk (1971, M=7.2) and Kronotsky (1997, M=7.8) earthquakes are analysed. Increase of absolute values of anomalies in time is observed, the dispersion increased. Anomalies of parameters don't depend on the level of seismic activity (number of earthquakes), and their energy class Ks. Average value of parameter TAU for long time period - 1.73, and now decreased to 1.68. Anomalies registered now probably testify to the change of stress state in the region and possibility of strong earthquake occurrence.

ES13/P4/ID65 **- DYNAMIC MODEL OF DETERMINING PERIODS OF THE HIGHEST SEISMIC DANGER**

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This paper deals with the search of the sign founded on the tidal forces which has been carried out in the southern part of the Kuril Islands. Proposing that the prognostic signs of the raising seismic activity are the processes of changing tidal forces during the definite period of time the dynamic model of determining periods of the highest seismic danger has been formed. There has been formed the database of "earthquake patterns", each of them representing the function fragments describing in time of strong earthquake the process of changing the first two main components of tidal factor being the linear combinations of initial signs. The day from the beginning of the year when the development of tidal process has been taking place according to the script similar to the pattern from the database has been announced as the day of the highest seismic danger. The testing of such a model both on the training majority and on the control one has shown that this model has been useful for practical application in the geographical area being considered. That is why the rating of the "earthquake patterns" has been made. It has been noted that the patterns taking part in the earthquake prognosis more that twice possess "minimum" amplitude of phase portrait range in the main component coordinates. As a matter of fact the highest seismic activity is being observed during the moments of the smallest changes of tidal gravity components. Besides it has appeared that between real earthquakes and plots of changing main components of tidal factors belonging to "minimum window" of their variation (or patterns of small dynamics) there exists some marked static connection on whose basis the algorithm of determining the periods of the highest seismic danger has been made without using "earthquake patterns" database. As a result of testing there have been obtained reassured data, namely: for the southern part of the Kuril Islands according to the method of making up the diagram of errors, the mean meaning of the efficiency index and for 4 sectors being considered, during the period of 1983-2008 has made up Γ=41%; for world's strong earthquakes being investigated that have taken place in the first quarter of 2010, the times of earthquakes in Haiti, Chili, Taiwan and Turkey belong to the time intervals of troubles being calculated according to the method of "the patterns of small dynamics".

ES13/P5/ID66 **- CONTROLLED RELAXATION OF TECTONIC STRESSES IN THE EARTH'S CRUST**

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Natural and anthropogenic impacts on seismicity are considered. Taking into account the importanceof the discussed problem, the authors propose to open the discussion on the questions considered. In thisconnection a wide circle of known experimental data is considered, which are indicative of the possibility in principle of active impact on the seismogenic medium for the smooth relieving of accumulated tectonic stresses in the Earthís crust. The reasoning is presented of one of the promising ways of the smooth controlled relaxation of the accumulated tectonic stresses in the Earthís crust at the places of the probable onset of strong earthquakes due to a considerable increase in the plastic slips, which facilitate the decrease of the number and energy of earthquakes. The approach proposed is based on the results of the works on the excited seismicity, obtained in different regions of the Earth. Special attention is given to the most detailed long-term investigations of the excited seismicity in the region of the reservoir of the Nurek hydroelectric station in Tadzhikistan and in the neighborhood of the actively mined Romashkinskoe oil deposit in the Republic of Tatarstan. The results of the laboratory investigations of the behavior of samples made of materials of crystalline and amorphous structures under the action of pressure and vibration are invoked for the substantiation of the physical nature of the observed effects. For the reduction of seismic hazard, it is proposed to use vibration actions and water injection in the bore holes at the places of the expected seismic catastrophes in a time mode matched with the tidal motions of the Earth.

ES13/P6/ID67 **- SEISMOTECTONIC DEFORMATION OF THE KURIL-KAMCHATKA SUBDUCTION ZONE: EVIDENCE FOR STRESS DISTURBANSES IN THE STRONG EARTHQUAKES SOURCE REGIONS**

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Seismicity and fault plane solutions in the Kuril-Kamchatka region have been studied to focus attention on the nature of deformation in the northwest boundary of Pacific plate. Predominance of typical earthquake mechanisms with more or less NW--SE pressure axes imply that corresponding compressive deformation is presumed to be the result of collision of north-west moving Pacific plate with the Eurasian plate at the Benioff zone of the Pacific lithosphere subduction in upper mantle. This deformation pattern is subjected however to local short-term variations due to stress state changes in zones of strong earthquakes genesis at preparing stages. These stress state disturbances theoretically are evaluated as a result of re-activation of localised deformation bend or large- scale faults. Statistical study of seismic moment tensors in terms of seismotectonic deformation is performed. Herewith summation of normalised seismic moment tensors for a representative set of seismic events within vicinities of strong earthquakes foci is used. Temporal variations are investigated on the basis of scalar product individual seismic moment tensor and seismic strain rate tensor obtained through this averaging procedure. This technique, together with the construction of classification diagrams of fault plane solutions enables us to rapidly examine the stress- field pattern and further discuss the deformation modes of faulting and fracturing, which may take place at a local scale. We have suggested that the local

variations of the stress tensor may be considered as an additional tool in solving earthquake prediction problem. . The precursory changes in forshocks source mechanisms were diagnosed retrospectively and in advance by this algorithm of the recent earthquakes: October 4, 1994, M = 8.3, South Kuril, Shikotan, and December 5, 1997, M = 8.0, Kamchatka. A geodynamic interpreta-

tion of the temporal-spatial focal mechanisms variations is proposed to highlight the role played by re-activation of major structural discontinuities in contemporary stress regim.

ES13/P7/ID68 **- THE GEOPHYSICAL AND HYDRODYNAMIC PROCURSORS OF MEDIUM AND LARGE SCALE (M>5.0) EARTHQUAKES OCCURRED IN URARTU PLATEAU, DURING PERIOD OF 1950-2010, EAST TURKEY-SOUTH CAUCASIA- NW IRAN.**

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The research area forms the second high volcano-tectonic plateau, after Tibet, in seismoactive tectonic zone, in alp- himalayan belt. This region situated on active south margin of Eurasian Plate, in front of Arabian-Eurasian collision suture. Major active fault zones originated during the late Miocene-early Pliocene are; East Anatolian Fault, North Anatolian Fault, North Tebriz Fault, Erzurum Fault, Big Agri -Noah-chevan Faults, Malatya Faults , Main Recent Fault , Mush- Gevash Fault and Abulsamsar-Tcevakhati Faults. This article focused on the geophysical and hydrodynamic parameters observed in the region by local amatuer researchers (historical data) and mostly by trained experts. Predictive data recorded at local seismic sensors as microseismic events, at geothermal springs as GW-level, temperature and gas content, at EME, ETP, AE and tilt measurements by geophysical networks. Selected events include 1952 Koprukoy, 1967 Varto, 1971 Bingol, 1972 Caldiran, 1983 Horasan, 1986 Malatya, 1988 Spitak, 1991 Xhinvali, 1992 Zencan, 1992 Erzincan, 1995 Askale, 2003 Bingol, 2004 Ahskale and 2010 Kovancilar earthquakes.

EME, ETP and Tilt precursors monitored at Artvin-Bolnitsia Continental block, NE Turkey and SW Georgia, during a period of 4 years project amoung Italy-Turkey-Georgia, revaled reliable evidencs of 3 events (5.7 < M < 7.0) during 1991-1994. Another example of procursors obtained by statistical analyses of microseismic records of Palandoken Fault zone (Erzurum , E Turkey) which sucessfully proved by Ashkale EQ, in 1995. Hydrodynamic procursors always revealed consistent results in terms of prediction. In general, these data not been seriously considered as scientific significance.

ES13/P8/ID69 **- NEW STRATEGY OF THE EARTHQUAKE PREDICTION**

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New strategy of the earthquake prediction combines the seismotectonic and seismologic achievements of study of model, real and potentional earthquake sources as well as a manifestation of the earthquake precursors. It is supposed that earthquake sources are some dynamic structures evolution of which is accompanied by set of precursors. Each stage of source evolution is characterized by specific seismological pattern. Such an approach allows the determination of the activate seismic sources and then to narrow the observation frame from the entire seismic active region to the most active local zones. A set of reliable and effective seismological precursors is founded. The system of seismological monitoring on the different temporal scale is proposed within the potential seismic sources.

ES13/P9/ID70 **- A VIEW ON EARTHQUAKE PREDICTION PROBLEM THROUGH LANDSLIDES MECHANICS**

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One of the main obstacles in tectonic earthquakes prediction problem probably is that we are unable to conduct direct monitoring of its preparation space zone, hidden beneath the earth daily surface. Geophysical prospecting methods render some capability to carry out the monitoring of the geophysical features of tectonic earthquake preparation processes, but this is an indirect approach. The similarity of preparation of land sliding and earthquake makes the earthquake prediction more vivid, because of one can follow visually the landslide preparation and triggering stages. The common feature for both earthquake and landslide is the sudden relative displacement of parts of geoblocks in case of earthquakes and rock fractures in case of landslides. In both cases the potential energy is transforming into kinetic energy. In both cases there is the potential energy accumulation and further energy release. Both preparations are going in definite space and time, depending on the power accumulation values. The larger is the potential energy accumulated the larger are the preparation zone and its time duration and the relevant magnitudes of events as well. There are a number of well known factors controlling the landslide triggering. There is volume density of rocks constituting the landslide body, friction and cohesion of rocks at the slide surface and inside the body. In some cases the vibrations and microseisms also can do impact on the body stability. These factors in real environments aren't definitely homogeneous and depend on geological structures of the rocks, humidity degree etc. While analyzing the role of different factors in landslide triggering one can see the role of each of them. The monitoring of these factors provides the data for assessments of the potential landslide failure hazard and thus to compose the procedures for their prediction. The geophysical methods of monitoring of the landslide body formation and its triggering provide principal basics to use common features with earthquake preparation for the observations, data collection and further prediction of the last.

SW2 - SURFACE WAVE SEISMOLOGY WITH DIFFERENT WAVELENGTHS

SW2/P1/ID71 **- IMAGING OF SURFACE WAVE PHASE VELOCITY BY STACKING OF MULTIPLE PHASE GRADIENT MAPS**

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While temporary deployments some 10 years ago were largely based on short-period seismometers, the availability of broadband instruments in instrument pools increased strongly in recent years and as such modern temporary deployments for passive seismological recordings often consist to a large extent, if not exclusively, of broadband instruments. This opens for new analysis approaches as the broadband seismic wavefield is obtained at a relatively high spatial sampling relative to the wavelength. We present a new approach to overcome the limitations of two-station phase measurements of surface wave phase velocities. Instead we exploit the two-dimensional nature of the wavefield by taking into account phase measurements at all stations of an array from a single event. By triangulation of the network region and interpolation of the phase gradient we get without further a priori assumptions a coarse image of the phase velocity variations within the network. Phase velocity anomalies measured from single event recordings are commonly biased and blurred by the non-planarity of the arriving wavefield and reflections and diffractions off heterogeneities. Therefore, by averaging over velocity fields from different events with varying backazimuths, artefacts are reduced and the recovered image significantly improved. This works exceptionally well for recovery of a synthetic model using synthetic data. However, the presence of (random) noise, representing measurement uncertainty deteriorates the results massively. By stacking multiple images from subsets of the available data for a single event, thus taking into account the average phase velocity in larger subregions of the network which is less sensitive to measurement uncertainty, the noise is effectively suppressed and the recovered image reflects the synthetic input model nicely in both geometry and amplitude. In our contribution we will present the methodological aspects of our approach, as developed by analysis of synthetic data to illustrate the power and limitations of the method. We also present application of our method to data from the USArray where published phase velocity maps are available for comparison. Most notably, it turns out that as few as 5 events (of high signal/noise ratio and azimuthally distributed) are required to obtain a good image recovery, both in the synthetic example as well as the USArray real data test.

SW2/P2/ID72 **- TRACE TRANSFORM FILTER AND ITS APPLICATION IN SURFACE WAVE ATTENUATION OF SEISMIC DATA PROCESSING**

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Abstract—A main target of seismic data processing is to remove the surface wave and improve the quality of seismic record. Here we introduce the Trace transform from image processing and construct a specific Trace transform filter to attenuate the surface waves from seismic record. This proposed filter based on the propagation and energy distribution significantly enhances proportion of surface waves in the Trace transform

domain, which is prone to cleanly attenuate the surface wave with a given threshold. Experiments of synthetic model and field data all demonstrate that the proposed algorithm performs better both in surface wave attenuation and effective signal preservation than the conventional methods.

SW2/P3/ID73 - SURFACE WAVE PHASE VELOCITIES BETWEEN BULGARIA AND THE CZECH REPUBLIC

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Surface phase velocities are measured along several profiles between Bulgaria and the Czech Republic using the modified two-station method. Love and Rayleigh waves identified at all three components, propagating from both directions and generated by several regional and teleseismic events (Turkey, North Atlantic Ridge) are processed by the Fourier transform-based modified multiple filtering technique which is a classical tool of the frequency-time analysis. A period range of 8 – 60 s is used. Five local maxima of the envelopes of quasiharmonic components are found and the fundamental mode dispersion ridge is estimated from the spectrogram using the criterion of continuity rather than by the traditional amplitude-based approach. Filtered fundamental modes at pairs of stations are relatively correlated and phase velocity of both Love and Rayleigh waves are computed from the delays of propagation times of all quasiharmonic components. True propagation backazimuths are estimated using the three-station method and confirmed by polarization analysis. Phase velocities are thus corrected for the effects of non-great-circle propagation. The determined phase velocity dispersion curves are inverted for the crust and upper mantle structure. The study presents a description of the methodology, points out the peculiarities of surface wave propagation and shows the structural interpretations.

SW2/P4/ID74 - INVESTIGATION OF SHORT-PERIOD SEISMIC NOISE AT THE BURAR SEISMIC ARRAY

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BURAR seismic array comprises 9 digital vertical short-period stations equipped with Geotech Instruments GS21 seismometers (response flat to velocity from 1 to 16 Hz). The tenth site of array contains a three-component broad-band (BB) Geotech Instruments KS54000 instrument (response flat to acceleration from 0.003 to 5 Hz). The array covers a 5 km^2 area, inter-element distance varying between 500 m and 2000 m.

The stations are sited in a bowl-shaped valley, at approximately 1000 meters elevation, with moderate relief, away from any major settlement, industry or traffic roads. The underground is represented by massive pre-Cambrian and lower Paleozoic deposits, consisting of epimetamorphic schist of green grade. A complex of quaternary alluvium several meters thick is also developed on top of the schist, and in some areas, limestone overlies the schist.

The short-period noise conditions at BURAR have been investigated by two methods: (1) power spectral density (PSD) calculation within the frequency range 0-20 Hz and (2) frequency-wavenumber (f-k) array technique. Regular recording of noise spectra for time window of 60 seconds, sampled at every six hours, has been calculated at short-period stations over one-year period. F-k analysis estimates were calculated for 9 frequency bandwidths between 0.1 and 16 Hz.

The average noise PSD shows relatively low noise at BURAR site comparing with the Peterson's Noise Model (NLNM and NLNM). For frequencies above 2 Hz, seasonal and diurnal fluctuations were observed. Noise level is higher in the summer, with a considerable increasing for large frequencies (>= 6 Hz), and thus affecting the BURAR detection capability for this period of the year.

Shallow geology influence within the BURAR site is emphasized as well, i.e. identifying the highest PSD values for BUR07 instrument, where geological conditions are different than the rest of elements.

Noise wave-field characteristics were studied using automatic f-k processing, in order to identify the distribution of the noise sources. The range of the measured apparent velocities was upper limited to 3.2 km/s, including Rayleigh wave velocities. At BURAR, azimuthally dependence of the noise characteristics is observed for frequencies below 2 Hz, with a consistent number of Rg detections observed in the 330° to 30° back-azimuth domain.

The Rayleigh-wave dispersion in the BURAR site was described by plotting the average dispersion curve (average velocities values as a function of frequency). The peak value observed at 2 Hz is followed by a rapid fall-off in the 3-5 Hz range.

SW2/P5/ID75 - MEASUREMENT OF THE SEISMIC WAVES PROPAGATION VELOCITY THROUGH SEISMOGRAMS

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The precise speed that a seismic wave travels depends on several factors; most important is the composition of the rock. The speed depends on the rock type because it allows us to use observations recorded on seismograms to infer the composition or range of compositions of the planet. But the process isn't always simple, because sometimes different rock types have the same seismic-wave velocity, and other factors also affect the speed, particularly temperature and pressure. Temperature tends to slow the speed of seismic waves and pressure tends to increase the speed. Pressure increases with depth in Earth because the weight of the rocks above gets larger with increasing depth. Usually, the effect of pressure is the larger and in regions of uniform composition, the velocity generally increases with depth, despite the fact that the increase of temperature with depth works to lower the wave velocity. But you should keep in mind that the specific speed throughout Earth will depend on composition, temperature, and pressure. As you might expect, the difference in wave speed has a profound influence on the nature of seismograms. Since the travel time of a wave is equal to the distance the wave has traveled, divided by the average speed the wave moved during the transit, we expect that the fastest waves arrive at a seismometer first. Thus, if we look at a seismogram, we expect to see the first wave to arrive to be a P-wave (the fastest), then the S-wave. The fact that the waves travel at speeds which depend on the material properties (elastic module and density) allows us to use seismic wave observations to investigate the interior structure of the planet. We can look at the travel times, or the travel times and the amplitudes of waves to infer the existence of features within the planet, and this is a active area of seismological research. To understand how we «see» into Earth using vibrations, we must study how waves interact with the rocks that make up Earth.

ES3 - RECENT SIGNIFICANT EARTHQUAKES

ES3/P1/ID76 - RECENT EARTHQUAKE IN RACHA REGION AND STATISTICAL ANALYSIS

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Georgia is situated in the seismically active (Caucasus) Region of Alpine-Himalayan collision zone. Strong earthquakes with magnitude 7 occurred here. Because of this seismic hazard assessment is a very important issue for scientists and engineers too. Today in the world the best way to avoid damage caused by earthquakes is a sufficient assessment of seismic hazard and usage of obtained results in engineering and urban planning. At this point of view some works in our region have begun since last century when the first seismic network had been operating in Caucasus Region owned by Russian Empire. Until now some of the old deterministic maps of seismic hazard have reached which are compiled in 1948, 1978 and 1992 years. It has to be taken into account that all those maps used to change dramatically after each strong earthquake that means that they could not have kept their main purpose that is long-term forecasting and they were based on only observed earthquakes.

During recent years many important work has been done in the field of seismology by help of Georgian funding as well as foreign funding. It has been compiled probabilistic maps of seismic hazard that needs to be updated continuously. Many works have been already done. Instead of general parameter of macroseismic intensity, it is used a peak ground acceleration and spectral acceleration approved by European, American and Japanese Building Codes. It has been improved scheme and parameterization of seismic active faults, after field exploration it has been added new seismic active structures (for example, at Javakheti plateau, in Tbi-

lisi) and such research have been continued until now. Apart, it has been done improvement and modernization of Georgian seismic network. It has been done seismic database and that is important since 2003 (when the first digital seismic station was installed) a huge number of data have been accumulated.

All mentioned above give us possibility to make one step forward in the field of seismic hazard and earthquake effect analysis. For this purpose the first necessary step has to be made is to analyze earthquake catalogue in details. In this work attention is paid on Racha region because of the seismic history of this region. The biggest event during instrumental period of Georgia was recorded exactly in Racha region in on 29th of April 1991 with magnitude 6.9 (Mw) that was followed by huge number of aftershocks. The recent event occurred on 7th of September 2009 magnitude 6.0 (Ml) which was followed by 300 aftershocks within a month.

In this work seismic catalogue is divided into several period: before 1991 earthquake, 1991 earthquake period with its aftershocks, then since this period until 2009 earthquake and earthquake period with its aftershocks itself. Statistical anaysis is done separately and then discussions and result analysis is done comparing this periods.

From analysis we can distinguish clearly quiescence phenomena. August and the beginning of September in 2009 before earthquake was very quiet similar to the 1991 Racha Earthquake.

We compare many statistical parameters for those two events and found similarities. Those events with their aftershocks gives a possibility to study Racha Region much better using new accumulated data and assess seismic hazard for the region.

ES3/P2/ID77 - THE CONTEXT OF EARTHQUAKE SEISMOTECTONICS OF BOUMERDES (21 MAI 2003 MW = 6.8)

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THE CONTEXT OF EARTHQUAKE SEISMOTECTONICS OF BOUMERDES (21 MAI 2003 Mw = 6.8)

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Summary

This paper is intended as a brief summary of work done on the earthquake of Boumerdes - Zemmouri of May 21, 2003 in geology, geophysics offshore (gravity, aeromagnetic seismic), the seismo-tectonics and seismology (magnitude, seismic moment , focal mechanisms . ..). The results refer mainly to different work mainly to those ad hoc group geoscientific study of the earthquake of May 21, 2003 published under the title (earthquake Zemmouri (Boumerdes, Algeria on May 21, 2003 Mw = 6, 8)
Key words: earthquake - magnitude-faults - tectonics - strain - break - Context - Zemmouri-Boumerdes - offshore - replica - the main shock.

ES3/P3/ID78 - SEISMICITY OF TEHRAN AND SURROUNDING REGIONS

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Historical documents, instrumentally recorded earthquakes during the past hundred years and the existence of many Geological faults all indicate that Tehran region has a high potential of seismic activity. Although in the past centuries many destructive earthquakes occurred around Tehran region, but no major instrumentally recorded earthquake has been reported during the past hundred years. From 1975, ILPA seismic network in southwest of Tehran has recorded many micro-earthquakes in Tehran region. In this study, all the recorded local events were extracted and analyzed. The results are in good agreements with the distribution of local faults. In some areas a kind of seismic gap can be understood. Taking into account the density of population in this region and of the economic and political conditions, it is necessary to carry on more extensive studies.

ES3/P4/ID79 - MICROSEISMIC ACTIVITY IN SOUTHERN KHORASAN REGION DURING THE PAST THREE YEARS REVEALED BY A LOCAL SEISMIC NETWORK

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Seismotectonics of east-central Iran as a part of the Alpine-Himalayan orogenic belt has been the subject of numerous investigators, in recent years. The region has a complex tectonic history of repeated folding magmatism, and metamorphism. The nearest prominent tectonic boundary is the main Zagros thrust line to the southwest, which marks the plate boundary between two continental masses of varied tectonic enviroment. Other structures bounding this region include Alborz and Kopeh Dagh to the north, Makran ranges to the south, and the east Iran-Harirud fault system to the east. The seismicity of east-central Iran is characterized by a diffuse pattern which dies out abruptly across the Harirud fault. Beginning in August 1968, there has been a significant increase in the level of activity over the reported seismicity in the previous decades.

The region in this study bounded between 28°-36°N latitude and 56°-62°E longitude. This region includes many active faults and has experienced several destructive earthquakes that caused extensive destructive and heavy human casualty. Recently a local teleseismic network has been deployed, and enabled us to investigate the local microearthquakes activity. In this study first we provide complete fault map of the region, next we overlapped the epicenters of local earthquakes that recorded during the past three years by local seismic network on the fault map. Then, converted the magnitude earthquakes to seismic energy and provide the seismic energy released map of the region. Thus, the seismically active areas as well as the areas with low rate of the seismic activity were distinguished.

The results indicate that the region is highly active. During the past three years about 1400 earthquakes with magnitude from 2.5 to 5.1 have been recorded. Amonge them 22 earthquakes had magnitudes greater than 4.5 and 5 earthquakes had magnitudes greater than 5.1. The seismic activity in Kerman province in southwest and the Zirkuh area in northwest were significant while in the southeastern part of the study region the recorded earthquakes were very limited. This partially due to limited seismic stations in the region and maybe due to low rate of seismic activity. Also the region has experienced many destructive earthquakes in the past, no earthquake greater than 5.1 has occurred in the region during the past three years. Therefore, the occurence of destructive earthquakes in the region especially in southern extension of the Zirkuh fault in east, is not out of expectation.

ES3/P5/ID80 - TACKLING SIGNIFICANT EARTHQUAKES IN REAL TIME – TIMELINES OF RECENT EVENT RESPONSE AT THE USGS NATIONAL EARTHQUAKE INFORMATION CENTER

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In the first two months of 2010, the USGS National Earthquake Information Center (NEIC) led a rapid response to two major global earthquake crises – the January 12th Mw7.0 Haiti earthquake, and the February 27th Mw8.8 Chile earthquake. Within 4-8 minutes of both earthquakes, the NEIC had detected the events and began to assess the details of each earthquake's seismological characteristics, tectonic setting and societal impacts. The subsequent release of initial estimates of earthquake location and magnitude triggered a collection of products and tools that inform governments, aid agencies, the public and the media of the earthquakes' occurrence (the *Earthquake Notification System - ENS*), its estimated shaking hazards (*ShakeMap*) and population exposure (*Prompt Assessment of Global Earthquakes for Response - PAGER*). For the Haiti earthquake, *PAGER* showed that approximately 3 million people were exposed to severe-extreme shaking (Modified Mercalli Intensity VIII or greater), indicating a large-scale disaster had occurred; similarly in Chile, 5.5 million were exposed to severe shaking, indicating the necessity of a similarly large-scale response. Rapid, independent W-phase, surface-wave and body-wave moment tensor solutions allowed confirmation and updates of magnitudes, identified the mechanisms of each earthquake and facilitated early assessments of the tectonic setting of the respective events, interpretations that have been supported by subsequent analysis and research efforts. Modeling of mainshock rupture processes was completed and refined within several hours, and used to update *ShakeMap* and *PAGER* exposure estimates to provide more accurate assessments of the scale and spatial extent of each disaster.

All of these products were distributed through the USGS Earthquake Hazards Program

web pages, where they were viewed over 10-15 million times within the first 24 hours of each earthquake, and reproduced by many major media outlets. Here we summarize these products, what they reveal about the earthquakes, and how they have been used by various outlets to communicate population exposure in addition to standard reports of earthquake location and size - a major step in increasing our awareness of vulnerability to earthquake shaking hazards.

ES3/P6/ID81 **- AN EVALUATION OF THE STRONG GROUND MOTION RECORDED DURING THE MARCH 08, 2010 KOVANCILAR-ELAZIG (TURKEY) EARTHQUAKE**

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The Kovancilar-Elazig earthquake of March 08, 2010 (Mw6.0) is occurred at 02:32:29 (GMT) near the city of Elazig in the east of Turkey. Epicentral coordinate of the earthquake is determined as 38.77N - 40.03E with a focal depth of 5 km. Large aftershocks with magnitude M > 4 were also recorded at the same day following the main shock. Epicentral area is located in the first and second degree earthquake zone in the Seismic Zoning Map of Turkey. According to the statement from the Disaster and Emergency Management Presidency, 42 people died in some villages near epicenter, due to heavily damaged or collapsed houses. According to the geological and geophysical survey, the Palu-Hazar Lake segment of the East Anatolian Fault System is responsible for the occurrence of the the Kovancilar-Elazig earthquake. Main shock has been also felt in the neighboring provinces such as Diyarbakir, Tunceli and Bingol cities. The National Strong Ground Motion Network of Turkey (TKYHG), operated by Earthquake Department at Disaster and Emergency Management Presidency of Turkey, consists of around 300 digital instruments dispersed around the country. The mainshock has been recorded by 12 stations belonging to the TKYHG in the region. The uncorrected peak ground accelerations (PGA) recorded in Palu station (38.695N, 39.931E), nearest distance (about 12 km) to epicenter were 66.5 cm/sec^2, 62.0 cm/sec^2 and 30.0 cm/sec^2 in the EW, NS and vertical directions, respectively. The Palu station record was very important for the near source and strong ground motion seismology. The effective duration of the earthquake determined based on Arias Intensity variations is estimated as 13.77 sec for EW direction, and 15.52 sec for NS direction. Fourier spectrums are also examined, and it has been seen that dominant frequencies are 1.65 Hz (0.6 sec) and 2.0 Hz (0.5 sec) for NS and EW directions, respectively. Dominant frequency and amplification values are calculated for the earthquake-affected region by using earthquake and noise records of stations located in the region within TKYHG and temporary stations installed to monitor aftershock activity. Peak acceleration values are also compared with attenuation relationships proposed by some researchers.References: Yilmaz, N. and Uran, T., 2010. Evaluation report of 8 March 2010 Elazig (Kovancilar) Earthquakes, Report No: 025.343/6056.1, Earthquake Department, Disaster and Emergency Management Presidency, Ankara, Turkey, May, 2010.Çeken, U., Beyhan, G., Gulkan, P., 2009. Strong Ground Motion Attenuation Relationship for NW Anatolian Earthquakes: 18th International Geophysical Congress and Exhibition of Turkey, Ankara, 14-17 October 2008.

ES3/P7/ID82 **- THE BENI-ILMENE (NORTH CENTRAL ALGERIA) EARTHQUAKE SEQUENCE OF MAY 14TH 2010: PRELIMINARY SEISMOLOGICAL INVESTIGATIONS.**

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A sequence of three earthquakes of moderate magnitudes (M>5) struck a region North of M'sila 130 km SE of the capital Algiers. A temporal short period network was installed around the epicentral area 1 day after the first main shock in addition to the permanent digital network. The first event (Md=5.2) occurred on May 14th, 2010 caused a loss of three human lives and material damage. The second (Md=5.0) and the third (Md=5.0) shocks which occurred respectively 2 days and 9 days later frightened the population more than the first one. The focal mechanism of the first and third events reveals a strike slip faulting with a small reverse component, consistently with some previous earthquakes in adjacent regions. The second shock which was located 10 km westward suggests a pure reverse faulting which demonstrates the complexity of the tectonic in the region. The preliminary data on the main shocks and aftershocks suggest that the three main shocks ruptured distinct fault segments adjacent and slightly offset from one to another. Note that the epicenter of the first main shock coincides with the macroseismic epicenter of a similar size earthquake occurred in 1960 in the same locality. Both earthquakes (1960 and 2010) were preceded before by a foreshock.

ES3/P8/ID83 **- MONITORING HAITI EARTHQUAKE AFTERSHOCKS: A TEMPORARY NETWORK ON LAND AND OFFSHORE.**

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During the first weeks after the catastrophic earthquake which struck Haiti last January it was impossible to install onshore stations in Haiti to monitor the aftershock activity. Given the peculiar geographic position of the EPGFZ, which runs all along a narrow peninsula, we decided to deploy a sub-marine seismological network all around the Peninsula. During a marine scientific cruise (Haiti-OBS), on-board the R/V L'Atalante, (Feb.5 to Feb.15, 2010, from and to Pointe-à-Pître, Guadeloupe), we deployed 21 OBS (Ocean Bottom Seismometers) in Haitian waters and completed this array with 4 onshore seismic stations. All OBS were 4 components instruments, three velocimetric channels and one 2 Hz hydrophone, while the land-station were 6 components instruments, including a 3-component velocimetric sensor and a 3-component accelerometric sensor. The R/V L'Atalante collected swath bathymetry data along the lines during the launching of the OBS. The first results of the aftershocks distribution is that the global pattern of the active zone is shifted NE compare to the one display by the NEIC catalogue information.

ES3/P9/ID84 **- UNDERSTANDING THE FEBRUARY 2010 CHILEAN EARTHQUAKE THROUGH THE PROPAGATION MODELLING OF THE ASSOCIATED TSUNAMI OVER FRENCH-POLYNESIA.**

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On the 27th February 2010, an earthquake with magnitude of 8.8 occurred 115 kilometers NNE of Concepción, Chile. The French Polynesia Tsunami Warning System (CPPT) , located on Tahiti, notified French Polynesia authorities through tsunami information bulletin about a red tsunami warning level, the highest warning level induced the evacuation from coastal areas of 68 inhabited islands. This major earthquake occurred in the Nazca subduction zone; as historical tsunami events it showed that the most concerned islands in French Polynesia were the Marquesas archipelago reached ten hours and half after the earthquake. Marquesas islands present few outer reefs, more gradual bottom slopes and large bays where we observed near the coast a maximum amplitude wave about 3.0 - 4.0 meters on the tide-gauges. Whereas due to the directivity and bathymetry effects, the maximum tsunami amplitude observed near the coast was only about 0.2 meter in Austral islands and about 0.28 meter on the tide-gauge of Tahiti which was reached after eleven hours.

In this context, the associated tsunami has been modelled over Pacific ocean using a water surface initialisation computed from Okada's formulation considering different source fault parameters that show up within the few hours after the earthquake from the CPPT, the European-Mediterranean Seismological Centre (EMSC) and from U.S Geological Survey (USGS) but also some recent finite fault model. The values of tsunami amplitudes, flow velocities and arrival times are compared to the observed data in French Polynesia obtained from tide-gauges and recent field surveys.

This model is developed in the framework of the CPPT and the future French Mediterranean Tsunami Warning System part of the North-eastern Atlantic and Mediterranean Tsunami Warning System (NEAMTWS) to enhance the pre-computed generation/propagation forecast database.

ES3/P10/ID85 **- VIBRATION EFFECT OF SEISMIC SWARM (KRASLICE AREA, CZECH REPUBLIC, 2008) IN MEDIEVAL JERONÝM MINE**

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Seismic swarm that occurred in Kraslice area, West Bohemia, in 2008, represents the most significant seismic loading of this area from 1985/1986. Study of this swarm is performed by staff of Geophysical Institute of the ASCR, Prague. About 35 km from this source area, large medieval mine named Jeroným is situated (Sokolov District). The Jeroným Mine is declared as National Cultural Heritage Site of the Czech Republic. This medieval mining locality is not open for public in the present time but in connection with the assumed utilization of the mine for the purpose of tourism, in 2001, works started to obtain more objective and specific information about the stress-strain and stability state of this shallow mine. Interpretation of seismic events recorded during period 2006-2009 shows that it is possible to divide records into following groups:
• blasting operations from adjacent quarries,
• traffic – road above the mine,
• earthquakes – intensive distant,
• microearthquakes from North-West Bohemia,
• other seismic events – e.g. mining induced seismic events from Lubin.In sum 451 earthquakes from Nový Kostel area were recorded on seismic station Jeroným within 6 Oct. –10 Dec., 2008. The most intensive shock occurred on 14 Oct (21:00); maximum value of component velocity reached 0.435 mm.s^{-1}. Damages of underground spaces (i.e. cracking of pillars, opening of observed fissures and discontinuities, more significant breaking off rock from the ceilings and walls …) were not visually observed during quarterly experimental geomechanical monitoring in autumn 2008 and spring 2009.

ES3/P11/ID86 – TIME VARIATIONS OF AFTERSHOCK DECAY PARAMETERS OF THE APRIL 6, 2009 L'AQUILA (CENTRAL ITALY) EARTHQUAKE: EVIDENCE OF THE EMERGENCE OF A NEGATIVE EXPONENTIAL REGIME SUPERIMPOSED TO THE POWER-LAW

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We studied the variations with time of decay properties of the L'Aquila aftershock sequence by considering time intervals of progressively increasing duration beginning at the main shock. In the first few days, the decrease of the rate appears very slow, compatible with an Omori's process with power-law exponent p≈0.5. The progressive increase of the exponent up to about p=1.2 in the following weeks can be interpreted as the emergence of a negative exponential regime that has been found to control the decay of other sequences occurred in Italy and California. In fact, two models that also include a negative exponential term reproduce the aftershock rate in the first 60 days significantly better than the Omori's law according to the Akaike information criteria. In this time interval, the evolution of the sequence does not show an evident epidemic character, as strongest aftershocks do not seem to have induced significant increases of the aftershock rate while a couple of them seem to be preceded, rather than followed, by a slight increase of the rate. About 80 days after main shock, the rate suddenly increased, after a relatively strong aftershock in the main fault area and the activation of a previously silent fault segment located at about 25 km from the main shock epicenter. A slow change of decay parameters seems to have preceded by few weeks this renewal of the rate. The L'Aquila main shock is one of the most productive ever observed in Italy, as it produced from 3 to 10 times more aftershocks that any previous earthquakes with similar magnitude.

ES3/P12/ID87 – AN IMPORTANT NUMBER OF RECENT SIGNIFICANT EARTHQUAKES IN GREECE

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Greece is characterized by high seismicity mainly due to the collision between the European and the African lithospheric plates. During the recent years strong earthquakes occurred in regions with different seismotectonic regimes. Moment tensor inversion was applied to determine the source properties, as well as the dynamic processes of these events. Waveforms recorded in teleseismic distances were used and P, SH and SV synthetic waveforms were calculated for the selected stations. The final solution is obtained by minimizing the difference between the observed and the synthetic waveforms. The obtained source parameters were compared to the seismotectonic characteristics of each seismogenic area. Slip models that were determined for the important events were used to compute the Static Coulomb Stress Changes. This computation was performed in order to examine possible stress transfer to a neighboring area or to explain the spatial distribution of certain aftershock sequences. No static stress transfer was revealed to the epicentral area of the 2008 Leonidion earthquake due to the occurrence of the 2006 Kythira earthquake. On the other hand, the aftershock distribution of the 2008 Andravida earthquake extended to an area significantly larger than the one expected according to the magnitude of the main event. On February 2008 an earthquake sequence including three strong events (Mw=6.7, 6.1 and 6.0) occurred South of Methoni, at a segment of the Hellenic arc which was not activated during the instrumental period. This sequence was followed by a large number of aftershocks, the strongest of which were processed to calculate their source parameters. The most recent significant events occurred north of Rhodes on 15 July 2008 (Mw=6.3) and south of Crete on 1 July 2009 (Mw=6.2). The first occurred at a depth of 55 km, was characterized by strike-slip faulting and followed by few aftershocks. On the contrary, the second one was followed by an important aftershock sequence with focal depths in the range of 10-30 km. The Crete earthquake was characterized by thrust faulting. Even though most of the above earthquakes are related to the Hellenic Arc, they are characterized by different seismotectonic features and stress regimes.

ES3/P13/ID88 – SURFICIAL CRACKS OBSERVED AFTER THE PARIAMAN (PADANG) AND KERINCI 2009 EARTHQUAKES, INDONESIA: RELATIONSHIP WITH THE NATURE OF SEISMIC WAVES

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On 30 September 2009 a 7.5 M_w devastating earthquake occurred as a result of oblique-thrust faulting near the subduction interplate boundary between the Australian and Sunda plates. Its epicentre located ~25 km WSW offshore Pariaman, West Sumatra. The published moment tensor solution suggests that a medium depth thrust fault striking NE-SW was the responsible trigger for the event, apparently perpendicular to the NW-SE striking subduction zone. This earthquake caused 1,117 fatalities and 3,942 collapsed constructions, including houses, medical facilities, government offices and bridges.

A day after the Pariaman earthquake, 1 October 2009, the Kerinci 6.6 M_w earthquake occurred as a result of shallow strike-slip in the Sumatra Fault Zone and damaged buildings and caused three fatalities. The epicentre was located near Lempur Hilir, about 40 km south of Kerinci Lake. The published moment tensor solution suggests that a shallow depth fault striking NW-SE was the responsible trigger for the event, which has good agreement with the Sumatra Fault Zone striking NW-SE. Although the Kerinci earthquake was shallow and strong, surprisingly it did not produce extensive damage. Sungai Penuh has a population of 95,000, is capital of Kerinci Regency, and is the nearest town to the epicentre, yet it did not experience any damage and people in the town hardly felt any strong ground motion.

One method to study the nature of earthquake is through examining surface cracks. Examining systematic cracks at the soil surface, asphalt roads and bridges will inform how the seismic waves propagate to deliver damaging forces. Observations (Pariaman earthquake) made on a basketball field and adjacent Junior High School of Enam Lingkung District, Padang Pariaman Regency, which is built on thick Quaternary volcanic deposits, revealed that the ground floor had a crack system aligned NNW-SSE across the floor. Closer observation revealed many features associated with strike-slip movement on a crack, with a distinctive NW-SE compression direction. Observations (Kerinci earthquake) at the severely damaged Lempur Hilir Mosque that is built on thin Quaternary lacustrine alluvium revealed that the ground floor had a particular crack aligned N-S across the floor. Closer observation revealed many features associated with strike-slip movement on a crack, with a distinctive NW-SE compression direction. Both observational results suggest that the floors of the basketball field and the mosque were cracked due to body primary waves released by these earthquakes, and they are consistent with moment tensor solutions derived from instruments.

ES3/P14/ID89 **- EXTENSIVE DATASET OF COASTAL UPLIFT AND TSUNAMI TRACE HEIGHT ASSOCIATED WITH THE MW8.8 EARTHQUAKE IN CENTRAL CHILE (33.2 º-39.8°S)**

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In the dawn of February 27, 2010, a subduction earthquake of magnitude Mw8,8 occurred off the coast of Cobquecura (73,24°W; 36,29°S). It affected the central zone of Chile and induced surface displacements in the coastal area. Later, a tsunami strongly flooded the coasts of the Regions O'Higgins, Maule and Araucanía. We here present a large set of data (vertical displacement and tsunami trace height) that have been collected in the few weeks after the event.

The coseismic coastal uplift was estimated from observations of the algal band of the group Lithothamnium (following the Ortlieb et al. (1998) methodology), together with other algae and typical mollusks from the subtidal to intertidal zone. These were vertically displaced in response to coseismic displacements. Evidences of vertical deformation were observed between 34.13°S and 38.34°S. The minimal observed uplift was of 15 +/-10 cm. The highest uplift values were measured in the closest sites relatively to the trough, mainly on the western coast of Arauco peninsula (between 133 +/-20 cm and 240 +/-20 cm). A maximum value of 310 +/-30 cm was observed in the Island Santa Maria. Uplift values decreases to the East with increasing distance to the trough. In some estuaries or coastal lakes, subsidence of up to 0,5-1 m was estimated. In regional terms, the data show that the change from uplift to subsidence happened at a distance of 110-120 km with respect to the trough.

The higher "trace heights" of the tsunami that affected the coasts after the earthquake, were observed immediately to the north of the epicentre. There, trace height reached even ca. 14 m, then diminishing progressively towards the north, up to values of the order of 2,5 m (south of Valparaiso). On the coast close to Cobquecura, trace height diminished up to 2-4 m, increasing locally up to 6-8 m in Dichato-Talcahuano's zones and Tirúa. The testimonies compiled (N = 10) coincide with that the times of flood arrival changed between 15-25 minutes in the epicenter zone, and 30-60 minutes in the most distant areas. Both the distribution of the maximum trace heights and the testimony information near the epicentre zone suggest that the tsunami could have had a complexity associated with the seismic event.

ES3/P15/ID90 **- SOURCE RUPTURE PROCESS, DIRECTIVITY AND COULOMB STRESS CHANGE OF THE 12 JANUARY 2010 (PORT-AU-PRINCE HAITI, MW7.0) EARTHQUAKE**

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The Haiti earthquake occurred on Tuesday, January 12, 2010 at 21:53:10 UTC. Its epicenter was at 18.46 degrees North, 72.53 degrees West, about 25 km WSW of Haiti's capital, Port-au-Prince, along the tectonic boundary between Caribbean and North America plate dominated by left-lateral strike slip motion and compression with 2 cm/yr of slip velocity eastward with respect to the North America plate. The earthquake was relatively shallow (about 13 km depth) with Mw 7.0 and CMT mechanism solution indicating left-lateral strike slip movement with a fault plane oriented toward the WNW-ESE. More than 10 aftershocks ranging from 5.0 to 5.9 in magnitude struck the area in hours following the main shock. Most of these aftershocks have occurred to the west of the mainshock in the Mirogoane Lakes region and its distribution suggests that the length of the rupture was around 70 km. Rupture velocity and direction was constrained by using the directivity effect determined from broad-band waveforms recorded at regional and teleseismic distances using DIRDOP computational code (DIRectivity DOPpler effect) [1]. The Results show that the rupture spread mainly from WNW to ESE with a velocity of 2.5 km/s. In order to obtain the spatiotemporal slip distribution of a finite rupture model we have used teleseismic body wave and the Kikuchi and Kanamori's method [2]. The inversion show complex source time function with a total scalar seismic moment of 2.2 x 10^{19}Nm (Mw=6.9) a source duration of about 18 sec with a main energy relesea in the first 13 sec. Finally, we compared a map of aftershocks with the Coulomb stress changes caused by the main shock in the region [3]. [1] Kikuchi, M., and Kanamori, H., 1982, Inversion of complex body waves: Bull. Seismol. Soc. Am., v. 72, p. 491-506. [2] Caldeira B., Bezzeghoud M, Borges JF, 2009; DIRDOP: a directivity approach to determining the seismic rupture velocity vector. J Seismology, DOI 10.1007/s10950-009-9183-x [3] King, G. C. P., Stein, R. S. y Lin, J, 1994, Static stress changes and the triggering of earthquakes. Bull. Seismol. Soc. Am. 84,935-953.

ES3/P16/ID91 **- DESTRUCTIVE EARTHQUAKE AT COAST OF CENTRAL CHILE ON FEBRUARY, 27TH, 2010. SEISMIC HISTORY AND THE PRELIMINARY ANALYSIS OF AFTERSHOCK PROCESS INITIAL STAGE**

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The seismic history of region on a course of the cumulative scalar seismic moment release has been tracked from 1570 up to 1960 (time of the Big Chilean earthquake of 22.05.1960); and from 1960 up to 2010. Cumulative scalar seismic moment (M_{0cum}) release analysis from 1570 up to 1960 has shown that time of earthquake 22.05.1960 preparation is approximately 180 years. Time course ofM_{0cum} during 1960 up to 2010 has revealed the expressed phase of seismic quiescence was observed from 1986 up to the beginning of 2010. An opportunity of occurrence of new strong earthquake in this area is specified too by abnormal low value of the ordering index, observed on the end of 2001 with its subsequent almost monotonous growth down to 27.02.2010 earthquake. However, the period of approximately 50 years between earthquakes of 22.05.1960 and 27.02.2010 has appeared insufficient for occurrence of earthquake withM_W = 8.8. Actual deficiency in M_{0cum} release on the beginning of 2010 was $3.73 \cdot 10^{21}$ N·m, that approximately in 5 times less the M_0 of the earthquake 27.02.2010.Aftershock process of 27.02.2010 earthquake in its initial stage develops enough slowly for seismic event of such force. For the first 3 months nearby 440 aftershocks with magnitudes $4.5 \le M_W \le 6.9$ has occurred. The value of the total scalar seismic moment released in aftershocks for this time was about $1.62 \cdot 10^{20}$ N·m or only 0.88% from the M_0 of the main event. The analysis of M_{0cum} release time course in the first day after 27.02.2010 earthquake has allowed to make a conclusion on an opportunity of new strong repeated pushes occurrence with moment magnitude up to 7.0 - 7.5. Thus, a series of three enough strong aftershocks on March 11 - 16, 2010 with M_W 6.9, 6.8 and 6.6 has been predicted in a mode of real time. Since March, 17th, 2010 the new phase of seismic quiescence in aftershock process was started. Predicted average speed of M_{0cum} release in the assumption of its linear release at least in the first weeks after earthquake of 27.02.2010 is estimated as $6.16 \cdot 10^{18}$ N·m/day. Presence of more or less long linear phase of liberationM_{0cum} releasein aftershock process (its duration depends both from earthquake magnitude and from the place of its occurrence) before by virtue of Omori law enters, proves to be true results of a number strong earthquakes aftershock process analysis.

ES3/P17/ID92 **- THE AFTERSHOCK ACTIVITY OF THE 8/6/2008 (MW=6.4) EARTHQUAKE OF NW PELOPONNESE, GREECE: STUDY ON FAULT GEOMETRY, SOURCE PARAMETERS AND STRONG MOTION OF THE MAINSHOCK**

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After the recent strong earthquake (Mw=6.4) of Achaia-Elia (NW Peloponnese, Greece) on June 8, 2008, a temporary network of 13 velocimeters and 5 accelerometers were deployed by ITSAK (Institute of Engineering Seismology and Earthquake Engineering) in the vicinity of the seismic fault. This temporary network has operated for almost 3 months and recorded an important amount of aftershocks ($0.8 \le M \le 4.3$). A very good azimuthal coverage of this network around the causative fault and its composition of high technology instruments (sensors' response from 30sec to 0.01sec and 24-bit digitizers) allowed us to obtain a very well defined and accurate aftershock space distribution as well as high quality seismic recordings.

The distribution of this aftershock activity helped us to define the geometry of the active fault which in combination with the properties of the seismic source, contributed to the simulation of the mainshock's strong motion in the near and intermediary field (R<50km) using the Empirical Green's

Function method (EGF). A comparison of synthetics with observed recordings helped in understanding fundamental properties of the seismic source, on the wave propagation path and cast light on the reliability and limitations of EGF method.

Furthermore a non-linear inversion technigue has been applied on our data set in order to define source parameters, ray path properties and site transfer functions. The magnitudes of the strongest aftershocks were then compared to the local (ML) and the (Mw) magnitudes computed by different institutes.

ES3/P18/ID93 - FIELD SURVEY OF THE 27 FEBRUARY 2010 TSUNAMI IN CHILE

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On 27 February, 2010 a magnitude Mw 8.8 earthquake occurred just off the coast of Chile's Maule region some 100 km NNE of Concepcion, which caused substantial damage and loss of life on Chile's mainland, the Juan Fernandez archipelago and Easter Island. The majority of the approximately 500 fatalities were located in coastal areas and attributed to the ensuing tsunami. PTWC responded and issued warnings soon after the earthquake but, because the tsunami arrived within 30 minutes at many locations, official evacuations were late. Fortunately, most coastal residents knew to go to high ground after an earthquake, because of ancestral knowledge from past tsunamis such as the giant 1960 event, as well as tsunami education and evacuation exercises. More than half of the victims were tourists staying overnight in low lying camp grounds along the coast. A multi-disciplinary reconnaissance survey team was deployed within days of the event to document flow depths, runup heights, inundation distances, sediment deposition, damage patterns at various scales, and performance of the man-made infrastructure and impact on the natural environment, per established protocols (Synolakis and Okal, 2005). The 3 to 25 March 2009 ITST covered an 800 km stretch of coastline grom Quintero to Valdivia in various subgroups.

The recorded Chile survey data includes more than 300 tsunami runup and flow depth measurements. In the Maule and Bioblo coastlines, the tsunami impact peaked with a localized maximum runup of 30 m on a steep slope within less than 2 km of the river mouth at Constitucion, while 10 m flow depth in the estuary are more representative for the tsunami. A significant variation in tsunami impact was observed along Chile's .mainland both at local and regional scales. Inundation and damage occurred several kilometres inland.

San Juan Bautista in the island of Juan Fernandez (aka Robinson Crusoe Island) was surveyed, highlighting maximum runup heights of 20 m above sea level maximum extent inland flooding of approximately 300 m and flow depths up to 9 m. The large variability in the maximum runup along Cumberland Bay suggests amplification due to local effects in bathymetry and topographic features. The team interviewed numerous eyewitnesses and educated residents about the tsunami hazard. Community-based education and awareness programs are essential to save lives in locally generated tsunamis.

Synolakis, C. E. and Okal, E. A. [2005] ''1992–2002: Perspective on a decade of post-tsunami surveys, in Tsunamis: Case Studies and Recent Developments, ed. K. Satake, Advances in Natural and Technological Hazards Research 23, 1–30.

ES3/P19/ID94 - FAST IMAGING OF SEISMIC RUPTURE PROCESS OF THE RECENT SIGNIFICANT EARTHQUAKES (2008 TO 2010) USING SLIP PATCHES METHOD

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The slip-patch method [Vallée and Bouchon, 2004] has been processed on the recent significant earthquakes of the 2008-2010 period. This method allows to quickly determinate, from teleseismic P and SH body waves, the first and second order characteristics of the event (focal mechanism, depth, duration, and also more refined kinematic parameters, such as spatial slip distribution on the fault and rupture velocity in terms of slip patch(es)). Judging by the fit quality of most of the studied earthquakes for frequencies lower than 5-10 seconds, the slip-path method appears to be very efficient for the three thrust, normal and strike-slip faulting, for shallow and intermediate-depth earthquakes (see examples). For these frequencies, the eventual observed complexities in the seismograms can often be well explained by a description of the source process with one or two main patches (see Mw8.8 Chili earthquake, Mw7.2 Haiti earthquake, Mw6.2 L'Aquila earthquake). Moreover, for the most damaging earthquakes, near-field synthetic signals corresponding to the obtained source patterns are calculated in order to estimate static displacement and the potential most damaged zones. The GUI interface available for the research community during the NERIES'project was developed to help the analyst for the waveform request and link kinematic source inversion results with other associated algorithms (static displacement field, radar interferogram, tsunami simulation …).

SW6 - SEISMOLOGICAL AND STRUCTURAL STUDIES IN THE EUROPEAN ARCTIC

SW6/P1/ID95 - SEISMOLOGY ON ICE PLATEAUS : PRACTICAL LESSONS LEARNED FROM CONCORDIA STATION (CCD) AND THE CASE-IPY EXPERIMENT.

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Running seismic stations on ice at high latitudes, whether in the Arctic or the Antarctic, poses technical difficulties related primarily to environmental conditions : temperatures that can reach -80°C, lack of sunlight during the winter months, extreme inaccessibility. Starting with the permanent station at Concordia (Dome C, Antarctica, station code CCD, continuously recording since 2005), and continuing with the Concordia Antarctica Seismic Experiment for the International Polar Year (CASE-IPY, 2007-present), we have built up considerable expertise in the technicalities of deployment in these conditions. We shall illustrate a number of the lessons we have learned over the past 5 years, using examples from both CCD and CASE-IPY, and indicate areas where improvements could still be made.

The waveforms recorded by seismic stations on ice plateaus are more complex than their counterparts recorded at rock sites, mainly because of low-attenuation reverberation within the approximately 3-km thick ice-layer. Exploitation of these data, therefore, requires special attention, but can also lead to recovering seismic information about the ice-layer itself. We shall present examples of this reverberation, including its effect on raw signals and receiver functions.

SW6/P2/ID96 - SEISMIC RESEARCH OF SUBPOLAR AREA OF RUSSIA

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At the station «Vorkuta» (northeastern European Russia; Vorkuta is characterized by the most severe climate in Europe) were provided by the apparatus complex that included seismometers SM3-KV (frequency band 0.5-30Hz) and complex STS-2/REFTEK-72A. It performs traditional seismological observations of local and regional seismicity, as well as registration of teleseismic events. However, the Northern part of European Russia is an aseismic region, so local earthquakes happen very seldom. One of the tasks of registration, besides recording earthquakes, is identification of industrial sources, whose signals may get to seismic catalogues. An important operating stage of the station «Vorkuta» are observations over explosions in the pits in that region. Registering explosions with known parameters allowed to plot the local travel time curve. The degree of seismic wave damping in the area near the deposit was estimated too. Besides the signals of industrial sources (explosions, mining activities, etc.) the anthropogenic activities may also trigger seismic events. Huge amounts of energy are accumulated in discontinuous media. So, even weak disturbances (for example, explosions, waves of teleseismic earthquakes) can trigger seismic events. For example, conservation of mines starts the process of relaxation or the transition to geophysical equilibrium of a rock massif. This process is accompanied by failure of appreciable rock masses, damaging hydrologic horizons, etc. According to some estimation, such a relaxation process can last several tens of years. A model of the seismic noise at Vorkuta has been constructed. Detection of signals from teleseismic earthquakes and local industrial

chemical explosions with high signal to noise ratio suggest that Vorkuta is a suitable site for a regional seismic array.

SW6/P3/ID97 - SKS SPLITTING ANALYSIS TO DERIVE MANTLE ANISOTROPY UNDERNEATH THE SCANDINAVIAN MOUNTAINS

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The ESF TOPO-EUROPE project TopoScandia-Deep (www.geo.uio.no/toposcandiadeep) aims at developing a geophysical model which explains the mechanisms that cause the present high topography of the Scandinavian Mountains far away from the present plate boundaries. We analyse a combined dataset which consists of different experiments: 1) The MAGNUS experiment consisted of 31 temporary stations of the KArlsruhe BroadBand Array and 10 permanent stations (NORSAR(7), KONO, BER and HFC2) which recorded continuously from September 2006 to June 2008. 2) The SCANLIPS 1&2 experiments in 2006 and 2008/09 with up to 38 stations. 3) The permanent NORSAR, HFC2 and KONO stations.

Shear-wave splitting analysis is carried out with the combined dataset for teleseismic events with Mw ≥ 6.0 at the distance range 85°-130°. The observed splitting of the core phases (SKS, SKKS) into two mostly orthogonally polarised waves with different propagation velocity (birefringence) is used to constrain the mantle anisotropy. Any observed anisotropy in the study area may be related to asthenospheric flow or alignment of anisotropic minerals in the lower lithospheric rocks due to recent or paleo deformation processes. These processes may be associated with the formation of the Scandes mountain range.

We present the first results concerning the SKS splitting parameters (fast polarization direction Φ and delay time δt) and a possible relationship with the recent high topography in Norway.

SW6/P4/ID98 - LITHOSPHERIC STRUCTURE BELOW SOUTHERN NORWAY FROM RAYLEIGH WAVE ANALYSIS

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The Scandinavian mountains extend from 60 to 70 degrees North on the northern rim of the European continent. They form the major topography of Northern Europe and the second major element of the European topography, just after the active Mediterranean orogenic area. Its origin, away from any presently active plate margin, is however not well understod. In particular, it is not clear if the mountains are sustained isostatically by crustal thickening or by light upper mantle material. Focus is put here on a refined model of mantle structure below the highest part of the mountains using surface waves registered from summer 2006 to summer 2008 by the MAGNUS network, a temporary regional network of broadband stations composed essentially of the KABBA stations (Univ of Karlsruhe) and the NORSAR stations.

An average model for the area is obtained by depth inversion of the average phase velocity dispersion curve of the Rayleigh wave fundamental mode in the period range 22 to 200s. The average dispersion is obtained by beamforming of about 200 Rayleigh waves well distributed in backazimuth and epicentral distances, and image deconvolution of the beam by the point spread function of the network. The S-wave velocity with depth clearly shows that Southern Norway is underlain by anomalous low velocities (at around 4.4 km/s) down to about 250 km depth. This confirms and puts a more realistic number on a previously detected low velocity in the area and suggests a mantle component to the isostatic balance.

A refined image of the lateral variations of the low velocity is also obtained by regional tomography of selected data using a novel approach based on interpolation of the phase gradient within the network to estimate phase velocity maps. Measurement uncertainties are efficiently suppressed by stacking of multiple maps, each derived from interpolation of different data subsets. The new Rayleigh wave phase velocity maps for Southern Norway confirm the low velocity feature imaged on average over the entire region but also show distinct lateral variations.

SW6/P5/ID99 - CHALLENGES AND CURIOSITIES OF SEISMOLOGY ON ICE FLOES – EXPERIENCES FROM THREE SURVEYS IN THE ARCTIC OCEAN

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Seismological studies on ultraslow-spreading mid-ocean ridges are not numerous due to the fact that the most prominent members of these ridges are located in polar regions. Investigations on Gakkel Ridge in the ice-covered Arctic Ocean and Lena Trough located in the Fram Strait between Greenland and Spitsbergen require special logistics and techniques. Above the latitude of 80°N ice floes endanger the deployment and recovery of ocean-bottom seismometers even during Arctic summer. DFG funded Emmy Noether group 'Mid-Ocean Volcanoes and Earthquakes' located at Alfred-Wegener Institute for Polar and Marine Research is carrying out seismological studies on Arctic mid-ocean ridges and developed adequate techniques to record local seismicity in ice-covered oceans.

We are using small-aperture seismic arrays equipped with Guralp broadband sensors which are deployed on drifting ice floes by helicopters operating from icebreakers such as RV Polarstern or RV Oden. Due to limited transport capacity and difficult weather conditions the stations' weight and the necessity to install them fast are important factors. The sensor needs to be isolated well against the strong solar radiation during the Arctic summer. An array consists of three to four single stations installed on one ice floe with a minimal diameter of one kilometer. During a time span of up to two weeks the stations are drifting several tens of kilometers according to local swell and wind direction and speed.

The broadband sensors record a wide variety of signals, for which we identified different sources. Those can be colliding ice floes, helicopters or ice breaking ships, seismic blasts from the ship during seismic profiling, earthquakes within local, regional or even teleseismic distances and sometimes even curious wildlife.

SW6/P6/ID100 - TELESEISMIC LOCATION OF EARTHQUAKES ALONG THE ARCTIC MID-OCEAN RIDGE SYSTEM

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Teleseismic location is heavily dependend on the spatial distribution of recording stations and the number of registered phases. In the Arctic Basin, a total lack of local or regional recording stations makes location of earthquakes especially challenging. In 1999 an unusually strong earthquake swarm at Gakkel Ridge, Arctic Ocean, which consisted of 252 events with body-wave magnitudes up to 5.2 lasted over 9 months. Using the ISC reviewed dataset, we relocated this swarm with the probabilistic routine NonLinLoc and tested extensively the influence of velocity model, station coverage and weighting on the location result. For calculation of travel times we used the velocity model AK135 combined with a regional velocity model for recording stations with epicentral distance < 30°. The dataset was reviewed with regard to the quality of the location and reduced to 63 well located events whose epicentre locations are largely independent of the above tested parameters. The 68% error in ellipse semi-major axes of the new localization is in the order of 15 km for the best events. We tested if the choice of location routine influences the resulting locations. Comparing our solution for the 1999 earthquake swarm to that for the L2-norm-based algorithm Hyposat, we found significant differences in the location for the 63 best constrained events, the epicenters not even matching within error-ellipses. Additionally, to improve locations within the cluster, we performed a simple master event relocalization and tested again the dependence of the results on the location algorithms.

SW6/P7/ID101 - LOCAL SEISMICITY ON AND NEAR BEAR ISLAND (NORWEGIAN ARCTIC) FROM A TEMPORARY DETECTION ARRAY INSTALLATION IN 2008

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As part of the International Polar Year project (IPY) „The dynamic continental margin between the Mid-Atlantic-Ridge system (Mohns Ridge, Knipovich Ridge) and the Bear Island region" a temporary test detection array has been installed on Bear Island during summer 2008. The aim of this project was to improve the understanding of the structural architecture, the stress conditions and sources, and the dynamics of the continental margin, to identify active tectonic structures. However, the vast majority of the detected events are of clearly local origin. By using the array as a network to

localize events with clear body wave onsets, by applying the NORSAR hyposat software, it was possible to identify different groups of events. First of all a major group was detected which can most likely be associated with wave and weather phenomena at the northern coast of the island. P and Rayleigh phases arrive at very shallow angles and the primary onset is dominant at the horizontal components indicating a lateral excitation at the steep northern coast. By using a waveform correlation code it was possible to determine the temporal distribution of those events and compare it with weather and climate data of the meteorological station at Bear Island. A second, smaller group that could be localized in or near the network of the array and which appears at the beginning of the recording time is assumed to be caused by snow melting and breaking of ice floes on the rivers and lakes on the island. Several acoustic events are of unclear origin. Finally, the probably most interesting group consists of small tectonic events located in the south-eastern part and the adjacent surroundings of the island respectively, indicating that there is active tectonics on or near Bear Island. They are characterized by strong amplitude differences between the stations of the network, source durations of one second and pronounced surface waves, suggesting shallow events. The source mechanisms of those events will be investigated in further steps.

SW6/P8/ID102 **- CRUSTAL STRUCTURE OF THE AREA WEST OF BEAR ISLAND, WESTERN BARENTS SEA**

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As an important part of the IPY project "The dynamic continental margin between the mid-Atlantic ridge system and the Bear Island Region" two wide-angle seismic profiles were acquired west of Bear Island, western Barents Sea in 2008. The main goal with the survey was to map the crustal and upper mantle structure along the sheared/rifted western Barents Sea margin and on the adjacent oceanic crust. More specifically we wanted to find the location of the continent-ocean boundary and investigate the nature of the crust below the shallow volcanic rocks in the Early Eocene Vestbakken volcanic province. This poster shows preliminary crustal P-wave velocity profiles generated by forward modelling and tomographic inversion of seismic traveltimes and density models generated by forward modeling of gravity data. Along both profiles the crystalline oceanic crust is buried by a thick sedimentary package with low velocities. The exception is the area west of the Knipovich Escarpment where the sedimentary package is of moderate thickness. One interesting observation is that the sedimentary thickness in the Knipovich rift valley is substantially thicker than on the rift flanks which indicate that the sedimentation rate is high in this valley. Close to the Bear Island we observe very high P-wave velocities just below the seafloor. This pattern is changing on the western side of the Knølegga fault. This observation is similar to previous studies and indicates that the Knølegga fault represents the boundary between the old, highly compacted rocks of the Stappen high and the younger, less compacted sediments in the Cenozoic basin areas west of the fault.

SW6/P9/ID103 **- SEISMIC ACTIVITY BETWEEN NORTHERN NORWAY AND SVALBARD OBSERVED WITH TEMPORARY AND PERMANENT NETWORKS DURING THE INTERNATIONAL POLAR YEAR**

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The main geodynamic structures contributing to the seismicity between Northern Norway and Svalbard are the Mohns Ridge and the Knipovich Ridge, as well as the Senja Fracture Zone to the South and the Hornsund Fracture Zone to the North. However, seismicity in the region is not restricted to these structures, but observed also in the area of the sedimentary wedge between the continental margin and the mid-ocean ridges and along several smaller tectonic structures. One of the aims of the IPY project 'The dynamic continental margin between the Mid-Atlantic-Ridge system (Mohns Ridge, Knipovich Ridge) and the Bear Island Region' was to study in detail the seismicity in this region. Several land and ocean-bottom seismic stations were installed temporarily within the framework of the project to provide supplementary seismic records to those of the sparse network of permanent stations in the wider region. The gain in terms of seismicity monitoring and quality of the event locations due to the IPY-related temporary installations is clearly evident and will be presented in this contribution. Data span the time interval between September 2007 and September 2008. We will discuss the influence of the additional observations on NORSAR's fully automatic event bulletin and on the precision of analyst reviewed seismic event locations in the region.

ES5 - EARTHQUAKE SOURCES AND SOURCE PARAMETERS

ES5/P1/ID104 **- SOURCE PARAMETERS OF THE 4 FEBRUARY 1997 GARMKHAN(NORTH-EAST BOJNOURD), NORTHEAST IRAN EARTHQUAKE OBTAINED BY THE NEAR FIELD ACCELEROGRAMS DATA**

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SOURCE PARAMETERS OF THE 4 February 1997 Garmkhan(North-East Bojnourd), Northeast Iran EARTHQUAKE OBTAINED BY THE NEAR FIELD ACCELEROGRAMS DATAM. Aminipanah [1]; M.R. Gheitanchi [2]; M. Gorashi [31]M. sc ofAzad University[2] Professor of Institute of Geophysics, Tehran University[3] Geological Survey of Iran AbstractOn 4 February 1997 at 10h 37m 51.2 GMT, 14h 7m 51.2 in the afternoon local time, a moderate but considerable destructive earthquake occurred in Bojnourd, a mountainous area in North-East Iran, in North Khorasan Province. The magnitude of the mainshock, given by ISC, was mb=5.8, Ms=6.6 The earthquake killed about 100 people, injured nearly 2000 and about 5,500 houses destroyed and 11,000 houses damaged in the Bojnurd-Shirvan area. The mainshock was preceded by a strong foreshock which acted as a warning and made people rush outdoors and save their lives. In this study, we calculated the ground motion parameters of the last event using digital accelerograms Data of Building and Housing Research Center (BHRC) by using Seismosignal and Sac softwares. we plotted all of the three components of the accelerograms, and then we measured ts-tp, Epicentral distance (R) and PGA for each record. After baseline correction and filtering of the accelerograms, we plotted Fourier Spectrum of accelerations. By using these plots, we obtained corner frequency (f) and flat portion spectrum (K) of the Fourier Spectrum. We used the acceleration spectrum of S-wave, recorded on horizontal components in SAC software. To estimate M_0 from acceleration spectrum, first we must estimate K, then we compute from =K. Finally, we could reach to M_0 andM_w. This event is a moderate earthquake and different seismological Agencies such as (IGTU, NEIC, IIEES) reported different location with 20-40 Km difference. Thus, we relocated this earthquake by using 8 accelerogram stations (near field) strong motion records, at a distance range 14-58 Km. We calculated seismic moment (Mo=6.7×10^{25} dyne cm) and moment magnitude (M_w=6.4)

ES5/P2/ID105 **- SOURCE CHARACTERISTICS OF THE 28TH MAY 2004 BALADEH-KOJUR DESTRUCTIVE EARTHQUAKE IN CENTRAL ALBORZ, REVEALED FROM FAR FIELD WAVEFORM DATA**

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Source characteristics of the 2004 Baladeh-Kojur destructive earthquake in Central Alborz Mountains is obtained by inverting far field waveform data. The information from field investigation and aftershock activity are considered as supplementary data to constrain the source parameters. The source characteristics of mainshock is explained in terms of at least three major subevents. Rupture initiated in epicentral area with the first subevent and mainly extended towards west in a unilateral manner. The major slip took place during the first 10 seconds and it is concluded that the directivity played main role for producing extensive intensity in the epicentral region. The source mechanism obtained in this study is predominantly trust and is in agreement with the mechanism of other earthquakes as well as the orinatation of tectonic forces in this region. The total seismic moment is calculated to be M_0= 4.1×10^{18} Nm and the total moment magnitude is Mw = 6.3. Although central Alborz had been seismicly active in historical times there was no evidence that earthquakes as severe as this earthquake had occurred in the vicinity of Baladeh-Kojur region during at least the past 100 years.

ES5/P3/ID106 **- IS THERE A NEED TO REDEFINE M_w AND M_e ON THE BASIS OF MODERN E_S AND MAGNITUDE DATA?**

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Seismic moment M_0 has been scaled to moment magnitude M_w via the classical eq. (1) $\log E_S = 1.5M_S + 4.8$ (E_S – radiated seismic energy, M_S – Gutenberg surface-wave magnitude measured at periods around 20 s), assuming that $M_w = M_S$ hold for large earthquakes and $\Theta = \log(E_S/M_0) = -4.3$ = const for complete stress drop. Later, seismic energy values E_S measured at the USGS and corrected for source mechanism, have been scaled to energy magnitude M_e by fitting best the Gutenberg-Richter slope of 1.5 through the $\log E_S$(USGS)-M_S(USGS) data cloud although M_S(USGS) is supposed to be 0.18 m.u. larger than M_S(Gutenberg) and the slope of 1.5 was not derived by regression analysis through original data. Rather, it was found by inserting the Gutenberg-Richter body-wave/surface-wave relationship eq. (2) $m_B = 0.63M_S + 2.5$ (which in fact should have been - according to Abe and Kanamori, 1980 - $m_B = 0.59M_S + 3.0$ when corrected for a sign error) into the original Gutenberg-Richter (1956) formula eq. (3) $\log E_S = 2.4m_B - 1.2$. Yet the latter was based on 20 data points only. This scaling history of currently accepted M_w and M_e formulas justifies the following questions:1.) Can eqs. (1)–(3) be reproduced with hundreds of modern M_S, E_S and m_B data fitted unambiguously by orthogonal least-square regressions?2.) If not, how this would affect currently used M_w and M_e formulas?3.) How much differ E_S and M_e data with (interactive USGS procedure) and without source-mechanism corrections (automatic near real-time GFZ procedure)? 4.) What is the effect on the M_w formula if it is not scaled to the $\Theta = -4.3$ for (not realistic) complete stress drop but rather to measured global average Θ_{av}?We found that modern m_B and $\log E_S$ correlate best when not corrected for source mechanism. Further, the Gutenberg-Richter $\log E_S$-m_B relationship is not well reproduced. Yet, $\log E_S$(GFZ) = $1.54M_S$(USGS) + 4.3 is rather close to $\log E_S = 1.5M_S$(USGS) + 4.4 of Choy and Boatwright (1995), better than a true orthogonal fit through their mechanism-corrected data. Further, Θ_{av} is -4.6 for GFZ and -4.8 for USGS E_S. New formulas for M_w and M_e based on these results yield values that agree with those of currently used formulas in the magnitude range 5 to 9 within +0.27 and -0.47 for USGS data and -0.01 to -0.16 m.u. for GFZ data. The latter is well within the uncertainty range of magnitude estimates.

ES5/P4/ID107 - SEISMIC ENERGY DISTRIBUTION IN THE SOUTH CASPIAN BASIN

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Due to the fact that magnitude is not a physical feature of the seismic source, it is necessary to estimate the released seismic energy by each earthquake. In this study, we use 1360 events since 1964 from ISC and USGS and apply the Gutenberg-Richter's Formula to draw the iso energy counters for every 5 years. The seismic energy distribution in the South Caspian Basin also has been investigated since 1900 by using local seismic data from IIEES and IGTU. This study also put an emphasis on the prior observations which shows the correlation between earthquakes and active faults surrounding the South Caspian Basin which appears to act as a relatively rigid aseismic block. The principal seismic belts around the basin are the Apsheron-Balkhan Sill in North, the Talesh in west, the Alborz in south and the Kopeh Dag in east. Probing the seismic energy distribution patterns leads us to find out that although the Apsheron-Balkhan Sill has been very active between 1974 and 1994, it does not release significant amount of energy since then. The Alborz has time gap, that is, it has been quiet for a period and in the next one it became active. The Kopeh Dag in the east part behaves just like central part of the Alborz. The SW part of the basin where it underthrusts beneath the Talesh and Alborz conjunction, there were always major activities except for the last 10 years. In fact the last 5 years was the quietest period of the region since 1964. Considering this point and observing the seismic energy distribution Patterns, we expect the next 10 years to be a seismically active period in the South Caspian Basin margins.

ES5/P5/ID108 - THE EARTHQUAKE, 17.OCT.2009, IN THE SOUTHEAST OF TEHRAN (IRAN): MW=4.0, A PRELIMINARY SEISMOLOGICAL OVERVIEW

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On the 17th Oct. 2009 an earthquake occurred in the southeast of Tehran (Tehran province). Its coordinates, obtained by the seismograms recorded in the Broadband Stations of IIEES were 35.51 N-latitude and 51.55 E-longitude. The moment magnitude and the depth of the earthquake were M_w=4.0 and 19.9, respectively. Regarding the political, economical and social importance of Tehran city as well as its geological position, studying the seismicity of this city is of great significance. Studying the historical earthquakes and the seismicity of the zone in the recent century shows that the east of Tehran is more active than its west, and the distribution of microearthquakes in the east and southeast of Tehran is in the local magnitude ranges of 2.6-2.9.The main seismic faults of Tehran zone are the important mountainous faults (between mountain and plain). 90% of these faults have compressive mechanisms or important compressive components. The mechanism of the earthquake, studied here, was compressive, obtained by the First motion solution method. The sources' parameters are determined by spectral modelling method. In this analysis the seismic moment, moment magnitude and stress drop of the earthquake are obtained. Keywords: Seismicity; Focal Mechanism; Source parameters; Seismic moment; Tehran.

ES5/P6/ID109 - EPICENTRAL RELOCATION AND SOURCE PARAMETERS OF THE JUNE 22, 2002, CHANGOUREH-AVAJ EARTHQUAKE

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Iran is located in a very complex tectonic environment, where shortening takes place due to Arabi-Eurasia convergence and many destructive earthquakes have occurred in the past centuries. Deformation and seismicity in this region is mainly due to the continental shortening between the Eurasian and Arabian plates.The Changoureh-Avaj earthquake of June 22nd 2002 is the largest shock since the occurrence of the 1962 Buyin-Zahra earthquake in Qazvin province. In this paper , we relocated the Changureh main shock by using regional data and Hypo71 software.Then the source parameters of the main shock are obtained by waveform inversion. The source time function indicates that rupture, during the source process, was initiated with the main shock and was followed by a small aftershock. Therefore, the major amount of seismic energy was released during the first 10 seconds. The mechanism for the total source is obtained as (strike, dip, rake) = (125, 45, 113).The total seismic moment is calculated to be $M_0 = 4.13\times10^{25}$ dyne cm and the obtained moment magnitude in this analysis is Mw = 6.4. The average stress drop is a bout 56 bar. The static displacement is calculated to be about 35 cm and the obtained rupture time is about 6 seconds. The results of the waveform analysis suggest that the rupturing was initiated in the epicentral region and was propagated in a bilateral manner towards northwest and southeast. The Changoureh-Avaj earthquake is one of the rare events with magnitude greater than 6 that has occurred in the vicinity of large densely populated cities. Therefore, the ground-motion characteristics during the main shock should be considered for the high safely design of structures in the region. Keywords: Changoureh-Avaj (southern Qazvin) Earthquake, Source mechanism, Source parameters, Rupture process, Waveform modeling, Active faults.

ES5/P7/ID110 - EARTHQUAKE FOCAL MECHANISMS IN THE PANNONIAN BASIN

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The Pannonian depression is an extensional back-arc basin in central Europe and is an integral part of the Alpine-Carpathian orogenic mountain belts. The central part of the basin (mostly occupied by Hungary) can be characterized by moderate seismicity with local earthquake magnitudes of mostly less than 3.5. The weak events are usually recorded at only a few stations, when the inversion of first-motion polarity data cannot produce reliable focal mechanism solutions. However, determination of mechanisms of weak local events is of prime interest while monitoring local seismicity, because they reflect the stress pattern acting in the area under study and may help to map even its small-scale tectonic structure.

Since full waveforms yield much more information than polarity data do, in this study we use a Bayesian waveform inversion procedure in order to retrieve the hypocentral locations and source mechanisms (moment tensors) of weak local earthquakes that occurred in Hungary. The applied probabilistic inversion procedure takes into account the effects of the random noise contained

in the seismograms, the uncertainty of the hypocentre determined from arrival times, and the inaccurate knowledge of the velocity structure, while mapping the posterior probability density functions (PDFs) for the hypocentral coordinates, the moment tensor, and the source time function. The final estimates for the focal parameters are given by the maximum likelihood points of the PDFs, while solution uncertainties are presented by scatter density plots. The estimated uncertainties in the moment tensor components are plotted on the focal sphere in such a way, that the significance of the double-couple, the CLVD, and the volumetric parts of the source can be assessed.

The moment tensor solutions for the selected events have negligible volumetric part, implying the tectonic nature of the events. The source time functions are usually very simple with time duration of about 0.1-0.2 seconds. The retrieved source mechanisms are in agreement with the available clear readings of first-arrival P-wave polarities and with the main stress pattern published for the epicentral regions. The resulting fault-plane solutions correspond to pure strike-slip or strike-slip with thrust faulting mechanisms, implying the compressional characteristics of the stress field in the Pannonian basin.

ES5/P8/ID111 - STUDY OF THE STRONG GROUND MOTIONS OF 31 MARCH 2006 SILAKHOR EARTHQUAKE: MW6.1

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The Silakhor earthquake of 31 March 2006 (Mw=6.1) occurred at 4:47:03 in local time near Chalan-Cholan village in Lorestan province in the west of Iran. The Silakhor earthquake was preceded by two large foreshocks with magnitudes Mn=4.7, 5.2 and followed by two aftershocks of Mn=4.9 and 5.3. The Silakhor plain seriously affected by this earthquake. The comparison of observed and simulated ground motion indicates that rupture started at 48.91° E, 33.62° N in the depth of 14km, and the Rupture were propagated from south east to the north-west. The determined focal mechanism from strong ground motion data is right lateral strike slip which it's strike and dip are respectively 313° and 78°. As the rupture propagate from the south-east to north-west, the directivity effects clearly observed with low duration and high amplitude in Chalan-Choolan station which is in front of the rupture and long duration with low amplitude in Dorud station in opposite side of rupture propagation. Maximum peak ground acceleration of 561 cm/s.s for vertical component and 447 cm/s.s for horizontal component was recorded at Chalan-Cholan station. Moreover, two sub-events were identified on the recorded strong ground motion records. Keywords: Silakhor; Strong Motions; Data processing; Source parameters; Simulation; Stress drop.

ES5/P9/ID112 - TOWARD UNDERSTANDING SLIP-INVERSION UNCERTAINTY AND ARTIFACTS

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Singular value decomposition (SVD) is applied to seismic slip inversion formulated for a linear forward problem $d=Gm$, where d and m denote the seismograms and discretized slip velocity functions along a fault, respectively, and G is the matrix containing the medium impulse responses (Green's functions and focal mechanism). Two simplifications allow applicability of the SVD to this problem: a 1D (line) source keeps the number of parameters low enough, enabling also simple graphic visualization, and the main features of the slip inversion features can be understood even without the non-linear slip-positivity constraint. Special attention is devoted to leading eigenvectors (associated to the largest singular values) representing directions in the model space most sensitive to the data. Linear combination of the leading eigenvectors provides the slip inversion result. An innovative approach is a parallel study of the eigenvectors of the inversion problem for a station network and for a suite of single-station problems, allowing understanding of possible bias and trade-off in the inverse solution. The eigenvectors associated to single stations have shapes of smooth inclined strips with angles given by the station azimuth with respect to the fault strike. Main components of the slip solution expansion, associated to the leading eigenvectors, are controlled by quantity GTd, representing the correlation between the complete observed seismograms and partial synthetics due to individual point sources in the x-t domain. The high-correlation patches (called 'dark spots') mark regions in which different slip-inversion techniques provide non-unique solutions. The dark spots can be also explained by extending the projection lines concept of the seismic source tomography. The SVD approach is demonstrated on synthetic models with two asperities (two unilateral and one bilateral rupture scenarios). The most interesting result is a strong false asperity in the middle of the bilateral fault; it represents a common, strongly persisting artifact of various inversion schemes. Opposed to traditional views, smoothed solutions do not prevent from the slip artifact, since the spurious slip patch is related to the most stable feature of the solution, controlled just by the leading eigenvectors. The spatio-temporal complexity of the eigenvectors is discussed to understand how to balance between over-regularized solutions (with possible slip inversion artifacts), and under-regularized solutions (vulnerable to data errors). The ideas are developed on synthetic tests, and are applied to the Mw 6.3 Movri Mountain earthquake, 2008, Greece.

ES5/P10/ID113 - FOCAL MECHANISMS AND MOMENT TENSORS OF MICRO-EARTHQUAKES IN THE MALÉ KARPATY MTS., SLOVAKIA

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We have analyzed selected micro-earthquakes with magnitudes between 1.2 and 3.4 that occurred in the Malé Karpaty Mts., Slovakia, within the period of 2001-2009. Three different methods were used to calculate the focal mechanisms: (a) a method using the polarities of Pg and Pn waves, (b) the P-wave amplitude inversion of moment tensors and (c) the waveform inversion of moment tensors. We have compared the three methods from the point of view of their sensitivity to the quality and amount of input data and accuracy of the structural model as well as from the point of view of their computational efficiency. All three methods show similar double-couple parts of the focal mechanisms, however the moment tensors comprise significant non-double-couple components. A detailed time-frequency analysis of seismic signals was used to identify appropriate frequency interval for the waveform inversion of the moment tensors. We have investigated a possible influence of not optimal choice of the frequency interval on the obtained results, in particular, on the stability of the double-couple and non-double-couple components of the moment tensors.

ES5/P11/ID114 - FAST MOMENT MAGNITUDE ESTIMATION IN THE SOUTHEASTERN ALPS

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A stable and automatic method is implemented at the SE Alps transfrontier network to estimate in the real time the seismic moment, moment magnitude and corner frequency of events recorded by broadband velocimeter and accelerometer. The procedure has two steps: the first one consists in an interface with Antelope system from which pre-processed waveforms are retrieved. The second step consists in estimating the seismic moment and the corner frequency by spectral analysis. The S-wave train is identified through an automatic procedure that estimates arrival times based on the hypocenter location, recording site and velocity model. The transversal componet of motion is used to minimize conversion effects. The analyzed frequency window is selected on the basis of the signal to noise ratio (SNR). The source spectrum is obtained by correcting the signals for geometrical spreading and intrinsic attenuation. For the latter, different relationships are tested for frequency-dependent Q value in order to characterize the anelastic proprieties of the seismic region. Source spectra for both velocity and dispacement are computed and, following Andrews (1986), the seismic moment and the corner frequency are estimated. The procedure is successfully validated using the recordings of some recent strong earthquakes like Carnia 2002 (Mw=4.9), Bovec 2004 (Mw=5.1), Parma 2008 (Mw=5.4) and Aquila 2009 (Mw=6.3) and the recording of some minor events in the SE Alps area for which independent seismic moment and moment magnitude estimates are available. The real-time procedure has been running at DiGeo since two years and there are available determinations of moment magnitude in the database in the magnitude range from 1.7 to 6.3.

ES5/P12/ID115 - SOURCE CHARACTERISTICS OF THE RECENT CRUSTAL EARTHQUAKES OCCURRED IN THE SOUTH-EASTERN PART OF ROMANIA

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Moderate-size crustal earthquakes recently generated in the south-eastern part of Romania, are located in four distinct areas: Ramnicu Sarat zone – 2 sequences on November 29, 2007 (main shock, 45.62°N, 27.22°E, h=19 km, M = 3.9) and December 6, 2009 (main shock, 45.39°N, 26.98°E, h=25 km, M = 4.2); Vrancioaia zone – one sequence on September 6, 2008 in (main shock, 45.80°N, 26.51°E, h=13 km, M = 4.4); Bucharest-Giurgiu zone - one earthquake and an associated aftershock on June 20, 2009 (44.17°N, 25.72°E, h=15 km, M = 3.9) and June 22, 2009, respectively; Fagaras (Voina) zone – one event on March 30, 2008 (45.29°N, 24.82°E, h=2 km, M = 3.3) with an associated aftershock in the same day.

In all cases, for the main shocks we found well-recorded aftershocks with similar location and focal mechanism (empirical Green's functions). The difference of about 1.0 magnitude unit between the main shocks and the largest aftershocks is typical for the aftershock activity in the crustal domain and allows us to use the empirical Green's function deconvolution and spectral ratios techniques.

The purpose of the present paper is to apply these techniques for the crustal earthquakes in the south-eastern part of Romania. Despite the relative small size of the events, high-quality waveforms for pairs of co-located events are available in different sites. The new results, together with previous determinations provide an excellent database to investigate the source scaling properties.

ES5/P13/ID116 - THE FOCAL MECHANISM OF LOW MAGNITUDE CRUSTAL EARTHQUAKES FROM THE EASTERN CARPATHIANS BENDING ZONE AND SURROUNDINGS

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An inversion method working with indirect parameterization of the seismic source is applied to retrieve the focal mechanism of low magnitude shallow earthquakes occurred at the Eastern Carpathians bending zone, from short period local records. In our approach the 3-D inhomogeneities characterizing the complex study area are substituted by 1-D structures, different for individual stations. Anticipating a rather strong mismodeling of the crust by this gross simplification we use a bootstrap-like procedure to estimate the fault plane solutions and their reliability: instead of inverting all the records altogether, we process records of subsets of stations and reject those mechanisms which are inconsistent with the average; the uncertainty in the orientation of the double couple part of the inverted moment tensor is evaluated from the distribution of the principal axes of the remaining consistent solutions. The investigated events have local magnitudes in the range 2.4 to 3.8, and depths between 7 and 39 km. Observed data are short period velocity seismograms, vertical component, recorded at epicentral distances up to 150 km. The multimodal summation in layered inelastic media, a method which allows to synthesize the complete wavefield in preassigned intervals of frequencies and phase velocities, is used to generate the Green's functions.The retrieved fault plane solutions comply with the orientation and characteristics of the main active fault systems in the region. A complex deformation field is pointed out, reverse faulting, strike-slip and normal faulting being equally present among the inverted mechanisms of the low magnitude earthquakes; this large variability is also observed at the available fault plane solutions of the moderate size crustal earthquakes from the Vrancea area and surroundings.

ES5/P14/ID117 - THE FINITE-ELEMENT TSN MODELING OF RUPTURE PROPAGATION WITH SLIP-DEPENDENT FRICTION LAWS - SPATIAL SAMPLING, ADAPTIVE SMOOTHING AND A POSTERIORI FILTRATION

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We present a finite-element TSN (Traction-at-Split-Node) algorithm for numerical modeling of dynamic rupture propagation on planar faults with the linear slip-weakening and Ohnaka-Yamashita friction laws. The key features of the efficient algorithm for simulating sufficiently accurate and smooth slip rates are proper spatial sampling and an adaptive smoothing algorithm applied to the trial traction on the fault plane.We present results of numerical investigations of the effect of the spatial sampling on the accuracy and smoothness of the simulated slip rates. The results may seem surprising with respect to the common intuitive notion of spatial sampling on the fault.The adaptive smoothing algorithm calculates a smoothed value of the trial traction at a grid point and time level if the slip is larger than 0 simultaneously at the grid point and 8 neighboring grid points on the fault. The smoothed value is a weighted average of the Gaussian-filtered and unfiltered values. The weighting coefficients vary with slip.Numerical tests for different rupture propagation conditions demonstrate that the adaptive smoothing algorithm effectively reduces spurious high-frequency oscillations of the slip-rate time histories without affecting rupture time. The algorithm does not need an artificial damping term in the equation of motion.We implemented the algorithm in the finite-element part of the 3D hybrid FE-FD method. This makes it possible to efficiently simulate dynamic rupture propagation inside a finite-element sub-domain surrounded by the finite-difference sub-domain covering a major part of the whole computational domain. If the spurious high-frequency oscillations of the slip rate do not change development of the rupture, smoother slip-rate time histories can be also obtained by a posteriori filtration. We present new approaches utilizing empirical mode decomposition and discrete wavelets, and compare them with the traditional low-pass filtration.

ES5/P15/ID118 - IMPROVEMENTS IN DEPTH ESTIMATION THROUGH GLOBAL NETWORK CEPSTRAL ANALYSIS AND BOOTSTRAPPED F-STATISTICS.

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Accurate hypocenter depth determination is still an acute problem in seismology. Surface reflections -pP and sP-, if accurately picked, can provide precise depth estimate. Unfortunately, depth-phases are the most prone to phase identification and picking errors, which often leads to large depth error. To overcome this problem we propose a novel method for robust depth estimation that doesn't rely on reported phase picks but exploits the informationAccurate hypocenter depth determination is still an acute problem in seismology. Surface reflections -pP and sP-, if accurately picked, can provide precise depth estimate. Unfortunately, depth-phases are the most prone to phase identification and picking errors, which often leads to large depth error. To overcome this problem we propose a novel method for robust depth estimation that doesn't rely on reported phase picks but exploits the information present in the full waveform. For events with mb grater than 5.0 and with traces at teleseimic distances (35° to 90°), we computed the envelope for waveforms in a time window around the predicted P arrival and the largest possible moveout (pP-P time). We computed the cepstrum for each trace, which allows us to determine if there is a depth phase present in the waveform. The cepstras are transformed to depth domain using depth-moveout relations predicted by ak135 at the epicentral distances of the stations. Stacks are made using bootstrapped F-Statistics in the depth domain, event depth and its variance is found in the second largest peak of the F-Statistics, which represents a robust depth estimate derived from the the entire network of recording stations.

ES5/P16/ID119 - SEGMENTATION AND MATURITY OF LONG-TERM FAULTS CONTROL EARTHQUAKE SLIP-LENGTH SCALING AND GROUND MOTIONS

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We explore the links between intrinsic properties of long-term geological faults, especially segmentation and structural maturity, and properties of the major earthquakes these faults produce, especially slip amplitude and ground motions. We analyze a population of about 1000 active normal faults of different lengths (0.3-65 km) and cumulative slips (1-1300 m), and find that 70% of these faults are segmented in a similar way along their trace, being divided into a similar number of major segments ranging between 2 and 5, and more generally equal to 3-4. Strike-slip faults, which we just started analyzing, seem to show the same number of major segments along their trace. The largest-scale segmentation of long-term faults therefore seems self-similar, offering the earthquakes a limited number of long fault pieces to break. We then analyze an extended set of surface co-seismic slip-length measurements that we have compiled for more than 270 large

continental earthquakes worldwide (M > 6). We find that the slip-length data cannot be fitted by a single function, whether it is of single crack-type or not; a minimum of four crack-like functions are actually requested to properly adjust the data. We suggest that each function results from the earthquakes breaking a variable, yet limited number of major segments along the faults on which they occur. We therefore propose new Dmax-L parameterizations based on that idea of multiple segment-ruptures. In such parameterizations, each broken segment roughly scales as a crack –hence has a roughly constant stress drop, while the total multi-segment rupture does not. We suggest that the number of broken segments depends on the strength of the inter-segment zones, which itself depends on the structural maturity of the long-term faults. To further determine the importance of the fault structural maturity on earthquake behavior, we analyze the near-field ground motions recorded at rock sites for 30 large (M > 5.6) worldwide crustal earthquakes of various mechanisms, whose broken faults and structural maturity are known. We find that the strong ground motions generated in the near-field by earthquakes occurring on immature faults are systematically higher (by a factor of about 1.15) than the strong motions generated by earthquakes on mature faults. Together our work thus shows that the structural maturity and the major segmentation of the long-term geological faults are important parameters that should be considered in seismic hazard assessment.

ES5/P17/ID120 **– SOURCE SCALING INVESTIGATION OF AFTERSHOCKS FOLLOWING THE 2009 MW 6.3 L'AQUILA EARTHQUAKE (CENTRAL ITALY) RECORDED AT AN UNDERGROUND ARRAY**

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Most of the studies about source parameters of large-to-small earthquakes uses far-field surface recordings from regional seismic network. Seismic noise, site and path effects can strongly bias the earthquake source spectral parameters, particularly for earthquakes of low-to-moderate magnitude. The use of seismic signals recorded in underground environment, where seismic noise is reduced, and the application of Empirical Green's Function (EGF) approach are strongly recommended for the investigation of source parameters such as stress drop and corner frequency. We show the preliminary results obtained on 7500 earthquakes of low-to-moderate magnitude ($0.5 < M_L < 4.1$), recorded at the underground array Underseis located near the town of L'Aquila.

First we identified 290 clusters of similar seismic events by applying a cross-correlation based criterion, then we apply the spectral EGF ratios approach among the events of each cluster to estimate the source parameters. The most of clusters are located close to the main shock of April 6, 2009, at a distance of 15-25 km from the array site. For each cluster, we apply EGF technique to evaluate source spectral parameters, such as the corner frequencies, and consequently the stress drop values by using a grid search algorithm. The S-wave spectra averaged on 7 stations of the array were used to evaluate spectral ratios. We averaged all results from different EGF events to obtain more stable corner frequency estimations. Each corner frequency in the average estimation was weighted by magnitude difference between the seismic events involved in the spectral ratio. The seismic moment was estimated from the low frequency part of the averaged S-wave spectra.

The stress drop vs seismic moment shows no self similar behavior for the investigated range of magnitude ($0.9 < M_L < 4.0$). The apparent

stresses clearly increase from 1 to 100 bars with seismic moment increasing from 10^{11} to 10^{15} Nm. The power of seismic moment scale dependence from stress drop is estimated in the range 0.4 - 0.6. Preliminary results show that spectral ratios EGF approach and array underground data are particularly suited to investigate the spectral source parameters of small earthquakes.

ES5/P18/ID121 **– THE RECENT SEISMICITY IN THE CHELIFF REGION (NORTHERN ALGERIA): WAVEFORM MODELLING AND REGIONAL STRESSES**

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The Cheliff region has experienced some significant earthquakes in the last century (1937, 1954, and 1980). The most destructive one is that of El Asnam on October 10th, 1980, Ms=7.3 (Io=IX), which destroyed the Chlef city (formerly El Asnam) and its surrounding villages. On December 16th, 2006 a moderate earthquake (Mw = 5.0) hit the Cheliff region. The maximum observed intensity (Io=V) was observed at Abou El Hassen, Benaria, Bouzghaïa and Tadjena. No damages or human losses were recorded. Nevertheless minor cracks on walls of old school at Tadjena were observed. The point source focal mechanism of the event was determined by inverting the waveforms of three regional broadband stations of the Algerian Digital Seismic Network (ADSN). It corresponds to thrust-reverse faulting with a strike-slip component. The stress tensor obtained by the inversion of the 15 focal mechanisms available in the Cheliff region exhibits a well constrained compression axis σ1 horizontal and trending N145°. The NW dipping nodal plane indicating a NE-SW thrust fault with a right-lateral component (strike, dip, rake = 249, 38, 137) is more compatible with the regional stress tensor than the steep dipping NNE-SSW nodal plane showing reverse faulting with a left-lateral component (strike, dip, rake) = (15, 65, 60). Accordingly, the Tadjena moderate size earthquake can be related to the Boukadir active Fault bordering the lower Cheliff basin to the North, a situation similar to that of the El Asnam fault bordering the middle cheliff basin to the North.

ES5/P19/ID122 **– SLIP INVERSION OF THE L'AQUILA (ITALY) APRIL 9, 2009 EARTHQUAKE (MW 6,3) FROM STRONG MOTION, BROADBAND TELESEISMIC, GPS, AND INSAR DATA AND ESTIMATION OF VELOCITY MODELS WITH STRONG MOTION DATA.**

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The space-time slip distribution of the l'Aquila earthquake (Italy) is investigated inverting strong motion, broadband telseismic, GPS, and InSAR data. This moderate size earthquake can be analysed with a good degree of accuracy due to the presence of strong motion stations near the epicentre, GPS stations deployed in the rupture area and the availability of SAR ascending and descending differential interferograms. In order to improve the modelling of the strong motion waveforms, we use one aftershock (near the mainshock) considered as a source point to search for optimal velocity models for each common source-station path. First we refine the aftershock location by combining the analysis of the first P wave polarities and polarization directions with the classical inversion of P and S waves travel times. The aftershock focal mechanism is redetermined using a waveform inversion procedure. We search for 5 layers crustal models which improve single station waveform inversions. The free parameters are the thickness and the P wave velocity of each layer as well as a common crustal Vp/Vs ratio. Those parameters are explored with a simulated annealing algorithm. The velocity models obtained with this procedure are then used in the computation of the strong motion synthetic seismograms of the mainshock. Separate and joint inversions of the four types of data, real and synthetic, are performed in order to estimate how each dataset constrains the coseismic slip distribution. The rupture, corresponding to normal faulting along a NW-SE plane, dipping to the SW, propagated in two directions: updip and toward the SE, exhibiting two or three asperities. Total rupture length is 14 to 16 km and rupture duration 12 seconds. We pay a special attention to the constraint of slip near the surface to determine whether the inversions can confirm the observation of very reduced surface breaks. The fault geometry and the hypocentral depth are also finely tuned using the whole datasets.

ES5/P20/ID123 **– THE 26TH JUNE 2009 SANTORINI ISLAND (CYCLADES) EARTHQUAKE SWARM IN THE HELLENIC VOLCANIC ARC: SOURCE CHARACTERISTICS USING FULL MOMENT TENSOR INVERSIONS**

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A moderate earthquake swarm burst on 26th June 2009 northeast of the Santorini (Thira) Island, directly over Mt Columbo an active submarine volcano in Cyclades, Aegean Sea. Most importantly the swarm occurred in the western boundary of the Santorini – Amorgos zone, a major structural unit in the Hellenic Volcanic Arc, where the strongest (Mw 7.5) instrumentally recorded event occurred on 9th July 1956, connected with a tsunami with a 25 m run-up in SE Amorgos Island. Two were the strongest events of the 26th

June 2009 swarm, which occurred on the same day (GMT 20:37 Mw 4.6 and GMT 22:14 Mw4.4), while the sequence was rich in earthquakes, with about 25 events with Mw larger than 2.5 within the first five days. The region of occurrence is well covered by the broad band stations of the Unified Hellenic Seismic Network and records from 10 to 15 stations are available with good signal/noise ratio including relatively low frequencies (< 0.1 Hz), suitable for source studies. We used full moment tensor inversion in the low-frequency range from 0.02 to 0.1 Hz to evaluate the double couple, CLVD and isotropic components of the tensor in order to shed light on the possible connection of the activity with the underlying Columbo volcano. We used two independent codes: the ISOLA code (authors: E. Sokos, J. Zahradnik, the software is available at http://seismo.geology.upatras.gr/isola/) and the TDMTISO_INVC code (author: D. Dreger). The centroid position was found by a 3D grid search. Stability of the moment-tensor solution was tested for different crustal models used to construct complete Green's functions and for different station subsets. Special tests (including synthetic ones) were performed to assess reliability of the non-DC components. All events were connected with the normal faulting along NE-SW trending planes with the T-axes trending NW-SE in accordance with the regional tectonics. The focal depths were less than 5 km which intensifies previous results about the location of the magma chamber related to the Columbo volcano.

ES5/P21/ID124 - SOURCE PARAMETER VARIATIONS OF SMALL TO MODERATE SIZED EARTHQUAKES IN SWITZERLAND

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We analyze spectra of small to moderate earthquakes in Switzerland using two different spectral methods to quantify variations in source parameters. Both methods analyze S-wave displacement spectra and carefully try to correct the spectra for path and site effects so that spectral variations can be attributed to source processes and near-source property variations. The first method is a spectral stacking approach that exploits the redundancy of the dataset to separate source, path, and receiver effects. The second method fits path attenuation, site effects, and source components of each displacement spectrum simultaneously. We estimate corner frequencies and compute Brune stress drop from the source terms obtained with both methods and compare them to each other. The results show a systematic difference in absolute values of source parameters that is explicable by the fact that the strong trade-offs between source, path, and site are resolved differently by the two methods. However, relative variations in stress drop are similar for both methods. We examine these relative variations for dependencies of stress drop with moment and event depth. Stress drops of Swiss earthquakes show a strong increase with event depth. A depth-varying shear-wave velocity and a depth-dependent Q model can explain part of the depth dependence. In addition, strong lateral variations of stress drop are observed in Switzerland. High stress drop regions are concentrated in the North and low stress drops around the northern edge of the Alpine deformation front.

ES5/P22/ID125 - HIGH-FREQUENCY GENERATION IN K-2 KINEMATIC SOURCE MODEL

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Simulating realistic time histories is a crucial issue for hazard assessment. We address this issue to better understand the high-frequency generation. The high-frequency content of ground-motion is strongly sensitive to the small-scale slip distribution. For realistic ground-motion simulations due to future earthquakes, it is thus imperative to properly a priori estimate the slip roughness distribution. We then investigate different approaches for assessing the degree of roughness of the slip distribution of future earthquakes. First, we analyze a database of slip images extracted from a suite of 152 finite-source rupture models from 80 events (M_w=4.1-8.9). This results in an empirical model defining the distribution of the slip spectrum corner wavenumbers (k_c) as a function of moment magnitude. Besides, the robustness of the empirical model rests on a reliable estimation of k_c by kinematic inversion methods. We address this issue by performing tests on synthetic data with a frequency-domain inversion method. These tests reveal that due to smoothing constraints used to stabilize the inversion process k_c tends to be underestimated. We then develop an alternative approach: (1) we establish a proportionality relationship between k_c and the Peak Ground Acceleration (PGA), using a k^{-2} kinematic source model; (2) we analyze the PGA distribution, which is believed to be better constrained than slip images. These two methods reveal that k_c follows a lognormal distribution, with similar standard deviations for both methods. High frequency finite-source simulations are also highly sensitive to the frequency dependence of the directivity effects. Following, Bernard and Herrero (1994) and Boatwright et al. (2002), we then analyze the frequency dependence of the directivity effects in the available ground-motion records of recent strike slip earthquakes; and notably the strong motion records of the Japanese database.

ES5/P23/ID126 - ON THE CONFIDENCE LEVEL OF NON-DOUBLE-COUPLE COMPONENTS OF SEISMIC MOMENT TENSORS FOR AFTERSHOCKS OF THE 1999 IZMIT EARTHQUAKE

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The Izmit 1999 M =7.4 earthquake ruptured a ~140km long segment of the North Anatolian Fault Zone (NAFZ) reflecting a pure right-lateral strike-slip mechanism. Propagation and focal mechanisms of aftershocks clearly indicate a segmentation of the fault plane into several segments. Of these, the Akyazi Plain is the most remarkable one. It reflects pure east-west extensional normal faulting in a regional strike-slip stress field. In this study, we intend to systematically analyze the aftershock sequence with respect to non-double-couple components in the seismic moment tensors using linear and non-linear full moment tensor inversions. We analyze data obtained by a 36-station network of 3-component short-period seismic stations completed four days after the mainshock and covering the entire Izmit rupture zone.

Non-double-couple components are sensitive to noise, velocity structure mismodeling and unfavorable azimuthal station coverage. Such inaccuracies can generate spurious non-double-couple components, which hamper the resolution of the true source mechanism. Therefore real data analysis should be preceded by synthetic tests in order to define a confidence level, for which the non-double-couple components can be considered statistically significant. Here, we present a synthetic case study simulating seismic observations of aftershocks of the 1999 Izmit earthquake. Synthetic P amplitudes for several shear-tensile source models are inverted, assuming a velocity structure mismodeling, the presence of noise in the data and varying station distributions. The reliability of the non-double-couple solutions is estimated on the basis of an error analysis.

ES5/P24/ID127 - MOMENT TENSOR INVERSION FOR SMALL EARTHQUAKES IN THE PYRENEES

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Quantification of strong magnitude (M > 5.5) earthquakes is routinely undertaken by many institutions. For instance, Global CMT solutions are available within a few hours over the Internet. In regions with moderate seismicity, efforts now focus on developing robust and rapid, if not automatic, inversion methods for small earthquakes. The present work describes such an attempt in the cross-border framework of the SISPyr project (INTERREG IVa France-Andorra-Spain 2007-2013 program). We developed a method which automatically determines the frequency ranges for each component that can be used for the inversion. The optimal focal mechanism is then determined by a systematic grid search exploration. Synthetic seismograms are obtained by using Green's functions computed with the Bouchon method. To check the robustness of the method, we compared its outputs with results obtained independently over a subset of the SISPyr database. This database was collected by the SISPyr working team; it consists of 129 events with ML > 3 between 2001 and 2008, yielding over 4000 accelerometric, broad-

band and short-period recordings. We chose 22 events within this database, with ML magnitudes (RéNaSS scale) ranging from 3.8 to 5.2, and a large geographical distribution. The comparisons were drawn along two axes : the mechanisms were compared with results from classical computations of polarity-based focal mechanisms, and the Mw values to the moment magnitudes recently proposed by Drouet et al. (2010) from S-wave spectra. The results are very encouraging; the mechanisms are in general very similar, and the magnitudes are in very good agreement. Robust moment tensors can therefore be obtained rapidly for earthquakes with Mw as low as 3.0 in the Pyrenees, with only 5 recording stations. Efforts should now be undertaken to make this method fully automatic, as required if its outputs are to be incorporated in shakemap computations (planned in the SISPyr project). From a tectonic point of view, the computed mechanisms are predominantly extensional, supporting recent geodetic and seismological results that point to extension across the Pyrenees.

ES5/P25/ID128 - EFFECTS OF THE RUPTURING MODELS OF AUGUST 17, 1999 IZMIT EARTHQUAKE ON THE RESULTS OF STOCHASTIC SIMULATION

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To define a co-seismic slip model of an earthquake finite-fault inversion procedure is usually used which is based on fitting the observed and synthetic seismograms in low frequency band (~0.01-1.0 Hz). Similar studies have been performed after the August 17, 1999 Izmit earthquake and many co-seismic slip models representing the rupture process arose. Some of these models are comprised of modeling SAR and GPS data. In this study, we investigate the effectiveness of the fault and slip models on high frequency simulations of the Izmit earthquake. Seven different rupturing models, one of which includes the common fault parameters and random slip distribution, were used at the stochastic finite-fault simulation technique. The synthetic seismograms computed in the frequency band 0.1 – 25 Hz were compared with the observations in both time and frequency domain. Six accelerometric stations located close to the observed surface rupture are chosen for the comparisons considering the fact that the slip contributions are visible at these station records better than the other stations. The results show that no one rupturing model is sufficient to simulate the observations at all stations. Most of the rupturing models underestimate the ground motions in frequencies lower than 0.4 Hz, whereas they overestimate the ground motions in high frequencies. The underestimation may arise from directivity effect which causes high amplitudes on the observed ground motions in low frequency band. While the whole rupturing models display similar average bias functions, the minimum average error is obtained with the rupturing model of Bouchon et al. (2002). The achievement of random slip distribution yields promising results. Acknowledgement: This study was supported by TUBITAK under the project Nr. 109M317.

ES5/P26/ID129 - DISPUTABLE NON-DOUBLE-COUPLE MECHANISMS OF SOME STRONG EARTHQUAKES – SECOND DEGREE MOMENT APPROACH

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Mechanism is the crucial parameter of an earthquake providing the first insight into physics of the source. Since 70's of the last century, moment tensors of moderate and strong earthquakes (M_w > 5) have been determined routinely by several agencies. The concept expands the earthquake focus description from the fault-plane solution corresponding to a pure shear slip (a double-couple (DC) as the force equivalent), to more general types of dislocation indicated by the appearance of non-DC components. At strong earthquakes, the non-DC components may however be spurious due to untreated finiteness in the point-source solutions applied by world seismological agencies. We verified the hypothesis in a synthetic experiment simulating a finite-extent source – a unilaterally propagating shear slip, and inverted the synthetic data into moments up to degree 2 (Adamová and Šílený, 2010). The concept of involving finite source characteristics through higher degree moments dates to early 80's of the last century (e.g., Doornbos 1982). Though it has been only rarely applied in seismological practice till now (e.g. Dahm et al. 1999, McGuire et al. 2001 and 2002), it provides useful insight into the earthquake focus characteristics beyond the standard point-source approach. We apply this method to several events from Pacific area, which exhibit considerable percentage of non-DC components in the mechanism. We evaluated classical moment tensor (MT) on one hand, which is in good agreement with the agency solutions, and second degree moments on the other. The latter provided indication on source finiteness, which was compared with evidences from geology and aftershock mapping.Adamova P., Silený J. (2010). Non-double-couple earthquake mechanism as an artifact of the point source approach applied to a finite-extent focus, Bull. Seis. Soc. Am., 100(2), 447-457.Dahm, T., and F. Krueger (1999). Higher-degree moment tensor inversion using far field broad-band recordings: Theory and evaluation of the method with application to the 1994 Bolivia deep earthquake, Geophys. J. Int. 137, 35–50.Doornbos, D. J. (1982). Seismic moment tensors and kinematic source parameters, Geophys. J. R. Astr. Soc. 69, 235–251.McGuire, J. J., L. Zhao, and T. H. Jordan (2001). Teleseismic inversion for the second-degree moments of earthquake space-time distribution, Geophys. J. Int. 145, 661–678.McGuire, J. J., L. Zhao, and T. H. Jordan (2002). Predominance of unilateral rupture for a global catalog of large earthquakes, Bull. Seismol. Soc. Am. 92, no. 8, 3308–3317.

ES5/P27/ID130 - NON DOUBLE COUPLE SEISMIC SOURCES REVEALING AND SOME NOTES OF ITS DISTRIBUTION IN ISLAND ARCHES

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Non double couple seismic sources are considered in framework of the hypothesis that the process of seismic rupture can be viewed as a result of complicated fault geometry and its segmentation. The study focuses on the comparison of the deformation modes of the NDC sources with the states of stresses in its vicinity. The states of stresses are revealed using as a first approximation summation of seismic moment tensors. A measure of NDC part of moment tensor or deformation mode is described by the value of seismic moment tensor matrix determinant as its sign determines the mode of seismotectonic deformation. Analytical approach is found to reveal reliability of NDC measure taking into consideration the values of seismic moment tensor (CMT) errors. Thus, criterion of reference of the source to NDC-type is preservation of CMT matrix determinant ($Det(M_{ij})$) sign within the limits of area of its definition that is inside of a six-measured cube [$M_{ij} - E_{ij}$, $M_{ij} + E_{ij}$], i, j = 1, 2, 3 (E_{ij} – errors of CMT components definition). For this purpose the program counting function Det (M_{ij}) in units of a grid, covering area [$M_{ij} - E_{ij}$, $M_{ij} + E_{ij}$] (i, j = 1, 2, 3) was used.The attempt of the statistical analysis of different depth intervals seismicity structure in island arches with use the above technique was undertaken. As examples the Kuriles-Kamchatka arch and Tonga arch were considered. As information basis CMT catalogue of the strongest earthquakes of the world with 1976 for 2007 received and constantly increased by research group of the Harvard University of the USA was used. Relative numbers of NDC seismic sources depending on magnitude and depth and seismotectonic deformation mode in various intervals of depths were studied. It has been established, that the relative number of NDC-type earthquakes quickly grows with magnitude - from 0.1 - 0.4 at M_w = 5 up to 0.6 - 0.9 at $M_w \geq 6.5$. At the same time there is no significant dependence of relative number of NDC-type earthquakes versus depth within each magnitude interval. However, the situation is those, that for depths less than 70-80 km number of the events occurring in conditions of a mode of compression ($Det(M_{ij}) < 0$), is counterbalanced by number of events described a mode of tension ($Det(M_{ij}) > 0$) so on the average in this interval of depths the situation as though corresponds to DC-sources.The results on investigation seismotectonic deformation mode in various intervals of depths are those: In different segments of Kuriles-Kamchatka arch (43° - 55°N) change of seismotectonic deformation mode with depth essentially differs, that, possibly, reflects some distinction in geodynamic conditions. In all segments of an arch the areas characterized by average NDC-mechanisms are traced, and most brightly average NDC-mechanisms are expressed in the Southern segment of an arch (43° - 47°N) - here they are presented on all intervals of depths except for the uppermost layer (up to 80 km), and is the least bright - in the Central segment of the Kuriles-Kamchatka arch (47° - 51°N).It is interesting to compare the results on Kuriles-Kamchatka arch with those for the Tonga arch that concerns to extreme Southwest frame of Pacific Ocean and being the area of three lithosphere plates joint. It

is possible to note the certain similarity in seismotectonic deformation mode changes with depth between Southwest segment of the Kuriles-Kamchatka arch and Southwest part of Tonga arch. In case of a southwest part of an island arch Tonga the average mechanism is characterized by a mode of compression on depths 0 - 150 km and 250 - 700 km, a part of the interval concerning intermediate depths (151 - 250 km), is characterized by tension mode. Average mechanisms, since depths more than 150 km, everywhere concern to NDC-type, and the tension mode on depths more than 250 km is replaced by a mode of compression. This situation almost in accuracy repeats those for a southern segment of Kuriles-Kamchatka arch.Thus, it is possible to consider established, that average mechanisms of NDC-type are widely widespread on greater depths in areas of island arches while average mechanisms in an earth's crust and the top part of lithosphere everywhere satisfy traditional double couple model without the moment. It can point out to some differs in seismicity nature on greater depths and lithosphere.

ES5/P28/ID131 - STUDY OF SOURCE PARAMETERS FOR THE MODERATE 2004 KOUJOOR & FIROOZABAD, BASED ON EMPIRICAL GREEN FUNCTION (RSTF)

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In this study we have considered the moderate event occurred on May 28, 2004 at western Mazandaran province in Iran (in close vicinity of the capital, Tehran). This event was recorded by relatively dense seismological networks with the minimum distance of 18 km from the earthquake epicenter. Since determining the time history of rupture (Source Time Function) results in a considerable amount of valuable information about the physical characteristics of the rupture, it can be well utilized to prediction of strong motion for future investigations. To obtain the Source Time Function, we used the aftershocks through a procedure of Empirical Green Function method (Zollo *et al.*, 1994). This process is accompanied by relocation of these events (through different techniques) and moment tensor inversion for the events based on a velocity model for the section of Alborz region in which the earthquakes have occurred. The focal mechanisms for these events are also acquired by a first motion analysis. The results from these processes are then used to determine various source parameters. We have applied our results (along with properties of stations recording the event) to comment on characteristics of the source such as rupture properties, asperities and the number of subevents. It should be noted that studying the directivity effect will culminate in a better understanding of the rupture and gives us a chance to validate our obtained results.

Key Words: Empirical Green Function, Source Time Function, directivity, moment tensor inversion, first motion analysis.

ES5/P29/ID132 - UPPER MANTLE AND CRUSTAL STRUCTURE OF THE KOREAN PENINSULA FROM RECEIVER FUNCTION ANALYSIS

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Receiver function images are calculated from 33 seismic broadband station network located in the Republic of Korea to investigate the upper mantle discontinuities and the stagnancy of Pacific plate in the Korean Peninsula. Topographic variations of the Lithosphere - Asthenosphere Boundary (LAB) and the discontinuities around 410km and 660km are determined from these images. The images reveal that the LAB and the 410km- and 660km- discontinuities are relatively simple and flat. The LAB is detected at 140 ± 10km and is relatively shallow at the central Korean Peninsula especially. The depth ranges of 410km- and 660km- discontinuities are deeper than those of global average, which vary from 410 to 430km and from 660 to 700km respectively. The 410km-discontinuity shows uplift of the western side and while the 660km-discontinuity shows depress of the north-west region of study area. The thickness of mantle transition zone is thickened more than 30 ~ 40 km in the north-west region of study area. This thickened mantle transition zone is the evidence of the slab accumulation.

ES5/P30/ID133 - EARTHQUAKES FOCAL MECHANISMS AND SEISMIC STRESS TENSOR IN EASTERN SICILY, ITALY.

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Seismic activity, recorded from August 2001 to December 2008, has been analyzed in order to estimate the seismic stress orientation in eastern Sicily and surrounding areas. Earthquakes having magnitude higher than 2.0 were considered with their focal mechanisms. The sub-areas of Aeolian Islands, Messina Strait and northeastern Sicily, Mt. Etna volcano and Hyblean Foreland have been separately analysed. The distribution of about 500 earthquakes highlighted the main tectonic features both inland and offshore. For the best located events, a shear wave polarization analysis has been performed with the aim to obtain more reliable focal mechanisms by combining P-wave polarities with S-wave polarizations. Different fault plane solution categories are present in the investigated region. A predominance of strike-slip and normal faults characterize the Hyblean Foreland and Aeolian Islands sectors, whereas a prevalence of normal dip-slip solutions was observed in Messina Strait and northeastern Sicily. The P-axes analysis showed a significant NNW-SSE orientation both in the Hyblean Foreland and in the northwestern slope of Mt. Etna. No preferential orientation was observed in other sectors.

About 260 focal mechanisms and various subsamples, based on the pattern of seismicity distributions, were subsequently inverted by using the algorithm of Gephart and Forsyth, for the best fitting stress tensor. The results show an extensional domain, characterized by a nearly vertical σ1 and a horizontal WNW-ESE trending σ3 axis in northeastern Sicily. A compressional stress regime, oriented from NNW-SSE to N-S was estimated in Aeolian Islands, Hyblean Foreland and in the northwestern side of Mt. Etna, respectively, which is consistent with the regional stress field.

ES5/P31/ID134 - EARTHQUAKES SCALING LAWS IN CENTRAL APENNINES

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The objective of this work is the estimation of the attenuation (P and S quality factors) and source parameters (seismic moment, source radius, seismic energy and stress release) of the 2009 L'Aquila earthquake sequence by using a spectral inversion technique. For this aim an accelerometric waveform archive of 605 earthquakes recorded between 30 March 2009 and 30 April 2009 by DPC-RAN (National Accelerometric Network) (35 stations) and by INGV (29 stations) permanent and temporary seismic networks has been formatted and compiled. The total number of analyzed three-component records is 32275 for events with local magnitude ranging between 2.5 and 5.9.

The S-wave displacement spectra have been inverted using the non-linear Levenberg-Marquardt least-square algorithm for curve fitting, assuming the Boatwright (1980)' source model.

Preliminary analyses have shown that the frequency dependent Q-model does not provide a significant misfit improvement relative to the constant-Q model, which has finally adopted to correct the spectra for the path attenuation effect. The optimal attenuation model is chosen according to the minimum of the Akaike Information Criterion in the frequency range 0.5-40 Hz.

To get more robust estimations of the attenuation parameter, a two step inversion procedure is applied to the S-wave displacement spectra. In the first step the spectra are inverted for estimating the $t^*=T/Q$ parameter for each source-receiver couple, as well as the event-average estimations of low-frequency spectral level Ω_o and corner frequency ω_c. In the second step the spectral inversion is performed by fixing Ω_o and ω_c at the previous found average values providing with estimation of parameter t^* only for each source and receiver couple.

The frequency-dependent site response function are retrieved by an iterative procedure based on the computation of displacement spectra residuals and stack at each receiver site.

Refined estimation of Ω_o and ω_c are therefore obtained by inverting the observed S-displacement spectra , corrected for estimated site response and the attenuation function.

The data set enables to investigate the scaling of source size, energy and dynamic/apparent stress release as a function of the seismic moment in a wide magnitude range in an dominant extensional tectonic environment. The radiated seismic energy is computed from the integral of the squared velocity spectrum applying the correction for the finite instrument bandwidth (Ide and Beroza,

2001). This allowed us to obtain estimates of the apparent stress release to be compared to the dynamic stress drop inferred from corner frequencies.

SD2 - COLLECTING THE MACROSEISMIC DATA AFTER DAMAGING EVENTS USING EUROPEAN MACROSEISMIC SCALE: A DECADE OF FIELD EXPERIENCE

SD2/P1/ID135 - COMPARISON BETWEEN DAMAGE MAP FROM VHR OPTICAL IMAGES AND FIELD SURVEY (EMS 98): 2009 L'AQUILA EARTHQUAKE TEST CASE

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Destructive earthquakes challenge Earth Observation (EO) systems to demonstrate their usefulness in supporting intervention and relief actions. The use of EO data in a disaster context has been widely investigated from a theoretical point of view, but only recently the developed methods seem to have reached near to the operational use. Moreover, sub-meter resolution images at visible frequencies are able to provide information at the scale of a single building. This kind of information is extremely important if provided with sufficient timeliness to rescue teams. In this paper a case study on the April 6th, 2009 earthquake event, which stroke L'Aquila, Italy, is presented and commented. The Mw 6.3 L'Aquila earthquake occurred during the night of the 6th (01:32 GMT); it hit a densely populated region of the Apennines and was felt all over Central Italy. About 300 people lost their lives and more than 60,000 people were evacuated from the City of L'Aquila and several nearby towns. The earthquake caused the partial or complete collapse of a significant number of,historical buildings and several RC buildings as well.The EO dataset is composed by two QuickBird images, one before and one after the seismic event, taken on September 4th, 2006, and on April 8th, 2009, respectively. The sensor has been used is the panchromatic one, which has the higher spatial resolution, up to 60 cm.This very high resolution (VHR) images have been used to show the capability of this data to map damage at building scale of L'Aquila city. The EO data have been coupled with the building shape on a GIS base in order to compare damage grade of each building extracted from EO images with the one provided by ground survey, according to the five level of the European Macroseismic Scale 1998 (EMS98). The comparison between the ground truth, obtained by means a detailed (building by building) survey, and the high resolution damage map was fairly satisfactory and allowed us to better tune the change detection algorithm devote to damage estimation from VHR images.

SD2/P2/ID136 - A TEN YEARS EXPERIENCE OF THE USE OF EMS98 IN FRANCE METROPOLITAN AND FRENCH WEST INDIES BY THE BCSF. IMPORTANCE OF THE STATISTIC APPROACH.

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Until 2005, BCSF (Bureau Central Sismologique Français) has been more involved in assessing macroseismic intensity for ML ≤ 5.5 earthquake than for larger earthquakes. Nonetheless, MSK intensity reached VIII for a moderate ML<5.5 earthquake in 1967 in the Pyrenees. In 2003, BCSF first apply EMS-98 to a maximum VI-VII event in metropolitan France (Rambervillers February 22, Mw=4.8). Experience of EMS-98 intensity for larger earthquakes comes from two events which occurred recently in Guadeloupe and Martinique in the French West Indies. The Mw=6.3 crustal earthquake which occurred next to the south of "Les Saintes" archipelago in Guadeloupe (November 21, 2004) caused a maximum ground shaking estimated at VIII EMS-98, dropping to IV north of Guadeloupe at 77 km from the epicentre. The Mw=7.4 subduction earthquake which occurred at 150 km depth just north of Martinique presents a very different macroseismic pattern with intensities ranging from V to VI-VII in Martinique (epicentral distances: 10-68km) and from V-VI to IV in Guadeloupe (epicentral distances: 104-172km). Assessing EMS-98 intensities on the occasion of these two earthquakes showed us how important is the use of correct statistics when describing building damages and how correct vulnerability assessment on presence of newly built concrete building is necessary in order not over - or under - estimate intensities. An extreme situation has been encountered for example with an isolated collapse of a one story building in a locality where EMS-98 intensity is not larger than V.

SD2/P3/ID137 - A REAPPRAISAL OF THE OCTOBER 30, 1901 EARTHQUAKE (LAKE GARDA AREA, ITALY) IN THE LIGHT OF THE RECENT 2004 EVENT.

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The October 30, 1901 event is considered the maximum historical earthquake in the Lake Garda area, but it is not well constrained. The general picture of the 1901 earthquake, coming from recent studies, is mainly based on journalistic sources and on some coeval reports. The same area has been struck on November 24, 2004 by a Ml=5.2 earthquake.

In this paper we reappraise the 1901 earthquake, reinterpreting the contemporary sources, issuing unpublished materials, assessing new intensity estimation and determining new source parametres. The macroseismic intensities are assessed also in terms of EMS and the specific problems of application of this scale to historical descriptions are pointed out and compared with the situations presented by the more recent earthquake.

Thus we try to demonstrate, by means of macroseismic analysis, if the 1901 and 2004 earthquakes could be connected with the same source, providing new clues on the seismicity of the region.

SD2/P4/ID138 - MACROSEISMIC SURVEYS OF RECENT ITALIAN EARTHQUAKES: SOME REMARKS ON THE USE OF EMS98 SCALE

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The European Macroseismic Scale (EMS98) is not yet systematically used for Italian earthquakes, as macroseismic surveys are traditionally still performed according to the MCS (Mercalli-Cancani-Sieberg) scale. However, in recent years things have started to change. Three damaging earthquakes occurred in Italy in the 2008-2009 period have given a chance to test the EMS98 by means of detailed macroseismic field surveys in the most damaged localities. The first one is the Ml=5.2 earthquake occurred in the P arma and Reggio Emilia provinces (northern Italy) on December 23, 2008; this is the case of a moderate event at significant depth (around 24 km), which was resolutely felt throughout Northern Italy and produced sporadic damage in some localities scattered over a wide area. The second event is the April 6, 2009 Mw 6.3 earthquake that struck the Abruzzi region of Central Italy producing severe damage in the city of L' Aquila as well as in many villages along the Middle Aterno River valley. After the event, a buildingto- building survey was performed in L' Aquila downtown aiming to collect data in order to perform a strict evaluation of the damage under the European Macroseismic Scale (EMS98). This damage survey represents the more complex application of the EMS98 in Italy since it became effective. More than 1700 buildings were taken into account during the survey at L' Aquila downtown, highlighting the difficult application of the macroseismic scale in a large urban context. The third earthquake is a small and shallow event (Ml=4.2) occurred on December 15, 2009 in the Tiber Valley, between the Terni and P erugia provinces (Central Italy); after the event a detailed survey in the most damaged localities was carried out.

The results of these field surveys highlighted that macroseismic investigations on built-up areas, where modern and ancient buildings coexist, cannot further be accomplished by the MCS scale, even if EMS98 is still not fully used in Italy. In this poster some open questions about the application of EMS98, arisen from the studied earthquakes, are shown and discussed.

SD6 - GPS, INSAR AND SEISMOLOGY

SD6/P1/ID139 - INTENSITY OF CRUSTAL DEFORMATION PROCESS IN THE TIEN SHAN

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Despite a high level of seismicity, large ear-

thquakes are rather rare in the Tien Shan, and significant earthquakes concentrate predominantly along the northern and southern boundary lines of the orogen. High density of GPS observation points on the territory, long-term regular measurements on this segment of the Central Asian GPS network and presence of the digital broadband seismological network KNET allow estimating the pattern of the present-day crustal deformation. Here, appears an opportunity to compare the deformation images obtained by different methods; at the same time, the usage of various data sources promotes more accurate assessment of deformation setting in the region.

In the process of seismotectonic deformation research the three regimes specific for the Northern Tien Shan were estimated: compression, transpression and a transient regime from compression to a vertical. Analysis showed that a considerable part of the examined territory is notable for compression and shear strain, and only a small part of the crust is in tension conditions, thus, the seismotectonic deformation rate intensity is $2 \cdot 10^{-9}$ year^{-1}. According to the GPS data, crust compression in the region, in general, occurs in the north-north-western direction. The considerable inhomogeneity of deformation field was estimated and areas of high dilatation rate and maximum shear strain rate were determined; several small areas of extension were localized. It was thus discovered that high seismicity zones predominantly are located in the areas of high dilatation rates and a high shear strain rates gradient. There was estimated the intensity of strain rate that according to GPS data equals $24{,}3 \cdot 10^{-9}$ year^{-1}.

The comparison of results of two different sources, seismotectonic analysis and the GPS data, indicates that there is a coincidence in the strain axes directions and deformation regimes. At the same time, despite the appearing tendency in the estimation results of strain rate intensity according to GPS and intensity of seismotectonic deformation rate, strain rate intensity on GPS is significantly higher than intensity of seismotectonic deformation rate. That is, the comparison of geodetic measurements and seismological estimations shows that the contribution of seismotectonic deformation to total strain of the lithosphere equals the 10 % size of order from total strain.

SD6/P2/ID140 - ANALYSIS OF DYNAMIC INTERACTION BETWEEN SEISMIC AND EARTH SURFACE DEFORMATION FIELDS

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Research of interaction between seismicity and modern horizontal movements is usually based on spatial fields of seismicity and average velocities according to GPS. In the presentation we research this relationship not only in space, but also in time. It is possible to expect manifestation of several types of interactions between two processes: causal relationship, the relationship that is the response of the environment to effect of some third process, and random coincidence. The research is fulfilled under the data received from the Bishkek polygon of the Scientific Station RAS (Tien Shan). Earthquake catalogue KNET (1994-2008, 708 events, K ≥7, epicenter depths <25km) and GPS data (horizontal displacements in 14 stations, 23.07.1997-5.25.2007, mean interval of measurements is 19 days) are used. The analysis is fulfilled by means of web-GIS GeoTime (http://www.geo.iitp.ru/geotime/index.htm) in several stages.Stage 1: analysis of the seismic catalogue. The analysis has shown that the seismicity of territory is inhomogeneous and must be divided into three zones.Stage 2: interpolation of GPS time sequences in time series, smoothing, and calculation of horizontal velocity components. Stage 3: interpolation of the GPS velocity time series in 3D grid-based fields East-West (V_x) and North-South (V_y).Stage 4: calculation of the 3D fields of deformation velocities $\partial V_x/\partial x$, $\partial V_y/\partial y$, $\partial V_x/\partial y$, $\partial V_y/\partial x$ and their invariants: divergence $divV=\partial V_x/\partial x+\partial V_y/\partial y$, rotor $rotV=\partial V_x/\partial y-\partial V_y/\partial x$, and shear deformation $shV=0.5\cdot((\partial V_x/\partial x-\partial V_y/\partial y)^2+(\partial V_x/\partial y+\partial V_y/\partial x)^2)^{0.5}$.Stage 5: analysis of spatio-temporal interaction between the fields of the deformation velocity invariants and seismicity.The analysis has shown that strong earthquakes with K>10 during 1998-2006 basically occurred in vicinities of extremes divV and rotV. It is shown that with probability more than 0.99 it is possible to consider that during these periods the strong earthquakes occurred not accidently. Earthquakes occurred before and after the extremes divV and rotV. It testifies that extreme variations of normal and tangential tectonic stresses can cause a strong earthquake. On the other hand the stresses vary after a strong earthquake that can cause changes divV and rotV. Both these phenomena can be a consequence of some regional or global process.Spatio-temporal relationship between the fields of seismicity and earth surface deformations is shown. Strong earthquakes occur during the periods of extreme rate of earth surface site compression or the extension as well as during the periods of extreme rate of earth surface site turns. However the statistical conclusion was received on rather limited data. Significant improvement of a satellite geodesy observation system is necessary for further researchIt is supported by the RFBR project 09-07-12077.

SD6/P3/ID141 - BOOKSHELF FAULTING IN THE SULAIMAN RANGE SYNTAXIS (PAKISTAN) REVEALED BY INSAR

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On 28-29 October 2008, within 12h, two similar Mw6.4 strike slip earthquakes occurred within the Sulaiman Range (Pakistan), generating a complex but poorly located cluster of aftershocks. These shallow earthquakes mostly affected Pishin and Ziarat districts, killing 150 inhabitants in an area where several active faults have previously been identified. To establish the relationship between these 2 earthquakes, first considered as seismic doublets, we computed a large number of radar interferograms. A total of 10 descending and 31 ascending Envisat radar interferograms from a database of respectively 5 and 12 images reveal the surface displacement field during the seismic crisis. These interferograms testify that the main active strike slip fault in the region was not activated during the earthquake sequence. The surface displacement is maximal around the Ziarat anticline, right in the Sulaiman Range syntaxis. This structure is a large active fold constricted by both dextral and sinistral active strike slip faults on its western termination.

We test direct fault slip models taking into account the seismic Moment Tensor solutions determined for both main shocks, testing NE-SW sinistral and NW-SE dextral plane solutions separately.

Both these solutions appear inadequate to generate the displacement field inferred from the interferograms, discarding the doublets solution as well as sequential segment rupturing along a single fault. However, models taking into account ruptures on two conjugate fault segments generate significantly lower misfit. We therefore advocate for such a model and further tie the location of the fault segments using available high resolution optical imagery available over the area. This last model allows determining the extent of the rupture along the faults as well as the amplitude of the mean coseismic and post-seismic slip.

Other active strike slip faults, further west, accommodated also some second order shallow deformation during the seismic crisis. Overall, the geometry of the activated fault system appears consistent with a bookshelf faulting model, helping accomodate rigid block rotations within the Sulaiman Range Syntaxis over a short time interval.

SD6/P4/ID142 - ON COMPARISON OF GPS DATA AND SEISMICITY FOR LADOGA LAKE REGION, NW RUSSIA

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GPS monitoring of some geodetic and permanent stations around Lakes Ladoga was used to compare its velocities with regional geodynamical features of the crust revealed from earthquake focal mechanisms. GPS field observations were made by the Institute of Physics of the Earth (IPE)RAS during the 1999-2009 summer seasons. All points (VALM, MELO, BOTS, GIRS) are located on the bedrock. Data of permanent GPS stations METS, JOEN, PULK, SVTL, VIRO, SUUR were used for the same period of time. The data processing was realized by means of GIPSY/OASIS v.5.0. The deformations of this region were estimated by residuals geodetic velocity of these stations after Eurasian plate motion removing (ITRF 2005). The horizontal strain field was evaluated using program GRID_STRAIN (Teza, 2008). The obtained strain field of this region is divided on two parts. The northern part is characterized mainly by unaxial dilatation of the north-western direction. The second part located on Karelian Isthmus has biaxial stress field. The border between these parts seems to mark the central fault of the Ladoga Riphean graben. It is very surprised but just instrumentally earthquake area connects with dilatation zone mentioned above. The focal mechanism parameters and Coulomb

stresses and deformation of 1981 Marth 27 earthquake (depth of 10 km) were studied to compare with GPS data. We revealed essential discrepancy between two kinds of data that is caused probably by a depth of estimated deformation.

SD6/P5/ID143 **- SURFACE DEFORMATIONS DETECTED BY GPS AND INSAR DATA IN THE EPICENTRAL AREA OF SEISMIC SWARMS, WEST BOHEMIA, CENTRAL EUROPE**

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The intermediately strong earthquake swarm occurred in the West Bohemia/Vogtland region in October 2008. It lasted about one month and more than 20,000 shocks released seismic energy totalling $2*10^{14}$ Joules at depths of 7–12 km. GPS campaigns carried out in the region detected just after the swarm 16-cm vertical movements between two sites which are in the epicentral area at a distance of 3.6 km from one another. In this area, the Earth's surface is formed by pastures with numerous undulations, moderately to well afforested valleys, so that the vertical subsidence between the two sites did not cause observable cracks with symptoms of motion. GPS and seismic data are analyzed and discussed together with additional information on preliminary InSAR data interpretations and geomorphological, geoelectrical and geochemical surveys. The relations between strain field variations detected by permanent GNSS stations, accumulation and release of earthquake energy are discussed from viewpoint of the energy balancing in the medium during the seismogenic process.

SD6/P6/ID144 **- STATISTICAL ANALYSIS OF EARTHQUAKE AND VOLCANO SOURCE PARAMETERS USING GEODETIC OBSERVATIONS**

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Deriving earthquake and volcano source parameters from geodetic observations requires an appropriate inversion methodology that considers not only the non-uniqueness of the model space but also the non-Gaussian nature of the a priori information of the parameters and noise structure in the data. In this work we propose a Bayesian framework together witha heuristic search algorithm to address the above complications of the inversion. Marginalprobability functions for individual parameters are first computed by sampling the model space in terms of pdf to determine the sensitivity of parameters to observations. Then a global optimization algorithm such as a genetic algorithm (GA) is used to estimate the most probable solution using the Baye's rule. We apply the above methodology for several case studies including InSAR observations associated with the September 2008 Qeshm earthquake in Iran and InSAR time-series results of the Uturuncu volcano in Bolivia.

SD6/P7/ID145 **- THE ANALYSIS OF PALSAR AND ENVISAT INSAR FOR MAPPING OF WATER LEVEL CHANGES IN ANZALI MORDAB, NORTH IRAN**

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Wetlands are among the most productive ecosystems in the world. However, many of these productive systems are subject to degradation due to pressures caused by human activities. Monitoring of hydrological alterations in wetlands plays a key role to identify sources and causes of degradations that affect wetlands. Interferometric Synthetic Aperture Radar (InSAR) has proven to be a powerful technique for this purpose. It provides high-resolution hydrological measurements that cannot be obtained by any other terrestrial-based technique. In this study, we evaluate the use of PALSAR L-band and ENVISAT C-band radar data acquired during 2007-2009 and 2003-2005, respectively, over Anzali Mordab in North Iran to monitor water level changes in this region. The result of this study has important implications for assessing the ecology and sustainability of this important wetland in North Iran.

SD6/P8/ID146 **- THE POTENTIAL OF ENVISAT AND ALOS INTERFEROMETRY IN MONITORING SLOPE INSTABILITY IN TALEGHAN, IRAN**

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Landslides are among the most dangerous natural hazards in the world. They occur over a wide variety of temporal and spatial scales in mountainous areas and can cause enormous property damages and human casualties, depending on their scales. The study of spatial and temporal evolution of surface deformation is required to understand parameters controlling mass motion and slope instability in landslide areas. Most of the monitoring studies in landslide regions to date are performed by conventional techniques such as GPS, leveling and lasermeter. These techniques provide only point measurements and thus are not able to reveal the complex heterogeneities of landsliding. This study evaluates the capability of SAR Interferometry to map small-scale surface deformation on landsides. We focus on a landslide region in central Iran, named Taleghan, and conduct an extensive study of the behavior of several landslides in this region using interferograms constructed from Envisat and ALOS images. The slope movement in this region has been monitored in the past by GPS. Therefore, we compare our results with those obtained by GPS to better assess the accuracy of InSAR measurements.

SH3 - GLOBAL, REGIONAL AND LOCAL INITIATIVES ON SEISMIC HAZARD ASSESSMENT: TOWARDS SETTING NEW STANDARDS

SH3/P1/ID147 **- AN STOCHASTIC APPROACH FOR SEISMIC HAZARD ESTIMATION OF BALKAN TERRITORY.**

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I An stochastic approach for seismic hazard estimation of Balkan territory. In a certain with geographical coordinates (φ, λ) it is necessary to determine the probability

$$P_{(\varphi,\ \lambda)}(t,n,m,I^k) \quad (1)$$

that during time t, n earthquakes will occur m earthquakes of which will have the intensity I^k. Each earthquakes can be imaged, as a point in some four-dimensional space E(φ,λ,h,m) which is the Descartes' product of ranges of the possible values of earthquake parameters. The intensity of the seismic shakes in location (φ,λ), caused by an earthquake with parameters φ, λ, h, m from some interval E_s, is considered a normally distributed random value:

$$p_1(k)=P\{I^k-0,5\le I \square I^k+0,5/E_s\} \quad (2)$$

The parameters of earthquake with probability π_s can belong to interval E_s, s=1.,,,. S. For estimation the distribution of earthquake parameters π_s, the Markov model is applied. Multiply the vector $\pi=(\pi_1,\ldots,\pi_S)$ on the left to matrix P(I/E) the vector of distribution of intensity of shakes caused by some earthquake can be estimated:

$$P(p_0,\ldots,p_{12})=\pi P(I/E), \quad (3)$$

p_k – is probability, that will occur the shake of intensity I^k. If a seismic region witnesses n earthquakes, than $0\le m_k\le n$ shakes with intensity I^k, k=0,…,12, can happen in location (φ,λ). The distribution of numbers of shakes will fit an polynomial distribution:

$$P(m_0,\ldots,m_{12}/n)=n!/m_0!\ldots m_{12}!\,p_0^{m0}\ldots p_{12}^{m12}, \quad m_0+\ldots+m_{12}=n \quad (4)$$

Multiply to probability P(t,n), that during time t, n earthquakes will occur, can be estimated the distribution of intensity of seismic shakes:

$$P(m_0,\ldots.,m_{12})=P(m_0,\ldots.,m_{12}/n)\ P(t,n) \quad (5)$$

Let the location (φ,λ) lay within the limits seismic effects of regions $\Omega_1,\ldots,\Omega_S$. Than:

$$P_{(\varphi,\ \lambda)}(t,n,m,I^k)=\Sigma\ P_{(\varphi,\ \lambda)}(t,n,m_1,I^k)\ldots P_{(\varphi,\ \lambda)}(t,n,m_S,I^k), \quad m_1+\ldots+m_S=n \quad (6)$$

Using this formula is estimated the average number of seismic shakes in Chisinau in 1000 years The following numbers of shakes have been observed for the intensities 1 to 12: 4314.1 (intensity: 1), 2313.2 (2), 1070.3 (3), 448.2 (4), 172.1 (5), 64.3 (6), 24.0 (7), 7.3 (8), 1.4 (9), 0.2 (10), 0.0 (12), 0 (12). The seismic regions of Balkan zone, is considered as a realization of Markov models. The positivity of the extreme distributions of states is a sufficient condition for the Markov chain's ergodicity. The elements p_{ij}, i,j=1,…,18 of transitional probabilities matrix determine the probability in which region can occur the next seismic events after earthquake in some region.

SH3/P2/ID148 **- EUROCODE 8 ALIGNED PGA, PGV AND PERCEPTIBILITY HAZARD FOR BULGARIA AND SITE-SPECIFIC SOFIA**

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The EUROCODE 8 building code is progres-

sively being adopted across Europe as the standard against which to construct both critical and non-critical anti-seismic structures. It aims to increase homogeneity between countries by requiring countries to estimate one basic seismic hazard parameter. The frequently used – but still debated – benchmark adopted by EUROCODE 8 is the 475-year return period peak ground acceleration (PGA). This is equivalent to the maximum ground motion forecast in a 50-year time interval at 90% probability of non-exceedance.However, ground velocity is now often considered to be more representative of a location's ground motion hazard, as velocity is directly related to the energy flux between ground and structure. Engineering seismologists and researchers are now starting to promote peak ground velocity (PGV) as one of a number of alternative and more appropriate measures against which to benchmark EUROCODE 8, either alongside or in place of standard PGA metrics.The border region shared by Bulgaria, Greece and the FYR of Macedonia has not yet been subject to a comprehensive probabilistic seismic hazard assessment, although geological, tectonic and seismotectonic reviews do currently exist. There have been past major earthquakes in this region that created a ground-shaking hazard that encroached on all three territories. For example, Kresna (1904) and Thessaloniki (2000) have all contributed to this trans-frontier seismic hazard in the past. The need for a uniform assessment is enhanced due to the close proximity of key urban centres and consequences of such large magnitude earthquake occurrences.Results are presented here from a recent study across Bulgaria – with emphasis on southwest Bulgaria – that adopted a new earthquake catalogue and carefully selected geographically relevant ground motion models to forecast peak ground motion. Hazard is presented as contoured maps for both the 475-year PGA and PGV metric at regional and localized (southwest Bulgaria) levels. A site-specific example is also provided for Sofia, whose 475-year return period estimates for PGA and PGV are found to be 177 cm s^{-2} and 27 cm s^{-1} respectively.These same ground motion models are then applied to estimate earthquake perceptibility hazard with respect to PGA and PGV to achieve a second useable design earthquake, the most perceptible magnitude, $M_{P(max)}$. Finally, specimen site-specific ground motion hazard curves are created for Sofia by integrating this city's earthquake perceptibility curves to estimate annual probabilities of exceedance for PGA and PGV within a 2° half-width cell centered on the city.

SH3/P3/ID149 – DAMAGE ASSESSMENT OF A REINFORCED CONCRETE BUILDING USING THE SUBSPACE METHOD FOR MODAL PARAMETER EXTRACTION

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The Baseline Stiffnesses Method, BSM, is presented to assess damage in buildings without knowing their baseline (undamaged) state. This method is aimed at determining the loss of stiffness of structural elements in buildings without knowing baseline modal parameters. To compute a baseline state, the BSM utilizes, solely, frequencies and mode shapes from the damaged system and the approximated lateral stiffness from its first storey based on eigenvalue calculations. This state is compared to the damaged one to detect and measure severity of damage. In order to determine the modal parameters the subspace method is utilized to extract frequencies, mode shapes and modal damping coefficients. This methodology is applied to an instrumented seven-story reinforced concrete building. The subspace method extracts modal parameters in a very straightforward manner and could be easily programmed. In addition the modal damping coefficients can be extracted directly from the state matrix subspaces of the identified system, which makes it advantageous. Results are analyzed and the potential of the proposed methodology is discussed to identify damage in buildings without baseline modal parameters.

SH3/P4/ID150 – A NEW SEISMIC ZONATION FOR MOROCCO BASED ON PROBABILISTIC SEISMIC HAZARD ASSESSMENT

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The Roads and Road Traffic Directorate of the Ministry of Equipment and Transport of Morocco has entrusted SETEC International a mission to draw up a seismic design guide for bridges. In this context, a new nationwide seismic zonation was conducted by GEOTER and its partners, following the PSHA state-of-the-art. For the first time, PGA seismic hazard maps for the entire territory were developed using a probabilistic approach. In areas with moderate seismicity, the approach is often faced with a lack of knowledge and a high variability of the occurrence model parameters, especially for strong earthquakes with very long return periods. Epistemic and aleatory uncertainties related to geological and seismological input data and models were addressed and processed in a logic tree and by Monte-Carlo sampling. To interpret the seismotectonic setting, two teams of experts (GEOTER and Moroccan teams) have independently developed two alternative zonations. A catalogue of earthquakes was compiled for Morocco and surrounding regions, using data from various national catalogs, the IGN of Spain and ISC. The Intensity of historical earthquakes was converted in magnitudes using empirical relations in order to homogenize the data into a single catalogue of homogenized magnitude. To satisfy the spatial and temporal principle of events independence, the foreshocks and aftershocks were removed to calculate the parameters of magnitude-frequency distributions. Uncertainties were propagated using a logic tree, whose the two first branches concern the conceptual models for calculating the seismic hazard (seismic zoning or smoothing). The second level comprises the branches associated to the zonations and the third level concerns the ground motion models. Three attenuation laws were selected. The other uncertainties on seismic sources parameters (Mmin, Mmax, depth, GR parameters) through Monte Carlo sampling. The statistical exploration of all the combinations leaded to the definition of PGA hazard curves at points of a regularly spaced grid covering the Moroccan territory. Maps of statistical values (median, mean, 15th and 85th percentiles) were derived at return periods of 100, 475 and 975 years. Those maps were finally used to propose a new seismic zonation supporting the regulation for the seismic of bridges. Several PGA thresholds were adopted to delineate five areas of increasing hazard. The most active areas are the Rif and in a lower level, the Middle Atlas and the Atlas. The final regulatory zonation was developed by intersecting the physical hazard with the communal administrative boundaries provided by the DRCR.

SH3/P5/ID151 – STATISTICAL ANALYSIS OF EUROPEAN ACCELEROGRAM PARAMETERS HOMOGENEOUSLY COMPUTED FROM NERIES DATABASE: A CONTRIBUTION TO OBSERVATIONAL HAZARD IN EUROPE

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A new accelerogram distributed database has been created recently in the framework of NERIES Project (2006). Data are open to the scientific and engineering community through the European Earthquake Data Portal (www.seismicportal.eu). The seven following European Networks, IGC, IST Azores, IST S. Portugal, LGIT/RAP, KOERI, ITSAK and ETHZ, have contributed with preliminary data from the last 15 years, making available requested waveforms from the Portal, and EMSC-CSEM has been in charge of the information concerning events and stations. Several parameters with engineering importance were computed in a homogeneous way, for a total of circa 8350 three-components records from 424 stations associated to 1379 events characterized by magnitude (M1-7) and hypocentral locations (0-863 km) were assembled in this work. In this work we use the collection of PGA and PGV parameters from accelerometric records at several regions to generate an estimate of the "observed hazard". Using the "ergodic assumption" we were able to estimate return periods (RP) with 30% uncertainty for "average sites" representative of the region covered by each network. With these considerations we obtained estimations of PGA and PGV for RP=10 yrs in the 7 networks: PGA varies from 2 cm/s^2 (ETHZ) to 24 cm/s^2 (ITSAK); PGV varies from 0.04 cm/s (ETHZ) to 2.0 cm/s (ITSAK). For RP=100 yrs only estimations for ETHZ, LGIT/RAP and ITSAK are reliable with 30% uncertainty: PGA varies from 20 cm/s^2 (ETHZ) to 130 cm/s^2 (ITSAK); PGV varies from 0.4 cm/s (ETHZ) to 9.0 cm/s (ITSAK). No more longer RP may be estimated with enough reliability.This is a first

tentative to use strong motion data on a regional basis (European-Mediterranean Area) to contribute to PSHA studies. The approach presented here should be extended to more regions and covering longer RP of engineering interest. It requires the availability of more data which come from the installation of more instrumentation enlarging the time window of observations.

SH3/P6/ID152 - COMPARISON OF PROBABILISTIC APPROACHES USING DIFFERENT ATTENUATION RELATIONSHIPS FOR AN AREA IN AEGEAN REGION

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In an era of strong global view, hazard assessment became a mandatory filed in highly seismic developing countries because of capacity of causing deaths, injuries, and property damages. Threat to human activities from earthquakes is sufficient to require their careful consideration in the design of structures and facilities. Thus, the earthquake engineering involves the identification and mitigation of seismic hazards. The area is located at north of the city of Izmir in Turkey has experience a destructive earthquake M=7.0 in 1949 Moderate sized earthquakes in Western Anatolia might not cause the extensive damage, by comparing to a possible large event in the Marmara Sea in Northwestern Turkey. Nevertheless, they are actually the dominant source of seismic hazard in the region, because of their larger amplitude at longer periods in deep basin structures of Western Anatolia Graben System. In this study the seismic hazard analysis for Izmir was carried out by using the probabilistic approach. The analysis considers seismicity occurring in the study area, tectonics and expected ground motion in terms of peak ground acceleration (PGA). Hazard for 65% 40% 20% 10% and 2% probability of exceedence in 50years is calculated. Spudich(1997), Boore(1997) and Akyol&Karagoz(2009) relationships are compared with Seisrisk III.

SH3/P7/ID153 - SEISMIC HAZARD OF THE NORTH CENTRAL SEISMIC ZONE, ALGERIA.

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ABSTRACTThe North Central Seismic Zone (NCSZ) is considered to be the most seismically prone area with the highest seismic hazard in Algeria. This area is situated along North African plate boundary. This active domain displays folds and thrust faults system. The region has suffered from several large to great earthquakes during the last three centuries devastating earthquakes struck this zone and caused majordamagetobuildingsalong withsignificantlossoflives (Benouar. 1994). We refer particularly to 1716 Algiers earthquake (I_0=IX, MSK), the 1980 El Asnam earthquake (M_w=7.3) and recently the 2003 Zemmouri Earthquake (M_w=6.8). In order to estimate the parameters to characterize the seismic hazard, we have subdivided the NCSZ into two sectors based on tectonic framework and spatial distribution of the seismic activity: a) the western part of the NCSZ which is characterized by the plioquaternary Cheliff basin, Dahra and Ouarsenis mountains, b) The eastern part which includes the most significant structures of the Neogene Mitidja basin, the Sahel anticline and the Kabylie's thrust front. In this study, we use the probabilistic approach to perform the seismic hazard zoning. From an actualized seismic data catalogue (1910-2009), we assessed the Gutenberg-Richter parameters and the maximum credible earthquake magnitude for each sectors of the NCSZ. An appropriate attenuation for Peak Ground Acceleration (PGA) for the zone of interest allowed us to compute the seismic hazard using the CRISIS 2007 computer program. Finally, we present the map of the seismic hazard of peak ground acceleration with 10% probability of exceedance for an economic life time of 50 years. The map will be useful to civil engineers for constructing safer infrastructures and to estimate the typical high building that cause soil-structure interaction effects.

SH3/P8/ID154 - CURRENT SEISMIC ZONING MAP OF TURKEY

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The current official seismic zoning map of Turkey, accompanying Turkish Seismic Code for buildings, was published and became effective in 1996. Different from the previous official seismic zoning maps of Turkey which were prepared based on deterministic procedures, the current map was prepared based on the peak ground acceleration (PGA) contour map that was constructed by Gülkan et al. (1993) using probabilistic seismic hazard analysis methodology for a return period of 475 years. After the seismicity, fault zones and neotectonics of Turkey were reviewed in detail, 17 main seismic source zones were defined. In addition, background seismic sources were defined in order to take account of seismic activity that could not be related with any one of the main seismic sources. All seismic sources were modeled as area sources with exponentially distributed magnitudes and Poisson model was used to predict probabilities of future earthquake occurrences in these sources. When the study was conducted, the existing strong motion records were not adequate to develop a local attenuation relationship for Turkey. Therefore, attenuation expression developed by Joyner and Boore (1981) from western U.S. ground motion data was used. Seismic hazard analyses were performed according to combinations of different assumptions made with respect to uncertainty in source boundaries, seismicity parameters and attenuation characteristics of the ground motion. The results were combined by utilizing the theorem of total probability within the framework of logic tree methodology. Based on the estimated PGA values, Turkey was divided into five seismic zones.

Within the last decade, a large number of additional strong motion records have been obtained from earthquakes in Turkey, which led to development of local attenuation relationships. In addition to increasing studies on seismicity and active faults in Turkey, there have been many developments in probabilistic seismic hazard analysis in terms of models describing temporal, spatial and magnitude distribution of earthquakes. As a result, current seismic zoning map should be re-examined in view of these new findings and developments and updated.

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SH3/P9/ID155 - PROBABILITY SEISMIC HAZARD ASSESSMENTS AROUND SAUDI ARAMCO FACILITIES

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Within the framework of Saudi Aramco interest in seismic activity in some areas of Saudi Arabia, the Geophysical Technology Team (GPT), EXPEC Advance Research Center has formulated a number of objectives that strives to achieve the effectiveness of seismic studies and research in specific areas of Saudi Arabia. Therefore, in the GPT, we are carrying out the following different functions related to seismic activities around Saudi Aramco facilities. First of all, we conduct all types of studies and research that necessary for observing and monitoring seismic activity around Saudi Aramco facilities and adjacent areas. In order to achieve this goal, we deal with international companies to install, operate and maintain seismic networks in specific areas in Saudi Arabia. In August 27th, 2009 a felt earthquake occurred near Yanbu Industrial City with local magnitude 4.1. No damage was reported in the epicenter area or the surrounding cities or Aramco facilities. Our stations recoded this event and also Saudi Geological Survey shared with us their seismic data which recorded by Saudi National Seismic Network that gave us a great opportunity to estimate the accurate earthquake source parameters for this event. Moreover, we are reading, analyzing, processing seismic data, and monitoring any changes to the levels of seismic activity and surface deformation. Furthermore, we direct and immediate reporting of all types of seismic hazard around Saudi Aramco facilities and issue scientific reports and maps, which identify areas of seismic activities and identify active geological structures and level of that activity. In addition, we are conducting statistical studies about earthquakes and its relation of the movements that have occurred in some region of Saudi Arabia. Ultimately, we plan to conduct studies of the distribution of micro seismic zones and probability seismic hazard assessment in some areas of Saudi Arabia to determine the rate of ground motion acceleration, identify areas of soil liquefaction, risk zonation and

issue maps relating to these studies. These data will help us to establish an accurate building code that will assists us in formulating seismic resistant specifications for our pivotal facilities.

SH3/P10/ID156 - CRISIS, A DYNAMIC PSHA TOOL NOW AVAILABLE ON THE WEB

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CRISIS is a code for Probabilistic Seismic Hazard Assessment (PSHA), originally developed by Instituto de Ingeniería - UNAM – Mexico. In the framework of a project for Italian Civil Protection Department new developments were carried out to improve both technical and scientific issues.Technical achievements:· The application, originally developed to be a desktop standalone program, was reorganized to have a more robust core thread-safe library and to allow separate presentation layers; a web presentation layer was completely developed.· The new presentation layer allows for user platform independence, accessible using any standard web browser and not constrained anymore by the Windows Operating System (OS). The web application removes the distribution and deployment issues, as the tasks are performed only on the centralised server. A common area to all the users is available, making it simpler to share data within the community and removing the problems of huge data file transmission.· The computational work (which makes intensive use of CPU) is in charge of the server, releasing local PC resources and allowing multiple, concurrent elaborations, which was not possible with the original desktop version.Scientific aspects that were introduced or improved in the new CRISIS core library:· Regarding source zones, the multi-point source type was enhanced and now it is possible to associate to each point an arbitrarily oriented rupture plane, useful when working with ground motion prediction models (GMPM) that use distance metrics for which rupture size is relevant.· Concerning earthquake occurrence models, a generalized non-parametric model was added.· The GMPM architecture was completely reviewed, converting GMPM's into external software modules hooked to the application, each one with parameters specific to the model (values, choices, flags and external files); therefore additional custom GMPM's may be freely developed and integrated without having to recompile the core code.· Among the GMPMs modules accompanying the release is a new generalized model intended to describe, in probabilistic terms, the ground motions computed by arbitrarily complex estimation models.· CRISIS has now the ability to include site effects described with arbitrary spatial resolution.· The code has now more powerful capabilities to make logic-tree computations.· Disaggregation charts for M-R-epsilon combinations are available for any point of the map; the charts were fully redesigned to allow maximum flexibility over the selection of M-R-epsilon bins.

SH3/P11/ID157 - PROBABILISTIC SEISMIC HAZARD MAPS FOR THE NEW NATIONAL BUILDING CODE OF BULGARIA

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The territory of Bulgaria represents a typical example of high seismic risk area in the eastern part of the Balkan Peninsula. Bulgaria contains important industrial areas facing considerable earthquake risk. Moreover, the seismicity of the neighboring countries, like Greece, Turkey, former Yugoslavia and Romania (especially Vrancea-Romania intermediate earthquakes involving the deeper lithosphere), influences the seismic hazard in Bulgaria as well. This study deals with the Seismic hazard maps proposed as a part of the new building code of Bulgaria which is based on the recommendations in EUROCODE 8 (EC8). The basic approach used for the creation of ground motion maps incorporate in GIS mode the source-geometry, earthquake occurrence model, the strength of the earthquake sources, and the appropriate attenuation relations. In the study, seismic hazard maps for Bulgaria are presented in terms of Peak Ground Acceleration (PGA) in agreement with EC8. As recommended in EC8, the maps are calculated for a 475 years return period (probability of exceedance of 10% in 50 years) for the design earthquake and for 95 years return period (probability of exceedance of 10% in 10 years) for weaker earthquakes with higher frequency of occurrence. The Probabilistic Seismic Hazard Analysis (PSHA) was performed, using the Bulgarian version of computer code EQRISK. It is shown, using a Monte Carlo approach, that uncertainties in seismic characteristics have relatively little effect on the final seismic hazard. It is found that source modeling (using areal or linear sources) has comparatively large influence on the PSHA. Disaggregation was applied to examine the spatial and magnitude dependence of PSHA results. It was aimed to determine the magnitudes and distances that contribute to the calculated exceedance frequencies at a given return period. Dissagregation of the calculated hazard in PGA for a 475 years return period was accomplished for 27 cities on the territory of Bulgaria.

SH3/P12/ID158 - SEISMIC HAZARD AND RISK ASSESSMENT FOR THE TBILISI AREA

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The risk always exists when cities are built on. The increase of population in cities and urbanization in seismic-prone zones causes the increase of infrastructure. The goal of society is to create infrastructure that are protected from destructive earthquakes and minimize the expected losses.Georgia is situated in the one of the seismically active region (Caucuses) of Alpine-Himalayan collision zone. The tectonics and recent geodynamics of the Caucasus is determined by its position between the still converging Eurasian and African-Arabian plates. The strong earthquakes (*Ms* > 6) in the Georgia (the 1991 Racha earthquake with magnitude 6.9, the 1992 Barisakho-Kazbegi earthquake with magnitude 6.2) mainly taken place along the boundaries of blocks at the Arabia-Eurasian convergence zone. Most of these earthquakes are shallow and was represent a hazard. However the Tbilisi area has been considered as a region of relatively low seismicity. At 22:41 local time, on Tuesday, April 25, 2002, a moderate earthquake with Ms= 4.5 took place in the Tbilisi. Moderate magnitude earthquakes have occurred quite often in Georgia, but the 2002 Tbilisi earthquake was of great interest, because the source was directly beneath the capital of Georgia, at shallow depth and caused a few death and large economic losses.The main goal of this work is to combine analysis of the contemporary elements at risk inventories, seismicity and vulnerability to assess seismic hazard and seismic risk for the capital of Georgia – Tbilisi. This problem is of vital importance for Tbilisi as it is a big city with the population of 1 500 000 and capital of Georgia. The city is characterized with the rapid increase of population density, high speed of urbanization and vulnerable infrastructure, which increases seismic hazard.The soil hazard map for the Tbilisi area has been computed. The seismic hazard of Tbilisi region has been computed according to the approache of the probabilism. A logic tree was used to take into account different attenuation model. Obtained value of ground motion are larger then those presented by official seismic zonation map of Georgia that was calculated in 1999. Building, population and life data inventory maps were compiled. Vulnerability map for Tbilisi area was constructed for cell with size 500mX500m. Seismic Risk for Tbilisi area was estimated. Seismic risk was estimated for scenario earthquake from newly discovered Tbilisi-Mtkvari fault.

SH3/P13/ID159 - TECTONIC REGIMES AND EARTHQUAKE SIZE DISTRIBUTION: NEW EVIDENCE FOR PSHA

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Earthquake catalogues, seismotectonic zonations and ground-motion prediction equations (GMPE) are the basic ingredients for probabilistic seismic hazard assessment (PSHA). Seismotectonic zones are commonly defined considering the style-of-faulting; contemporary GMPE's also differentiate by the style-of-faulting. Here we present a case study for Italy to show that style-of-faulting should also be incorporated into the recurrence rates estimation. In the past 40 years many studies relating *b*-values of the Gutenberg and Richter law to physical properties have been performed, from laboratory rock specimens to observations in different tectonic regimes. Various authors analyzed the correlation between b-value and tectonic regimes and the results are generally consistent: as power laws indicate scale invariance, the inverse dependence of the b-value on the differential stress is universally valid and the parameter can therefore be interpreted as a 'stressmeter' in the Earth's crust. A consequence of the inverse dependency of the b-value on differential stress is that tectonics regimes with different dominant faulting styles should exhibit significantly different b-values, in particular the highest values for normal events (b_{NR}), fol-

lowed by strike-slip (b_{SS}) and reverse (b_{TH}): $b_{TH} < b_{SS} < b_{NR}$. In this study, we evaluate this hypothesis for the first time, using data from the Italian Peninsula, whose complex geology is reflected in a strongly variable stress field and distinctly different faulting regimes. Extensional, compressional and strike-slip regimes are simultaneously present. The study region fulfils two other critical requirements: 1) the regional seismic monitoring of the microseismicity of the past two decades was good enough to allow detailed mapping of the b-value and 2) a rich catalogue of focal mechanism exists that allows a detailed seismotectonic zonation. Because the b-value is a critical parameter in PSHA, linking it firmly to regional faulting style has significant implications for future regional PSHA studies. At present the b-values are not used for zonation purposes, but they are either assigned regionally or computed for each zone, where zones are in general defined based on expert judgment. We suggest that future seismotectonic zonation models should take into account the knowledge on faulting style dependence of b-values. There are a variety of way how this can be achieved, for example using high resolution mapping of b as an input for zonation, or by using the b-values of the large scale tectonic zones as a prior, deviating only if local b-values are found to be significantly different from the regional ones.

SH3/P14/ID160 - REASSESSING THE DEAGGREGATION OF PROBABILISTIC SEISMIC HAZARD ASSESSMENTS OF SELECTED JORDANIAN CITIES

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Probabilistic Seismic Hazard Analysis (PSHA) approach was adopted to investigate seismic hazard distribution across Jordan. Potential sources of seismic activities in the region were identified, and their earthquake recurrence relationships were reevaluated based on instrumental and historical data. Maps of peak ground acceleration and spectral accelerations (T=0.2 and T=1.0 sec.) of 10% probability of exceedance in 50 years were developed. This study revised the deaggregation results of the PSHA results of 10% probability of exceedance in 50 years results of twelve Jordanian cities to understand the relative control of these sources to the expected seismic hazards of each city in terms of distances and magnitudes. For the investigated cities, results indicated that seismic hazard is mainly controlled by area sources located along the Dead Sea Transform (DST) fault system. However, cities located at short distances from the DST tend to show close deaggregation behavior. Some discrepancies may exist due to the proximity or remoteness of these cities relative to the DST seismic sources and local seismicity. The modal or most probable distance distribution indicated that the distance to the earthquake which contributes most to the hazard at each city is mainly controlled by shaking along faults associated with near seismic area sources. The influence of adjacent seismic sources to the seismic hazard of each city is more evident for the long period spectral acceleration. Distant sources, such as the eastern Mediterranean, Cyprus, Suez and the southern region of the Gulf of Aqaba are relatively low, but can not be ignored due to the intrinsic uncertainties and incomplete seismic data. The results of the study provide insights for the definition of possible earthquake scenarios for future urban seismic risk studies.

SH3/P15/ID161 - SITE AMPLIFICATION AT STRONG-GROUND MOTION STATIONS IN METROPOLITAN IZMIR, TURKEY

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In the frame of a national cooperative initiation between Dokuz Eylul University in Izmir, and Earthquake Research Directorate of the Disaster and Emergency Management Presidency in Ankara, a 16-stations local strong-motion network was established in Izmir towards to the end of 2008. All stations are free-field and equipped with three-component built-in CMG-5TD accelerographs (Guralp Systems) with CMG-5T force balance accelerometer and 24-bit AD converter for data acquisition.Installed system stores continuous waveform data by sampling at 100 sps. The IzmirNET is critically important to addressing earthquake hazard issues in the city which is known to have historical damaging earthquakes. Izmir is the third largest city (after Istanbul, and Ankara) of Turkey in terms of population, industrial density and economic growth. In the frame of this study, site response at the IzmirNET local strong-motion stations has been studied by using weak motion records (2.5<=Mw<=4.7) and standard spectral ratio (SSR) technique. The mean amplification factor obtained for soft sediment sites (Quaternary alluvium; Site D) generally varies from 4-10 times for 0.3-1.0 Hz (for Balcova-BLC, Bayindirlik-BYN, Konak-KON, Karsiyaka-KSK and Camdibi-CMD stations). The upper bounds of the larger mean amplification factors for lower frequencies are found as 11 (at 0.5 Hz) in Bostanli (BOS), and as 13 (at 1.0 Hz) in Mavisehir (MVS) stations where deep sediments and quaternary alluvial deposits present over there. Mean amplifications are estimated as 3.0-4.0 in Buca (BUC), Yesilyurt (YSL), and Guzelyali (GZLY) stations where clay and silty stones units demonstrate in the area. Similar geologic pattern show lower and higher amplification as 4.0 and 9.5 in Pinarbasi (PNR) and Guzelyali (GZL) stations, respectively. These five stations can be classified as Site C. The Kaynaklar (KYN) and Urla (URL) stations give good correlation for B-type soil with its amplification values of 2.0 and 3.0, respectively. Finally, site response estimated at Bayrakli (BYR), Manavkuyu (MNV), and Yamanlar (YMN) suggest a typical hard-rock site behavior (Site A). Amplifications range from 1.5 (at BYR) to 3.0 (at YMN) times for 3-10 Hz. Estimated site response shows good correlation with the distribution of geological formations as well as expected ground deformation in the city. Acknowledgement: This study was supported by TUBITAK under the project Nr. 106G159. References: Polat,O., Ceken,U., Uran,T., Gok,E., Yilmaz,N., Beyhan,M., Koc,N., Arslan,B., Yilmaz,D. and Utku,M., 2009. IzmirNet: A Strong-Motion Network in Metropolitan Izmir, Western Anatolia, Turkey, Seismological Research Letters, 80-5, 831-838

SH3/P16/ID162 - TIME-INDEPENDENT PROBABILISTIC SEISMIC HAZARD ASSESSMENT IN WESTERN INDONESIA – ISSUES, INSIGHTS AND NEW APPLICATIONS

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The issue of earthquake hazard and risk in western Indonesia has gained prominence in recent years following several deadly earthquakes that have occurred along the Sunda Arc (e.g. Aceh, 2004 [M_W 9.0]; Nias, 2005 [M_W 8.6], Padang, 2009 [M_W 7.5]). The mechanism and behaviour of major subduction events has become an important focus of earthquake research in this region; however, there are still many challenges in modelling the seismic hazard and risk across Sumatra and Java. This must take into consideration damaging shallow crustal earthquakes onshore (e.g. Bantul, 2006 [M_W 6.3]), in addition to the major offshore seismogenic sources. New seismic hazard maps have recently been produced for Indonesia for the publication of the 2010 seismic design code, but there remain many aspects of the hazard analysis for which new developments and alternative approaches could be considered. The Monte Carlo method of seismic hazard analysis is used to illustrate some of these alternative techniques. This work explores the delineation of seismogenic sources in Indonesia, and the extent to which they are reconciled with observed seismicity. The selection of appropriate attenuation models is also considered, as are strategies for validating the seismic hazard analyses given the limitations of existing earthquake data. The current national seismic hazard maps clearly illustrate the development of the Indonesian seismic design code in the context of design practice across the globe. As Indonesia develops economically and undergoes greater urbanisation it is necessary to assess the potential needs of seismic hazard analysis in the future. This may require greater consideration of performance-based seismic design objectives, seismic risk to increasingly complex structures and the potential for secondary co-seismic effects such as landsliding and liquefaction. New modifications to seismic hazard in western Indonesia are introduced with these issues in mind.

SH3/P17/ID163 - SEISMIC HAZARD ASSESSMENT IN BEHBAHAN (IRAN)

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Seismic hazard assessment is carried out for 49.20 - 51.30 °E and 29.5 – 31.5 °N including Behbahan (Khozestan Province, Iran). To do this seismotectonic map of the region has been provided by using geology maps 1:2500000, tectonic maps, available reports, earthquake and minor earthquake catalogues.According to geology parts, this region located in Folded-Zagros Zone. Zagros is a part of big fold Alpine-Himalayan and it's located in intercept the Arabian plate with plate of Iran. So this zone tolerates the most pressure and it has a lot of seismic activity. A destroyer earthquake happened in this region and it destroyed the city that called «Arjan» in 1085. Unfortunately, the survivors of that earthquake made a new city close Arjan it called «Behbahan». Because of this and important structures there, like «Maroon Dam» this study has become important. According to USGS data analyzing hazard for this region can estimate.

SH3/P18/ID164 - INVESTIGATION OF TECTONICS AND SEISMICITY IN TEHRAN

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This study is including tectonics and seismic hazard for 51.8-51.37 oE and 35.34-35.50 oN including Tehran. To do this seismotectonic map of the region has been provided by using geology maps 1:2500000, tectonic maps, available reports, earthquake and minor earthquake catalogues. Population and ecological conditions problems like liquefaction and ground waters will cause lot of hazard when the earthquakes happen. Tehran's faults like the north fault, Rey, Hesarak and Baghfeiz and construct building near these faults make seismic hazard to become double, Because of Tehran hasn't had destroyer seismic for 180 years, probably a destroyer seismic threats Tehran with m=7 richters.

SH3/P19/ID165 - INCREMENTAL INTENSITY AMPLIFICATION RELATED TO GEOLOGICAL PROVINCES IN YOGYAKARTA SPECIAL PROVINCE, JAVA

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Earthquake hazard and risk in Indonesia has been conspicuous in recent years, dramatically brought into the public eye by the great tsunami earthquake (Acer 2004, 9.0 M_W), collapse of public buildings and hotels (Padang 2009, 7.5 M_W) and by extensive destruction of private dwellings caused by the relatively smaller magnitude Bantul, Yogyakarta 2006 (6.3 M_W) earthquake. The 2006 Bantul earthquake occurred on 27 May at 05.33a.m. (local time or 22.54 on the 26th UTC). Dwelling collapse rates reached 60% with over 60,000 houses destroyed, 5,700 fatalities and 37,000 injured, over 200,000 homeless and heavy damage at more than 300 school buildings. Yogyakarta has a history of strong earthquakes, for example, 10 June 1867, 27 September 1937 and 13 March 1981. It is also reported that a devastating eruption of Merapi was induced in 1006 by an earthquake similar to that of 2006. The Yogyakarta community is vulnerable to major geophysical hazards and a vital step towards community empowerment and resilience is the identification of disaster prone areas. This earthquake underlines the need for better understanding and simple display of the factors that may influence variations in strong ground shaking.

Earthquake strong ground shaking hazard is influenced by many factors. These obviously include earthquake size and proximity but also include more subtle influences, for example, predominant rock type, thickness of sedimentary cover and water table depth. These latter influences provide a means to map spatial variation of intensity enhancement attributable to spatially known and fixed geological features. The existing detailed geological mapping of Yogyakarta Special Province (YSP) is used to identify eight characteristic geological formations and further lithologic units. The early Miocene Nglanggran Formation (andesitic intrusion and basaltic lava) has high S-wave velocity and density, hence highest seismic impedance of the characteristic geological formations and is adopted as the reference unit. Following approaches attributable to Thomson and Evernden, intensity increments relative to the Nglanggran base level, for a uniform intensity field, are determined for all representative geologies. The results are collectively shown as a map of intensity increment relative to the igneous base Nglanggran throughout the YSP. Results can be extended further to, for example, superimposition of expected increments onto a spatially non-uniform intensity field e.g. of a predicted isoseismal map, or to commensurate PGA maps.

SH3/P20/ID166 - INTRODUCTION OF SEISMIC SOURCE DIRECTIVITY ON HAZARD MAP

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The seismic hazard maps are mainly influenced by the uncertainty associated to the ground motion predictive equation (GMPE). This uncertainty represents the unexplained part of the ground motion and it is mostly related to the choice of the model's variables. In fact the representation of the ground motion through the GMPEs is simple compared to the complexity of the physical process involved: if only the magnitude and distance are taken into account, GMPEs predicts isoseismals curves that are expected to be isotropic around the hypocenter or along the fault. Instead, the presence of a fault plane across which a process of failure in shear develops makes this general formulation reliable only on average. In fact this failure is responsible of an asymmetry in the seismic radiation known, since Ben-Menhaem (PhD1961), as *directivity effect*. While the general knowledge of the earthquakes is treated explicitly in the empirical prediction, specific trends like the directivity effects are hidden in the uncertainty sigma. A way to reduce the sigma is therefore to refine the seismic seismic source description inside the GMPEs (e.g. NGA project, Power et al, Earthquake Spectra, 2008). In this framework we propose a strategy to introduce the directivity in the GMPEs and to study its effect on uncertainties and on hazard maps. For this purpose, we have used two different directivity models acting on the GMPE as corrective factors: one proposed by Somerville et al. (Seis.Res.Lett.1997) and the other one proposed by Spudich and Chiou (Earthquake Spectra 2008).The first factor depends on geometrical parameters and comes from theoretical deduction. The second one includes many source parameters and it is a hybrid factor, which functional formulation is deduced from the theory, calibrated on synthetic simulations and scaled on data. The classic hazard equation is then adapted in order to increase the number of source parameters (i.e. adding one integral over the parametric space for each new variable involved) and taking into account the corrective factors for directivity (Spagnuolo, PhD2010). We present the comparisons of hazard maps depending on the directivity factor and on the probability density functions of the fault strike and of the rupture "laterality".

SH3/P21/ID167 - SEISMIC HAZARD ASSESSMENT IN TALEGHAN (IRAN)

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Iranian plateau is located in central part of Alpin-Himalayan orogenic and seismological belt which is considered as one of the most seismological zone in world.Convergance of Arabian plate and Eurasian plate caused Alborz creases in north and Zagros in west. Central Alborz is one of the most deformed part of Alborz which its deformity has been controlled by main thrust faults.These faults generate macro earthquakes like Kh azar,Candovan,Taleghan,Mosha,Ipak,North Tehran,… .This zone has a disorderly seismic activity pattern and most earthquakes, like Iran area,are shallow.Taleghan region is placed in the southern mountainside of the Central Alborz mountains.The restrict that have been studied in this article is between 35to 37 degrees N and 49 to 52 degrees E.Taleghan is main center of seismological studies which located in 36°10´27˝ N and 50°45´48˝ E .We shoud emphasis to seismological studies in this region because of Taleghan dam.This article has been studied below items:1.Seismicity characteristics include specifying a and b values of the Gutenberg- Rechter that had a good applicability correlation with seismicity characteristics of this zone.2.Estimating return period of earthquakes.3.studing of seismotectonic4. Preparing map of faults and indicating relation of faults with macro earthqukes by GIS (Geographic Information System)software.5. Estimating the maximum magnitude that be generated by a particular active fault.

SH3/P22/ID168 - GEM1 HAZARD ENGINE: SOME EXAMPLES OF HAZARD CALCULATIONS ACROSS THE GLOBE

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The Global Earthquake Model (GEM, www.globalquakemodel.org) is a public-private partnership initiated by the OECD to develop state-of-the-art open source software and databases as a necessary basis to reliably map, monitor, and communicate earthquake risk at a global scale. The opening phase of GEM, named GEM1, aimed at developing the preliminary IT infrastructure. The newly developed system represents a synergy between IT resources (i.e. databases, high performance hardware) and hazard/risk knowledge capable to offer an infrastructure for seismic hazard/risk computation, and ultimately to facilitate capitalization and sharing of data throughout the community. The GEM1 hazard engine, built on top of OpenSHA (www.opensha.org), was used to calculate probabilistic seismic hazard using fourteen input models with distinct characteristics in terms of seismic source geometry, seismicity recurrence parameters, activity rates, and management of epistemic uncertainty. We present the newly developed hazard engine, its main components and some simple benchmark tests completed against existing PSHA codes for validation purposes. Additionally, we show some examples of the hazard calculations performed using standardized PSHA input models for distinct parts of the globe. The standardization of the input data was formalized in XML (extensible Markup Language) scheme. A brief description of the proposed XML scheme, denoted as shaML, will also be provided. In particular, this contribution will focus on showing the capability of the GEM1 hazard engine to deal with different source typologies and its flexibility in accommodating input models with different levels of complexity and distinct characteristics.

SH3/P23/ID169 **- THE EMEELT ACTIVE FAULT, REVEALED BY THE OUTBREAK OF MICROSEISMICITY, AND ITS IMPACT ON THE PSHA OF ULAANBAATAR, CAPITAL OF MONGOLIA. PART I: SEISMOTECTONIC ANALYSIS.**

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Mongolia is a large country of about 1,5 Million km2 with about 1/3 of its population concentrated in the Capital, Ulaanbaatar (1.2 Million of inhabitants). The assessment of the seismic hazard and risk at Ulaanbaatar is then of first importance for economic stability and human protection. A first probabilistic seismic hazard assessment (Schlupp et al., 2006) was based on 1) a model of active faults deduced from previous work, field studies and satellite image analysis, 2) a seismic zoning related to the various geodynamic regions, 3) a seismic model for each fault (characteristic events and recurrence time base on local study) and each zone (Gutenberg-Richter law based on reviewed instrumental and historical catalogue), and 4) a published attenuation law. An amplified frequency zoning of Ulaanbaatar was performed using H/V and site to reference analysis. In hazard studies of Ulaanbaatar, the main sources were related to the large active faults including those associated with the four earthquakes of magnitude 8 that struck the country between 1905 and 1957. The nearest fault to Ulaanbaatar considered was the Hustai fault with its northeastern tip located 10 km from the city of Ulaanbaatar. This 92-km-long fault may produce, if it breaks at once, a magnitude about 7,5. No known historical earthquake occurred on the Hustai Fault in the last 500 yrs while instrumental seismicity shows regular activity with five M 4+ since 1974, some of which were actually felt by inhabitants. In 2005, we observed a very strong increase in seismicity below the International Airport of Ulaanbaatar and north of it, over the Emeelt area (See abstract Munkhuu Ulziibat and al in same session). This change dramatically altered our view on the relative seismic quiescence observed until then in the region. Immediate field observations revealed a new active fault -now called the Emeelt fault- located less than 15 km from westernmost area of Ulaanbaatar which is associated with the seismic activity observed since 2005. Further investigations over the Emeelt fault area in 2008 and 2010 include morphotectonic mapping, near-surface geophysical imaging (magnetic mapping, GPR), microtopography (differential GPS) and paleoseismic trenching. Our results show that: 1) the fault is weakly segmented, 2) its trace can be mapped over more than 40 km, 3) the deformation zone is relatively wide and 4) earthquake ruptures have reached the surface in the recent past. The recurrence time of events, their size and 3D analysis of the seismicity are under process. Here we present our preliminary results and discuss the potential impact of such discovery for PSHA and hazard assessment for Ulaanbaatar.

SH3/P24/ID170 **- THE EMEELT ACTIVE FAULT, REVEALED BY THE OUTBREAK OF MICROSEISMICITY, AND ITS IMPACT ON THE PSHA OF ULAANBAATAR, CAPITAL OF MONGOLIA. PART II: TIME AND SPATIAL BEHAVIOR OF THE REGIONAL SEISMICITY.**

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An important seismic activity has been taking place near and within Ulaanbaatar area since 2005 and is still active up to today. This area, which could be one of most seismic active zone around Ulaanbaatar, dramatically increases the seismic hazard of the capital of Mongolia where is concentrated about of 1/3 of the Mongolia population and the majority of industries of the country.The seismicity recorded by local permanent and temporary networks reveals an important increase of seismic activity rate in region around U.B. For instance, 2 times as many earthquakes were recorded during the last five years (2005-2010) as between 1970 and 2004. Moreover, these swarms, consisting in more than 1600 events with a magnitude between 0.5 until 4.2, are mainly located close to 2 major active structures: NS Emeelt and EW Hustai striking faults. At the beginning (2005-2009), the swarm activity mainly concerns the Emeelt fault and was characterized by a strong time dependency consisting in a propagation of the activity toward North and South fault edges with an increase of the seismicity rate. In 2009, the swarm extended his activity to the eastern edge of the Hustai fault which is the largest known structure near Ulaanbaatar able to produce large destructive earthquake on the city.Despite the relatively low magnitude of these earthquakes, the lack of large magnitude earthquake in this area combined with the clear active fault morphology of the Hustai and Emeelt structure (see Schlupp et al. in the same session) make the study of this recently triggered seismic swarm fundamental for the estimation of Ulaanbaatar seismic hazard. In this presentation, we will discuss some preliminary results of the analysis of this high seismic activity recorded by permanent and dedicated mobile networks, such as its spatial and time evolution or their relation with the regional seismo-tectonic context, as well as its impact on the seismic hazard assessment of Ulaanbaatar area.

SH2 - MAGNITUDE SCALING AND REGIONAL VARIATION OF GROUND MOTION

SH2/P1/ID171 **- SOURCE AND ATTENUATION PARAMETERS FROM WEAK MOTION DATA RECORDED IN NE ITALY.**

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We investigated the high-frequency attenuation of S-waves in southeastern Alps and northern Dinarides, using waveforms from 302 earthquakes ($3.0<M_D<5.6$), and the source properties of 14 events ($2.9<M_D<5.1$) of the 2004 Kobarid seismic sequence (western Slovenia) recorded by the North-Eastern-Italy (NEI) network, managed by CRS-OGS. The spectral decay parameter, k, was estimated in a wide (0-250 Km) range of distances and the observed trend of k with epicentral distance, R_E, was modeled through a generalized inversion procedure. The results evidence that k is independent on earthquake size while it shows both site and distance dependence. Stations of the NEI network present the same increase of k with distance and show values of the 0-distance k parameter between 17 and 53 ms. For the whole region, the curves $k(R_E)$ can be approximated through a piecewise linear function with slopes of 0.10 ms/Km and 0.17 ms/Km, for $RE < 90$ Km and $R_E > 90$ Km, respectively. This is in accordance with a three layers model where, moving from the intermediate to the bottom layer, both quality factor and S-wave velocity decrease. Different attenuation properties were evidenced for the areas located westward and eastward to the NEI network. Data from earthquakes located westward show weaker attenuation, probably because of S-wave reflections from different part of the Moho discontinuity beneath the eastern

Po Plain, at about 25-30 Km depth.

The curves $k(R_E)$, calculated for each station of the network, were employed to correct the observed S-wave amplitude Fourier spectra for the frequency independent part of the quality factor, before the estimation of the source properties of the strongest events occurred during the 2004 Kobarid sequence. The k-correction was applied taking into account that k values estimated from data of the Kobarid area are, on average, 17 ms higher than predicted mean values obtained with the $k(R_E)$ functions, probably because of the high level of fracturing that characterizes fault zones. Observed spectra were also corrected for geometrical spreading and for the frequency dependent part of the quality factor. The results show corner frequencies in the band 1.5-5.5 Hz and seismic moments ranging from $5.0x10^{12}$ to $2.0x10^{14}$ Nm.

SH2/P2/ID172 - ESTIMATION OF PEAK GROUND ACCELERATION ATTENUATION IN AUSTRIA

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Peak Ground Acceleration (PGA) is a key parameter for the earthquake hazard research that is one of the most important tasks for the Austrian Earthquake Service. We will present you studies and results about the PGA attenuation estimated for Austria, i.e. a relationship between PGA, and epicenter distance and magnitude. Data recorded by STS2 sensors at Austrian Seismic Network are employed to this study. After filtering waveforms, instrument response removal is performed. By differentiating the velocity traces recorded by the STS2 instrument, acceleration traces are therefore obtained and used as the input data to our study. Investigation of PGA attenuation is conducted for acceleration traces obtained for the single Z/N/E channels and also for the squared sum of three-components. As known, the earthquake damage is not only dependent on the shaking amplitude but also on its duration, defined for cumulative energy between 5% and 95%. We will present the statistics of earthquake durations obtained from our study as well.

SH2/P3/ID173 - VS30 AND KAPPA FROM ACCELEROMETRIC DATA ANALYSIS

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We investigate recordings from weak to moderate earthquakes, magnitudes ranging between about 3 and 5, recorded by the French Accelerometric Network. S-waves spectra are modeled as a product of source, propagation and site terms. An inversion procedure of large data sets of multiple earthquakes recorded at multiple stations allows us to separate the three contributions. Source parameters such as moment magnitude, corner frequency and stress drop are estimated for each earthquake. Moment magnitudes (Mw) are linearly correlated with local magnitudes (ML) in the 3-5 magnitude range but when magnitude increases Mw becomes lower than ML. Stress drops are found to be regionally dependent as well as magnitude dependent, and range from about 1 bar to several hundreds of bars. The attenuation parameters show that, at the scale of the national French territory, variations of attenuation do exist. Site transfer functions are also computed giving the level of amplification at different frequencies with respect to the response of a generic rock site characterized by an average 30 meters S-wave velocity (vs30) of 2000 m/s. From these site terms, we compute the high-frequency fall-off parameter modeled as $\exp(-\pi Kf)$ (with f the frequency) for all the stations. We also determine the vs30 for the rock stations by comparison of the site transfer functions with the ratios between the responses of generic rock sites with different vs30 values. We finally show the K-vs30 relationship for 21 rock stations compared with data coming from other regions.

SH2/P4/ID174 - IRAN EARTHQUAKES, A UNIFIED CATALOG WITH MOMENT MAGNITUDES

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A homogeneous and complete earthquake catalog is very essential component in seismic hazard studies; therefore, in this study seismic catalog of Iran and adjacent areas is assembled using global and local databanks. There are some priorities in choosing magnitude and location in different catalogs from various databanks. In general local catalogs are in higher position for detecting location of an earthquake and global catalogs are preferred for magnitudes. Earthquakes data corresponding to a region limited by latitudes 42°-65° N and longitudes 23° W-42° E and magnitude range 4.0 - 8.2, until first of 2010 were collected. As mentioned this catalog will be used in seismic hazard assessment so the area of collecting data is bigger than Iran borders not to have problems in margins. The catalogue is built by merging historical and instrumental data. Fortunately a comprehensive historical catalog for Iran earthquakes is compiled by Ambraseys and Melville in 1982 and also by Berberian in 1994. The first event in the historic catalog has happened in approximately 4th century BC, with an estimated magnitude of Ms 7.6 (Ambraseys and Melville). To achieve a homogeneous catalog we used proper relations to convert all kind of magnitudes to moment magnitude. To use the Gutenberg – Richter relation, the earthquake catalog should follow Poisson distribution, i.e., events occur independently of the time since the last event. Therefore aftershock and foreshocks were removed based on the method described by Gardner and Knopoff (1974). Magnitude completeness for three main Seismotectonic zones of Iran, (Zagros mountain range, Alborz mountain range and central Iran) is also calculated.

SH2/P5/ID175 - GROUND MOTION PREDICTION FROM NEAREST SEISMOGENIC ZONES IN AND AROUND GREATER CAIRO AREA, EGYPT

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This paper reviews the likely source characteristics, focal source mechanism and fault patterns of the nearest effective seismogenic zones to Greater Cairo Area. Furthermore, Mmax and ground accelerations related to the effective seismic events expected in future from those seismogenic zones are well evaluated. For this purpose, the digital waveform of earthquakes grater than ML=3 occurred in and around Greater Cairo Area from 1997 to 2008 which have been recorded by Egyptian National Seismological Network, are used to study source characterization, focal mechanism and fault pattern of seismogenic zones around Greater Cairo Area. The ground motions are predicted from those seismogenic zones to assess seismic hazard in the northeastern part of Greater Cairo, where three effective seismogenic zones, namely Abou Zabul, southeast Cairo trend and Dahshour area, have the largest effect to the Greater Cairo Area. The Mmax was determined, based upon an empirical relationship between the seismic moment and the rupture length of the fault during the earthquake. The estimated Mmax expected from Abou Zabul, southeast Cairo trend, Dahshour seismic sources are of Mw magnitudes equal to 5.4, 5.1 and 6.5, respectively. The predominant fundamental frequency and soil amplification characteristics at the area were obtained using boreholes data and in-situ ambient noise measurement.

SH2/P6/ID176 - ABRUZZO EARTHQUAKE OF APRIL 2009: GROUND MOTION ATTENUATION, SIMULATION SCENARIO AND DAMAGE ASSESSMENT

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An earthquake of Mw 6.3 occurred on April 6 2009, at 03:33 a.m. local time, in the Abruzzo region (Central Italy), close to the city of L'Aquila. The earthquake nucleated at a shallow depth of 9 km and ruptured a North-West–South-East oriented normal fault dipping about 55^0 toward the southwest and passing directly beneath the town of L'Aquila, lying on the hanging wall at about 5 kilometers from the epicenter.The main shock has been recorded by fifty-eight digital accelerometers with very high values of peak ground acceleration (0.3-0.65g) close to the centre of L'Aquila. The strong motion recordings are clearly affected by source effects and show a directivity towards south-east direction, with a systematic decrease of PGA and PGV at sites located in the backward direction of the rupture propagation. The predictive equations available in literature, underestimate the PGA values closest to the epicenter and overestimate those in the backward directivity direction. Better results are obtained with NGA models including an anelastic attenuation coefficient. The overestimation of far data is reduced when considering PGV and lower frequency response spectral values. The response spectra of the recordings closest to L'Aquila town, show very high values of acceleration in the interval 2-10 Hz, corresponding to the fundamental frequencies of most of the buildings in the area. The acceleration spectra, in the short period range, are higher than those

considered by the new Italian Building code NTC-08.The earthquake affected globally a territory of about 2,400 Km^2 with a population of 140,000, causing severe loss of lives (308 victims and 1,600 injured) and damage (about 18,000 unusable buildings, 53,000 homeless) in particular in the largest town of the area, L'Aquila, where the macroseismic intensity reached IX degree of EMS-98 scale. The simulation scenario available about 30 minutes after the main event underestimates the effective losses subsequently obtained from the field. Six months after the earthquake more than 70,000 building surveys were performed giving a percentage of about 52% safe and 32% unsafe buildings.In this paper the characteristics of the strong ground motions recorded during the Abruzzo seismic sequence and of their attenuation with distance are presented together with a comparison of the recorded response spectra with former and recent Italian building code. Loss simulation scenarios and damage and safety building surveys are also discussed and compared.

SH2/P7/ID177 – DISSIMILARITY OF REGIONAL CHARACTERISTICS OF RADIATION AND PROPAGATION OF SEISMIC WAVES IN KAMCHATKA AND THE NORTHERN CAUCASUS (RUSSIA)

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According to Russian construction regulations, calculation of acceleration time histories of scenario earthquakes is necessary when buildings are constructed in high-seismicity areas. These accelerogramms are used for estimation of various ground-motion parameters; at the same time, they represent input motions for earthquake-resistance testing of the designed buildings. This approach requires knowledge of regional characteristics of radiation and propagation of seismic waves, which are necessary for calculating synthetic accelerogramms. Kamchatka and the Northern Caucasus are the areas of the highest seismicity in Russia. We estimated regional parameters of radiation and propagation of seismic waves by solving the inverse problems of stochastic finite-fault simulation of earthquake records made in Kamchatka and the Northern Caucasus. Acceleration time histories of Kamchatka earthquakes (*Mw*=6.8-7.5, depths 45-55 km) were simulated at rock and soil stations at epicentral distances of 67-195 km. In these calculations, we used the source spectra, attenuation $Q(f)\sim 180\, f^{0.7}$, and geometrical spreading obtained earlier for Kamchatka. Parameters of radiation and propagation of seismic waves were obtained, which describe the studied earthquakes rather accurately, and for two of the earthquakes, models of slip distribution over the fault planes were constructed. Station "Petropavlovsk" can be considered as a reference rock station having the minimum site effects. The intensity of seismic oscillations at the other stations is higher due to the soil response or other effects, primarily, topographic ones. At some soil stations, parameters of the soil profiles (homogeneous pyroclastic deposits of ~100-200 m thickness probably wide-spread in Kamchatka) were estimated, and nonlinear models of their behavior in the strong motion were constructed. Records of local earthquakes (*Mw* > 4.0) made by seismic stations "Sochi" and "Anapa" in the Northern Caucasus were used for estimation of *S*-wave attenuation *Q(f)* by the coda-normalization method. Geometrical spreading was estimated based on the decrease of PGA- values with distance. The obtained *Q(f)* for Sochi and Anapa show the difference in attenuation in these areas at low frequencies (indicating different structures of the upper lithosphere) and similarity at high frequencies. Finally, acceleration time histories of the strongest recorded Northern Caucasus earthquakes (*Mw*> 5.4) were simulated. The performed studies show substantial dissimilarity between Kamchatka and the Northern Caucasus in parameters describing path effects, resulting in drastically different wave forms of the acceleration time histories. Evidently, this is due to the different geological structure in the two regions.

SH2/P8/ID178 – STRONG GROUND MOTION VARIABILITY DURING THE MW 6.3 APRIL 2009 L'AQUILA EARTHQUAKE

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The Mw 6.3 April 6, 2009, 01:32 TU earthquake in the Abruzzi region (Central Italy) has been recorded by 57 stations of the Italian Accelerometric Network (RAN). High Peak Ground Acceleration values were observed close to the center of L'Aquila city. In this study we analyzed the ground motion characteristics of the data acquired close to the mainshock. In particular we studied the spatial variability of several accelerometric parameters (Peak Ground Acceleration, Peak Ground Velocity, Response Spectrum, Arias Intensity, Cumulative Absolute Velocity, Housner Intensity and Trifunac Duration). These accelerometric parameters show a huge variability of the seismic motion for a given distance. One important part of the variability close to the fault is due to the source property and in particular to the rupture directivity toward the south-east. For some stations, the H/V spectral ratio highlights the resonant frequency of the site. In particular, the stations located in the Valley dell'Aterno show H/V peaks that are consistent with the thickness of the geological layers and their geotechnical properties. The accelerometric data from this earthquake shows that, close to the fault, we can reach near-field horizontal accelerations close to 1 g for events with magnitude close to the maximum historically known earthquakes in France. For seismic hazard applications it appears therefore important to make a special effort on the seismic sources activity characterization. When feasible, it is recommended to attach the main events to a tectonic structure geographically identified instead of considering large homogeneous seismotectonic areas of diffuse seismicity with comparable maximum magnitudes for seismic hazard applications.

SH2/P9/ID179 – ESTIMATION ON PEAK GROUND ACCELERATION IN TAIWAN AREA

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Since the Taiwan area is situated on the subduction zone, where the Philippine Sea Plate is subducting underneath the Eurasian Plate, much attention is focused on seismic risk mitigation. The purpose of this paper is to study the potential of earthquakes hazard in the Taiwan area, using the seismic acceleration data collected by the Central Weather Bureau from 1993 to 2008. The theoretic Peak Ground Acceleration (PGA) is calculated basing on well developed velocity and attenuation models. The deviations between the observed and theoretic PGA of 163 seismic stations in Taiwan area can be obtained. The results show that most of the deviation is small than 30%. It indicates that we can predict the maximum amplitude of ground acceleration for any events occurred in Taiwan area under the accuracy of 70 % (probability). The estimation of PGA for any earthquake will be obtained using the theoretic and corrected with these deviations.

SH2/P10/ID180 – ESTIMATING AND COMPARISON OF ATTENUATION PARAMETERS FOR THE SOUTH OF ZAGROS (IRAN)

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Shiraz digital seismic network comprises five, three component seismic stations installed in south of Zagros (Iran). This network started its digital operation at the middle of 2002, and has recorded more than about 15000 events during 8 years. The availability of a large number of amplitude data collected by this network has motivated this study to develop reliable empirical distance attenuation for this network. Waveforms of recorded events are processed to extract synthetic Wood-Anderson seismograms. First we used generalized inversion theory (GIT) but we found a negative anelastic attenuation coefficient which in not correct physically, so we used an iterative method. In regression fitting we have calculated *n* and *k* parameters related to the geometrical spreading and anelastic attenuation. The resulting coefficients evaluated for this region as whole: R1=82 km; R2=128 km; n1=1.5; n2=0.14; n3=0.5; k=0.0018.

Then we have compared our results with coefficient of anelastic attenuation which has been obtained for this region before. One of the studies has been done by Nuttli (1980) on different seismic phases by World Wide Standard Seismograph Network (WWSSN) in Shiraz, Tabriz and Mashhad. Moreover, Shoja-Taheri et al (2007) have determined the coefficient with strong motion data records by National Strong Motion Network of Iran recently. Comparison between our average Q factor which is 205 and Nuttli's value which is 200, illustrates a good correlation in contrast with the study of Shoja-Taheri et al.

SH2/P11/ID181 – REGIONAL VARIATION OF GROUND-MOTION IN ITALY

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In the past decade, the improvement and expansion of strong-motion networks installed worldwide, led to an increase of the number of regional ground motion prediction equations (GMPEs), as reported by Douglas (2003), a number that has been certainly increased in the recent years. The idea behind the derivation of regional GMPEs is that the aleatoric uncertainty can be reduced, as the examined areas are expected to be homogeneous in terms of source, attenuation and site effects. Opposite to the expectation, the aleatoric uncertainty increases when compared to that obtained by global GMPEs (Douglas, 2007). Bindi et al.(2009) used the strong-motion data collected in the ITalian ACcelerometric Archive (http://itaca.mi.ingv.it) in order to develop a set of GMPEs for the Italian territory in order to update the well known GMPEs developed by Sabetta and Pugliese (1996). The recent M_w 6.3 L'Aquila earthquake, occurred in central Italy on April 2009, and the upgrades of the ITACA database gave us the possibility to validate the predictive capability of the newly developed GMPEs and to explore the regional variability inside the Italian territory. Moreover the predictive capability of European (Akkar and Bommer, 2007a;b; 2010) and global (Cauzzi and Faccioli, 2008; Boore and Atkinson, 2008) GMPEs, with respect to the Italian data, was investigated. The results are presented in terms of goodness of fit between observed and predicted values, using the maximum likelihood approach as proposed in Spudich et al. (1999).

SH2/P12/ID182 - ANALYSIS OF VARIOUS FREQUENCY CONTENT PARAMETERS FOR GROUND MOTIONS RECORDED DURING STRONG VRANCEA EARTHQUAKES

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The paper presents the results of an extensive study, based on the analysis of over 300 accelerograms recorded during the strong Vrancea seismic events (M_w>=6.4) that occurred during the past three and a half decades. Various scalar parameters which characterize the frequency content of strong ground motions were calculated, i.e.: the predominant spectral period (based on acceleration, velocity and input energy spectra), the smoothed spectral predominant period, the average spectral period, the central period and the spectral characteristic period. The capacity of the analyzed parameters to describe the frequency contents of the ground motions was assessed. Comparisons were made with available estimations of predominant period, performed by other methods. Correlations with other characteristic ground motion parameters, including bandwidth measures, were investigated, on an event-by-event basis. The variability of the analyzed parameters from an event to another was pointed out, as well as regional variability.

SH2/P13/ID183 - THE ITALIAN ACCELEROMETRIC ARCHIVE (ITACA): GROUND MOTION PREDICTION EQUATIONS AND ANALYSIS OF THE ERROR DISTRIBUTIONS

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In the framework of the project "Italian Strong Motion Database " funded by the Italian Civil Protection (DPC), a new version of the ITalian ACcelerometric Archive (ITACA, http://itaca.mi.ingv.it) has been released, including revised strong-motion data recorded in Italy from 1972 to 2007 and some data from recent seismic events, such as the April 6, 2009 L'Aquila earthquake (M_w 6.3) and its main aftershocks. In this work, we use recordings from earthquakes in the magnitude range 4 - 6.9, recorded at distances smaller than 300 km, to derive ground motion prediction equations (ITACA-GMPEs) for peak ground acceleration (PGA) and velocity (PGV) and ordinates of acceleration response spectra at 5% damping, considering the geometric mean of the horizontal components. To investigate the presence of regional features in the derived models, the predictions obtained with the ITACA-GMPEs are compared to the models recently derived for Turkey (Akkar and Çağnan, 2010) and Europe (Akkar and Bommer, 2010). A comparison with the Atkinson and Boore (2008) model is performed as well, as it is based on a global data set. Finally, the inter-event, inter-station and record-to-record distributions of error are evaluated using a random effect approach (Abrahamson and Youngs, 1992), and the different components of variance are analyzed as function of the period.

SH2/P14/ID184 - PREDICTION OF THE GROUND MOTION IN LEBANON BY THE EMPIRICAL GREEN FUNCTIONS TECHNIQUES AND THE GROUND MOTION PREDICTION EQUATIONS.

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Historically, Lebanon experienced strong earthquakes produced by the Yammouneh fault that crosses its territory from the north to the south dividing it into two parts. An example is the 1202 A.D. earthquake, estimated to 7.6's magnitude and felt from Armenia to Egypt. The present study intends to perform a site-specific estimation of the ground motion caused, within the heavily populated Beirut area, by such potential large earthquakes on the Yammouneh fault. A multi-step procedure was adopted in that aim:The first one is to simulate the effect of a M6.5 event at a Broad Band rock station using the empirical green function method EGF. After reviewing the list of recorded events along the fault during three years, a digital seismogram of a representative small event of Md 3.1 is chosen. The variability of the source, directivity and roughness is assessed. Furthermore, due to the lack of accuracy in the determination of many parameters of the empirical Green function, the uncertainties of the corner frequency, the epicentre distance, the magnitude and the depth are also evaluated. Finally the median and the standard deviations of the ground motion are estimated on the reference rock station BHL.The second step consists in evaluating the same ground motion M6.5 by a set of ground motion prediction equations GMPE. Five models representing different regions of the world with different databases are used. The predicted ground motions are then compared to the simulated event by EGF. The rock ground motion prediction equation that gives results in good agreement with the simulated earthquake by the EGF is considered as the model that represents the best the region of Lebanon. This estimated rock ground motion is then transferred to various other sites with different subsoils within the greater Beirut area, using empirical transfer functions derived from a temporary seismological survey with the standard spectral ratio technique. The response spectra, associated to a M6.5 earthquake, are calculated in all the sites and the amplification factors are deducted. The final step consists in estimating the effect of a M7.5 event that could occur on the Yammouneh fault. The «best suited" rock ground motion prediction equation as identified in the step 2, is used to predict the ground motion on the reference station BHL. By applying the amplification factors, the response spectra are also calculated on the sediment and the rock sites of Beirut. Finally, a comparison of these response spectra with the actual response spectra used in the Lebanese regulations is presented.

SH2/P15/ID185 - GROUND MOTION MODELS FOR DISTANT OFFSHORE EARTHQUAKES IN WESTERN IBERIA: CONSTRAINS FROM INSTRUMENTAL DATA

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The distant plate-boundary seismicity has been a concern for engineers in Portugal since long time, and the seismic codes currently enforced reflect this concern. The reason for this worry is the general belief that plate boundary offshore distant earthquakes display an anomalously low attenuation of ground motion, which might explain the widespread damage in Portugal due to the 1755 earthquake. The effects of hazard-relevant historical and early-instrumental events are characterized in terms of intensities, and the absence of quantitative ground motion parameters is a hindrance to accurate seismic hazard assessment. During the last decade, the occurrence of four earthquakes in the M4.8-6.2 magnitude range, recorded by the accelerometer and broadband-seismometer networks of IST and Instituto de Meteorologia, provided the first instrumental dataset for moderate magnitudes. We use visual inspection and residual analysis to compare the ordinates of response-spectra ground motion for these data, with NGA attenuation models and attenuation models for Eastern North America (ENA). The ENA Atkinson and Boore (2006) model shows a good fit to the observed motions for the periods analyzed (PGA to 5 seconds). The NGA Boore and Atkinson (2007) model unde-

restimates observed ground motions at high frequencies (2-10 Hz). The analogue record from the M7.9 1969 earthquake supports the results obtained with weak motion data. The thorough comparative study of Stafford et al. (2008) concludes that NGA models are suitable for Active Europe. Our results suggest that attenuation in Western Iberia may require particular attention. However, the present study contradicts the general belief that the attenuation ground motion from distant earthquakes offshore Western Iberia is anomalously low since models for stable continental regions can represent it.

SW3 - FINITE FREQUENCY TOMOGRAPHY - THE FIRST TEN YEARS.

SW3/P1/ID186 - FINITE FREQUENCY TOMOGRAPHY FORT THE NORTHWESTERN PACIFIC REGION

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The subducted slabs in the northwestern Pacific region show a complicated morphology; the slabs subducted from the south Kurile, Japan, Izu-Bonin arcs tend to be trapped in the mantle transition region, while to the north beneath the north Kurile and to the south beneath Mariana the slabs tend to penetrate the 660-km seismic discontinuity. To understand the relationship between such different behaviors of the subducted slabs, broadband seismic networks in the western Pacific Ocean and in the Russian Far East were deployed along with the Stagnant Slab Project (Japan) from 2005 to 2007. We also collected the seismograms of the islands in and around the north Philippine Sea.

In general the background noise level of the broadband ocean bottom seismogram (BBOBS) is high in the periods less than 5 second due to the microseisms (pressure variations on the ocean floor induced by ocean waves) and in the periods around 100sec due to the infragravity waves. However the noise level takes a minimum and is comparable to that of the seismograms on the land in the periods in between. Therefore we applied the band-pass filter at the corners 0.03 and 0.08 Hz to measure P-wave arrival times. The finite frequency tomography takes advantage of such frequencies of data.

We measured relative arrival times of P-waves using a waveform cross-correlation. After visual evaluation of the waveform data, we collected approximately 4300 relative times for western Pacific Ocean BBOBS data and 900 for Russian Far East data. We calculated the finite frequency kernels for the data. Our first result of the inversion will be shown at the meeting.

SW3/P2/ID187 - OBSERVABILITY OF MULTIPLY REFLECTED P WAVES

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In order to constrain the shallow structure of the Earth in global tomography, Love and Rayleigh waves are often used. However these waves are mostly sensitive to the S wave velocity structure. P-wave energy is evanescent and leaking away at every surface reflection that generates an S wave which travels much deeper into the mantle. For that reason, to study the shallow P velocity structure of the Earth, we need to study P-waves at regional distances if a good seismic station coverage is available. Otherwise we can use multiple P reflections at teleseismic distance when regional data are not available (as in the oceans for instance). The major aim of this work was first of all to ensure that these multiply reflected P waves can adequately be observed in real data and also to investigate after how many reflections at the surface these waves can still be seen.We also investigate how strongly the amplitude of multiply reflected P diminishes because of energy loss into S waves and attenuation. For this study we are stacking real data in the Tau-P domain.We used data records from the dense network of US ARRAY, which allows us to make a very large number of observations. Our study shows that both PPP and PPPP waves show a clear maximum of energy in the Tau-P plot. Which means that they can be well observed for epicentral distances > 60 degrees and for events with Mw >6.0, despite the ray-theoretical prediction that at certain distances almost all of their compressional energy is converted to shear waves. The maximum of energy associated to these multiple P wave consistently shows a negative slowness perturbation (dp). Indicating the waves may deviate from the great circle.

SW3/P3/ID188 - TOMOGRAHYC RESEARCH IN BANAT AREA (WESTERN ROMANIA) USING LOCAL EARTHQUAKE DATA

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The main goal of this study is to investigate the crustal structure in the western part of Romania, in Banat seismic area. The seismicity in this area is characterized by shallow activity of moderate magnitude (magnitude below 6) with frequent multiple sequences. The region is divided in many tectonic blocks bordered by intracrustal faults and with relative different structural position, like horsts and grabens. These ones belong to two major Alpine structural units developed in the region: the Pannonian Basin with a thin lithosphere (cca 6o km) subsiding in Neogene-Actual times and four Dacidic units with a thicker lithosphere (100-140 km), uplifted in the last orogenic stages of their evolution, respectively. An updated and revised catalog with well-located events, occurred between 1982 and 2010 in the Banat region and surroundings is considered as input data. The earthquakes were recorded by the permanent national seismic network and during campaigns of intense observation by denser temporary networks, like CALIXTO' 99 experiment (Wenzel et al., 1998) and South Carpathian Project started in 2009. We obtained tomography results by inverting the P- and S-wave arrival time data using the tomography approach of Koulakov et al. (2007).

SW3/P4/ID189 - NEW ARGUMENTS FROM LOCAL EARTHQUAKE TOMOGRAPHY AND ANISOTROPY FOR MARMARA REGION

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The Marmara region is an area of exceptional neotectonic activity because active crustal movements take place combined with very high seismicity. The main neotectonic elements can be defined as: the dextral North Anatolian Fault Zone (NAFZ), regional faulting and tilting, block rotations, and the N-S extension of the Aegean realm including Western Anatolia. Strong earthquakes occur at shallow depths (less than 30 km) in the target area. In this study we investigated the crustal structure beneath Marmara region using a local earthquake tomography approach and Seismic anisotropy. We used only micro earthquakes from 2006 to 2009 that are obtained from both permanent (Bogazici University, Geophysics Department, Kandilli Observatory and Earthquake Research Institute) and temporary (Multi-Disciplinary Earthquake Research in High Risk Regions of Turkey) stations. Simultaneous tomographic inversion for the Vp and Vs anomalies and the Vp/Vs ratio and source locations are done using the LOTOS code. The aspect ratio method, cross-correlation method and systematic analysis of crustal anisotropy are also applied to the data to measure seismic splitting parameters. The main motivation of the study is to compare the velocity structure of the area with seismicity and also construct a seismic anisotropy model for explaining the complexity of the region.

SW3/P5/ID190 - LITHOSPHERIC IMAGING FROM TELESEISMIC DATA BY FREQUENCY-DOMAIN ELASTIC FULL-WAVEFORM TOMOGRAPHY

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Teleseismic data recorded by dense multicomponent surveys are potentially amenable to multichannel processing such as waveform inversion in order to obtain high-resolution lithospheric images. In this study, frequency-domain full-waveform inversion (FWI) is tailored to suit teleseismic geometries. FWI seeks to minimize the misfit between the recorded and modeled full wavefields to infer images in order to infer subsurface elastic properties. Frequency domain FWI is performed by successive inversions of few increasing frequencies to progressively inject shorter wavelengths in the model space and mitigate the non-linearity of the inversion. The full wavefield is computed at each iteration of the inversion with a discontinous Galerkin frequency domain method.

In the teleseismic framework, seismic sources are planar incident wavefields impinging the base of the lithosphere with an arbitrary incidence angle. The full teleseismic wavefield in the heterogeneous medium we want to reconstruct is computed using a scattered-field formulation in the frequency domain. For simplicity, we assume an infi-

nite homogeneous background model and the background corresponding plane wave solution. The scattered field follows the same elastodynamic equations as the full wavefield with a source terme depending on the background solution. The source term is non-zero where the heterogeneous medium has same values as the background model. The full wavefield required by FWI is built by summation of the background plane wave and the computed scattered wavefield.

When considering free surface, we assume an half-space homogeneous bacground model and the associated background solution which includes incident and reflected plane waves. Scattered wavefield does include directly-arriving forward-scattered and back-scattered wavefields, successively reflected from the free surface and from the lithospheric reflectors before recording at receivers. Back-scattering events are crucial for broadening the aperture (or diffraction) angle illumination of the target and improving imaging resolution. We illustrate this critical feature through simple examples.

Compared to ray-based migration technique, FWI does not rely on the single-scattering approximation in the forward problem and can model accurately wavefields that propagate over a broad range of incidence angles and scatters with large diffraction angle. This implies that FWI can invert both forward-scattered and backward-scattered data. Parameterization of model parameters in terms of absolute values rather than relative values is another advantage of FWI compared to migration.

SW3/P6/ID191 - THE COMPUTATION OF FINITE-FREQUENCY KERNELS WITHOUT THE PARAXIAL APPROXIMATION.

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The computation of finite frequency kernels using dynamic ray tracing, as originally proposed by Dahlen et al. (GJI, 2000) is very efficient, but the method has several disadvantages: it is prone to ambiguities and errors whenever the radius of curvature of a ray is smaller than the effective width of a kernel, and it breaks down completely for rays, such as PP or PKP that may reach as far as the antipode.

Motivated by the development of a wavelet parameterization in a 'cubed sphere', we have developed a new method for the fast computation of travel times and geometrical spreading factors. First, we confined our calculations to a finite set of discrete radii.

The goal then is to find the travel time and spreading factors for an arbitrary location along one of these radii. We use a traditional method to compute a fine fan of rays through a spherically symmetric model. For each ray we obtain the travel time and its second derivative with respect to distance from the ray in the ray plane, and the geometrical spreading at a series of nodes, typically spaced 15 km apart. These values are then interpolated to obtain data along each of the radii, resulting in a finite set (for each radius) of closely sampled data. Different arrivals are recognized by non-monotonic behaviour of the time as function of distance.

Travel times and geometrical spreading at arbitrary locations can be computed in two ways from this grid: either one interpolates from the times and spreading stored on the grid points, or one extrapolates a small distance from the nearest ray using dynamic ray tracing. We compare the two methods for efficiency and accuracy.

SW3/P7/ID192 - HIGH-RESOLUTION TOMOGRAPHY OF THE LOWERMOST MANTLE

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The lowermost mantle, the D'' layer, plays a key role in the global dynamics of the Earth, as a thermal and chemical boundary layer.

It is thus essential to better constrain its detailed structure in order to better understand mantle convection, birth of hot spots, and stability of superplumes.

Since diffracted waves (*Pdiff* and *Sdiff*) possess a strong sensitivity to D'' layer heterogeneities, they should be crucial to decipher the fine structures in the D'' layer. For this purpose, a global data base of broadband seismograms is being constructed with the objective of using it for high resolution tomography of the lower mantle.

Measurements of travel time delays will be done by cross-correlating observed with synthetic seismograms, calculated with the GEMINI method.

Future work will also consist in developing methods to compute travel time and amplitude kernels for diffracted waves.

SW3/P8/ID193 - MOHO DEPTH AND CRUSTAL VELOCITY STRUCTURE BENEATH THE RTC (MOROCCO) AND TAM (ALGERIA) STATIONS, FROM TELESEISMIC RECEIVER FUNCTIONS ANALYSIS

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In this study, we apply the P-receiver function technique to invert teleseismic data in order to investigate the S-velocity structures underneath the RTC and TAM stations. The teleseismic waveform receiver function analysis is a technique used in earthquake seismology to study the crustal structure beneath broadband seismic stations. The modeling procedure consists of seismograms rotation, deconvolution and inversion in the time domain that allows to isolate the P-wave converted to S-wave from incident P-waves, and to produce an image of the crust and upper mantle. While the RTC station is installed on top of thick sediments in Rabat, Morocco, the TAM station is seated on the Tamanrasset craton, Algeria. The observed velocity models indicate the distribution of S-velocities from the near surface to the uppermost mantle and indicate the Moho depth beneath each station, revealing the different geological environments. The modeling results show that the crust beneath the RTC station is relatively complex with large velocity fluctuations. Within the upper crust, a low velocity layer that extends from 8 to 12 km-depth is observed. This shallow depth LVZ is mainly due to the station location, which is on a zone of transition between a thick continental crust and the thinner Atlantic oceanic crust. Underneath Rabat, the crust-Moho boundary is characterized by a gradual S-velocity increase, thus, indicating that the Mohorovicic discontinuity is rather of a transitional type.For the Tamanrasset station, the internal crustal structures east and west of the station are different. Thus, we find a high velocity zone between 2 and 8 km to the East which is attributed to a high conductivity unit corresponding to some of the intrusions mentioned in the literature. No similar feature is observed west of the station. For the middle to lower crust, the velocity profiles are quite similar, except for the SW model, which shows a low velocity layer between 28 and 36 km-depth. For Tamanrasset, the velocity also gradually increases from the lower crust to the Moho, thus, indicating a transitional Moho under the TAM station as well.Thus, the comparison between the velocity models obtained for the Rabat RTC and the TAM stations strongly reflects the differences between their tectonic environments. This geological-environment difference is reflected both by the nature of the crustal velocity distributions and by the depth to the Moho, which is about 20 km underneath the RTC station and nearly 38 km beneath the TAM station.

SW3/P9/ID194 - IMAGING THE SLAB BENEATH CENTRAL CHILE USING THE SPECTRAL ELEMENTS METHOD AND ADJOINT TECHNIQUES

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This work focuses on imaging the subducting slab beneath Central Chile using novel inversion techniques based on the adjoint method and accurate wave propagation simulations using the Spectral Elements Method. The study area comprises the flat slab portion of the Nazca plate between 29 S and 34 S subducting beneath South America. We will use a database of regional seismicity consisting of both crustal and deep slab earthquakes with magnitude 3 < Mw < 6 recorded by different temporary and permanent seismological networks. Our main goal is to determine both the kinematics and the geometry of the subducting slab in order to help the geodynamical interpretation of such particular active margin.

The Spectral Elements Method (SPECFEM3D code) is used to generate the synthetic seismograms and it will be applied for the

iterative minimization based on adjoint techniques. The numerical mesh is 600 km x 600 km in horizontal coordinates and 220 km depth. As a first step, we are faced to well-known issues concerning mesh generation (resolution, quality, absorbing boundary conditions). In particular, we must evaluate the influence of free surface topography, as well as the MOHO and other geological interfaces in the synthetic seismograms. The initial velocity model from a previous travel-time tomography study, is linearly interpolated to the Gauss-Lobatto-Legendre grid. The comparison between the first forward simulations (up to 4 seconds minimum period) validate the initial velocity model of the study area, although many features not reproduced by the initial model have already been identified.

Next step will concentrate in the comparison between finite-frequency kernels calculated by travel-time methods with ones based on adjoint methods, in order to highlight advantages and disadvantages in terms of resolution, accuracy, but also computational cost.

SW3/P10/ID195 **- HIGH ORDER UNSPLIT AND NON-CONVOLUTION PERFECTLY MATCHED LAYER BOUNDARY CONDITIONS FOR WAVE PROPAGATION USING VARIATIONAL FORMULATION**

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To solve the inverse problem in seismology it is necessary to accelerate forward and backward wave propagation modelling. For this purpose efficient boundary conditions (like the Perfectly Matched Layer conditions) must be designed to truncate the computational domain and to compute 3D models in thin slices at a cost close to 2D models. Unsplit convolutional perfectly matched layers (CPML) for the velocity and stress formulation of the seismic wave equation are classically computed based on a second-order finite-difference time scheme or spectral element methods at the second order in time. However it is often of interest to increase the order of the time-stepping scheme in order to increase the accuracy of the algorithm. This is important for instance in the case of very long simulations. A full displacement formulation is introduced in order to reduce the number of arrays involved inside the PML layer and dampjng corrections are added in all directions in order to avoid possible instabilities and to treat anisotropic materials. Viscoelastic materials are also computed. We study how to define and implement a new unsplit non-convolutional PML called the Auxiliary Differential Equation PML (ADE-PML), based on a high-order Runge-Kutta time-stepping scheme and optimized at grazing incidence. We demonstrate that when a second-order time-stepping scheme is used the convolutional PML can be derived from that more general non-convolutional ADE-PML formulation, but this new approach can be generalized to high-order schemes in time, which implies that it can be made more accurate. We also show that the ADE-PML formulation is numerically stable up to 100,000 time steps.

ES2 - INTRAPLATE SEISMICITY OF CENTRAL AND NORTHERN EUROPE

ES2/P1/ID196 **- NON-TYPICAL PHASES IN RECORDS DUE TO LOCAL SWARM EARTHQUAKES IN WESTERN BOHEMIA.**

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Typically, only direct P and direct S waves are picked in local seismograms from Western Bohemia seismoactive region. Many records, however, show systematically certain other important phases, which can be detected using new observational techniques. For instance, small-aperture arrays are useful to observe converted S to P waves transmitted throw a structural interface at 5 km depth and reflections from interfaces in the middle and lower crust. Another non-conventional observation methodology is based on seismic rotation measurements. For this purpose, the small-aperture arrays can also be used in principle, but better results can be reached with help of a specialized device (called Rotaphone), which we have developed recently to measure seismic rotation rate. The most interesting rotation rate records have been obtained within the earthquake swarm in Western Bohemia in autumn 2008. Rotational components complement information carried by translational motions. Moreover, when recorded in very short epicentral distances, they can reveal new features of seismic field, connected with earthquake source properties. Methodological aspects of recording of these non-typical phases as well as their interpretation are discussed in detail.

ES2/P2/ID197 **- RÉSONANSS: A REGIONAL CONTRIBUTION TO SEISMOLOGICAL OBSERVATIONS IN THE WESTERN FRANCE**

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The western part of the metropolitan France is characterized by a persistent intraplate seismicity: approximately 80 events of magnitudes lower or equal to 2 every year and few greater magnitudes (5 earthquakes of Mw > 4 over 20 years). However, due to a severe lack of coverage of the current permanent seismological stations, the source parameters are not accurately resolved: the locations may vary by several kilometers, and the source depths are regularly fixed during the inversion processes. Significant efforts are currently undertaken by the French seismological community to increase the number of permanent seismological stations (RESIF). The Laboratoire de Planétologie et Géodynamique of Nantes (LPG Nantes) is in charge of the deployment and of the maintenance of the Western stations. Thanks to various fundings, the LPG Nantes acquired a portable array of 12 short-period (< 20 s) seismometers in order to improve the coverage in the Brittany area, and to participate to the national observation effort. Our network (named RÉSoNANSS) is deployed around specific geological targets for several months, with a spacing of about 30 km. The first deployment was achieved in mid-2007 around the Southern Armorican Shear Zone (SASZ, South Brittany). It allows us to precise the spatial distribution of the seismicity along the Hercynian structures. Within the SI-HEX project, we relocate several typical intraplate events, looking for earthquake clusters in relation with the structural junctions of the SASZ, and focus our attention on the detection/location of small earthquake swarms.

ES2/P3/ID198 **- GROUND-MOTION DIFFERENCE BETWEEN TWO MODERATE-SIZE INTRAPLATE EARTHQUAKES IN THE UNITED KINGDOM**

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Two moderate-size earthquakes occurred in the United Kingdom, the first near Folkestone in 2007 with Mw 4.0 and the second near Market Rasen in 2008 with Mw 4.5. Both were strongly felt and caused some nonstructural damage. The earthquakes occurred at significantly different depths, the Folkestone earthquake at 5 km and the Market Rasen earthquake at 20 km. We determined the seismic moment and the stress drop of the two mainshocks, and two smaller earthquakes in the same locations, by modeling the source displacement spectra. We found stress drops of 30 +/- 34 bar and 344 +/- 136 bar for the Folkestone and Market Rasen mainshocks, respectively. This is a significant difference considering the earthquakes are only 275 km apart and both are of intraplate origin. We applied the stochastic groundmotion modeling technique and used the stress drop and seismic moment to compute vertical component peak ground acceleration. The modeled ground motions are consistent with the observations. We also computed vertical peak ground acceleration for a hypothetical Mw 6.0 high stress-drop (200 bar) earthquake and found that it would be 4.6 m/sec2 at 20 km hypocentral distance.

ES2/P4/ID199 **- ASSESSMENT OF ACTIVE BASEMENT FAULTS, CAPABLE OF PRODUCING DESTRUCTIVE EARTHQUAKES, IN DENMARK?**

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Whether geologically known faults are active is obvious in earthquake zones, while an assessment is needed for intraplate non-earthquake zones. The inactive area Denmark must naturally be seen in a regional frame of Scandinavia. And the assessment of faults, which could eventually produce a destructive earthquake, must include long-term evidence from geology of time scales thousands of years, as well as short-term evidence from seismology and geodesy. The medium-term evidence from paleoseismology on time-scale a few thousands of years is non-existent. The assessment must besides the Scandinavian arguments include parallel arguments on other continents of similar structure and

of similar global tectonic situation. Comparisons can be made to other earthquake-free intraplate areas like eastern North America. Discussions on the importance of uplift/subsidence in Denmark/southern Scandinavia are once more taken up these years in the lithosphere project DynaQlim, which covers Upper Mantle Dynamics and Quaternary Climate in Cratonic Areas. An evaluation of the earthquake potential in the Danish area is here presented with improved background material. None of the faults in Denmark are found to show potential for destructive earthquakes.

ES2/P5/ID200 **- EARTHQUAKE RELOCATION IN INTRAPLATE CONTEXT**

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Since 1985, 1532 earthquakes were recorded in and around Belgium (0° to 9° East, 49° to 52° North) by the Belgian seismic network. Additional observations came from the KNMI and Cologne University network. The lowering of the detection threshold by the still-evolving seismic networks and the occurrence of seismic sequences confirm the need of automated techniques to map the cross border regional seismic activity. The aim of this work was to evaluate the ability of available relocation software to provide reliable solutions for the whole Belgian catalogue. This allows locating main active structures, the first step before looking for geomorphologic evidences of their activity.

The routine location of any earthquake in the catalogue is obtained with the HYPO2000 software, which is a 500-iteration version of HYPO71: it calculates 500 locations of the same dataset, adding or subtracting random error on the P- or S-wave arrival times for each station. The solution is the centroid of the cloud. The relocation is achieved by using COMPLOC and HYPODD. We also use LOTOS_10, a 3D Vp-Vs anomaly calculation software, where the event location is a by-product of the process. We compare the spatial distribution of the output of the three relocation algorithms and study the influence of the station distribution. We finally check the consistency of the event distribution with recalculated focal mechanisms and available geological data.

ES2/P6/ID201 **- IDENTIFICATION OF FAULTS IN THE SEISMOACTIVE REGION OF WESTERN BOHEMIA, CZECH REPUBLIC, BY MEANS OF REFRACTION MEASUREMENTS**

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Refraction measurements were performed along an EW profile between quarries Horni Rozmysl and Liba in western Bohemia. The profile passed close to the epicentral regions of earthquake swarms near the village of Novy Kostel. A mean 1-D seismic velocity model was derived for the profile using the Wiechert-Herglotz method. Distinct delays of the measured travel times from the mean curve were observed to the east of the epicentral region where the profile crossed the Libocky stream (the Horka water reservoir). Moreover, significant absorption of high-frequency seismic waves occurred at the same place. We interpret this anomalous zone as a narrow fault zone, in particular, as the probable outcrop of the seismoactive fault beneath Novy Kostel. The anomalous zone does not coincide with the margin of the Cheb Basin, but is shifted a little towards the east. Note that the same seismic method has recently been applied also in identifying a fault zone beneath the Vltava River valley in central Bohemia (Malek et al., 2010).

ES2/P7/ID202 **- PRELIMINARY RESULTS ON ATTENUATION CHARACTERISTICS OF S-WAVES IN WESTERN ANATOLIA, TURKEY**

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Western Anatolia Region is one of the most seismically and tectonically active continental regions in the world and which contains one of the world's best examples of a rapidly extending intra-continental tectonic regime. Moderate sized earthquakes in the region are actually the dominant sources of seismic hazard with their larger amplitude at longer periods in deep basin structures of the western Anatolia graben system. Because of the real earthquake threat, estimation of the attenuation mechanisms is an important issue for the region. For that reason, we have analyzed the amplitude decay of S-wave transverse components in the western part of Turkey. The data of 322 events which are mainly came from two clusters with distance range from 4 to 205 km and magnitude range between 2 and 5.6 were used in this study. Utilizing non-parametric inversion scheme, attenuation functions including geometrical spreading and Q(f) effects were obtained. Attenuation-distance curves are significant in two different distance ranges with different characteristics. For the first part of these curves ($10 < r < 70$ km), the quality factor was found as $Q(f) = 32.88\ f^{1.26}$ in the frequency band analyzed ($1 < f < 20$ Hz). Low geometrical spreading values ($n < 1$) support possible low velocity layer previously suggested for the crust in the region and/or inhomogeneties which modify the wavefront geometries. Obtained frequency dependence of Q(f) suggests that scattering and perhaps other frequency-dependent mechanisms are important factors contributing to the attenuation of body waves in the region.

ES2/P8/ID203 **- INTRAPLATE SEISMICITY OF THE HOGGAR REGION (SOUTH ALGERIA)**

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The Hoggar region, located in the Sahara (south Algeria), is principally made from the Archean to the Pan-African age. It is also characterised by an Eocene to Quaternary volcanism and is associated with a swell. A model proposed by Liegeois et al. (2005) links this volcanism to the intraplate consequence of Africa-Europe convergence. The seismic activity in the Hoggar region is intermittently recorded but rarely felt by the population. The seismic character of the Hoggar massif was firstly pointed out by Grandjean (1962). This autor describes the weak seismic activity recorded, in the 1950s, by the Tamanrasset seismological station (TAM). The reported epicenters are located as far as 240 km and some of them at a distance of 500 km. However, 70% of 48 earthquakes were located at a distance between 50 and 100 km of TAM and were associated with the recent Hoggar volcanism. Since that time, a relative quiescence is observed in the region where the seismic character has never been validated. Thus, we propose to revise this intraplate seismicity by analyzing all the available seismic records of the three-components broadband station operating at Tamanrasset since 1983. In this work, we present the analysis of continuous recordings of the period 1999-2010.

ES6 - PHYSICS OF SEISMICITY: FIELD, LABORATORY AND THEORETICAL STUDIES

ES6/P1/ID204 **- APPLICATION OF THE HYBRID WELL PROGRAM TO HASSI MESSAOUD OIL FIELD (ALGERIA)WITH IMPLICATIONS FOR BETTER RESERVOIR MANAGEMENT AND EXPLOITATION.**

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Hassi Messaoud Field, Algeria has been under continuous development since 1958. Until 1997 vertical wells were drilled exclusively. Vertical wells were generally fully cored and logged. Geophysical analyses showed high degrees of reservoir anisotropy both vertically and horizontals. Vertical wells located in areas of the reservoir with good petrophysical properties produced many times better than others. After 1997 an aggressive horizontal well program was initiated. Horizontal laterals (long slant holes) which were, more or less, positioned randomly in the reservoir resulting in a kind of average producer. Horizontal wells generally have higher initial production rates than vertical wells but have steeper declines. To date, there has been little effort to specifically target good petrophysical properties for long term production and bore hole stability has not been seriously considered. A new well program, the Hybrid Pilot Well (HPW), is being initiated at HMD today. For HPW wells, a vertical pilot hole will be drilled through the reservoir. The pilot hole will be used to core, log, and test the reservoir. Surrounding vertical pilot wells will also be drilled sufficiently close together to permit geocellular interpolation via modeling between the data points. These wells will be specially designed so that reentry and conversion to a lateral is easily facilitated. In effect, we will have sufficient high quality information from the pilot holes to selectively target the laterals in precise layers of reservoir rock. The question remains, given the wide range of petrophysical conditions present in the reservoir which layers should be targeted to best provide long-term exploitation from the perspective of 1) production rates; 2) pressure maintenance; 3) formation damage; and 4) bore hole stability?Approach: A general analyses of horizontal well performance will be made1. A study area will be selected where the initial HPW pilot wells

are going to be drilled2. Petrophysical data from both old existing wells and new HPW wells will be introduced to a small scale geocellular model which will be used to evaluate:a. Core permeabilityb. Porosityc. Water saturationd. Rock mechanical propertiese. Lithology3. Special core tests will be performed to evaluate the performance of the various rock types with respect to asphaltene precipitation and borehole stability4. Rock types that appear to have the ability to produce at reasonable rates for long periods of time without significant damage will be identified.5. Analyses, including dynamic simulations will be performed to evaluate the theoretical reservoir performance if laterals are positioned specifically in the rock types identified.6. An evaluation of bore hole stability will also be performed relative to identifying the rock types that provide the best stability and also well bore orientation.

ES6/P2/ID205 - ESTIMATE OF THE SEISMIC EFFECT OF THE LARGE-SCALE EXPLOSION AND OF THE SEISMICITY AT AREA OF DAM OF THE KAMBARATA HPS-2, KYRGYZSTAN

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In 2008, the construction of the Kambarata HPS-2 was restarted. On the blocked in the late eighties and nowadays being finalized project the hydroelectric station dam is being erected through the explosion, in which result the rock mass is crushed and dumped to the Naryn river.The application of the large-scale explosion is linked with risks of the seismic impacts for the HPS construction site objects, which is located in 3,5км distance from the Shopokovo Village. Apart from the potential danger radiated by the explosion of seismic energy, basically, it is possible to speak on the issue of activation of manifestations of the natural seismicity of the territory containing the HPS. Unlike the hypothesis on the dangerous level of the caused, including the explosion, seismicity of the area, the probability of which (the hypothesis) causes doubts, in any case, should be made dependable on the intensity of the explosion impact, the area natural seismicity is the imperatively significant condition for providing the reliability of the HPS objects.The complex of the indicated issues makes their analysis and prognosticated appraisal necessary of the factors acting when exploding and during the construction of the dam.

ES6/P3/ID206 - RESULTS OF THE SEISMOMETRIC OBSERVATIONS OF LARGE-SCALE EXPLOSION ON CONSTRUCTION OF DAM OF THE KAMBARATA HPS-2, KYRGYZSTAN

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According to the accepted procedure for measuring with registering processes the instrumental complex was used that ensured the undistorted reproduction of initial processes under research, generated by the Large-Scale Explosion (LSE) in the neighborhood environment. The seismometric registration was carried out by the GeoSIG computer-controlled complexes of the three-axle accelerometers.

The registration items of the seismic signals were located according to the directions of the actions program on the following scheme:
- the Building Operational Spillway(BOS) tunnel lining concrete in its midpoint is the seismic station No.2, equipped with the GeoSIG with the three-component sensor, the measuring is in accelerations;
- the mass concrete on the 888 mark of the Hydro Power Station (HPS) building foundation on the pebble behind the southern break (concerning the location of the LSE charges) is the seismic station No.3, GeoSIG, the accelerometer;
- the installation mark is 970; the seismic station No.7, the GeoSIG accelerometer;

The accelerograms overall view corresponds to the conditions of the near zone of the explosion actions where the volume waves interfere with the surface, but in this case, already at the fronts essentially drifting apart, on the damped vibrations of the first type of waves.

The manifestations of actions of the surface waves are revealed during the rotation of phases of maximums of accelerations by the low frequency low amplitude oscillations (3-20Hz) of the subsequent phases. On the visible shift velocities the maximums of indicators of action of the volume and surface waves differ less definitely: whereas on the radial component the velocities on the front of the longitudinal wave almost 2 times exceed the values in the surface waves, on the vertical components these indicators are correlated in the reverse mode.

ES6/P4/ID207 - EARTHQUAKE ACTIVITY AT GREAT DEPTHS AS A RESULT OF ROCK SUPERBRITTLENESS AT THESE CONDITIONS

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The presentation shows new experimental results evidencing dramatic embrittlement of hard rocks with increase in confining pressure with maximum brittleness at stress conditions corresponding to the depths of maximum earthquake activity. The brittleness variation in this case follows a typical pattern of initially increasing, reaching a maximum and than ultimately decreasing since all rocks become ductile at very high confining pressure. The harder the rock the greater is the effect of embrittlement. Most hard rocks become hundreds of times more brittle compared with uniaxial compression approaching absolute brittleness. The shear rupture energy at these conditions becomes vanishingly small. Estimations made for Westerly granite show that the maximum brittleness corresponds to depths of about 10 km. A special shear rupture mechanism is proposed to explain this phenomenon. The obtained results give ground to suppose that earthquake depth activity is a function of rock brittleness variation with depth: the more brittle the rock behaviour the greater is the earthquake activity.

ES6/P5/ID208 - STRESS AND STRAIN MODELING DERIVED FROM EARTHQUAKE DATA IN BULGARIA

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In this report an attempt to elucidate the stress and strain fields in Bulgarian territory and the very adjacent lands from seismological view points is proposed. For this purpose a short analysis of the historical and nowadays seismicity is made. The fault plane solutions of about two hundred earthquakes and corresponding stresses are also analysed. For the purposes of the quantitative stress and strain modelling some seismic zoning is discussed and the main seismological and focal mechanisms characteristics for each zone are presented. The mean stress tensors for the most zones are calculated by means of an inversion of the focal mechanisms data using the technique of Gephart. The released strain is computed from the moment tensors of the focal mechanisms according to the relation of Kostrov. In general, the obtain mean strain tensors of deformation show some agreement with the calculated mean stresses. Several local misfits and the whole geodynamic situation are analysed under the lights of some present geodynamic hypothesis. On the base of the analysis of the nowadays seismicity, stress and strain in the territory of Bulgaria some speculations about the ongoing geodynamic processes in the central Balkans are drawn. In Bulgaria and the very adjacent lands, the focal mechanisms and stress tensor inversion show that the present acting state of stress is strictly connected to the complex geodynamics of the Central Balkan area. The prevailing normal extensional stresses obtained from the seismological data could be explained by two main regional processes. The first one is the post-collisional extensional collapse of the Central Balkan orogens under influence of the paleosubduction in the Vardar paleobasin and the present days pushing of the Adriatic plate towards ENE. The second process is the complex influence of the existing SW horizontal movements along the North Anatolian fault while passing through the Aegean Sea; it causes extension stress of the south-eastern parts of Bulgarian territory and formation of an extensional province to the North from the North Aegean Trough.

ES6/P6/ID209 - THE BACKGROUND SEISMICITY OF THE JUNE 22, 2002,CHANGOUREHAVAJ EARTHQUAKE AND ITS AFTERSHOCK SEQUENCE ,IN NORTH CENTRAL IRAN

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The (Mw=6.5; NEIC) Changoureh–Avaj earthquake occurred On 22 June 2002 at 02:58:20.0 GMT in Qazvin province, north central Iran. The early field observation reported that the epicenter of the main shock (35.67N; 48.93E; h=10. km; USGS) was located at Changoureh (Gheitanchi et al., 2003) in the southern part of Qazvin province. The main shock occurred in a region well known for its earlier shock that produced extensive destruction. This earthquake is the largest shock since the occurrence of the 1st Sep-

tember, 1962 destructive earthquake with magnitude 7.2, in Qazvin province. The quake killed 230 people. In this paper, the seismotectonic setting and the background seismicity of the affected area are discussed. Then, the recorded aftershock sequence is analyzed and the results are discussed. Geological evidences and fault plane solutions of earthquakes in the region indicate the existence of mainly thrust faulting (Jackson & McKenzie, 1984). Using the geological information and air-photos, an attempt has been made to provide a detailed fault map, including the observed local faults in this region. Several major faults with almost northwest trends such as Arab fault in northwest, Avaj fault in west, and Kushke-Nosrat fault in southeast are examples of well known major faults in the region. During 1996-2002 and before the occurrence of the Avaj mainshock, about 703 local earthquakes were recorded by the local seismic network. The epicentral distribution of the locally located earthquakes is indicated on the fault map. The epicentral distribution of recorded earthquakes and the observed faults are in good agreement. The major seismically active area in the region, during 1996-2002 before the mainshock, is located in the vicinity of the epicenter of the 1962 destructive earthquake with surface magnitude 7.2 in the area. Considering the field observation and the extent of aftershock distribution, an average source dimension of about 40-50 km, a NW-SE strike and a NE dipping fault plane could be estimated. Regarding the epicenter of main shock as the initial break, the distribution of locally recorded aftershocks indicates that the rupture should be initiated in epicentral area and extended in a bilateral manner. This fact is also understandable from the location of the main shock and the extension of surface rupture (Alavijeh and Nayyeri, 2002). The Changoureh-Avaj earthquake is in some respects comparable with the 1962 Buyin-Zahra earthquake: They have similar mechanisms and occurred in similar fault systems. Keywords: Changoureh-Avaj earthquake, Seismotectonics Setting, Historical Earthquakes, Microearthquake activity, Aftershock activity.

ES6/P7/ID210 - ROLE OF FAULTS IN EARTH CRUST LOCAL PARCELS TIME VARIATIONS BY SEISMIC OBSERVATIONS DATA

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The rapid evolution of geometry, mechanical characteristics and rheological properties compared to contain massif is a major property of fault zones which distinguishes them from the most areas of the Earth crust. Pronounced discreteness of fault zones comes to estruction old ones and forming new effective ways of stress translation. Fault structure complex relations with stress-straining state and effective mechanical characteristics are still remaining poorly studied. Since fault zones effective strain modulus are at least on one order less than surrounding massive corresponding characteristics, it is naturally to assume that the largest variations of medium parameters should be observed in fault zones. In this paper the seismic observation results carried out by two different ways are presented. In the first case (Semipalatinsk site) the measurement were carried out along the linear profile that permitted us to locate the areas with pronounce properties dynamics. In the second case (Mikhnevo geophysical station of the Institute of Geospheres Dynamics) the measurements were carried out by small aperture array that permitted to investigate the medium variations integral characteristics along the seismic rays trace. It was common for both data rows the seismic source position (explosions) , points of observation and measuring equipment were permanent during all the period of observations, that is the indispensable condition of studding effects detection. The measurements were carried out in nonseismic regions with different geological and tectonic conditions. It has shown the similar effects of seismic waves parameters substantial dependence on time of explosions. The maximum vibration amplitude variations that are not connect with seasonal changes and local conditions reached two times. The typical periods of these variations are months- years included pronounced one year rate. Apparently these periodicities are the fragments more low frequency . Considering the obtained results, the causes of these variations are connected with changes of active faults zones stress-strain state. These changes in turn can be caused by large blocks macromovements which were triggered by tidal strains, tectonic forces, and perhaps Earth rotational velocity variations.

ES6/P8/ID211 - ROTATIONAL SEISMIC SENSOR SYSTEM FOR FIELD MEASUREMENTS AND ITS IN-SITU CALIBRATION: APPLICATION TO WESTERN BOHEMIA REGION

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A newly developed mechanical sensor system, shortly called Rotaphone, for recording the rotation rate components is described. The sensor system is based on measurements of differential motions between paired sensors (low-frequency geophones) attached to a rigid (undeformable) skeleton. The same differential velocity (and, consequently, the same rotation rate component) is obtained from more than one geophone pairs, which allows for in-situ calibration of individual sensors. The calibration method is explained in detail. The new rotational seismic sensor system is characterized by a flat frequency characteristic in the wide range from 1 Hz to 200 Hz and the sensitivity limit of the order of 10E-8 rad/s. Its advantages are small dimensions, portability, easy installation and operation in the field. We present two examples of the vertical rotation rate records obtained by this device: first due to one of the local microearthquakes which occurred in Western Bohemia in May 2010 and second due to a regional earthquake of mb=3.2 in Southwestern Poland. Both records are from Novy Kostel station, Czech Republic. We found good agreement of the rotation record with the transverse acceleration, as predicted by theory. This measurement demonstrates that this device has a much wider application than just prospecting measurements, for which it was originally designed.

ES6/P9/ID212 - VRANCEA (ROMANIA) INTERMEDIATE-DEPTH SEISMICITY NEST: GEOMETRICAL CONSTRAINS AND IMPLICATIONS ON SEISMIC CYCLE EVOLUTION

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The Vrancea seismic region is located beneath the SE Carpathian bending zone in Romania, where frequent strong earthquakes are generated at intermediate depths (between 60 km and 170 km) in an extremely concentrated focal volume. The geometrical configuration of the background seismic activity is persistent in space and time, close to a NE-SW oriented fault plane. This particular alignment is probably related to a particular process of deformation and stress release, such as a shear running phase transition and allows numerical simulations in a 2D geometry. We define the main active fault as the median plane, which minimizes the hypocenter relative distance and contains the centre of mass of the hypocenter distribution. Although the slab is very narrow along the entire depth range (60 – 170 km) in a direction perpendicular to the Carpathians Arc, its thickness being comparable with the double value of locating precision, considering a revised catalog data and a special 3D graphic software, we identify a significant change in the foci distribution around 100 km depth. The seismicity configuration above and below 100 km depth is approximated by two segments close to fault planes, roughly parallel each other, but apparently displaced by about 9 km laterally. The seismicity in the transition zone between the upper and lower segments is more dispersed. The two segments hosted the major Vrancea events recorded in the last two centuries (for which we have available location of acceptable accuracy). The narrow transition zone at about 100 km depth is interpreted as a weaker segment, possibly caused by a dehydration process or by a infiltration of asthenosphere material from the back side of the arc system. It is still debatable if the hypothetic breaking process in this zone occurred between two different blocks (continental – upper part and oceanic – lower part) or within the same continental block. Another notable result of the present investigation refers to the asymmetric distribution of the hypocenters in the high-velocity lithosphere body. It looks like that the larger Vrancea shocks are generated always at the frontier areas of the slab. The segmentation of the descending lithosphere and the edge effects are apparently stationary, but we can test this hypothesis over a catalog spanning less than 50 years.

ES6/P10/ID213 - EARTHQUAKE CYCLE SIMULATION IN THE VRANCEA (ROMANIA) SUBCRUSTAL SOURCE BY A 2-D ALGORITHM WITH CHARACTERISTIC DISCRETIZATION

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For a seismogenic area like Vrancea (Romania) with well-defined geometrical features of the seismicity production in space and time, the numerical simulation of the earthquake process of cellular automaton type looks extremely attractive. Here a remarkable earthquake activity is located at the South Eastern Carpathians arc bend, in Romania, at intermediate depths (between 60 and 170 km), characterized by a narrow active volume and an unusual high strain rate. The major shocks of magnitude above 7 are generated in seismic cycles of about 30 to 40 years average duration. The delimitation, as accurately as possible, of the geometrical features of the seismic active system in the Vrancea subcrustal zone is essential to constrain the simulation modeling. As a first approximation, the seismicity pattern is close to a fault plane NE-SW oriented, extended roughly vertically between 60 and 170 km depth. A characteristic median plane is defined by minimizing the distance of hypocenters. The average distance of the hypocenters to the median plane is around 5 km. Implications upon the seismic cycle evolution are tested using the numerical simulation algorithm on a discrete 2D grid with three characteristic earthquake mechanisms at different hierarchical levels: crack like mechanism for the background seismicity, asperity like mechanism for the moderate size earthquakes and percolation mechanism for the major shocks. At each level, a critical surface is required to nucleate the corresponding characteristic earthquake. The simulation algorithm states that the generation of moderate and large earthquakes is controlled by the growth of weak surfaces over the seismic active area by background seismicity of small magnitude which is generated continuously with quasi constant rate within a well defined geometry in Vrancea. Parameter analysis and multiple simulated cycles are investigated against the observed cycles (several cycles are available for Vrancea in the last hundred years). The fit of the simulated with recorded seismicity patterns for the last cycle, for which the best catalog data are available allows the optimization of the algorithm parameters.

ES6/P11/ID214 - NONEXTENSIVE ANALYSIS OF MAGNITUDE SEQUENCES IN JAVAKHETI REGION, GEORGIA

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Increasing number of scientific publications witnesses that nonextensive concepts and related statistical mechanics are actively used to study complex earthquake generation phenomena which exhibit the scale free nature. This is caused by expectations that nonextensivity analysis may shed new light on features of spatiotemporal and energetic behavior of seismic processes which presently are not fully understood. In present research we studied sequences of earthquakes magnitudes in Javakheti region of southern Caucasus using both Gutenberg-Richter b-value and nonextensive statistical characteristics testing. Exactly, data sets of earthquakes magnitudes from 1960 to 2008 have been compiled from data bases of Seismic Monitoring Center at Ilia State University,Tbilisi, Georgia.Javakheti Region of Georgia was selected because of its specific geological structure and high seismic activity. Together with calculation of *b* values of Gutenberg-Richter relationship, we evaluated nonextensive characteristics in the framework of recent earthquakes fragment-asperity interaction model. Exactly, nonextensive parameter *q* and energy density value *a* have been calculated. All these characteristics have been assessed for the whole observation period as well as for overlapping consecutive 10 year sliding windows. It was observed that calculated nonextensive characteristics both for whole Javakhety catalogue and for sliding windows are in range q=1.6-1.72 and thus are close to those found earlier for other parts of Globe. Besides, according to our analysis both *a* and *q* values vary in the investigated period for consecutive sliding windows. Generally, increased value of nonextensivity parameter physically points to transition of dynamics of seismic process to nonequilibriom conditions. Indeed amount of earthquakes and released seismic energy at Javakhety highland for these time periods have been increased.At the same time energy density value *a*, which is assumed to be related with spatial distribution, decreases after strongest event for the considered time period. Results of our analysis on nonextensivity magnitude distribution points to the quantifiable changes in long range correlations characteristics of seismic process for considered time period. It is important to mention, that changes found in nonlinear nature of seismic process in general agree with changes detected by linear *b* value calculation analysis.

ES6/P12/ID215 - DYNAMICS OF SEISMIC SWARMS IN CORINTH RIFT IN 2000-2005 YEARS

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On the base of analysis of the local catalogue from Corinth Rift Laboratory for 2000-2005 years two swarm activity zones are revealed in Corinth rift region. The primary analysis of the catalogue is carried out; estimations of completeness magnitude and accuracy of the microearthquake location are found. Changes of these parameters owing to development of the seismic network (the completeness magnitude decreases from 1.4 in the beginning of the period of observation to stationary value 1.0, accuracy of a location of earthquakes - from 5 km to 1 km). Gutenberg-Richter b-value and the fractal cluster's dimension of set of the hypocenters d are calculated, their changes in time (in process of development of swarm activity) are revealed. Cluster's dimension increases during swarm excitation and falls to background value during relaxation while b-value at first decreases, and then grows to background value. Contraction of seismic events to destruction area are observed, swarm migrations on gulf's area is found. The revealed behavior of b- and d-value is similar to their variations which have been found out earlier in laboratory and natural experiments for modeling of transitive seismic processes, and also in aftershock sequences of strong earthquakes. It specifies that processes of excitation and relaxation in seismicity occur, apparently, in the similar way for swarms, aftershocks and the induced seismicity.

ES6/P13/ID216 - PROTRUSIVE INTRUSION, DEHYDRATION AND POLYMORPHISM IN MINERALS AS POSSIBLE REASON OF SEISMIC ACTIVITY, RELATION BETWEEN OPHIOLITE BELTS AND SEISMIC ZONATION OF THE TERRITORY OF ARMENIA

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In the basis of multiple geological and geophysical data, also on the results of investigations seismic and density properties of rocks at high termobaric conditions, we proposed the petrophisical section and model of evolution of Earth crust of the territory of Armenia.The origin of earthquakes in different depths of the Earth's crust is diverse. In particular the mechanism of originating centers of earthquakes in Armenian upland is described in publication . Consider some possible reasons of forming the seismic centers at closure of the oceanic crust. As it is already marked, at serpentinized rock submerging of the 3rd layer of oceanic crust, owing to high plasticity and low density the protrusive intrusion of rocks in plutonic faults in the upper horizons of the crust takes place. Naturally, intrusion of large masses occurs permanently and spasmodically resulting in fault and seismic centre formation. This can be explained by allocation of the earthquake centers in ophiolite zones in the whole depth from 5 to 50 km. Owing to tectonic processes in different depths of the Earth's crust, increasing of pressure and temperature takes place resulting in dehydration of rocks, at which, as experiments demonstrate at high thermobaric conditions, melting of rocks with spasmodic variation of volumes up to 30 % takes place. The large volumetric variations in the process of rock dehydration are also considered as a reason of originating seismic centers. The studies at high pressures have shown that in some calcite-containing magmatic rocks as well as in marbles and marbled chalkstones the spasmodic variations of volumes connected with polymorphic and phase transitions in calcite mineral take place. The plastically deformed calcite is spread by fractures and extends them, and large volumetric variations take place.The process is compared with the process of a dilatation, where the role of water executes calcite mineral. According to the introduced model of the Earth's crust evolution the calcite-containing rocks have a wide distribution in the metamorphosed layer in the form of marbles and metamorphosed chalkstones in the depths of 10-20 km. The centers of earthquakes with rather low force are fixed in the Central flexure of Armenia in the mentioned depths.Based on numerous geological-geophysical investigations introduced a detailed map of seismic zoning on the territory of Armenia. The comparison of crust evolution model and map of seismic zoning have shown full concurrence of both zones of the greatest seismic hazard

(a=0.5g) with ophiolite belts. Based on comparison of a seismic zoning map, locations of ophiolite belts and petrophysical section a block diagram of the Earth's crust on the territory of Armenia is constructed .

ES6/P14/ID217 - ASSESSMENT OF MICRO-CRACK PRESENCE AND 3D ANISOTROPY OF ROCKS

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In this paper an experimantal attempt has been made to study the micro-cracks using the ultrasonic and acoustic emission techniques. The study was made on two different types of rock samples (granite and granulite). The first aim of this experiment was to show elastic anisotropy of P-wave velocity determined from direct laboratory measurements on rock samples of granites and granulites; the second aim was to analyze the acoustic emission, as a result of uni-axial loading of both rock types. The elastic anisotropy measurement of P-waves velocities was made on spherical rock samples in 132 independent directions at selected levels of confining pressure up to 400 MPa. The study shows that with the increase in confining pressure, the coefficient of anisotropy is decreased. The monitoring of acoustic emission was carried out on the cylindrical samples loaded by uniaxial increasing stress up to their total rupturing. Different course of acoustic emission rate in the dependence to acting stress was detected for both type of samples. It was deduced that this difference reaction of rocks to the acting stress is related to microcraks contain. This conclusion is in a good agreement with P- wave velocity measurements.

ES6/P15/ID218 - PROPAGATION OF QUASI-LONGITUDINAL AND QUASI-TRANSVERSE ELASTIC WAVES AT AN INTERFACE BETWEEN ISOTROPIC AND ANISOTROPIC MEDIA: THEORETICAL AND EXPERIMENTAL INVESTIGATIONS

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The means for the simple assessment of the reflection and refraction of elastic waves on the interface between the isotropic and anisotropic media (or two anisotropic media) were proposed and developed in recent papers (Nikitin et al., 2009; Ignatovich and Phan, 2009). To describe the medium with one distinguished anisotropy direction a so-called "anisotropy vector" was introduced and a specific "wave function" was used for the representation of elastic wave. Several examples of reflection and refraction on the interface was considered, and interesting effects such as wave splitting or transformation of the body waves to the surface waves are predicted. This work focuses on the experimental verification of the aforementioned theoretical calculations. The propagation of elastic waves of different polarization was studied in several samples composed of two parts: the isotropic and the anisotropic ones. The acrylic glass was chosen as the isotropic material. Synthetic quartz bars of different crystallographic orientations and the polycrystalline graphite sample which displays weak preferred orientations of grains were used as the anisotropic materials. Texture measurements of graphite sample were determined by means of neutron diffraction at the time-of flight texture diffractometer at JINR (Dubna, Russia). The propagation time of the ultrasonic wave between two resonant piezoelectric transducers was measured during the experiments. The transmitter was fixed in a certain point of the isotropic part of the sample, while the receiver was scanning the surface of the anisotropic part. As the first arrival time is dependent on the receiver position, it also depends on the grazing angle of the propagating elastic wave at the interface. The measured first arrival time patterns are compared with the theoretically predicted ones. The satisfactory agreement between calculated and measured data will allow to complete by a new characteristics the processing and interpretation of field seismic data, for example, seismic wave records from different sources including technogenic ones.

The work was supported by the Russian Foundation for Basic Research, Grant No.10-05-00722 and JINR Grant for young scientists and specialists.REFERENCES:Nikitin A.N., Ivankina T.I., Ignatovich V.K. (2009). The wave field patterns of the propagation of longitudinal and transverse elastic waves in grain-oriented rocks. Izvestiya Physics of the Solid Earth. V.45. №5. P. 424-436.Ignatovich V.K., Phan L.T.N. (2009). Those wonderful elastic waves. American Journal of Physics. V.77. №12. P. 1162-1172.

ES6/P16/ID219 - MOMENT TENSOR ANALYSIS OF ACOUSTIC EMISSION DATA FROM A TRIAXIAL LABORATORY EXPERIMENT

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The interpretation of microearthquakes is an important tool to improve the understanding of stress field changes in and around hydrocarbon reservoirs, CO_2 storages, and enhanced geothermal systems. In addition to earthquake location, source parameters as magnitude, stress drop, rupture size, slip, and corner frequency can be used to characterise events. For data recorded in the field, however, the determination of e.g. the full moment tensor often fails due to inadequate instrumentation, insufficient knowledge of the velocity structure, and poor data quality. The advantage of laboratory experiments is the full control over receiver coverage and the possibility of repeated measurements of axial and radial P- and S-wave velocities during the experiment. We analysed full waveform data recorded during laboratory experiments carried out in a triaxial cell. The purpose of the experiments was to study initiation of micro-fractures and development of borehole breakouts during triaxial loading. To this end, acoustic emissions were monitored by 12 piezoelectric receivers mounted evenly on the surface of a sandstone sample. The rock sample consisted of a Vosges sandstone cylinder with a small cylindrical hole drilled horizontally at mid-height through the sample. Due to the inhomogeneous stress field around the borehole, tensile type events are expected to occur at the top and bottom of the borehole, whereas shear type events are expected in orthogonal direction. Full waveforms were recorded with a sampling rate of 10 MHz. 2500 events were detected (due to limitations of the data acquisition system, this does not represent the full number of events), thereof 305 events on a minimum of 10 receivers. At first, 22 events having a good signal-to-noise ratio were selected to manually perform a full moment tensor inversion using P-wave first motion amplitudes (Manthei, 2005). Several challenges arise during the automation of the moment tensor inversion: many records are too noisy to automatically pick P-wave amplitudes with sufficient confidence, changes in P- and S-wave velocity throughout the experiment complicate the interpretation of non-DC components, and the anisotropy of the sample may cause artificial ISO and CLVD percentages even for pure shear cracks (Vavrycuk, 2005). References: Manthei, G. (2005). Characterization of acoustic emissions in a rock salt specimen under triaxial compression. BSSA, 95(5), 1674-1700. Vavrycuk, V. (2005). Focal mechanisms in anisotropic media. GJI, 161, 334-346.

ES6/P17/ID220 - SHIVA: A NEW APPARATUS TO REPRODUCE THE EARTHQUAKE CYCLE IN THE LABORATORY

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Despite considerable effort over the past several decades, the mechanics of earthquakes rupture remain largely unknown. In order to complement fault drilling projects and field and seismological observations, recent friction experiments strive to reproduce as closely as possible in-situ (natural) conditions of slip velocity and acceleration on intact and fault rocks. In this contribution, we present a novel state-of-the-art experimental rotary shear apparatus (SHIVA or Slow to HIgh Velocity Apparatus) capable of shearing samples at sliding velocities up to 9 m/s, accelerations of ~ 65 m/s^2 and normal stresses up to 70 MPa. In comparison with existing high speed friction machines, this apparatus extends the range of sliding velocities, normal stresses, sample sizeand, more importantly, accelerations. The apparatus consists of a pair of brushless electric motors (a low velocity motor, 10^{-6}-10^{-3} m/s, power 5 kW, and a high velocity motor, 10^{-3} – 10 m/s, power 270 kW), that are connected by a sprag clutch that allows a switch between motors without loss of velocity and force. The motors drive a rotary shaft which clamps ring-shaped samples (diameter 30-50 mm). On the other side of the rotary shaft, a stationary shaft holds the other half of the sample assembly. The shaft is held stationary by a pair of stainless steel arms, one of which is attached to the side of the concrete-filled base where torque is measured by

a tension cell. Axial force (maximum 37 kN) is applied on this side by a piston-cylinder couple with an arm to increase the force. The entire machine measures by 3.5 by 1.2 meters and weighs 4000 kg.

We aim to perform experiments on rock samples of a variety of compositions using slip velocities and accelerations that simulate slip velocity functions that occur during earthquakes. In addition, we will install a pore fluid system + pressure vessel and a vacuum/environmental chamber to investigate the physical-chemical processes that occur during both coseismic and slow interseismic periods. Moreover, experiments will be run where we control the shear stress rather than the shear displacement. By doing so, we will simulate the transient load variation expected during seismic failure on natural faults and measure the related frictional evolution and slip velocity on the sample. The characterization of rock frictional behavior under combined conditions of high slip velocity and extreme and rapidly variable load is expected to provide important insights into the mechanics of earthquakes.

ES6/P18/ID221 - FRICTIONAL PROPERTIES OF GRANULAR MATTER

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In a 'microscopic' view, natural faults generally consist of gouge layers, the frictional properties of which are much richer than the celebrated rate-state friction law. One of such examples is intermediate-to-high slip velocity (mm/sec-m/sec) regime, where anomalous weakening and, at the same time, strengthening are reported; namely, the results differ from experiments to experiments. In order to understand such a complicated phenomenon, one must carefully control the physical processes that potentially affect the frictional properties.

Here we adopt a standard computational model for granular matter to investigate the frictional properties in a wide range of slip rate. We report: (a) steady-state constitutive law describing the velocity dependence of the friction coefficient, and (b) time evolution law describing a relaxation process.

In a steady state, it is found that the friction has velocity-strengthening nature in a wide range of shear rate (up to four orders of magnitude). Furthermore, the parameter-independent 'master curve' is found, in which the friction coefficient increases as the power of the slip rate with a nontrivial exponent [1]. This is mainly due to the increasing random motion of gouge particles, which increases the dissipation in sheared granular layers. Furthermore, the density and granular temperature (a quantity that describes the random motion of particles) also obey power-law master curves with different exponents. The effect of particle size distribution to their frictional properties is briefly discussed. We also report the time evolution law for the friction coefficient. It is found that the time evolution law does not contain any length constant; i.e., it is length-free [2]. As a result, we can easily show that the critical slip distance, over which the friction coefficient decreases from the static friction, is proportional to the total slip distance. This result is consistent with the seismic inversion, which shows that the critical slip distance is on the same order of the total slip distance.

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ES9 - APPROACHES TO MODELLING SEISMIC SCENARIOS

ES9/P1/ID222 - EARTHQUAKE SCENARIOS FOR THE GREATER TEHRAN AREA, IRAN

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With a population of about 11 million, Tehran is a very large capital city located in a continental intraplate region within Alborz seismic zone (ASZ), north part of Iran. The Metropolitan Area, about 50 km by 50 km, is crossed by a number of active faults, including the North Tehran, Mosha and Ray faults which are capable of causing massive damage and casualties. Due to the lack of recorded strong motion data for earthquakes on these faults, in this study, a hybrid simulation method is used to calculate broadband (0.1–20 Hz) ground-motion time histories for deterministic earthquake scenarios on the adjacent faults. Low frequencies (0.1–1.0 Hz) are calculated using a deterministic approach and the discrete wavenumber-finite element method in a regional 1D velocity model. High frequencies (1.0–20.0 Hz) are calculated by the stochastic finite fault method based on dynamic corner frequency developed by Motazedian and Atkinson (2005). Calculation for each frequency band is performed separately and the total ground motion is obtained by summing up the outputs of the two methods in the time domain. For simulation of the low-frequency motion, a method that implements the model, including asperities, was employed to synthesize slip distribution of a scenario earthquake on an active fault. The deterministic scenarios were defined in terms of acceleration and velocity time series for events caused by different rupture models along seismic faults. Computations are linear and are performed at bedrock level for typical rock sites, and therefore do not take local site effects into account. The results were validated by comparing the simulated peak values and response spectra with the empirical ground motion models available for the area. Simulated values are within one standard deviation of the empirical regressions.

ES9/P2/ID223 - A SEISMIC LOSS ASSESMENT METHODOLOGY AND ITS APPLICATION TO NORTHWESTERN TURKEY

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Estimating the seismic losses a region will experience after a potential earthquake is essential for purposes of disaster mitigation, calculation of insurance premiums and risk management. In this study, we present an interdisciplinary methodology employing both seismology and earthquake engineering for seismic loss assessment of residential buildings in regions of high seismicity. In this method, ground motion simulations using stochastic finite fault technique are utilized for determining the spatial variation of peak ground motion intensity parameters within the region of interest. The distribution of these parameters is then entered into the fragility functions of the existing building stock in the region which relates the hazard intensity to the predefined damage states. Consequently, we obtain the seismic loss distribution within the region of interest. In order to test the applicability of the method, a verification study is performed in the Düzce region, Northwestern Turkey. We initially simulate the 1999 Düzce earthquake (Mw=7.1) and combine our results with the fragility information of the buildings existing in the region. The estimated seismic loss distribution is compared with the observed damage distribution during the 1999 Düzce earthquake. Having experienced two major consecutive earthquakes in 1999, the cities of Düzce and Bolu are seismically very active because of the North Anatolian Fault Zone that the cities are located on. To assess other potential earthquakes in the region, we perform seismic loss assessment using the methodology outlined above for scenario earthquakes with magnitudes ranging from 5.5 to 7.5. We present our results in terms of intensity maps and damage distribution charts.

ES9/P3/ID224 - HIGH-FREQUENCY MAXIMUM OBSERVABLE SHAKING MAP OF ITALY FROM FAULT SOURCES

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This study presents the innovative concept of Maximum Observable Shaking (MOS) maps. Our approach makes use of the improved understanding of the Italian regional tectonic setting and utilizes composite seismic sources (CSS) taken from the Italian database of individual seismic sources. The CSS are merged with the high-frequency scenario calculations of expected maximum shaking in a given area. For a given CSS, we consider the associated typical fault, and compute the ground shaking for a rupture model derived from its associated maximum credible earthquake. As the maximum credible earthquake and typical fault "float" (i.e. the computational fault plane takes on different spatial position) along the CSS, the high-frequency ground motion is computed at each point surrounding the given fault, and the maximum from the observable shaking according to that scenario is plotted on the MOS map. In the analysis, we use bilateral point-of-rupture initiation, considering both

random and Gaussian slip distributions. To verify and test our simulated ground-motion predicted against observations, we examine the resulting uncertainties and analyze the variability of ground-motion for a given typical fault using 5 slip Gaussian distributions, and considering 2 nucleation points. Additionally, the results of MOS evaluation in terms of peak ground acceleration and peak ground velocity have been converted into Mercalli-Cancani-Sieberg intensities and compared with historical felt intensities from the Italian macroseismic database DBMI04. The MOS shaking maps computed directly from fault-based seismic source models provide reference shaking levels that constitute a new approach in seismic hazard assessment and seismic risk mitigation studies.

ES9/P4/ID225 **- GROUND-MOTION SIMULATIONS FOR THE M 6.9 IRPINIA 1980 EARTHQUAKE (SOUTHERN ITALY) AND SCENARIO EVENTS**

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To investigate the performances of simulation techniques in near-fault strong-motion modeling and prediction from past and future events is an important issue in the perspective of using synthetic seismograms for seismic hazard applications. In this work, we compute ground motions for the 1980, magnitude 6.9, Irpinia earthquake (southern Italy) and scenario events using three different simulation codes, two of which are based on the stochastic approach and one on a broadband integral-composite method.First, we synthesize the near-fault strong motion recordings and evaluate the capability of the simulations to reproduce the main features (amplitude and frequency content) of observed data. The local site amplification is included in the synthetic time-series either by means of HVSR-based amplification functions or of 1D theoretical transfer functions based on soil profiles The results show that the adopted modeling techniques are able to reproduce fairly well the observed peak values and spectral ordinates and confirm that the high-velocity/low-acceleration character of the Irpinia earthquake can be ascribed to the characteristics of the source combined with the crustal attenuation properties.The next step of the study is the generation of ground motion from scenario events, associated to the Irpinia fault, in order to quantify the variability in ground motion prediction for future events. We construct a large set of rupture models for various positions of the nucleation point, final slip distributions, and rupture velocity values and compute synthetic accelerograms, for generic hard-rock sites, at a grid of virtual receivers, densely distributed around the fault.The calculated peak ground acceleration and velocity are then statistically treated to evaluate the median ground motion and the total, inter-scenario and intra-scenario variabilities. The median values are consistent over the three simulation methods. On the other hand, the components of variability show significant differences, depending on the approximations, made in each simulation method, in describing the source and wave propagation processes.Finally, the synthetic median curves are compared with some recent empirical ground motion prediction equations. Good agreement is found for PGA and PGV at short distances, while for distances larger than about 10 km, synthetic PGAs decay faster than the empirical predictions.

ES9/P5/ID226 **- COMPARISON BETWEEN DETERMINISTIC AND PROBABILISTIC EARTHQUAKE SCENARIOS BASED ON MACROSEIMIC INTENSITY VALUES FROM REAL EARTHQUAKES - CASE STUDY FOR THE CITY OF PLOVDIV**

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The territory of Bulgaria (situated in the eastern part of the Balkan Peninsula) represents a typical example of high seismic risk area. Over the centuries, Bulgaria has experienced strong earthquakes. At the beginning of the 20th century (from 1901 to 1928) five earthquakes with magnitude larger than or equal to M_S=7.0 occurred in Bulgaria. However, since then, there was not such strong quake, which may induce underestimating of the earthquake risk by non-professionals. Plovdiv is the second - largest city in Bulgaria with a population of about 400 000. It is situated in the southern part of the country on the banks of the Maritsa River. History of the city of Plovdiv spans some 6000 years, with traces of a Neolithic settlement dating to roughly 4000 BC. Over the past century, the city of Plovdiv has experienced several strong earthquakes. The events which have had the main influence on the hazard for Plovdiv originate near the city. The contemporary tectonic activity of the area is associated with Maritsa fault system striking in WNW-ESE direction. The strongest known earthquakes occurred on that fault system are those in 1928 (on April 14th, M=6.8 and on April 18th , 1928, M =7.0). In the present study both deterministic and probabilistic earthquake scenarios (expressed in seismic intensity) for the city of Plovdiv are generated. The scenarios are compared and the results are verified using the intensity assessments of the 1928 earthquakes. Distribution of macroseismic effects over the city of Plovdiv is estimated on the base of available observations and documented damages caused by those two destructive earthquakes.

ES9/P6/ID227 **- MEAN AND MODAL SCENARIOS FOR MAIN CITIES IN NORTHERN ALGERIA**

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Keywords: Probabilistic seismic hazard, deaggregation, probabilistic seismic hazard curve, stochastic simulation of accelograms, Algeria.

ES9/P7/ID228 **- TO WHAT EXTENT ARE WE ABLE TO PREDICT THE L'AQUILA EARTHQUAKE (MW=6.3) GROUND-MOTIONS USING SMALLER EVENTS?**

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On April 6th, 2009 the L'Aquila earthquake M_w=6.3 struck the Abruzzo region (Central Italy) and was at the origin of strong damages and human losses. This destructive mainshock was followed by numerous aftershocks recorded by a large number of accelerometric stations of the Italian Strong Motion Network (RAN).

The goal of this study is to simulate the ground-motions generated by the L'Aquila mainshock M_w=6.3 from accelerometric records of aftershocks, by using an empirical Green's function simulation method easy to apply. It consists in simulating ground-motions produced by a large earthquake by using stochastic summations of small earthquake recordings regarded as an empirical Green's function (EGF). This method has the advantage of necessitating only three input parameters: the corner frequency and the seismic moment of the small event used as EGF and the stress drop ratio between the large and the small events.

To take advantage of this interesting dataset, we propose to use successively different aftershocks as empirical Green's functions in order to produce 500 different synthetic accelerograms of an M_w=6.3 earthquake for each station and each component. In order to include an uncertainty on the stress drop value of the target event, we run different simulations for which the stress drop ratio parameter is set at different values. We also investigated how directivity effect of the rupture process can be taken into account in our simulation method. Our results are compared with a numerical approach and with the actual L'Aquila mainshock recordings. Several ground-motion parameters are investigated: Spectral Accelerations, PGA, PGV, Arias Intensity and Ground-motion duration. Ground-motion simulations are also compared with the estimations given by different empirical ground-motion prediction equations.

ES11 - THE STATE OF EUROPEAN STATISTICAL SEISMOLOGY

ES11/P1/ID229 **- SEISMICITY PARAMETERS OF NW ANATOLIA: KEY STUDY FOR MARMARA REGION**

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Turkey has long been affected by damaging earthquakes. The recent Tunceli (27.01.2003), Izmir (10.04.2003 and 17-21.10.2005), Bingol (01.05.2003, 12-14.03.2005 and 06.06.2005), Denizli (23.07.2003), Elazig (11.08.2004, 27.12.2007 and 08.03.2010), Antalya (24.01.2005), Hakkari (25.01.2005)

and Ankara (20-27.12.2007) earthquakes caused severe damage to life and property in the country. The Izmit and Duzce earthquakes (Ms7.4, Ms7.2; August and November 1999) of the NW Anatolia have increased awareness of the need for seismic disaster mitigation in Marmara region. Thus, no part of Turkey is free from earthquake hazard. Marmara database compiled from homogeneous earthquake catalogue of Turkey (Kalafat et al., 2007; KOERI) spans the time period 1950-2008 in a rectangular area between 26.0-31.5oE longitudes and 40.0-41.5oN latitudes. One of the basic seismicity parameters used to describe an ensemble of earthquakes is the *a*- and *b*-values in the Gutenberg-Richter frequency magnitude relation. They characterize the distribution of earthquakes over the observed range of magnitudes, and are important parameter in seismology for its association with several tectonic features of an area (Scholz, 1968, Wiemer and Wyss, 1997). It is important to understand the frequency–magnitude relation and seismicity parameters (*a*- and *b*-values) in assessing the earthquake hazard of a tectonically active region. Starting from the necessities and views, we performed a statistical analysis in the Marmara region following by Gutenberg-Richter magnitude-frequency distribution. Study area has been divided into the seven sub-zones according to the seismotectonic patterns. We detected a spatial correlation of 2.26-3.79 for *a*-parameter as indicative for more clustered events in the region, while the *b*-value of 0.69-1.18 implies a high tectonic activity in the region. This result suggests structural variability and high heterogeneous tectonic elements in the region. Acknowledgement: The authors are grateful to the National Earthquake Observation Center (UDIM) of the Kandilli Observatory and Earthquake Research Institute (KOERI), and to Dr. Dogan Kalafat for accessing earthquake database via internet (www.koeri.edu.tr). References: Kalafat, D., Gunes, Y., Kara, M., Deniz, P., Kekovali, K., Kuleli, H.S., Gulen, L., Yilmazer, M. & Ozel, N. 2007. A Revised and Extended Earthquake Catalogue for Turkey Since 1900 (M≥4.0), *Bogazici University Library Cataloging*, ISBN 978-975-518-281-0, Istanbul-Turkey, 572p Wiemer, S., and Wyss, M., 1997. Mapping the frequency-magnitude distribution in asperities: An improved technique to calculate recurrence times, *Journal Geophysical Research* 102, 15.115-15.128

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ES11/P2/ID230 - FEATURES OF THE BETIC CORDILLERA (SOUTHERN SPAIN) DERIVED FROM THE FRACTAL PROPERTIES OF EARTHQUAKES AND FAULTS

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Several studies on earthquake occurrence and associated faulting have demonstrated that both phenomena have a scale-invariant behavior which can be analyzed by means of a set of non-integer dimensions (D_q) describing their fractal properties and the calculation of multi-fractal spectra. It is the case that the behavior of these spectra is asymptotic at the ends of the variation interval of *q*, which is the representation of the partition function of the dataset. The difference between the extreme values, called multi-fractal spectrum slope, is used to investigate the heterogeneity of the spatial distribution of earthquakes and fault systems. In this paper we focus on the Betic Cordillera, southeastern Spain, which is commonly considered the contact between the Eurasian and African plates and has an important seismic activity in the context of the Iberian Peninsula. Some of the most conspicuous Iberian earthquakes, such as the 1829 m_b 6.3 Torrevieja and the 1884 m_b 6.1 Alhama de Granada earthquakes occurred in this mountain range and both reached intensity X. The present work implies a new analysis based on the slope of multi-fractal spectra and referred to the historical seismicity of the region, specifically *b*-value (frequency distribution of earthquakes respect to magnitude), epicentral location, seismic energy and faulting. On this basis we propose a seismotectonic zonation that is contrasted with the stress state and the geodynamical evolution of the Betic Cordillera.

ES11/P3/ID231 - GLOBAL EARTHQUAKE STATISTICS IN GEOCENTRIC SOLAR MAGNETOSPHERIC COORDINATE SYSTEM

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Many different physical phenomena are easier understood in a coordinate system that is appropriate for the phenomenon. To investigate spatial scale earthquake statistics at the globe (latitudinal variations, for example) one uses, as a rule, a geographic coordinate system. At the same time, it was found recently that global spatial distribution of seismicity is organized better in geomagnetic coordinate system. For example, latitudinal variation of number of earthquake is rather organized according to angles of Geomagnetic Inclination and Declination then the geographic latitude. Mentioned results were interpreted in a such way to support a modern idea that earthquake is an element of global electric circuit, which has its external boundary on the magnetopause with included electro-motive force generator driven by the solar wind. The reality of mentioned modern idea is supported also by recent findings that boundaries of some lithospheric plates, along which the main amount of earthquakes occur, are magnetically conjugate in corrected geomagnetic coordinates. It is known that the interaction of the solar wind with the earth's magnetic field is ordered in geocentric solar magnetospheric coordinate system (*GSM*). Thus, in present study, the data on earthquakes with M≥5.0 occurred at the globe in 1973-2008 were taken from the NEIC catalogue, andfor each of the epicenters (56596 events) the parameters of the main geomagnetic field in GSM coordinate system were estimated. Then, the histograms for number of earthquakes in dependence on X_{GSM}, Y_{GSM}, and Z_{GSM} were obtained. The results showed that for largest amount of earthquakes the values of X_{GSM} and Y_{GSM} in their epicenters were equal to zero, while the values of Z_{GSM} were large and positive. This statistical result may advance in understanding physical earthquake mechanism.

ES11/P4/ID232 - LIKELIHOOD-BASED TESTS FOR EVALUATING SPACE-RATE-MAGNITUDE EARTHQUAKE FORECASTS

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The five-year experiment of the Regional Earthquake Likelihood Models (RELM) working group was designed to compare several prospective forecasts of earthquake rates in latitude-longitude-magnitude bins in and around California. This forecast format is being used as a blueprint for many other earthquake predictability experiments around the world, and therefore it is important to consider how to evaluate the performance of such forecasts. Two tests that are currently used are based on the likelihood of the observed distribution of earthquakes given a forecast; one test compares the binned space-rate-magnitude observation and forecast, and the other compares only the rate forecast and the number of observed earthquakes. In this article, we discuss a subtle flaw in the current test of rate forecasts, and we propose two new tests that isolate the spatial and magnitude component, respectively, of a space-rate-magnitude forecast. For illustration, we consider the RELM forecasts and the distribution of earthquakes observed during the first half of the ongoing RELM experiment. We show that a space-rate-magnitude forecast may appear to be consistent with the distribution of observed earthquakes despite the spatial forecast being inconsistent with the spatial distribution of observed earthquakes, and we suggest that these new tests should be used to provide increased detail in earthquake forecast evaluation. We also discuss the statistical power of each of the likelihood-based tests and the stability—with respect to earthquake catalog uncertainties—of results from the likelihood-based tests.

ES11/P5/ID233 - BBOOTCOMP: A SIMPLE R SCRIPT FOR THE EFFICIENT ANALYSIS OF B-VALUES USING COMPUTER-INTENSIVE TESTS

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An R programming script is developed that can be used to compare estimates of Gutenberg-Richter b-values from different data sets. Since its presentation in 1966, the Utsu's test has been the more commonly used method to determine the statistical significance of variations in b-values. Using several data sets, we show that the Utsu's test (e.g. used in ZMAP software) is biased towards rejection of the null hypothesis in favor of the hypothesis that

b-values are significantly different. BBootComp is a free downloadable script that takes advantage of the outstanding per-

formances of the R language for statistical computing. Calculations include estimates of threshold magnitude values, determinations of b-values and their uncertainties, and tests of hypotheses. An R programming script is developed that can be used to compare estimates of GutenbergRichter bvalues from different data sets. Since its presentation in 1966, the Utsu's test has been the more commonly used method to determine the statistical significance of variations in bvalues. Using several data sets, we show that the Utsu's test (e.g. used in ZMAP software) is biased towards rejection of the null hypothesis in favor of the hypothesis that bvalues are significantly different. BBootComp is a free downloadable script that takes advantage of the outstanding performances of the R language for statistical computing. Calculations include estimates of threshold magnitude values, determinations of bvalues and their uncertainties, and tests of hypotheses. An R programming script is developed that can be used to compare estimates of GutenbergRichter bvalues from different data sets. Since its presentation in 1966, the Utsu's test has been the more commonly used method to determine the statistical significance of variations in bvalues. Using several data sets, we show that the Utsu's test (e.g. used in ZMAP software) is biased towards rejection of the null hypothesis in favor of the hypothesis that bvalues are significantly different. BBootComp is a free downloadable script that takes advantage of the outstanding performances of the R language for statistical computing. Calculations include estimates of threshold magnitude values,determinations of bvalues and their uncertainties, and tests of hypotheses.

ES11/P6/ID234 - MAGNITUDE OF COMPLETENESS OF THE SPANISH NATIONAL EARTHQUAKE CATALOGUE

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This work maps the magnitude of completeness (M_c) of the Spanish national earthquake catalogue (http://www.ign.es/ign/es/IGN/SisCatalogo.jsp) from 1985 to the present. To obtain a detailed view of the temporal evolution of M_c, this time span is divided into several separated periods. These begin at significant milestones in the network development, or when methodological changes for earthquake location and magnitude determination were introduced.

M_c is the minimum magnitude that an earthquake must have to be reliably detected by a network and recorded in a catalogue. At any magnitude below M_c, events are missing in the catalogue. This parameter varies in space and time, and should be taken into account before any statistical analysis of seismicity.

The whole catalogue includes historical and instrumentally-located earthquakes, and is elaborated by the National Geographic Institute of Spain. The latter manages the National Seismic Network, which has been improved throughout decades, and is currently integrated by 64 stations, plus a special seismic array of the International Monitoring System comprising 27 instruments. Data borrowed from stations belonging to other institutions are also taken into account for hypocentral determinations.

For each period, a map of M_c was calculated using the «entire magnitude range» method [Woessner, J. & Wiemer, S. (2005) Assessing the quality of earthquake catalogues: Estimating the magnitude of completeness and its uncertainty. Bulletin of the Seismological Society of America, 95, 684–698]. The studied region is covered with a dense lattice of nodes. The method analyses the entire range of the non-cumulative, magnitude-frequency distribution of the earthquakes closest to each node. For high magnitudes, all earthquakes are recorded, and their frequency is fitted to a Gutenberg-Richter distribution. For low magnitudes, not all the earthquakes are recorded, and their frequency is fitted to a Gaussian. The crossover magnitude between the two best fits (Gaussian and Gutenberg-Richter) is the M_c at the node. This result is recalculated with a bootstrap procedure to estimate its uncertainty.

The calculated M_c is heterogeneous in space, and tends to decrease with time thanks to the network improvement. The best (lowest) values diminished from 2.4 in the first period to 0.9 in the last one. M_c increases with the distance from stations, and rises abruptly offshore the Iberian Peninsula.

The results emphasize that to obtain a meaningful estimate of M_c it may be necessary to consider periods of relatively constant methodology and network instrumentation.

ES11/P7/ID235 - MAGNITUDE OF COMPLETENESS (MC) IN EARTHQUAKE CATALOGUES FROM THE TAIWAN CENTRAL WEATHER BUREAU (CWB) AND FROM THE CHINA EARTHQUAKE NETWORKS CENTER (CENC)

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Assessing the quality of earthquake catalogues is essential before any scientific analysis of the data. Determining the magnitude of completeness (Mc) is one particular aspect of this quality control. We compare Mc estimates from a number of published techniques, parametric and non-parametric, on two data sets: the earthquake catalogue from the Taiwan Central Weather Bureau (CWB) and the catalogue from the China Earthquake Networks Center (CENC). We discuss the influence of spatiotemporal variations in Mc on the results from two non-parametric techniques (MAXC and MBASS algorithms) and investigate the role of dequarrying, declustering and seismic station distribution on Mc changes in space and time. This work is part of the quality control process that we aim to implement in the Global Earthquake Model (GEM) and in the Collaboratory for the Study of Earthquake Predictability (CSEP) efforts.

ES11/P8/ID236 - PROBABILISTIC SEISMIC NETWORK COMPLETENESS: THEORY, APPLICATION, AND RESULTS

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An important characteristic of any seismic network is its detection completeness, which should be considered a function of space and time. Many researchers rely on robust estimates of detection completeness, especially when investigating statistical parameters of earthquake occurrence.

We present the Probability-based Magnitude of Completeness (PMC) method for computing the spatial variation and temporal evolution of detection capability of seismic networks based on empirical data only: phase data, station information, and the network specific attenuation relation.

We present studies of regional networks from California, Switzerland, Italy, Japan, New Zealand, and compare the result with estimated completeness levels of other methods. We report on the time evolution of monitoring completeness in these regions and show the depth dependence of detection probabilities. Scenario computations show the impact of different possible network failures and offer estimates of possible network optimization strategies. All presented results are published on the CompletenessWeb (www.completenessweb.org) from which the user can download completeness data from all investigated regions, software codes for reproducing the results, and publication-ready and customizable figures.

ES11/P9/ID237 - MAPSEIS: A MATLAB BASED TOOLBOX FOR SEISMICITY ANALYSIS

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Earthquake catalogs are a fundamental product of seismology and remain arguably the most useful for tectonic studies. Modern seismograph networks can locate more than 100,000 earthquakes annually, providing a continuous and sometime overwhelming stream of data. MapSeis is a set of tools driven by a graphical user interface (GUI), designed to help seismologists analyze catalog data. MapSeis is primarily a research tool suited to the visualization and evaluation of catalog quality, parametric data mining and to addressing specific hypotheses; however, it can also be useful in routine network operations. MapSeis is the successor of ZMAP, it offers most of the existing functionalities but adds many new features and flexibility. Typical applications of MapSeis are mapping completeness of monitoring as a function of space and time, searching for changes in the homogeneity of reporting, imaging b-values in map view or cross-sections, or analyzing aftershock sequences. MapSeis is build using a function-based and object-oriented programming framework, which offers increased robustness and flexibility when compared to the largely script based ZMAP.

The first release of MapSeis, Version 1.0, is available as part of the CORSSA community (www.corssa.org) and introduces a structured, extensible data format for storing earthquake catalogs, import and export functionalities for various commonly used data formats and the capacity to use parallel processing for most calculations. MapSeis easy to use graphical user interface it suitable

for users not familiar with Matlab, advanced users can benefit from the integrated scriptability. A plug-in system allows expanding MapSeis by adding new calculations through dragging files into the appropriated folder, or using the framework functions to write new scripts.

ES11/P10/ID238 - **PROBABILITY-BASED MAGNITUDE OF COMPLETENESS OF NORTHERN CALIFORNIA: IMPORTANCE OF IN-DEPTH DATA ANALYSIS**

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The probability-based magnitude of completeness method (PMC) was introduced by Schorlemmer and Woessner and has been applied to different regions, such as Southern California, Italy, Japan, and Switzerland. This method determines the recording completeness of a seismic network based only on empirical data: earthquake catalog, phase picks, and station information.

We analyze the detection capabilities of the Northern Californian Seismic Network (NCSN) and present probability-based magnitude of completeness and detection probability maps for 1 January 2010. With the northern California data set as an ideal test bed, we analyze the influence that clusters of seismicity can have on the detection capabilities of a large regional network. We illustrate this influence with two clusters of different origin; one from a highly monitored geothermal field which generates fluid-driven swarm-type activity and one from an aftershock sequence following the 2003 Mw=6.5 San Simeon earthquake. We show how estimates of detection probabilities are reduced at various stations and for the entire network due to different analysis procedures for seismicity clusters.

We demonstrate that larger seismicity clusters have to be removed since they contradict one requirement of the PMC-method: homogeneous recording procedures in the entire region. We introduce an automated procedure to analyze clusters with a single clustering algorithm. This algorithm allows one to automatically detect large clusters, examine their influence, and remove them if necessary.

We find that the probability-based magnitude of completeness of northern California varies between MP=0.5 in highly monitored regions to MP=2.5 in regions with a sparse station spacing. We find an overall completeness of MP=3 throughout the authoritative region, as it spans a wide area and station spacing becomes sparse at the edges.

ES11/P11/ID239 - **RECENT PRECURSORY SEISMICITY RATE CHANGES IN GREECE**

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The recent seismic activity in different areas of Central Greece is analysed to investigate seismicity rate changes prior to strong crustal main shocks. The statistical methodology uses the earthquake catalogue of the Institute of Geodynamics of the National Observatory of Athens (NOA) and the ZMAP software to investigate the models of precursory seismic quiescence and precursory accelerated moment release. This approach has been recently developed to complement the investigations that use the newly developed concept of 'natural time' in order to forecast the epicentral area and the time of occurrence of strong (Ms>6) main shocks in Greece.

ES11/P12/ID240 - **RECONSTRUCTION OF FAULT NETWORKS FROM SEISMICITY CATALOGS INCLUDING LOCATION UNCERTAINTY INFORMATION**

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The 3D Optimal Anisotropic Dynamic Clustering (OADC) is a pattern recognition method that is able to reconstruct the three-dimensional structure of the active part of a fault network. It is an iterative scheme, which consists in updating the geometrical characteristics of the fitting planes using the spatial location of their closest events. OADC assumes that earthquakes occur at a single location without considering location uncertainties. The number of fault segments needed to describe a given distribution of earthquakes, i.e. resolution, depends on location accuracy, which is assumed to be uniform and isotropic for OADC. Hypocenter locations, however, are affiliated with uncertainties, which are generally different from event to event. As OADC disregards this information, it may lead to undesirable clustering results. We extend the OADC by using the earthquake location probability density function (PDF), which represents the probabilistic solution to the earthquake location problem including the complete information on uncertainty and resolution. The earthquake location PDF is taken into account during the clustering process by computing a novel distance, the expected square distance (ESD), between the PDF and the plane. The resolution is derived from the earthquake location PDF of individual earthquakes associated with the same cluster. Given an earthquake catalog with uncertainty information on the hypocenter location, the output of the clustering is an optimal set of plane segments that fits the spatial structure of the data. Each plane segment is fully characterized by its location, dimension and orientation. Important to note is that plane segments may have a finite thickness that can represent damage zones rather than only traditional plane structures. We validate our new method by using synthetic earthquake catalogs that include the earthquake location PDF for each event as given by station network geometry, picking uncertainties, etc. Synthetic earthquake catalogs include simple fault structures as well as more complex and realistic fault networks. We further apply our new method to real data sets, and compare clustering results with and without using the earthquake location PDF to assess the effect of the PDF on the clustering.

ES11/P13/ID241 - **MAPPING SPATIAL VARIABILITY OF THE FREQUENCY-MAGNITUDE DISTRIBUTION OF EARTHQUAKES IN TURKEY AND DETECTION OF QUARRY AND MINE BLAST CONTAMINATION IN TURKEY FROM EARTHQUKE CATALOGUE**

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In this study, Earthquake catalog of the events within the time period of 1900-2009 prepared by Boğaziçi University Kandilli Observatory and Earthquake Research Institute is analyzed. The catalog consists of earthquakes occurred in Turkey and surrounding area (32-45N/23-48E). The current earthquake catalog data has been checked in two aspects; the time dependent variation and compliance for different regions. Specifically the data set prior to 1976 was found deficient.As the development of earthquake seismic stations took place in different regions no contemporarily, catalog data set have been analyzed for different time period and regions. In total, 7 regions were evaluated according to the tectonic specifications and data set.In this study for every region original data were used without any change; b-values, a-values, Magnitude of completeness (Mc) were calculated by using ZMAP software package (Wiemer, 2001). For the calculation of b-values and depth was estimated h= 0-50 km.In addition to this, for each region; Depth-Time, Magnitude-Time, Magnitude-Earthquake occurrence number, Earthquake occurrence number-Depth, Earthquake occurrence number-Time graphics, b-values, SdtDev-b-values, a-values, Earthquake Density Map (Ed) and Magnitude of completeness (Mc) map were prepared. For the assessment of the current catalog all explosions within the selected region is cleaned out with the algorithm developed by Wiemer and Baer (2000). As a result seismic events produced by quarry blasts, mine blasts and large excavations were removed. Current moment tensor catalog prepared by Kalafat and et al., 2009 the faulting type map of the region was prepared. By using the current data set and strike, dip, rake values for each earthquake 7 different dominant stress axis directions were found and regional stress analysis have been done. As a result for each region it is examined if there is a relation between fault type and b-values. In this study, the hypothesis of the relation between previously evaluated and currently ongoing extensional, compression, strike-slip fault regimes in Turkey and b-values are tested one more time. We found normal faulting events (such as Western Turkey, Marmara Region) have the highest b-values, strike slip events (NAFZ, EAFZ) intermediate values and thrust events (SE Turkey) the lowest b-values.

SD13 - MACHINE LEARNING IN SEISMOLOGY AND HAZARD ANALYSIS

SD13/P1/ID242 - **EARTHQUAKE CLUSTERING AND SELF-ORGANIZING MAP FOR EARTHQUAKES FORECASTING IN IRAN**

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[1]*IIEES*

This paper propose a clustering method to forecast earthquakes and describes a set of long-term (five-year) forecastsof M>5.5 earthquakes for Iran and some adjacent areas. To illustrate this, I obtained the Self-Organizing system from earthquake catalog of M> 4.0 from 1970 to 2008 for the region of figure 1 and removed all foreshocks and aftershocks using the time-space windows of Gardner and Knopoff (1974). The formulation of Omori's law of Allamehzadeh and Farahbod (1999) with their generic Iranian parameters will then be used to calculate the expected rate of earthquakes with any magnitude greater than 4.0.

SD13/P2/ID243 - SEISMOLOGICAL SIGNAL CLASSIFICATION IN AN URBAN ENVIRONMENT USING SELF-ORGANIZING MAPS

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A steady uplift of up to 1 cm/month is observed in the historic town centre of Staufen im Breisgau (Upper Rhine Graben, Germany). Probably this damaging uplift is caused by geothermal drillings done in September 2007. Since May 2009, up to 9 Karlsruhe BroadBand Array (KABBA) stations have been operated with the objective of finding possible seismic signatures related to the uplift. The high noise level and the plenitude of transient seismic signals make visual assessment unfeasible. Signal characteristics of uplift induced seismic events may differ from other events that are clearly correlated with traffic. Based on Köhler et al. (2009), we thus calculate physical properties of the measured seismograms. Using Self-Organizing Maps (Kohonen, 2001), we then try to cluster those properties with respect to their time dependence in order to distinguish several event classes in the urban environment. Furthermore, the frequency of each cluster occurrence is compared with traffic counts to verify traffic induced events. However, determining properties for complete time series might be inefficient. In order to reduce computing time, further investigations have been made into combining an established STA/LTA picker and Self-Organizing Maps. This may be especially useful when using large datasets.

SD13/P3/ID244 - SEARCHING FOR GLACIER-INDUCED SEISMIC EVENTS USING AN UNSUPERVISED PATTERN RECOGNITION SCHEME BASED ON SELF-ORGANIZING MAPS

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Making use of machine learning techniques in seismology is becoming increasingly important and popular. Mostly, supervised classification algorithms are employed to detect seismic events based on manually prepared training data sets. On the other hand, unsupervised pattern recognition may be used to generate an initial understanding of the unknown data properties without utilizing existing class or event labels as done for supervised learning. Here, we present a processing scheme which combines unsupervised learning, manual labeling and automatic classification. The method is applied to single-channel geophone data recorded close to Kronebreen, a calving glacier on Svalbard. Our approach is suitable and reasonable within this context, since no detailed information about the character of potentially observable glacier seismic signals was available a priori. We aim to identify and investigate suspicious signals, which could possibly be related to glacial activity. Self-Organizing Maps are used for data visualization and clustering. The method is made up of four phases: 1. Unsupervised clustering based on spectral amplitudes of short time windows (0.4 seconds): Event clusters are identified for different data sections. 2. Generation of a representative SOM clustering using the visually inspected training data from step 1. The event cluster is labeled. 3. Event (pre)classification based on the nearest neighbors cluster membership using the entire record. Condition for classification is that the event has a fixed minimum duration. 4. Unsupervised clustering of classified events based on different event properties (amplitude statistics, spectrum, temporal characteristics) in order to distinguish event types. The results show that it is possible to identify a large amount of suspicious signals. Given the final event clustering, we are able to distinguish between false alarms (increased background noise level), instrumental noise/artifacts, and seismic events of different characteristics. Due to the lack of man-made noise in the remote study area, most of the detected events are most likely related to glacial actively, besides a few recorded local earthquakes. In fact, the temporal occurrence of seismic signals correlate very well to glacial activity at the front of the glacier for a time period where visual observations are available.

SD13/P4/ID245 - PROBABILISTIC SEISMIC HAZARD ANALYSIS: PRINCIPLED ENSEMBLES OF GROUND MOTION MODELS

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Probabilistic Seismic Hazard Analysis: Principled ensembles of Ground Motion Models

In Probabilistic Seismic Hazard Analysis (PSHA) partly overlapping or even seemingly conflicting expert knowledge comes into play. Such knowledge can be quite diverse, e.g. coming from humans, empirically recorded data or literature. Rather than considering disagreement and diversity as a problem that should be avoided at all costs, one should instead appreciate the joint character that such «conflicts» may have when trying to capture the body and the range of technical interpretations within the community. In fact the guideline for PSHA (colloquially referred to as the SSHAC guidelines - Senior Seismic Hazard Analysis Committee) puts a significant emphasis on knowledge compiled from «ensembles» of experts rather than on individual experts.

We focus here on the exploration of combinations of ground motion models, an important aspect of a probabilistic seismic hazard analysis. Developments in information technology and the recent upcoming of the «intelligent data analysis»-paradigm now provides a viable approach to implementing many of the procedural guidelines sketched in the SSHAC in a principled and formally correct way. Departing from a data-driven multivariate probabilistic approach to the problem, we define ensemble methods based on hierarchical and graphical modeling principles. Cast in a Bayesian statistical context making use of Markov Chain Monte Carlo, this allows for a flexible combination of existing ground motion models and data: mixture modeling and other algebraic combinations yield concrete implementation of a broad range of model combination ideas. Moreover, from a semantic perspective these combined models are very flexible and allow for the introduction of latent variables that can be interpreted as representing the «degree of fit» or «rank» of the individual ground motion models involved in the overall committee description. Additionally, the Bayesian framework in which we operate provides an opportunity for incorporating prior knowledge at various levels of the ensemble, such as e.g. in the predictor variables of the individual ground motion models.

This purely probabilistic approach presents an alternative to the entropy based perspective described in (Scherbaum et al., 2009; Delavaud et al., 2009) and/or the vector quantification based method described in (Scherbaum et al., 2010).

SD13/P5/ID246 - FAST GENERATION OF GEOPHYSICAL SCENARIOS BY CONSTRAINT SOLVING FOR SEISMIC PHASE LABELLING

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This work aims at improving an existing automatic location system for seismic surveillance. The present system is a three-step workflow. First, it uses the signal from several stations which collect the waves of the event in order to determine the arrival times of the different phases. It then classifies the different phases into five classes (Pg, Pn, Sg, Sn and Reject), depending on the time-frequency distribution of their signal. Finally, it deduces the position of the seismic event from these labelled phases. Unfortunately, the automatic arrival times may be inaccurate and the classifier may misclassify some phases. All these mistakes strongly affect the location of the event because they can lead to impossible geophysical scenarios. In order to improve the current system, we propose to insert another step which consists in determining the most probable phase labelling from the classifier outputs. This idea basically consists in considering the labelling of all the phases of the network at the same time instead of considering each phase individually, in order to ensure the geophysical consistency of the overall labelling. The main difficulty is the huge number of scenarios which must be examined: for an average seismic event, the automatic picker can find 4 arrival-times for 20 stations. Each arrival-time matches with a phase which can take five values. The number of scenarios to

be examined is thus $5^{4x20} = 8.3\ 10^{55}$. However, constraint programming helps us to quickly generate geophysically coherent scenarios. The problem was first split into several models working on different variables. More precisely, a first model is devoted to manage phase labelling at a station level (*e.g.* by taking into account phases order, delay…) and a second one introduces geophysical constraints at the network scale. The introduction of a subsumption-like method lets us significantly reduce the number of possible scenarios. By coupling this approach with an efficient strategy for scenarios generation and a good choice of constraints, we propose a fast architecture for solving the problem. Simulations demonstrate that this new architecture lets us browse such search-spaces much faster, even in the worst encountered cases. Finally, we show that using scenarios such as those proposed in this work vastly improves classification results.

SD13/P6/ID247 - SEISMIC SIGNAL ASSOCIATION USING MACHINE LEARNING

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Inferring possible nuclear events from the set of signals recorded on a global network of stations, i.e. «association», is perhaps the most formidable routine data processing task for a nuclear explosion monitoring system. Expert human analysis is necessary to achieve high quality results since minimizing the number of missed events by automated systems (very problematic for nuclear explosion monitoring), while at the same time keeping the number of false events low, has historically been very difficult to achieve with computers alone. The availability of many years of historical data (observables) for known sources and the steady improvement in machine learning techniques and computational power provides an opportunity to address the automated association problem in a new manner. A set of observables readily available from IDC database tables., such as relative arrival time, amplitude, signal-to-noise ratio, slowness, and azimuth, from all monitoring stations over a window of time (e.g., 1 hour) can be combined in elemental and differential form to create a global feature vector representing all source events occurring in the specified time window. Location information from historical event bulletins is used as ground-truth target information in supervised machine learning to train a model that maps these features to event probabilities for a given location. Dividing the Earth into a 3D grid of location cells, each cell has a unique machine learning model trained to estimate the probability that a seismic event occurred at that location and generated a subset of the observations in the feature vector. The training probability ranges from 1 at the cell containing the event location to 0 far away from the cell. Variable-sized location cells are used to accommodate differences in the density of seismic events around the globe. A subset of the global feature vector can be customized for each cell, thereby reducing the complexity of the system. Since each cell has a unique model, both training and operational use are fully parallelizable.

SD13/P7/ID248 - MACHINE LEARNING AND DATA FUSION FOR COMPREHENSIVE TEST BAN TREATY VERIFICATION: HIGHLIGHTS AND FUTURE WORK

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Each day, the Comprehensive Test Ban Treaty Organization's (CTBTO) International Monitoring System (IMS) collects approximately 10 gigabytes of seismic, hydroacoustic, infrasound and radionuclide data which are relayed to the International Data Center (IDC) in Vienna, Austria. An automatic processing system sifts through the data, building all potential seismo-acoustic events seen by the IMS network and reporting them in a series of three Standard Event Lists (SELs). The events in the final list, SEL3, are then carefully examined by a team of highly trained professional analysts before they are published in the Reviewed Event Bulletin (REB). As technology evolves, the CTBT mandates the incorporation of new techniques into IDC data processing to continually improve the quality of its products. In the recent past, a wide variety of sophisticated algorithms have been developed by computer scientists to find patterns and relationships in large amounts of data. In order to explore the potential application of new computing technologies to IDC data processing and analysis, a team of CTBTO representatives, computer scientists and earth scientists has been meeting regularly at a series of workshops held over the past two years. A number of focused projects have emerged as a direct result of these meetings. Several teams showed that, using SEL3 and REB as training data, a variety of off-the-shelf algorithms are able to predict with approximately 85% accuracy which automatically identified events will eventually be discarded by analysts. By flagging these events, analyst workload could be considerably reduced. Probabilistic models have been developed that are capable of not simply testing events but adjusting them or even proposing new ones in order to better explain the data. A virtual Data Exploitation Centre (vDEC) has been proposed as a virtual development environment in which data processing technologies could be tested and benchmarked before being handed off to become operational and implemented to upgrade the IDC operational system. A distributed database is being designed to give even a casual user massive super-computing capabilities through an intuitive, web-based interface, making it simple to build, compare and test algorithms. The need for data fusion algorithms which synergistically combine different modalities of IDC data has been discussed as well as potential data-centric requirements of an On Site Inspection (OSI) team.

SD13/P8/ID249 - REPRESENTING GROUND MOTION IN SEISMIC HAZARD ANALYSIS BY BAYESIAN NETWORKS

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Empirical ground-motion models for use in seismic hazard analysis are commonly described by regression models, where the ground-motion parameter is assumed to be dependent on a set of earthquake- and site-specific parameters such as magnitude, distance or local vs30. In regression analysis only the target is treated as a random variable, while the predictors are not; they are implicitly assumed to be complete and error-free, which in general is not strictly the case (e. g. for magnitudes or distances in earthquake catalogs). Here, we investigate a multivariate approach, so-called Bayesian networks, which have become quite popular in the field of machine learning and artificial intelligence, for the representation of the ground-motion domain in seismic hazard analysis. The Bayesian network formalism allows for reasoning under uncertainty by directly modeling the joint probability distribution of all variables, while at the same time offering explicit insight into the probabilistic relationships between variables. Efficient algorithms exist to compute any marginal or conditional distribution of any subset of variables. In particular, if some earthquake- or site-related parameters are unknown, the distribution of the ground motion parameter of interest can still be calculated. In this case, the associated uncertainty is incorporated in the model framework. Hence, in a Bayesian network framework it is straightforward to see how the probability distribution of one variable changes when evidence on another variable is presented.

Here we demonstrate different aspects of Bayesian networks which might be useful in the context of seismic hazard analysis, such as learning from data and using them to explore the sensitivity of hazard results to certain (groups of) variables/parameters. Due to their modular structure, Bayesian networks are easily extendable, which can be used to add further variables that can influence the ground-motion or hazard distribution.

SD13/P9/ID250 - GROUND-MOTION PREDICTIVE MODELS USING NEURAL NETWORKS APPROACH: APPLICATION TO THE KIK-NET DATA.

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We have tested the ability of Artificial Neural Network method (ANN) to derive new predictive ground-motion models. ANN does not imply the use of any a priori functional form and then gives the opportunity to obtain full data-driven predictive models. The models inputs are the moment magnitude, the focal depth, the epicentral distance, the site resonance frequency and V_{s30}. The models output is the Horizonthal Peak Ground Acceleration. We apply this new methodology to the KIK-NET seismic database. 6485 records and 398 sites are used in the training phase while 1297 events are kept for the test phase. The obtained standard deviation for the model is equal to 0.34, i.e comparable to or slightly

lower than for "conventional" GMPE. These results show a clear magnitude and depth dependency of the ground motion distance decay. The method also allows us to quantify the relative importance of the input parameters (magnitude, epicentral distance, depth, v_{s30}, f_0) on ground motion.

SD13/P10/ID251 **- TOWARDS A BAYESIAN SEISMOTECTONIC ZONING FOR USE IN PROBABILISTIC HAZARD ASSESSMENT (PSHA)**

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The mathematical representation of seismic sources is an important part of probabilistic seismic hazard assessment. This process reflects the association of the seismicity with the tectonically-active geological structures provided by seismotectonic studies. Given that most active faults are not characterized well enough, seismic sources are generally defined as area zones. These area zones are delimited with finite boundary polygons, within which the geological features of active tectonics and the seismicity are deemed homogeneous (e.g., focal depth, seismicity rate, and maximum magnitude). Besides the lack of data (e.g., narrow range of recorded magnitudes), the application of this method engenders different problems: 1) a large sensitivity of resulting hazard maps on the location of zone boundaries, while these boundaries are set by expert decision; 2) the zoning can not represent any depth-variation in faulting mechanism; 3) the seismicity rates are distributed throughout the zones and we lose the location of the determinant information used for their calculation. We propose an exploratory study for an alternative procedure in area source modeling. First, different data (e.g., geomorphology, geology, fault orientations) will be combined by using automated classifications in order to obtain several information classes, which may be defined as areal source zones. Two methods of automated classifications will be investigated : supervised and unsupervised classification. Then, a given hypocenter, belonging to a given «zone», from now on called seismicity model, will be expressed by a probability computed from the 2D (spatial) probability density function (pdf) for the active tectonic model used as an a priori and updated with specific data from seismicity catalogs (e.g., focal mechanism) or other new data sources (e.g., geomorphology, subsurface exploration). This hypocenter will thus be allowed to contribute to several models, with weights given by the value of the pdf for each model. The annual rate of occurrence, for a given model, will be calculated by the weighted average of the different hypocenter contributions contained in this model. In consequence, the results will provide the full spectrum of variability in the hazard. We will start with a simplified case of the Lower Tagus Valley area (Lisbon). This study may help, afterward, to show the alternative sets of seismicity models and to propagate all sources of uncertainties through simplified ground motion prediction equations to the resulting hazard maps, in order to highlight zones badly constrained and deserving to be more studied.

OS4 - SEISMOLOGY AT SCHOOL

OS4/P1/ID252 **- A SHORT INTRODUCTION TO THE SWISS "SEISMO AT SCHOOL" NETWORK**

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To promote public awareness of major environmental hazards, especially the risk of earthquakes, «Seismo at school», an educational program of Swiss Seismological Service (SED) leading by Prof Domenico Giardini installs permanent seismic stations in schools, records real time seismic activities, and provides both the real time seismic data and high quality event data on the «Seismo at School» website, which includes also a rich set of data processing software such as traveling time calculation, seismic phases determination, signal processing, earthquake localization, and so on. Besides the permanent seismic stations, the schools use also other nonpermanent stations like the SEP seismometer system, and the Stanford QCN with a USB accelerometer to teach the students in the classes.First, SED plans to install 15 permanent seismic stations in the schools, all of which will use strong motion seismometers to provide high quality wave data for the regional seismic activities. The website «Seismo at School» displays all the real time data, extracts wave data for the earthquake events from these data, and lists the events and the corresponding wave files on the web pages, which can be downloaded and analyzed by the teachers and students. Second, 15 permanent SED stations are also included in the «Seismo at School» network, which are carefully selected by considering both their quality and reliability, and their geographic localization. By combining wave data of these stations with those of the stations in the schools, we are able to localize the regional earthquakes more precisely, thus offering better scientific training for the students.Third, we use other seismic stations to allow as many as possible schools, teachers and students to participate in this program. The cheaper stations, such as SEP, Stanford QCN, therefore, are a good complement for our network. They are cheap, so any school could afford them; the stations all come with mature software to record and analyze data, so they are good for educational purpose. The schools can use these stations in the classes to demonstrate the earthquake science. And if they want, they can also install these stations to be «permanent», just by finding a quiet place and providing a computer to save the data. The «Seismo at School» website also has interface for the teachers and students to upload their seismic data recorded by these stations.

OS4/P2/ID253 **- SPEED OF SEISMIC WAVES AND TEMPERATURE OF THE ROCKS CROSSED BY THESE WAVES.**

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Many seisms in the Carribean (West Indies) are recorded by the stations of the school seismologic network.While analysing the recordings with the SeisGram2K software program, we can see that: -for some seisms, P waves arrive ahead of the arrival times given by the model. -for others, P waves arrive behind the times given by the model.The purpose is then to determine whether it is a mistake due to the use of the global model IASP 91 or an anomaly due to the characteristics of the rocks crossed by the waves. To answer these questions, the pupils carry out calculations in order to find the theoretical arrival times of the P waves, by using the "hodochrone" of the West Indies zone. As the volcanic activity is very important in this area, they measure the effect of the temperature variation on the speed of one wave with a simple model using Plasticine and piezoelectric sensors. With "Educarte", they solve the problem by locating the centre of the seism and the way taken by the waves to reach the recording station .They thus reveal, in the subduction area, a positive thermic anomaly under the volcanic arc and a negative thermic anomaly at the above plate level.

OS4/P3/ID254 **- RELATION BETWEEN STRESS, MAGNITUDE, INTENSITY**

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Purpose: to show that the waves recorded by the seismometers of the seismic stations represent a fraction of the energy released during the seism, energy which is the cause of the experienced vibrations.We record seismic waves when some materials(such as chocolate, tiles …..) break while they are submitted to increasing stress, thanks to piezoelectric sensors and to the software program Audacity.When the stress exerted on the material becomes too important, the rock breaks. This breaking releases the accumulated energy in the form of waves that can be recorded thanks to the piezoelectric sensors.After the recording and a simple processing, these waves are "performed again" thanks to the Audacity software program and the vibrating table SISMO2D or SISMO3D (model which can reproduce a seism), to show that they are the cause of the vibrations experienced during a seism.If several sensors (representing the stations) are placed at different distances from the breaking place (centre), we show that the intensity of the experienced vibrations is proportional to the amplitude of the recorded waves.So, the seismic energy released in the centre is scattered in the form of seismic waves.The amplitude of the recorded waves represents the amount of energy reaching the station.

OS4/P4/ID255 **- THE 'SEISMO COOKBOOK' OR GEOSCIENCES HANDS-ON ACTIVITIES FOR THE CLASSROOM**

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In line with diverse initiatives regarding scientific culture and education to seismic risk, the 'Seismo Cookbook' is part of the French educational program 'Sismos à l'Ecole' which aims at creating a network of seismic stations installed in schools. Signals recorded in the schools feed an online database that centralizes all the information received from the network. While seismometers are the departure point for pedagogical

activities, simple, concrete, and fun tools are necessary to aid teachers and students in exploiting all these geophysical data.

Thus, we propose a workbook and accompanying kit including pedagogical models enabling teachers and students to explore various themes such as geophysics, instrumentation, seismic hazards and risks, and geosciences, placing scientific culture and education of environmental risk at the heart of the learning experience. These tools are the fruit of a collaborative effort between teachers and researchers over several years to promote the results of the educational program within the school environment. Through the activities proposed by such tools, students are encouraged to reflect beyond a specific discipline by working on real objects and phenomena. Comprehension is facilitated through practical activities and reasoning drawing from various disciplines such as geology, physics, geography, technology, mathematics, languages, *etc*. Whether middle school or high school students, they interact with researchers who have throughout the years generously offered their time and skills. The students discover that other students throughout the world, using the same experimental material, contribute to scientific enrichment by collecting the same type of data and addressing the same phenomena. Through its suggested activities and associated reasoning, this 'Seismo Workbook' strongly encourages reflection on models and modeling. A model, whatever it may be, addresses a particular phenomenon but cannot perfectly reproduce it. What are its contributions and its limitations? On what scale in terms of space, time, constraint, viscosity, *etc*. has the model been configured and therefore what is it capable of simulating, demonstrating or predicting? This line of thought is not dependent on sophisticated materials: students can achieve an excellent command of scientific reasoning through use of the simple and ingenious devices described in this book.

OS4/P5/ID256 - PEDAGOGICAL MODELS FOR TEACHING SEISMOLOGY AT SCHOOL

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In education, at school (middle or high school), it is sometimes necessary to use analog models to understand sometimes complex phenomena.

These models are «tools» that the student can manipulate to understand and to test his working hypotheses. He becomes an actor in the construction of knowledge.

• Using piezometric sensors, it can be easily demonstrate concepts of magnitude and intensity, concepts which students cannot understand the mathematical explanation before the end of the high school.

• With seismic tables 2D or 3D, students understand that the intensity of the earthquake was recorded related to the energy received on the surface, and the energy is represented by the amplitude of the wave recorded.

• On the thematic of seismic risk, 2D or 3D seismic tables show that the intensity of earthquake is not the only factor to consider but that the size and characteristics of the buildings are also criteria to consider.

• The use of play tools like the 'Wiimote' allows to make relations between the game world and Science. A play tool can be transformed into a seismometer model, like our seismic stations, capable to record seismic waves in three directions of space.

OS4/P6/ID257 - LES ANCIZES HIGH SCHOOL WORK GROUPIS HAPPY TO PRESENT ITS SISMO STATION

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We are happy and proud of being able to present pou station and the various works we have achieced up to now.

Our station is situated in our school in the little town of Les Ancizes, near the volcanoes chain in Auvergne, in the centreb of France.

Our school, though a little school (with only 200 students) has been offered the opportunity of creating a sismic station. Thus, we have been able to develop various activities around sismology : we have been to involve not only the students from our school, but also the pupils from all the primary schools around and the public. With the station, the aim is to study the origin of seism, the propagation (spread) of waves and the recording of them. We also study how to localize a seism when it occurs, the major sismic zoes, the major risks and how to protect people and buildings from them.

We will present a poster. In the poster, we will deal with the historic of the station. We will also present the sismic school work group and its activities (voluntary students from any levels) and the sismic school projects : «Tout, tout, tout...sur les séismes» (all the pupils from 4ème).

Our esposé will end with a presentation of a «sismic break model» created a few many years ago by the students from our school. Finally, we wil expose how to calculate the speed of the waves in various materials.

OS4/P7/ID258 - 10 YEARS OF SEISMOLOGY AT SCHOOL

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Students in the south of France, and especially in the Aix-Marseille area, have benefitted from three educational seismological programs which have been gradually built up over the last 10 years. - EDUSISMO-PROVENCE is the local network. On a regional scale, it is the functional unit of the big "Sismos à l'Ecole" project. Since 1990, it has offered both students and teachers, practical activities based on local data, in a multi-subject approach. - SISMOS à l'ECOLE is a "post-tsunami" project with as many as 46 stations set up in French high schools all over the world. Thanks to this global network, students can study remote earthquakes and outline the inner Earth structure. - Recently, O3E came to extend the school earthquake surveillance project. This 2 year old trans-frontier program is established in the southern Alps sector (Switzerland, northern Italy and our region). This project enables students to go beyond language differences, and share data found on this active and hazardous zone which has such a high human risk potential. Each of these programs has its own function and each brings specific help in understanding and establishing the seismology topic across the curriculum.

In each school, pupils carry out the installation and the regulation of the seismometer themselves. It makes seismology a more realistic element in their community and enables them to become more aware of the natural risks.

OS4/P8/ID259 - ACTIVITY AT SCHOOL : THE EFFECT OF SITE AND CONTRIBUTION OF THE SEISMIC WAVES BEING STUDIED OF THE INTERN STRUCTURE OF THE GLOBE

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A) Activity 1: the effect of site From the seism of the 23/12/08 (Italy), it aims at showing that the nature of the ground influences the amplitude of the seismic waves and will thus have to be taken into account during the evaluation of the seismic risk of an area. Step: ! Comparison of the seismograms of 3 stations: PERF, CAIF and SPVF, a problem arises: how to explain that the amplitude of the waves P with PERF is higher than with SPVF whereas it is further away from the epicenter?! Study of the nature of the rocks on the website Infoterre ! Modeling of the phenomenon of effect of site: use of a table 2D of the SAMS.! Answer to the problem. B) Activity 2: contribution of the seismic waves being studied of the intern structure of the globe The goal of this activity is to show the relation existing between the speed of the waves and the density of crossed materials. ! Comparison of the seismograms of a seism (recent seism) and determination the speed of the waves P to show that the further away from the hearth, the quickler they go. How can we account for it? ! Modeling to test the assumption: piezoelectric sensors and bars of rocks of known density (granite, limestone and iron). ! Application to the knowledge of the intern structure of the globe (interpretation of the profil speed of the waves P and S according to depth).

OS4/P9/ID260 - AN EDUCATIONAL SEISMICITY MAP FOR THE FRENCH SCHOOLS

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The Euro-Mediterranean Seismological Center (EMSC) has created in collaboration with the Fondation MAIF (a foundation created by a French insurance company) an educational seismicity map. This map was developed for a national audience and has been distributed in French junior high schools. It aims to present to the general public the seismicity in France in its regional tectonic context, allowing the comparison of the seismic hazard level with neighbouring countries. Mainland France is a low hazard region (the last des-

tructive earthquake occurred in 1909) and the population has little perception of the risk, as it is not related to experiences or memories. To provide a breadth of information, recent seismic events are described, common seismological concepts are defined, and a detailed box on French seismicity accompanies the main Euro-Med seismicity map. This poster contributes to a better perception of the seismic risk in Europe, with examples of the last major events of the region (such as the L'Aquila earthquake, Boumerdes, and Izmit events) and the Sumatra tsunami of 2004 described in parallel with the Lisbon earthquake of 1755. Specific terminology is explained, such as the difference between hazard and risk, what magnitude and the macroseismic intensity are, and the magnitude distribution of earthquakes. All the information provided can be used by the reader to understand the notion of hazard and the multiple consequences of seismic events, as well as to compare the seismic hazard level in France with that of other Euro-Med countries. The seismicity map on itself was obtained by using 10 years of information available in the Euro-Med Bulletin (Godey et al., 2009), which is one of the major activities of the EMSC and is computed by merging bulletins from 77 Euro-Med network operators. Thanks to the Fondation MAIF, the EMSC was able to adapt a purely scientific product for the general public. Though this poster is currently only available in French, the EMSC is looking for partners to prepare and distribute a similar educational map in English.

OS4/P10/ID261 **- PEDAGOGICAL SHAKE TABLE EXPERIMENT: SIMPLE STUDY OF BUILDING'S RESONANCE AND EARTHQUAKE RESISTANCE IN THE CLASSROOM.**

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http://www.ac-grenoble.fr/webcurie/bio/seismes These experiments simulate seismic vibrations on very simple plastic buildings, and are accomplished with the available equipment in secondary schools: Plastic buildings built by the students are set on a polypropylen table (20cm x 20 cm) shake by the vibrator which converts an electrical tension set by an earthquake signal put by the computer via a pedagogical interface (power-cassy) or a low frequency generator, to a mechanic vibration in one horizontal direction. The pedagogical goals are to understand, in a simple way, how buildings behave in case of earthquakes, and to understand photographs of real buildings destructions, which shows that in the same place, certain buildings are destroyed by earthquakes but not the others.In a second time, students test different ways to build earthquake-resistant buildings, or to prevent building's falling down. The study begin first by sending a real earthquake signal with the computer to the shake table, and students observe different resonance modes on the different buildings put on the table, which depends of the frequencies presents in the earthquake signal, and of course of building's height.Secondary, students applies a controlled frequency signal, with a low frequency signal generator to understand resonance problems, and different resonance modes.Finally students try to prevent buildings from the falling down issue, and applies all classical systems to change building resonance frequency or to amortize the vibration (put a heavy mass upon then building, use rolling foundations, use system to protect building shape…) Site effects of rock basins is simulated by a flexible support where we put the table and the buildings. Ground liquefaction is also simulated with dry sand, heterogeneous ground and heavy building.The free software uses in that experiment shows that in certain earthquake signals, all frequencies are not amplified in the same ratio (Fourier transform) and this observation set a lot of new questions and reflections about earthquakes prevention and statistics studies.It is a really multidisciplinary project (earth sciences, physics, mathematics) Scientists which help us: François Thouvenot (CNRS LGIT Grenoble), Julien Frechet (CNRS Strasbourg), Françoise Courboulex (CNRS Valbonne)

OS4/P11/ID262 **- "SISMOS AT SCHOOL": SISMO TOMO - SISMO MOHO ACTIVITIES**

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SISMO TOMO, Year 12, Lower Sixth / 1ère S

The purpose is to understand the significance of variations in seismic waves velocities on earth. Measures showing differences in the velocity of propagation in cold or hot modelling clay will help to establish an analogic model that can explain the use of seismic waves in tomography on a global scale.

Process

A shock is created (with a hammer) on a cold bar of modelling clay (the temperature of the clay is recorded with the probe) and the wave train is recorded using Audacity with the first then the second piezoelectric transducer connected to the sound card of the computer. The experiment is renewed with a bar of clay at higher temperatures.

Variant: a series of measures can be recorded with a bar from the freezer that will warm up very quickly.

SISMO MOHO, Year 12, Lower Sixth / 1ère S Assessment of the depth of the Moho beneath the Alps.

This is a case study available on the website "SISMOS at School": http://www.edusismo.org/docs/outils/educarte/ec/dossier_ec.moho_alpes.zip

The objective is to assess the thickness of the earth crust from seismograms, using Educarte, Séisgram softwares and a spreadsheet program.

With «Educarte» you can select one of the earthquakes of the study area and retrieve the seismograms which open in «Séisgram". The analysis of these seismograms permits to identify the reflected waves (PMP) and determine the time lag compared to the P waves and calculate the depth of the Moho thanks to the epicentral distance, using a spreadsheet program.

Finally the data obtained by the students can be compared to a map of the Moho drafted by scientists, which can be visualized on "Educarte".

OS4/P12/ID263 **- SPRING-SLIDER BLOCK MODEL EXPERIMENT IN CLASSROOM: IS IT POSSIBLE TO PREDICT EARTHQUAKES ? AN HELP TO UNDERSTAND FAULT MECHANISM REPRESENTATION.**

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http://www.ac-grenoble.fr/webcurie/sismo/web_patin/This classical experiment in earth science consists in pulling a block connected to a spring and studying it's stick-slip movement. This experiment is possible in classroom after simplification: only one block, and one spring, but each student is able to do it in the classroom if the material is present: block of cellular concrete, a step to step engine driven by the computer (phytex) to pull the rock, a spring, an interface which is able to record slipping with piezometer sensor putting on the block. (it is also possible to simplify that experimental material in using the computer sound card to record signal from the piezometer and the Audacity software which is a classical software to record or read sounds.) The software which records slipping (Cassy-s from leybold http://leybold-didactic.de) is able to calculate, in real time, the square of signal, which gives an idea about the energy which is spent along time, and to integrate it in real time. The results on these experiments shows that it seems not possible to predict the exact moment when the block slips, and after treatment with excel man cannot see any correlation between the time which separates 2 slips and the energy spent. Of course it might be necessary to use some statistics tools to be sure that nothing is visible between factors (time and energy). It's a new work that we're going to do. At the beginning we done that experiment to study the return period of earthquakes, but the curves we obtain shows that sometimes the earthquake does not catch up all the theoretical energy, and then it's possible to predict that one of the future earthquakes will be the "big one". However it is not possible to say that the next earthquake will be the big one, because the it can fill the delay accumulated by the rock, very partially. We also do very similar experiment with 2 springs and 2 blocks, one upon the other to understand a little better, fault mechanism. The upper block is pulled by the step to step engine until the rupture: the 2 blocks move in an opposite way (pull by the 2 springs) and make a compression in front of the movement and a depression behind it. It helps to understand the focal sphere representation. A little freeware allows to understand that it exists 2 hypothesis about the fault direction when the focal sphere representation is done.

Help from scientists: François Thouvenot (CNRS LGIT Grenoble), Denis Hatzfeld (CNRS LGIT Grenoble),Françoise Courboulex (CNRS Nice)

OS4/P13/ID264 **- ANALOGUE MODELLING OF SITE EFFECT IN THE POST-GLACIAL SEDIMENTS OF THE GRENOBLE REGION : AN ORIGINAL EXPERIMENT AT SECONDARY SCHOOL**

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The city of Grenoble is built over thick quaternary sediments which filled the Isère and Drac valleys after glacial melting. Their thickness reach 900m below the town, and the surrounding cristalline basement and Mesozoic rocks show much higher seismic velocities. Regional seismic activity of moderate amplitude is recorded by the Sismalp permanent survey (Thouvenot et al., 1990), but ground motion near the center of the city shows >10x amplification.

In order to experiment this amplification of seismic waves in the post-glacial infill, we built a 1/25000 scale 3D model of the glacial basement in the area of Grenoble, using the map of Vallon (1999) which was acquired by geophysical methods. The shell is made of fiberglass and was filled with agar-agar gelly, with marker spots on top of it. The gelly's velocity is approximatively respecting the scaling law for such dimensions.

A low-frequency vibrations generator was applied on different sides of the model, with a movie camera fixed over it. We observe horizontal movements of the gelly infill: the frequency of resonance clearly depends on the location : in the center of the model (representing Grenoble downtown), the maximum amplitude is observed at 7Hz, whereas further south (location of the city of Echirolles), the gelly is only 1cm thick and resonance occurs at 18Hz. These results compare well with both the theoretical relationship N(frequency)=V(velocity)/λ(wavelength), and with the observed range of resonance in this area, ~0,3Hz in Grenoble and ~1,3Hz further south in Echirolles.

This is the first attempt to build a scaled analogue model of this critical area. This project was carried out by 3 secondary school-girls from Lycée Marie-Reynoard in the framework of their studies, with the technical support of Lycée Marie-Curie (Echirolles) and the help of researchers from LGIT and LGCA laboratories (Observatory of Grenoble).

Thouvenot, F., Frechet, J., Guyoton, F., Guiguet, R. and Jenatton, L. (1990). SISMALP: an automatic phone-interrogated seismic network for the western Alps. Cah. Centr. Eur. Géodyn. Séism., 1, 1–10.

Vallon M. (1999) - Estimation de l'épaisseur d'alluvions et sédiments quaternaires dans la région grenobloise par inversion des anomalies gravimétriques. Document LGGE, université J. Fourier, Grenoble, Inédit, 33 p.

OS4/P14/ID265 **- MODELIZATION AND PIEZO-ELECTRIC UNITS USED TO UNDERSTAND SEISMOLOGICAL CONCEPTS.**

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Seismology is a fascinating goal for secondary school students, mostly due to the disasters and the suddenness of their occurrences. Earthquakes retain part of mystery, since causes and events remain largely invisible under their feet. Because of this, it can be a very good support for investigative approaches on which they can study during their schooling. Most of the time, technical and practical works were firstly used in the classroom to trigger them to elucidate experimental questions. For example, they can easily see that earthquakes are largely unpredictable in time, but not absolutely geographically. Thus, in order to define the concept of breaking a pre-existing fault, we simply developed an adapted model. Successively, students built the model themselves, then use it sequentially with entire or partially cut piece of wood, firmly or weakly joined. They showed that only the pre-cut up piece of wood is breakable and that the break strength is not the same in the various cases of joining. Finally, they used piezo-electric units to visualize the link between accumulated constraints and amplitude of seismic waves. In another demonstration, to understand variations of seismic waves propagation in Earth's depths, the students worked with piezo-electric units and various materials of various densities. They showed that seismic-waves accelerate in growing density and slow down in lowering ones. They take advantage of this study to use spreadsheet to communicate their results. Altogether, these activities have allowed the students to be involved in mastering geosciences concepts that, for them, remain complex and abstruse without using models. Manipulating such models offered training and rewarding approach for future scientist students, but also at least for future informed citizens.

OS4/P15/ID266 **- SEISMOLOGY AT SCHOOL: FROM THE EXPERIENCE OF THE EDUSEIS PROJECT TO A NEW APPROACH IN TEACHING AND LEARNING THE EARTHQUAKE RISK**

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EduSeis (The Educational Seismological Project) was a scientific and educational project involving Universities, scientific museums and high schools, aimed at promoting the Earth Sciences among students. The first EduSeis seismic station in Italy (MSNI) was installed in 1996 in the Science Centre "Città della Scienza" in joint cooperation with the University of Naples "Federico II". In Italy since 1997 to 2002 more than ten stations have been installed in several high schools and research centres in Central and Southern Italy. The basic idea of EduSeis was to use a network of seismic stations installed in high schools to confront school students with the current practice of scientific data acquisition and management, using data and tools only accessible in research laboratories. Further, the students were involved in operating and maintaining a high-tech, but low-cost seismic station (sensor, data acquisition system and data acquisition software and processing). In this framework we experimented new approaches to the formation/information on Seismology and Seismic Risk addressed to the large public and to the high school audience. Such approaches were realised through an interactive seismological lab (SISMALAB) operated and maintained by "Città della Scienza", and through the design and experimentation of an e-learning environment in an high school located close to the Mt.Vesuvius volcano. In this direction, we plan to introduce seismology in schools through the modern technologies for teaching and learning the scientific knowledge based on e-learning platforms and to involve the school community in establishing a scientific objective. These are exactly the principle and basic ideas of a new educational project that we are pursuing in the schools of Irpinia region installing a seismic station inside the school. Since the Irpinia region is characterized by an elevated seismic risk, the increasing of knowledge about the earthquake phenomena and their effects at the earth surface can contribute to raise the awareness about the earthquake risk and possible mitigation actions.

OS4/P16/ID267 **- 8 MONTHS AGO ... HAITI PRESENTS HIS EDUCATIONAL SEISMIC STATION**

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On January 12, 2010, Port au Prince was suffering the effects of a major earthquake very destructive.

The quake and its aftershocks have been recorded by the seismic educational station in the French school at Port au Prince. This seismogram is a very important document for the scientific community because the seismometer of this school was the only one which recorded ground motion in Port-au-Prince that day and the following days.

A few months later, the college Catts Pressoir also realized a new installation of a educational seismometer, integrating the network 'Sismos à l'Ecole'. This new station, called HPAP, provides important data daily on the local seismicity, and allows the students to work on the thematic of seismic risk.

Students from Catts Pressoir College will present their seismic station, the site where the seismometer is located, and initial school activities performed with these data.

OS2 - EARTHQUAKE EDUCATION FOR RISK REDUCTION: EUROPEAN AND NON-EUROPEAN EXPERIENCES

OS2/P1/ID268 **- TAKING STOCK OF THE EDURISK PROJECT, AFTER 7 YEARS OF LABORATORY WORK AND AN HANDS-ON EXPERIENCE WITH A REAL EARTHQUAKE**

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The EDURISK project (Earthquake Education: A Journey for Seismic Risk Reduction) is an educational joint venture of the Istituto Nazionale di Geofisica e Vulcanologia and the Osservatorio Geofisico Sperimentale of Trieste, financed by the Italian Department for Civil Protection. The EDURISK project started in the school year 2002-2003. For almost six years from its inception, the EDURISK staff was mostly concerned with "laboratory work": educational tools for the schools (from nursery to secondary) were planned, developed and tested within the frame of a large-scale educational experiment, involving about 2,600 teachers and more than 40,000 students from hundreds of Italian scholastic institutes. Their response to the EDURISK input found expression in a wide range of works, activities, studies, artifacts and so on, now available via the EDURISK project Internet website (www.edurisk.it).

The educational tools created by the EDURISK project are available in Italian (in several editions) and also in the main European languages. Recently, in the frame of the O3E INTERREG project, new editions of the two books for primary and secondary school were printed for the Euro-Mediterranean area.

In April 2009, the EDURISK project had to meet a new challenge when, for the first time ever, its methods and products were put to the test of a strong earthquake (Mw 6.3 L'Aquila earthquake of April 6, 2009).

On the spot, the EDURISK staff had to devise completely new ways to carry out its work in the field, in circumstances no less demanding and infinitely more difficult than the friendly scholastic environment they had previously worked with. Completely new and original educational activities had to be devised to meet the psychological needs and answer the numberless questions of the suffering population of Abruzzo in a constructive, humanistic way.

We present a final outcome of the experience of the project, with special references to the problems encountered in Abruzzo during the 2009 earthquake sequence and the ways we devised to solve them.

OS2/P2/ID269 – EARTHQUAKE EDUCATION PROJECT: SOME EXPERIENCES IN ABRUZZO E LAZIO

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This work describes some activities of information and earthquake education in Abruzzo and Lazio started some months later the 6 April L'Aquila earthquake. The "La Terra tretteca… Ji No! – Ritorno a scuola" project: in September 2009 we provided support to teachers in the most damaged areas at the beginning of the school year. We met more than 2700 teachers to provide detailed information on earthquakes, how a seismic sequence evolves and what to do to reduce the risk. 18 schools in Abruzzo (L'Aquila, Teramo and Pescara Provinces) are still working in the EDURISK Project, a project aimed to school for seismic risk reduction (described in another work of this session). Another initiative started after a seismic sequence with more than 400 small earthquakes in southern Lazio in August-September 2009: the "Tutte je munne trèma... Je nò!" project in February and March 2010 allowed us to meet more than 1000 teachers to provide information about recent and historical seismicity and seismic hazard of the Frosinone Province. These initiatives arise from different experiences and skills gained in recent years in seismic risk reduction projects (EDURISK Project) and in the field of information and emergency management.

Seismologists and psychologists:

C. Nostro, R. Camassi, F. La Longa, M. Crescimbene, Bernardini, T. Braun, G. Cultrera, E. Ercolani, Faenza L., Frepoli A., Pignone M., Pino N. A., Piromallo C., V. Castelli, Zarrilli L., M. Rossi, F. Rossi, G. Vaudo and «Psicologi per i Popoli»-Abruzzo and Lazio.

OS2/P3/ID270 – VIRTUAL SEISMIC ITINERARIES AS AN EDUCATIONAL TOOL: EARTHQUAKES AND GHOST TOWNS IN CALABRIA, SOUTHERN ITALY (PART II)

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In the framework of the EDURISK Project (Earthquake eDUcation: a journey for seismic RISK reduction), we have developed an innovative multimedia product inspired by the most traumatic effect of a seismic catastrophe, namely the abandonment of an inhabited centre. This situation represents an event of wide historical, cultural and anthropological impact because it determines the loss of a piece of history and culture but, at the same time, it witnesses the fragility of a territory with respect to earthquakes. The rediscovery and re-evaluation of localities abandoned after an earthquake is therefore a unique opportunity from a cultural standpoint when dealing with earthquake education strategies, enhancing the awareness of seismic risk as an element of daily life. Following this guideline, we have published in 2006 the first DVD-Rom for a virtual seismic itinerary through Sicily, including 17 localities destroyed by the 1693, 1783 and 1968 earthquakes. Here we present the case-history of Calabria, another region where the ghost towns represent a constant element in the landscape of the region. In fact, more than 40 localities have been recognised as abandoned in consequence of earthquakes, landslides, social or environmental causes. As for seismic destructions, we have documented 23 settlements throughout Calabria which were abandoned following large and moderate earthquakes. The largest group, 17 sites, is associated with the 1783 seismic sequence, which caused extensive destruction in a large part of the region. Other case-histories concern the following earthquakes: 1832 in eastern Calabria (Crotonese), 1905-1907 in southern Calabria and, more recently, 1982 in the northern part of the region (Pollino). Different kinds of materials have been collected and merged together in order to explain the seismic history of the sites: images documenting how they appeared in the past and their present status, historical documents accounting for the effects of earthquakes as well as for subsequent social impact associated with reconstruction dynamics, information on the earthquakes and the seismic classification of the territory. The interactive technique adopted for virtually visiting the ghost towns is the Quick Time™ Virtual Reality format (QTVR).

OS2/P4/ID271 – AN APPRAISAL OF THE EFFECTIVENESS OF SEISMIC PROTECTION AND CLIMATE CHANGE ADAPTATION OF HOSPITAL BUILDINGS IN SOUTHERN GHANA AND MALDIVES

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Hospitals play a major role within the society especially during disasters. They do not only serve as hotels but critical in saving vital lives. In countries such as Ghana and Maldives, which have long return period of seismicity and threat from changes in the climate, it is critical to protect these facilities. The paper examines current hospital buildings and maintenance standards in the two countries in relation to seismic threat and climate change. Because major earthquakes have a long return period, there is widespread apathy amongst the public concerning these matters, and the tendency on the part of politicians to pursue other, more "immediate" concerns, which have a more obvious political "pay-off". The study further extended to Maldives which is at high risk to climate change and seismic influence from neighbouring countries. Data was obtained both from stakeholders in the two countries, through questionnaires, interviews and from a wide range of literature in the field. In addition, the author examined specific hospital buildings. Those consulted included politicians, planners, structural engineers, disaster managers, seismologists, hospital administrators, and public representatives. The views of international professionals working in the field of earthquake risk reduction and climate change adaptation were also considered. This comparative experience provided a vital context for the assessment of current and potential future seismic protection and climate change adaptation for hospital safety.The findings showed that the safety of hospitals during earthquakes and hazards from climate change require enhanced political commitment, major policy developments, implementation strategies and broad public acceptance of such measures. The western part of Greater Accra Region is most at risk to the earthquake while the eastern coast is threatened by sea level rise. An earthquake of magnitude 6.5 occurring in the present urban environment of Accra, it is estimated that more than 6,000 people in hospitals will be killed and there will be about 10,000 seriously injured. Projections

suggest that 11 hospitals will suffer heavy damage and will have grim consequences for the care of 10,000 injured victims. Hospitals in the east are also at risk to the average recession of the shoreline which increases 3m/year due to sea level rise. In Maldives, in view of the low lying nature of the country it is estimated that a significant number of hospitals could be damaged if a magnitude 9.5 were to occur close to the country. These hospitals are also at risk to sea level rise.

OS2/P5/ID272 **- EARTHQUAKES AND EDUCATION**

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The earthquake events are numerous, various and irregularly distributed. Generally the quake epicenters are concentrated along the plate margins. In several cases the intra plate territories are also seismically dangerous. The earthquakes are of natural or artificial origin. They are very often of natural origin. Mainly they occur as results of tectonic, sometimes - of volcanic manifestations, rarely - of karst deformations etc. The seismic events of artificial origin are rare. They are related to man-made (technological) activities or to mixed natural-artificial (geological-technological) causes. During the recent Anthropocenian evolution of the civilization, our human and technological development is very intensive. Respectively this development provokes an increasing number of technological and tectonic-technological earthquakes. Numerous seismic events have not any direct influence to the people, but a part of them are disastrous for the population, its cultural heritage and technological constructions. The society needs special preparation for disastrous earthquakes. The preparation includes knowledge, specific skills and wide application of high quality products of the contemporary civilization in the life of people, in the building and the exploration of constructions. The distribution of the main seismic knowledge represents an essential task. People need education about seismic processes in schools, in social clubs and via media. The information from books, publications and maps is based on seismological and geological data, illustrations of seismic damages and notes for people impressions from earthquakes. The knowledge could be enlarged over the degree of local and regional engineering security in technological constructions. The interest to seismic knowledge increases in territories with earthquake damages. The applied specific skills are various. They are created on the basis of local practices for the preparation of people for actions before, during and after earthquakes, on visits of localities with seismic traces on the earth surface, on receiving data for seismically most saved constructions in localities. The education puts accent to importance of the seismotectonic position and building qualities, of intensities of the exploration in the strategic and personal constructions. It is of importance in all cases, but it is very significant for people and constructions in seismic active territories. Well educated societies and countries of good development are capable to reduce the seismic damages. Limited seismic dangers are created in territories with perfect transport and communication, in well organized and constructed settlements and among population with seismic knowledge.

OS2/P6/ID273 **- SOCIAL-PSYCHOLOGICAL PREPAREDNESS OF POPULATION TO AN EARTHQUAKE**

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After Spitak`s earthquake we have done a great deal of work with population behavior rules before, during and after an earthquake. The trainings were realized with various age groups of population. We have paid great importance to pupils in training process. In order to reveal the effectiveness of training we examined the level of social-psychological vulnerability of population. We started the research since 2006 and we revealed the level of neuron-psychological stability and disadaptation risks of population. Our research included more over 3000 data. These data help to explain the effectiveness of trainings and adoption of new methods. The investigation was curried out in 4 towns of RA.

OS1 - EARTHQUAKES AND SOCIETY: IS THE WAY SEISMOLOGISTS COMMUNICATE SATISFACTORY?

OS1/P1/ID274 **- AN EMSC WEBSITE FOR THE MOBILE USERS**

F. ROUSSEL[1], *B. SAUVETON*[1], *R. BOSSU*[1], *M. CAROL*[1]
[1]*EMSC*

It is now known that after a widely felt earthquake, a lot of people rush on the internet to find out more information about the earthquake they have just felt. However, if the shake is very strong and frightening, people obviously run out of the buildings. In such a situation, their only access to internet is provided by their mobile phone. This is particularly true after damaging earthquakes where wired internet networks may be out of order while mobile network may still be available. The current EMSC web site is not adapted to mobile phones. Therefore, we decided to develop a website prototype dedicated to mobile phones. The new generation of mobile phones, called *smartphone*, offers better hardware potency and better internet connexion than the previous mobiles phones capable to use internet. A website for *smartphone* imposes new requirements. The bandwidth limitation, the screen size, the processor capacity need to be taken into account. It is therefore crucial to adapt the earthquake information to be convenient to this technology and to organise the earthquake information in a different way as on the current web site. For this we propose new functionalities: Most recent and most significant earthquakes as well as the latest events that occurred near the user's location are highlighted. The access to the questionnaires, rather than answering a list of questions, the user will simply select among a list of thumbnails the one that fits the most the shake he just felt. These new tools should help the users to correctly identify the earthquake they have just felt and should encourage the users to answer the questionnaire, provide their comments and send pictures of the observed damages that are crucial to quickly assess the impact of an earthquake.

OS1/P2/ID275 **- A NEW SCOPE FOR THE ISC: REACHING BEYOND THE SEISMOLOGICAL COMMUNITY**

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Every time a damaging earthquake occurs there is an outburst of public interest in seismology and related subjects. If an event turns out to be catastrophic the interest quickly escalates into a demand for answers. Seismology, like most of the sciences, uses a rather complex vocabulary which sometimes fails to attract people's interest and explain complicated issues in a simple manner. This is a must when dealing with the media or non scientific users. Following the example of other seismological data centres such as the EMSC and NEIC, the ISC has been working on an automated page for special events. We have targeted the widest range of users: from scientists looking for waveforms and historical seismicity to journalists interested in the most damaging events within a zone as well as members of the public looking for humanitarian information and ways to help. This automated webpage is part of an ongoing project to support the ISC outreach officers with readily available information to address requests from media at the time of catastrophic events.

OS1/P3/ID276 **- SIRIUS – A NEW INDICATOR OF SEISMIC URBAN RISK**

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A complex global indicator, which contemplates physical (buildings and infrastructures), social and functional aspects of an urban system is being built to measure the earthquake overall urban impact. Comparing different alternatives it is possible to make recommendations for a variety of objectives of mitigation earthquake risks, namely, for the definition of priorities of interventions, rehabilitation policies, land-use which will cause minor earthquake urban impact for a life time and emergency preparedness. This global indicator is folded into several other indicators ranking from a very simple and crude deficit of vulnerability, to a more thorough indicator as the one presented in this paper (SIRIUS), or to a more complex indicator measuring the disruption index (DI) of a society inflicted by an earthquake. DI is under development. The Seismic Risk Indicator in Urban Spaces (SIRIUS) was created to identify actual critical areas within an urban space, taking into consideration three main parameters: (i) the exhibiting earthquake hazard; (ii) the deficit in vulnerability as the difference between the required and the actual vulnerability of the building stock; and (iii) the population at stake. For the SIRIUS indicator we first compute for each building

type (and to each building importance class: II to IV) the difference (ΔVu) between the actual vulnerability and the required vulnerability based on EMS-98 scale and soil type (according to EC-8). In this context, ΔVu means that a building is considered risky only if its vulnerability is far from what is desirable taking into account the expected ground motion. Then, we applied the people concentration, taking into account a maximum population per hectare arriving to a numerical index. Having found this numerical risk index to measure the seismic risk, yet useful, it is not a sufficient way to communicate (or capture our perception of) risk. People usually express themselves in a semantic (linguistic human) language, not in a scientific or more abstract one. So, we want some form of mapping the numeric risk index into a semantic scale. Stated in another way, we want to find "how much risk are we expressing" when we say that risk is "Extreme", "Weak", "Strong", …, which is the way we, humans, perceive the external stimulus. We used the "Weber–Fechner law" to convert the numeric index into a semantic description. To illustrate the interest of this indicator we made an application in two completely different environments and results enhance clearly their peculiarities.

OS1/P4/ID277 **- WHAT CITIZENS TRULY KNOW ABOUT «BE PREPARED FOR AN EARTHQUAKE»**

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Slovenia is located in the seismically active Mediterranean region. From historical sources it is evident that more than 60 major earthquakes have happened in the past. Not only destruction of the buildings but also civil casualties were reported. Only in the last century 20 earthquakes are recorded, exceeding the intensity of VII according to EMS scale. In the regions of Idrija, Ljubljana, Krško-Brežice and Upper Posočje more earthquake energy was released in the past then in other areas of Slovenia.

The question is, whether there exists a difference in the knowledge about preparedness for an earthquake among the population living in the regions that are more endangered by earthquakes in comparison with those living outside these regions. For that reason people from two towns, one located in the «earthquake» area and the other outside of that area, were tested by the help of few «be prepared for an earthquake» statements. In the questionnaire 171 (81+90) persons were included.

Results show that the knowledge is similar in both areas. The problem is that also lack of knowledge is equally present. It will be interesting to find out why they are misinformed. The fact is that citizens should be educated about some things in a more appropriate way

OS1/P5/ID278 **- AFTER THE L'AQUILA EARTHQUAKE: TWO MAGNITUDES, ONE DISPUTE**

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The attention devoted by the media to the l'Aquila earthquake (2009) has taken the italian seismologists, probably for the first time ever, to face the problem of how to and to which technical level disseminate earth science information to the public.

The many questions arisen about the predictability, and of course the relative answers, the debate about what could be done before the earthquake and even the discussion on the reconstruction presupposed a scientific knowledge from the public. This preparedness was hardly given before, mainly because of the limited interest from the media to this kind of problem in rest time.

During the emergency the mixture of basic information, in the attempt to recover from the initial lack, the responses to advanced questions, the quarrels about the role of seismology in modern society, all filtered through the difficulties of the seismologists to explain to a greater and demanding audience (choice of the language, level of technical details, necessity to strengthen the role of science towards the society) caused several misunderstandings.

In this presentation we describe the consequences of the transferring to the public of a very common and acknowledged situation in seismology like the dual determination of magnitude. After the l'Aquila earthquake, the existence of a double estimate for the magnitude has been misinterpreted by the public and considered, especially by the bloggers, which are the most active part of the society, as a limitation, a failure or even a fake news created for political purposes.

The case is a good starting point for a discussion about the role of seismologists towards communication and dissemination.