Global Seismic Noise Synchronization and Seismic Danger Increasing in Connection to Irregularity of Earth's Rotation

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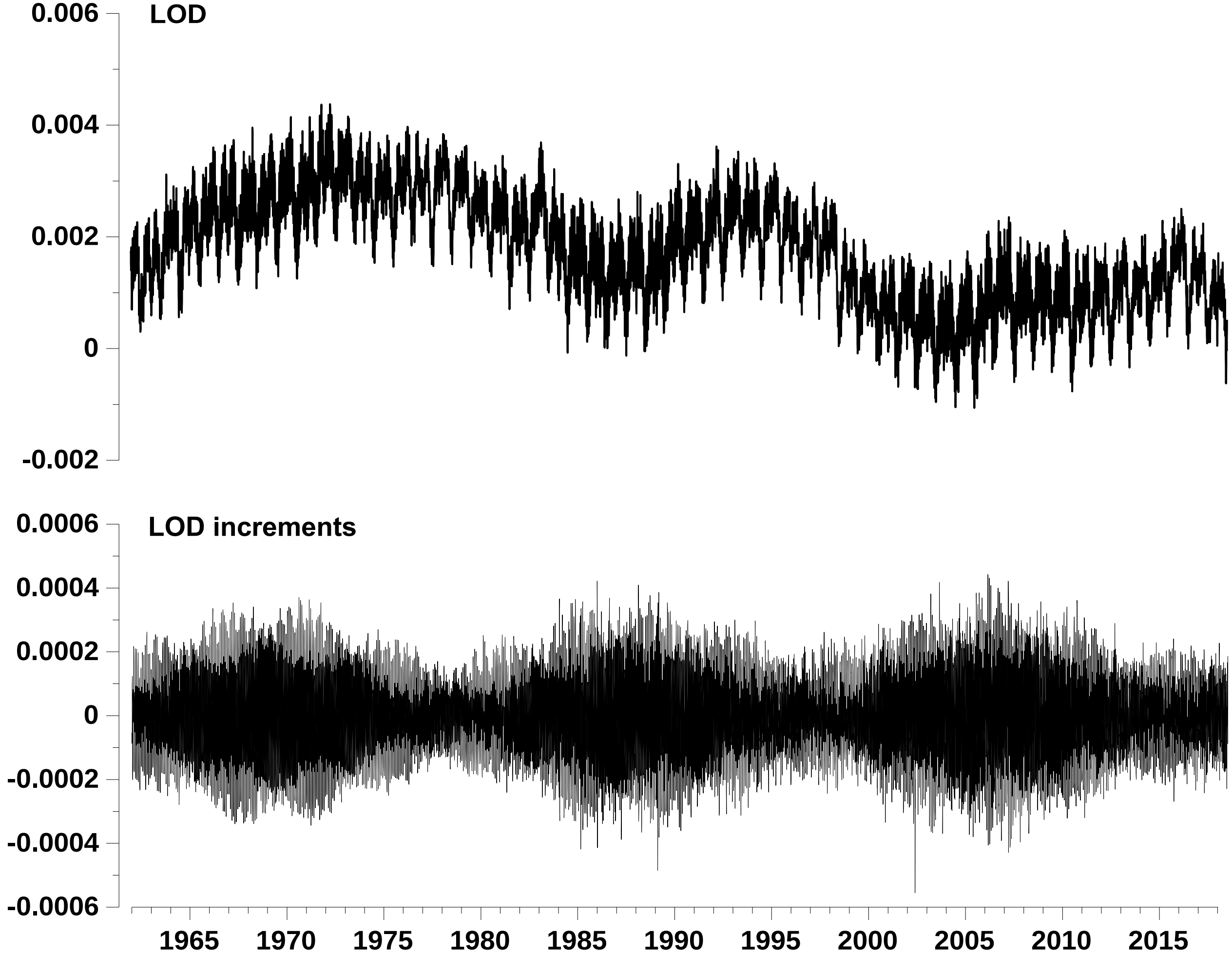
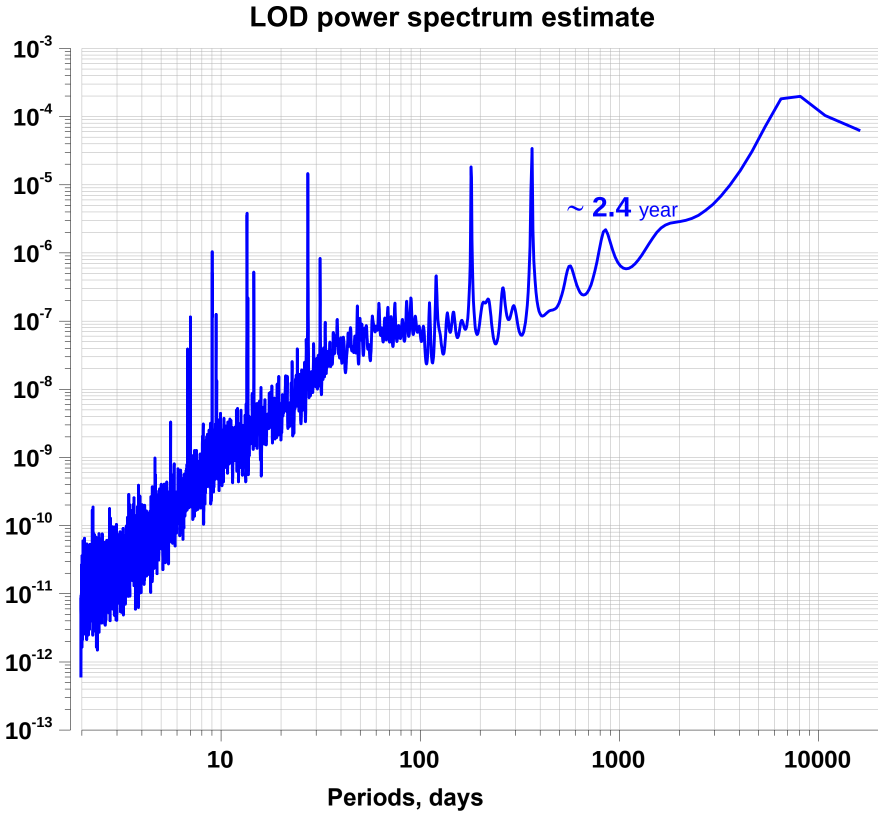
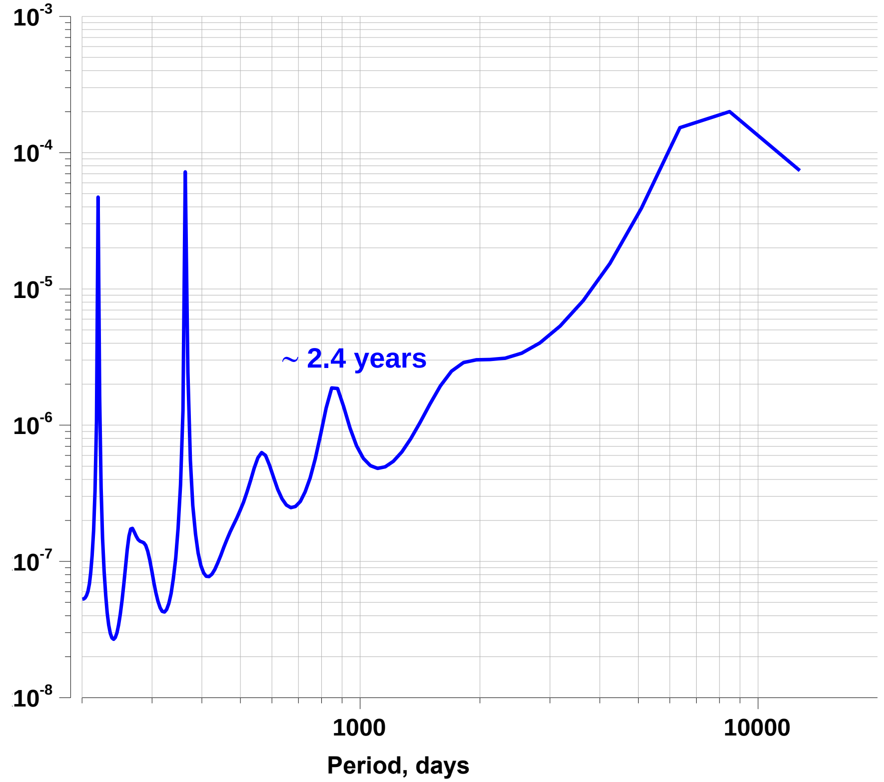
Part I. High-frequency anomalies of LOD variations

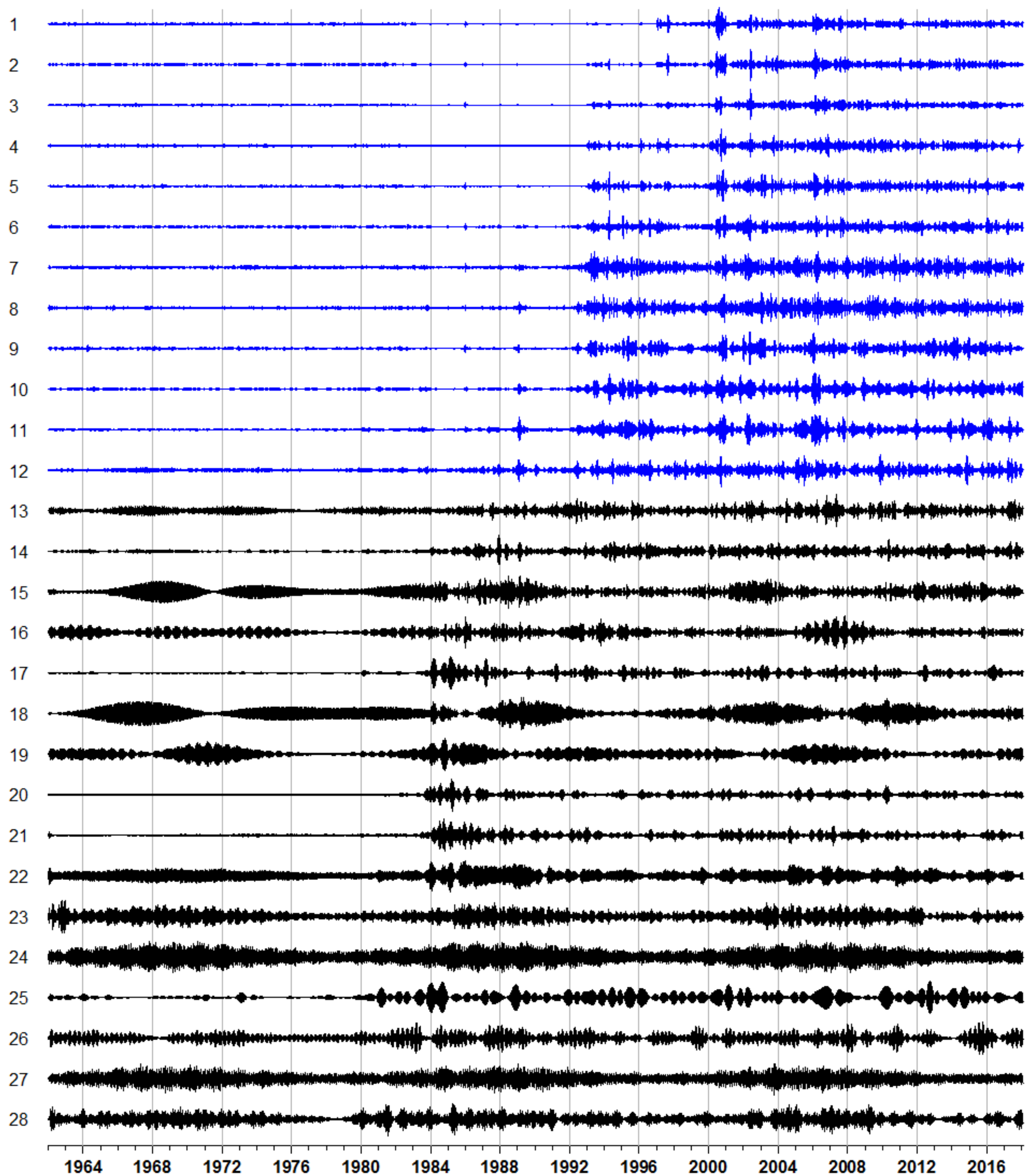
Daily LOD (Length of Day) time series, 1962 – 2018,
http://hpiers.obspm.fr/eop-pc/index.php?index=C04&lang=en



LOD power spectrum estimates, existence of 2.4 years periodicity







Wavelet-packet decomposition of LOD increments. Wavelet Daub20, 10 vanishing moments

#	PeriodMin	PeriodMax
1	2.00000	2.13333
2	2.13333	2.28571
3	2.28571	2.46154
4	2.46154	2.66667
5	2.66667	2.90909
6	2.90909	3.20000
7	3.20000	3.55556
8	3.55556	4.00000
9	4.00000	4.26667
10	4.26667	4.57143
11	4.57143	4.92308
12	4.92308	5.33333
13	5.33333	5.81818
14	5.81818	6.40000
15	6.40000	7.11111
16	7.11111	8.00000
17	8.00000	8.53333
18	8.53333	9.14286
19	9.14286	9.84615
20	9.84615	10.6667
21	10.6667	11.6364
22	11.6364	12.8000
23	12.8000	14.2222
24	14.2222	16.0000
25	16.0000	17.0667
26	17.0667	18.2857
27	18.2857	19.6923
28	19.6923	21.3333

Starting from 1992 due to using modern methods of space geodesy high-frequency LOD variations became representative

Wavelet-packet-based measure of time series non-stationarity

Let $x_\alpha(t)$, $1 \le t \le N$, be orthogonal wavelet-packet component of time series, where α is an integer number of wavelet-packet sub-level, $\alpha_0 \le \alpha \le \alpha_1$, more is the number α , more is the period τ_α of the middle frequency corresponding to the frequency band of sub-level. The widths of wavelet-packet sub-levels depend on the number of sub-levels within each usual wavelet detail level. We will use splitting into 8 sub-levels. Let's perform preliminary normalizing operation:

$$y_\alpha(t) = \frac{x_\alpha(t)}{\max\limits_t |x_\alpha(t)|}$$

Let s be a center of sliding time window of the length $(2m_\alpha + 1)$ samples, where $m_\alpha = [\tau_\alpha]$. Let's calculate sums of squared amplitudes of normalized wavelet-packet components $y_\alpha(t)$ in the left-hand and right-hand vicinities of the moving central point s :

$$Z_{\text{Left}}^{(\alpha)}(s) = \sum_{t=s-m_\alpha}^{s-1} |y_\alpha(t)|^2, \quad Z_{\text{Right}}^{(\alpha)}(s) = \sum_{t=s+1}^{s+m_\alpha} |y_\alpha(t)|^2$$

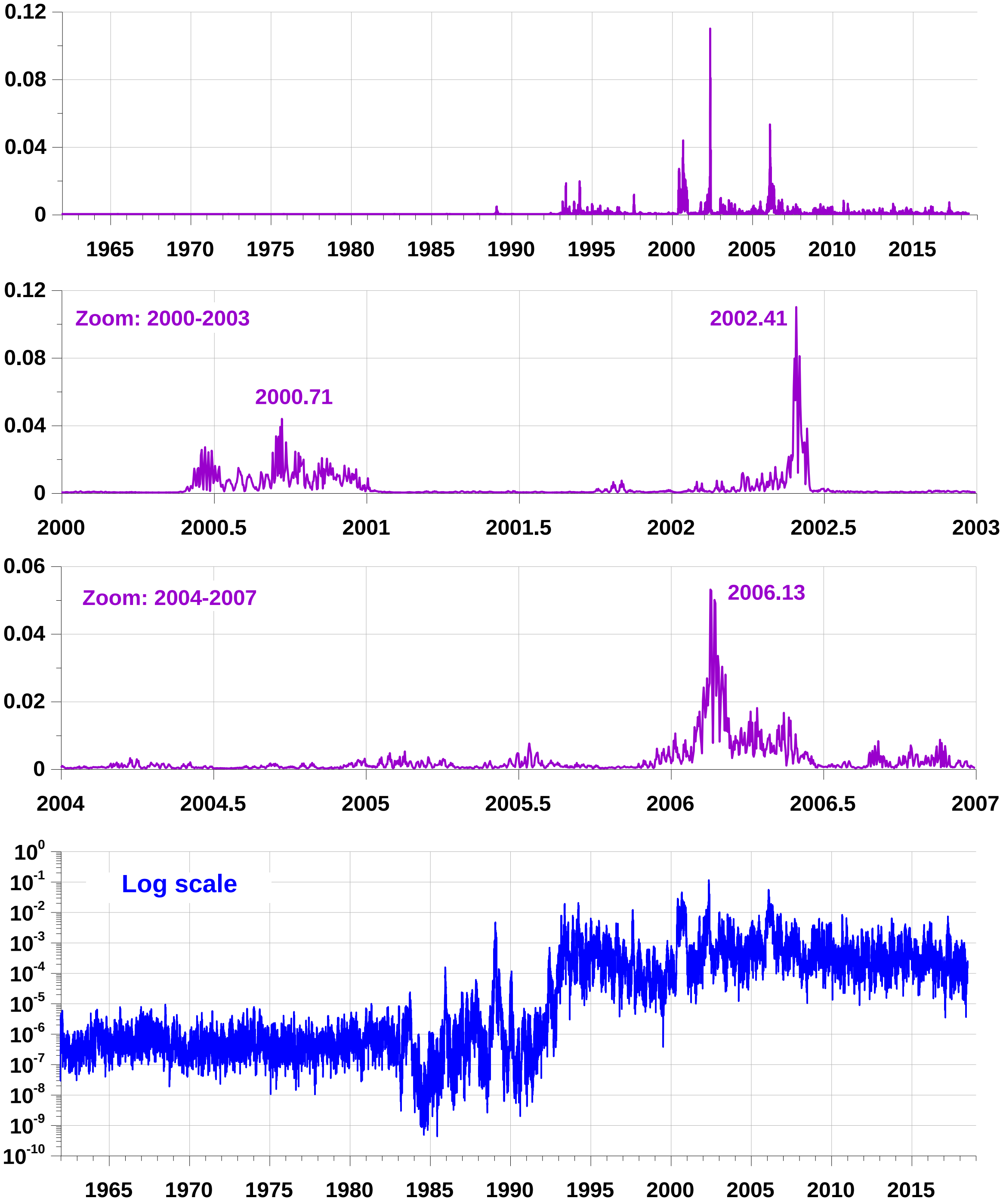
and calculate their mean difference:

$$\Delta Z^{(\alpha)}(s) = \left(Z_{\text{Left}}^{(\alpha)}(s) - Z_{\text{Right}}^{(\alpha)}(s)\right) / m_\alpha$$

A wavelet-packet-based measure of non-stationarity is defined by the formula:

$$r^2(s) = \sum_{\alpha=\alpha_0}^{\alpha_1} |\Delta Z^{(\alpha)}(s)|^2 / (\alpha_1 - \alpha_0 + 1)$$

This measure is defined for time points s satisfying condition $1 + m_{\alpha_1} \le s \le N - m_{\alpha_1}$.



Measure of high-frequency LOD non-stationarity based on wavelet-packet decomposition with splitting each detail level into 8 sub-levels.

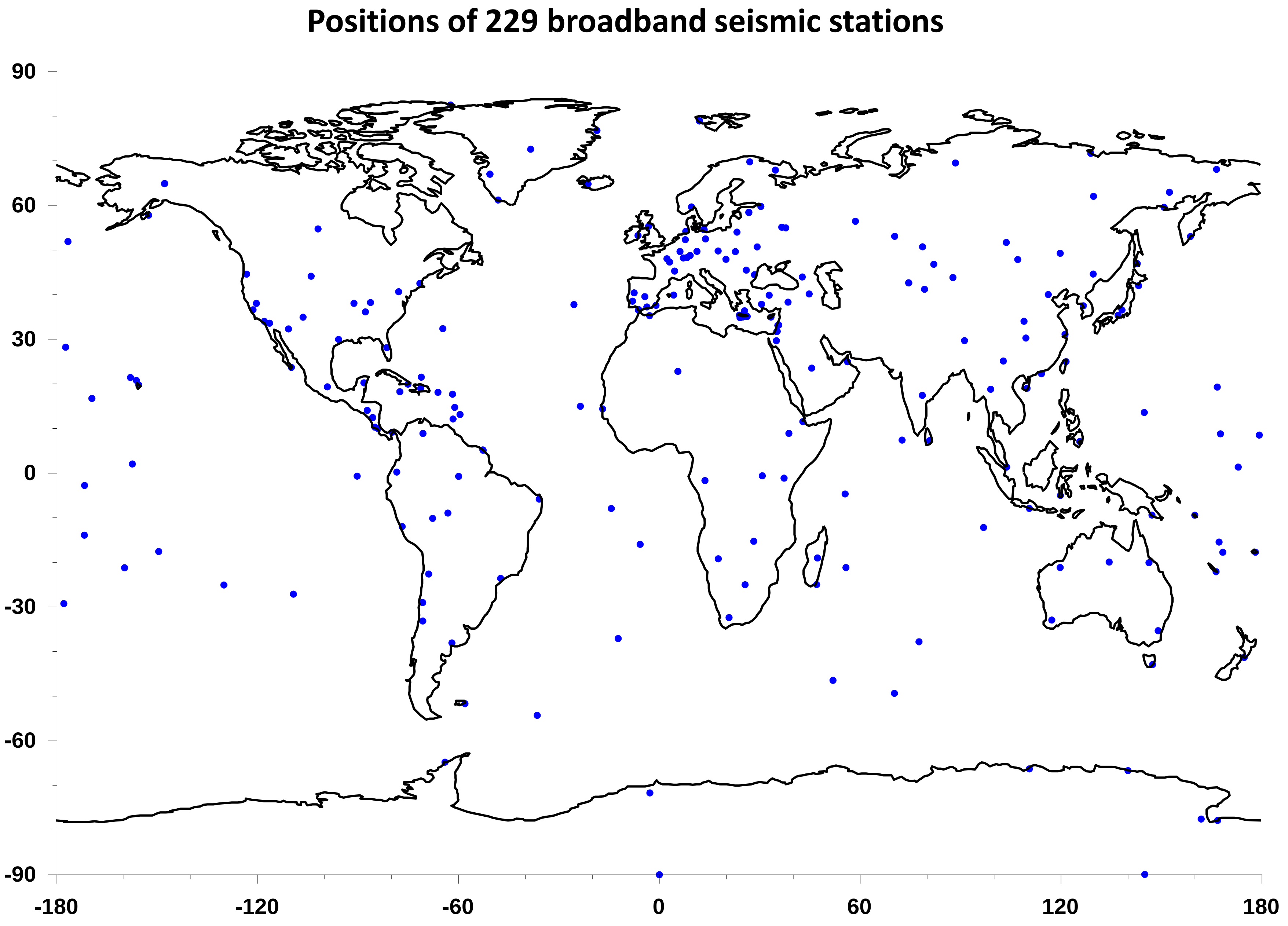
Daubechies orthogonal wavelet with 10 vanishing moments was used.

Measure was calculated for first 12 sub-levels with period range from 2 up to 5.33 days.

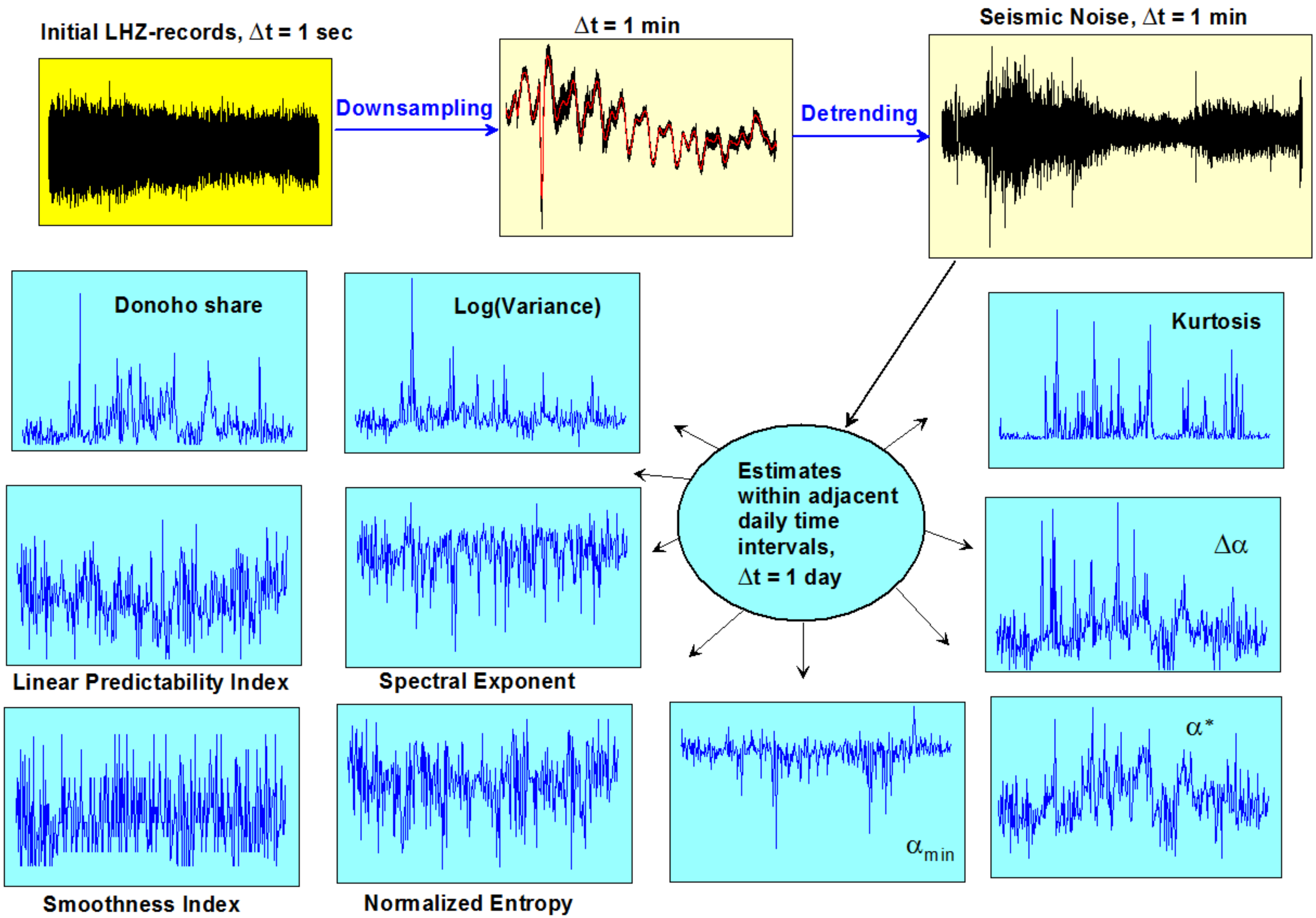
Radius of averaging vicinity = 5 days.

Series of 3 peaks of Earth's rotation irregularity is observed within time interval 2000 – 2007.

Part II. Trends of global seismic noise properties daily median values



Data transform: from seismic noise waveforms with 1 Hz sampling rate to time series with 1 day time step of the noise properties



Minimum normalized entropy of squared orthogonal wavelet coefficients distribution

$$\text{Minimum normalized entropy}:$$

$$En = -\sum_{k=1}^{N} p_k \cdot \log(p_k)/\log(N) \rightarrow \min$$

$$0 \le En \le 1, \qquad p_k = c_k^2 / \sum_{j=1}^{N} c_j^2,$$

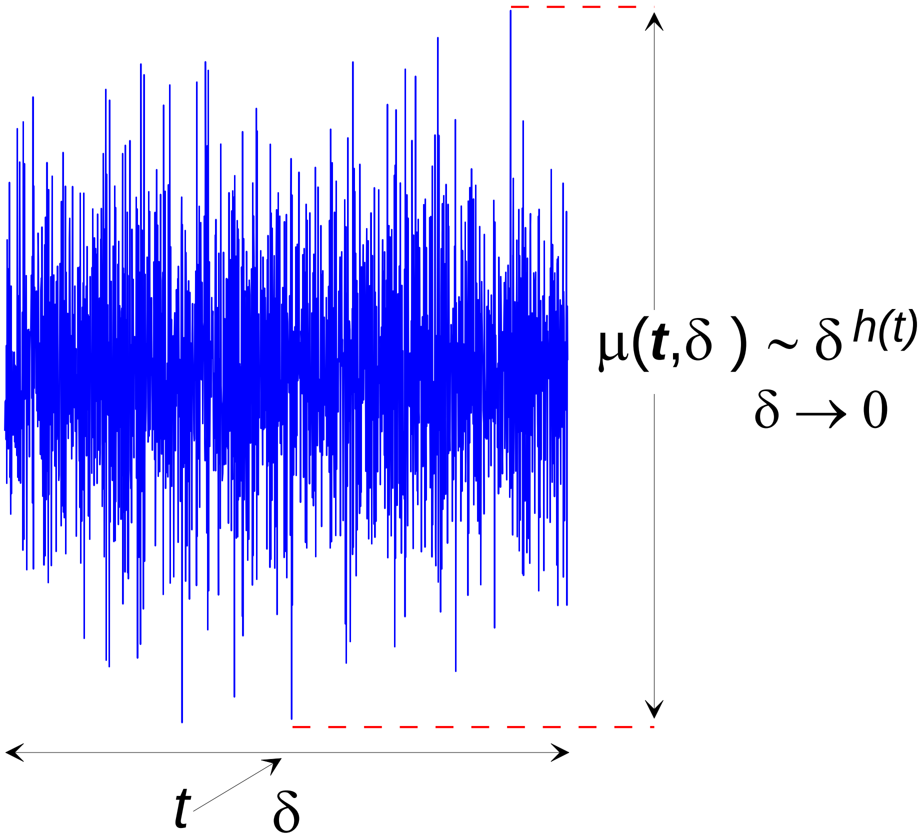
c_j - orthogonal wavelet coefficients,

minimum is taken by wavelets from Daubechies family.

Smoothness Index (*SI*) **is the number of vanishing moments for orthogonal wavelet which was found from minimum of entropy *En*.**

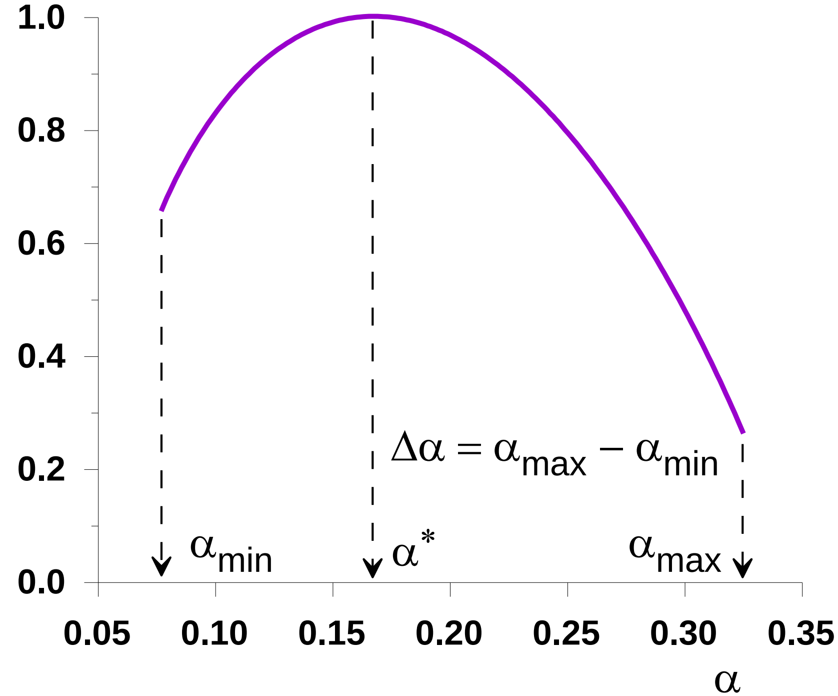
Multi-fractal singularity spectrum

Measure of the random signal variability at the time interval [$t - \delta/2$, $t + \delta/2$]



Multi-fractal singularity spectrum $F(\alpha)$ and its parameters: $\Delta\alpha$ - support width and α^* - generalized Hurst exponent.

$F(\alpha)$ - fractal dimensionality of the set of time moments t for which $h(t) = \alpha$



Index of Linear Predictability

Trivial predictor 1-step ahead by previous n samples : $\hat{x}_0(t) = \sum_{s=t-n}^{t-1} x(s)/n$

$$V_0 = \sum_{t=n+1}^{N} \varepsilon_0^2(t)/(N-n), \quad n < N \quad \text{where} \quad \varepsilon_0(t) = x(t) - \hat{x}_0(t)$$

$N = 1440$ (1 day) - "long" window; $n = 60$ (1 hour) - "short" window;

$AR(2)$ predictor 1-step ahead : $\hat{x}_{AR}(t) = a_1 x(t-1) + a_2 x(t-2) + d$

Vector of $AR(2)$ – parameters $c = (a_1, a_2, d)^T$ is defined by least squares approach by previous n samples :

$$\hat{c}(t) = A^{-1}(t) \cdot R(t), \quad A(t) = \sum_{s=t-(n-2)}^{t-1} Y(s) \cdot Y^T(s), \quad R(t) = \sum_{s=t-(n-2)}^{t-1} x(s) \cdot Y(s),$$

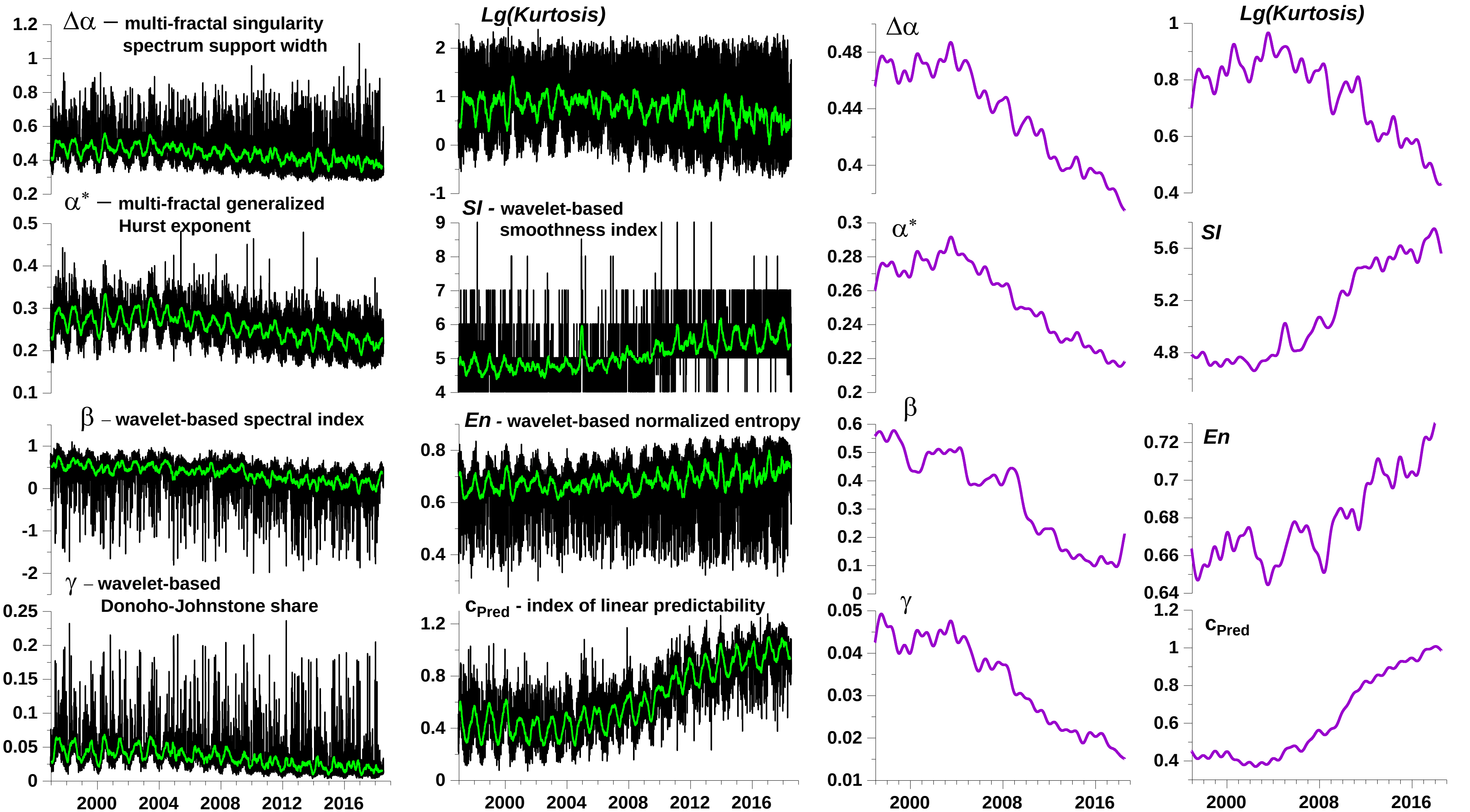
where: $Y(t) = (x(t), x(t-1), 1)^T$

$$V_{AR} = \sum_{t=n+1}^{N} \varepsilon_{AR}^2(t)/(N-n) \quad \text{where} \quad \varepsilon_{AR}(t) = x(t) - \hat{x}_{AR}(t)$$

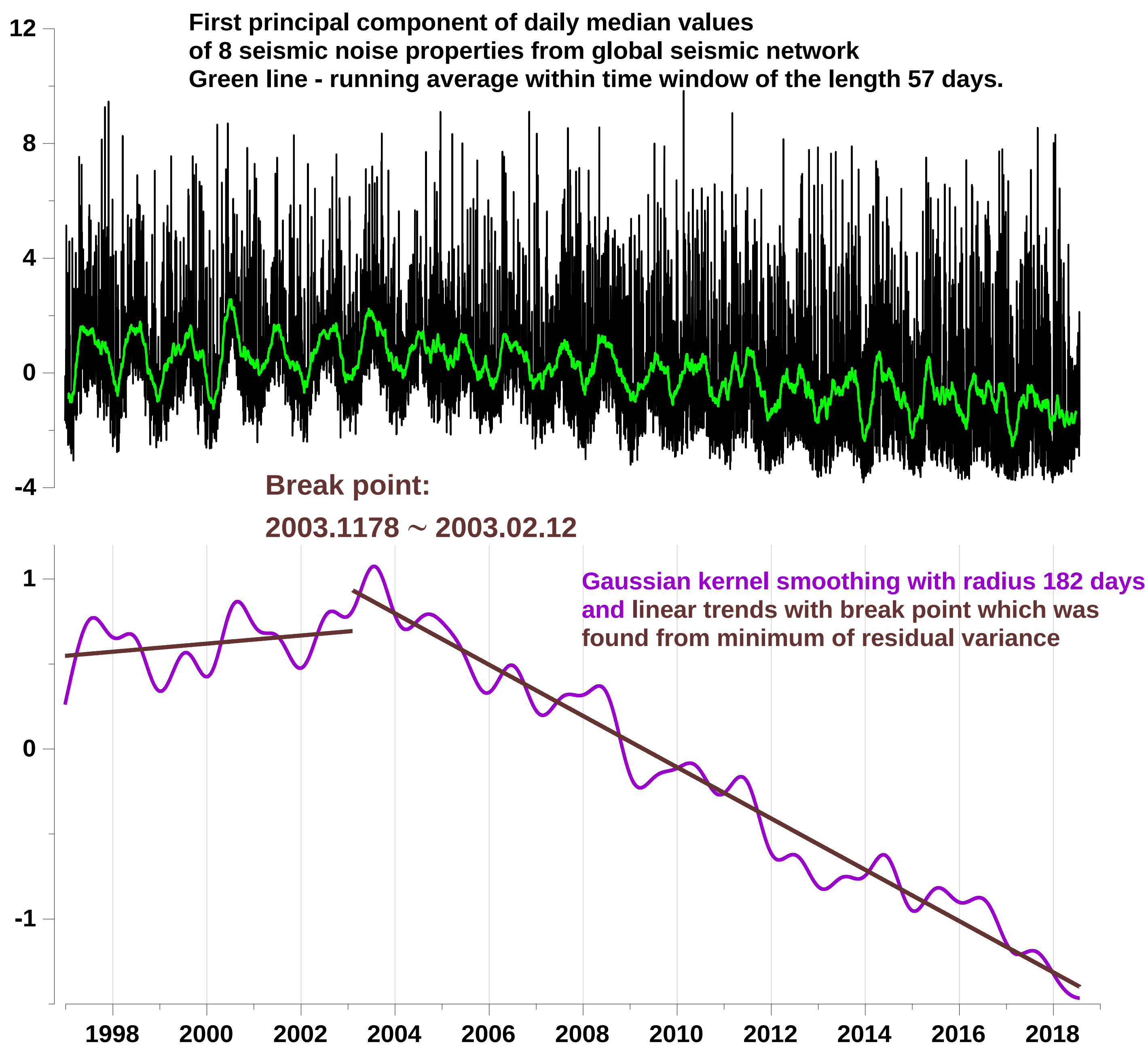
$\rho = V_0 / V_{AR} - 1;$ for linearly predicted signals $\rho > 0$.

Daily median values of 8 global seismic noise properties from all stations over the world. Green lines - running average within window of the length 57 days

Trends of 8 global seismic noise properties
Median values of seismic noise properties after smoothing by Gaussian kernel with radius 182 days

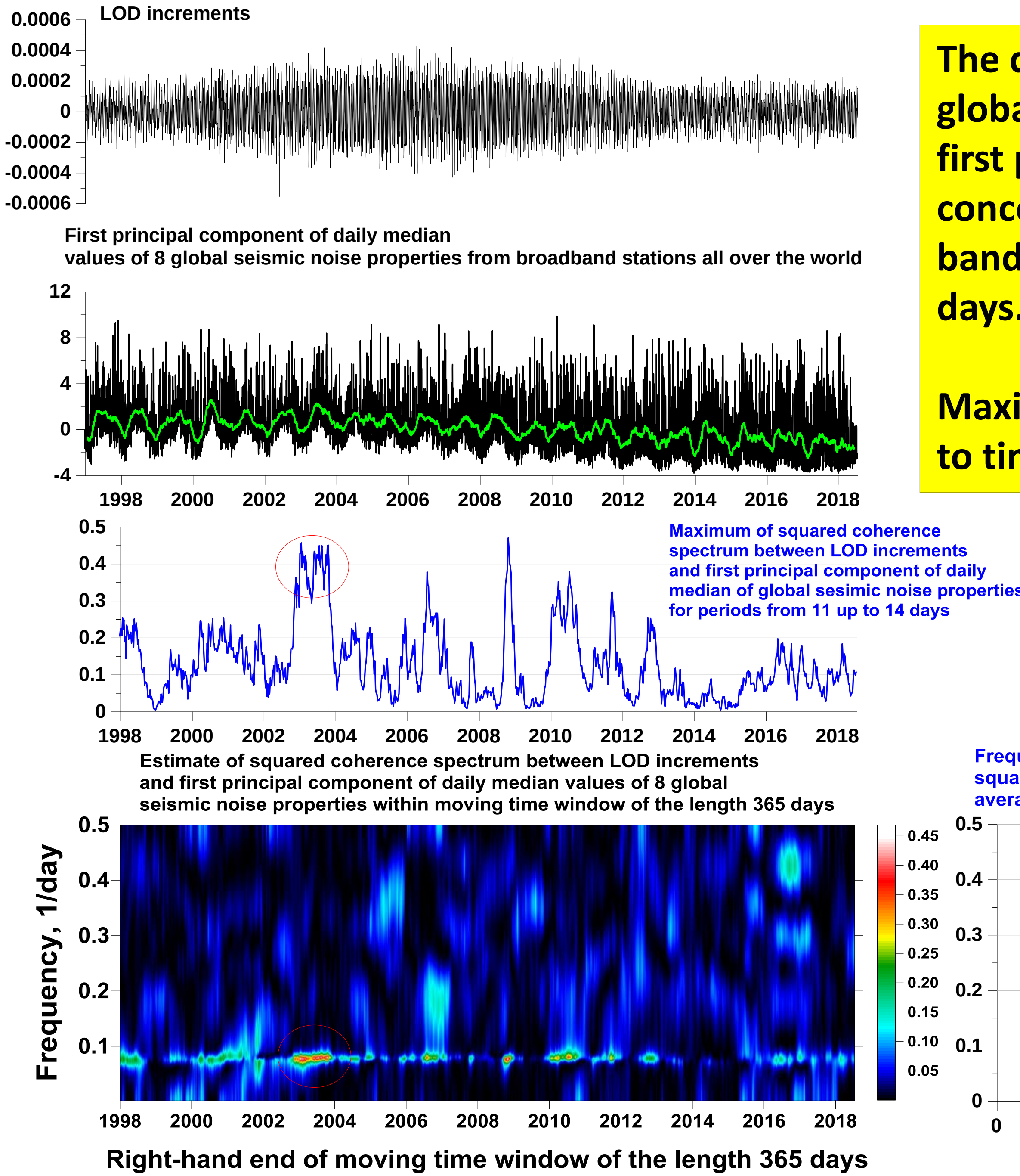


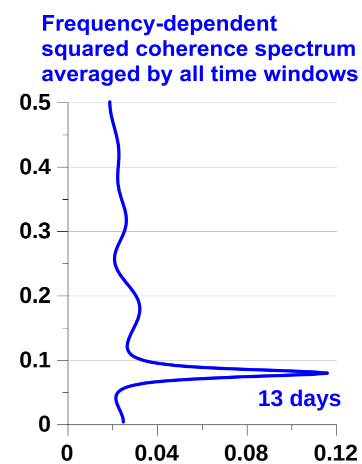
Seeking for change point of global seismic noise trends



The direct influence of the LOD on the global seismic noise properties (their first principal component) is concentrated within narrow frequency band with periods from 11 up to 14 days.

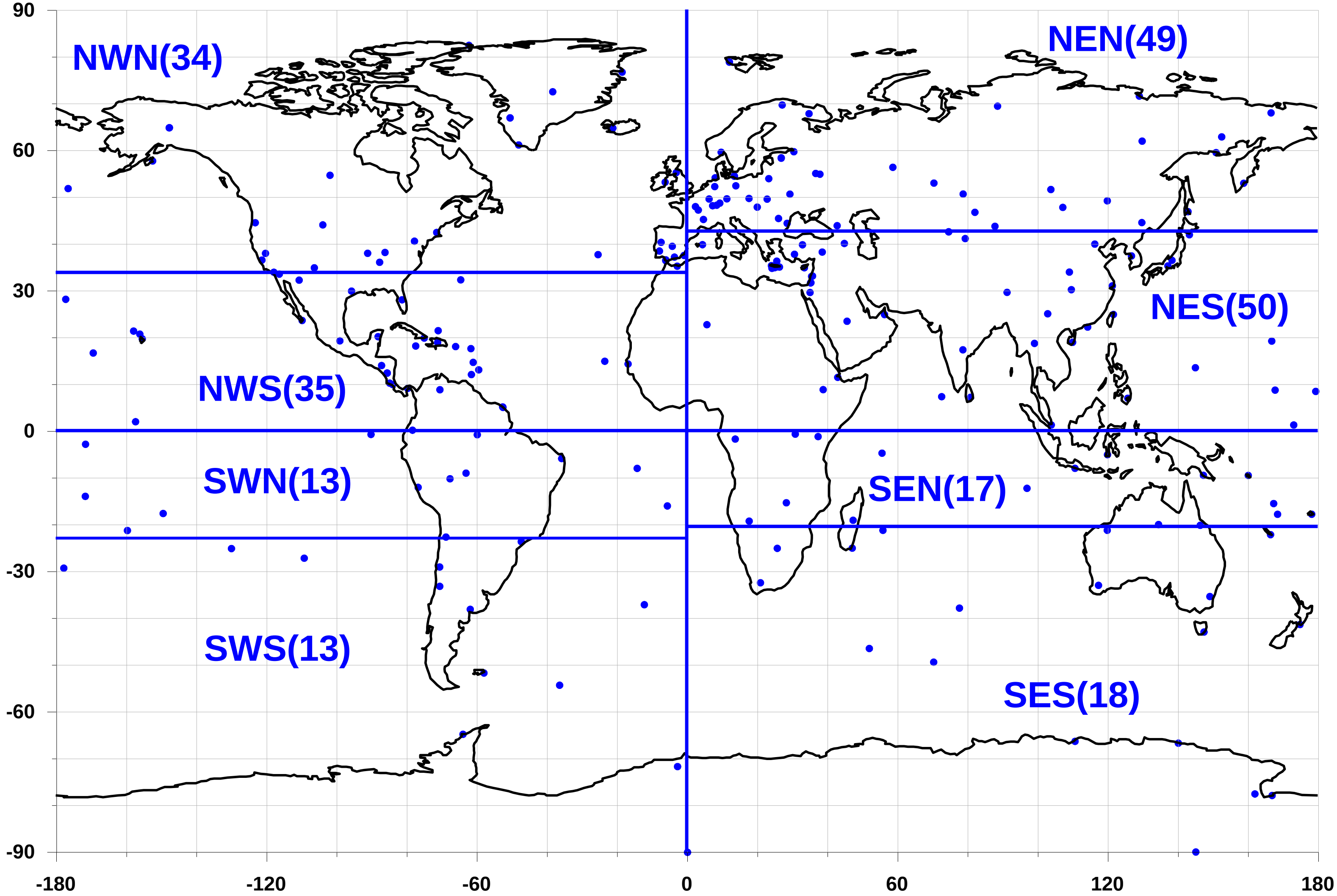
Maximum of coherence corresponds to time interval 2003-2004

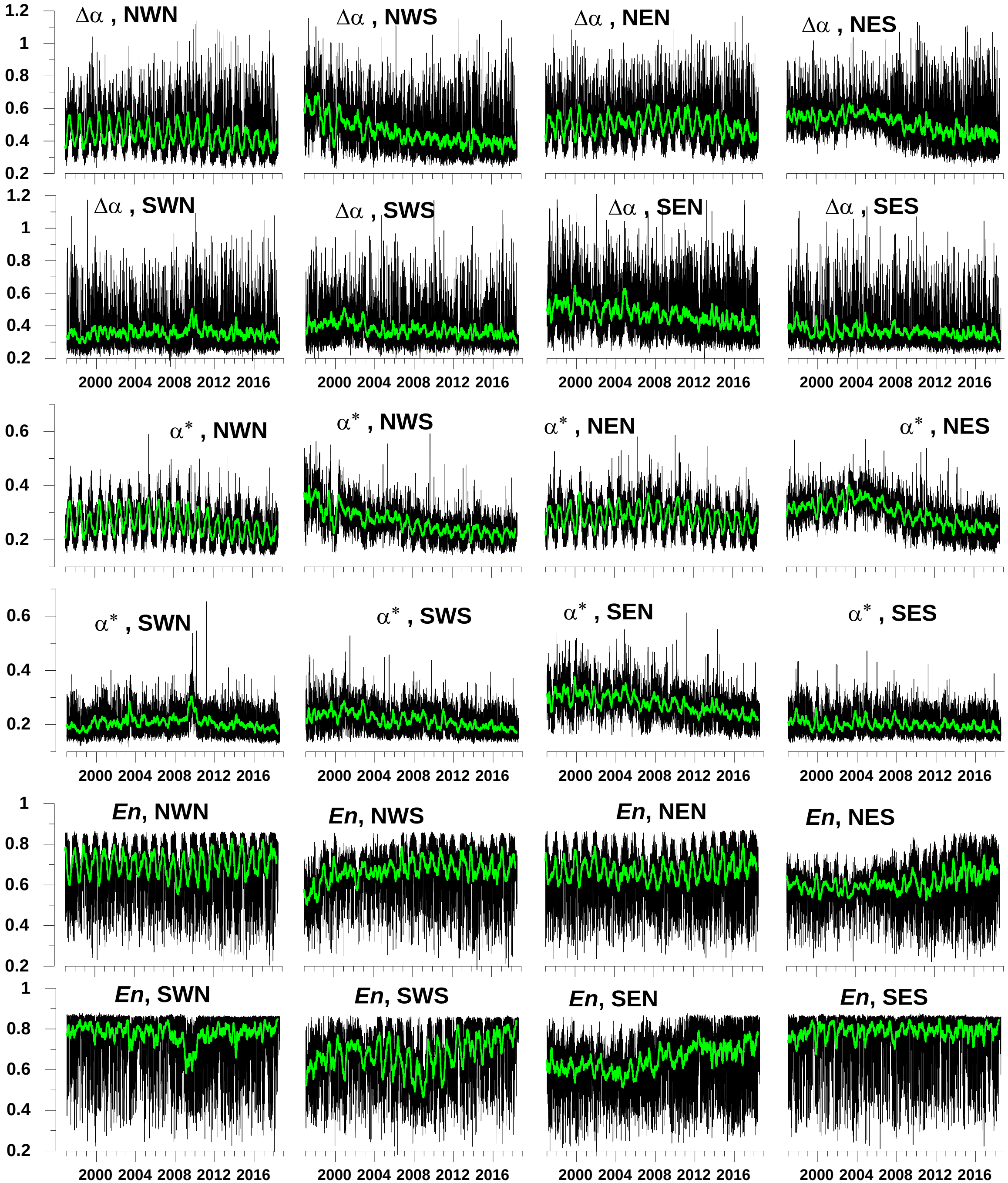




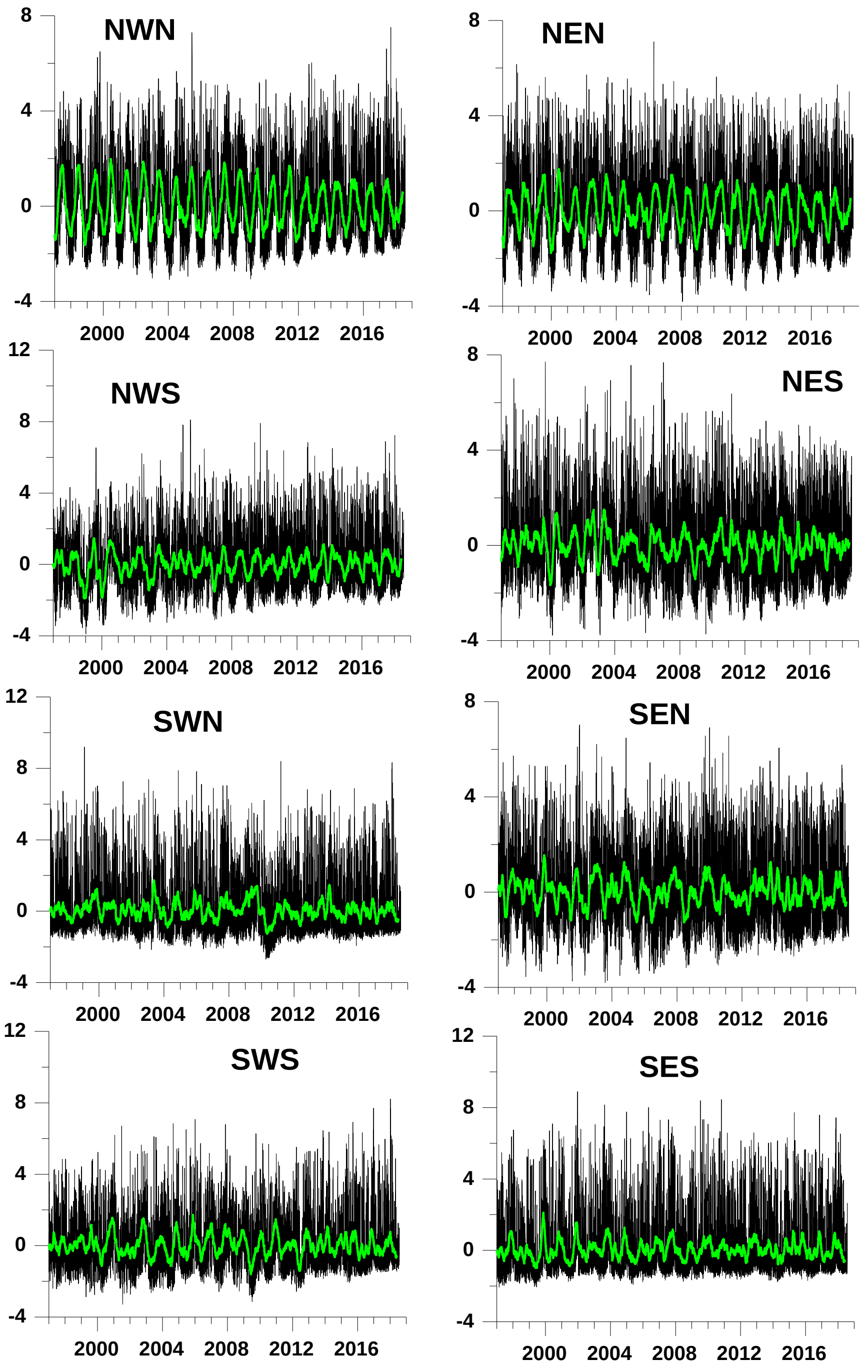
Part III. Multiple correlations and wavelet-based coherence of global seismic noise properties

Positions of 229 broadband seismic stations and their splitting into 8 parts with number of stations within each part

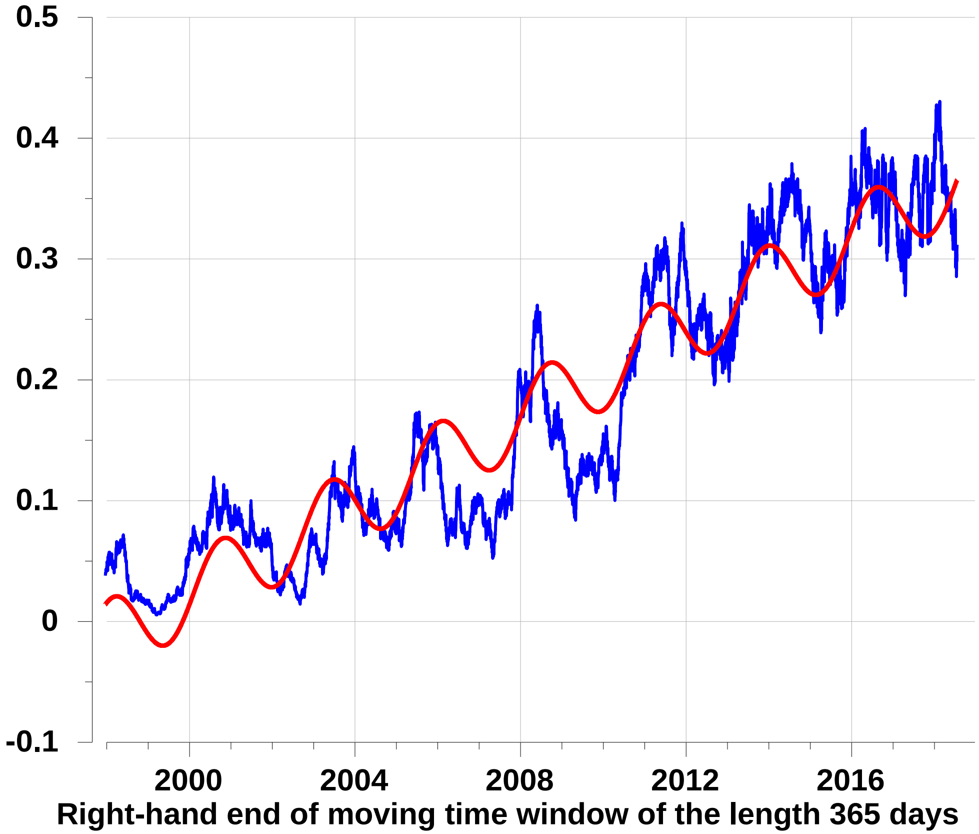




Daily median values of seismic noise multifractal singularity spectrum support width $\Delta\alpha$, generalized Hurst exponent α^* and multi-scale wavelet-based normalized entropy *En* from 8 parts of worldwide broad-band seismic network.



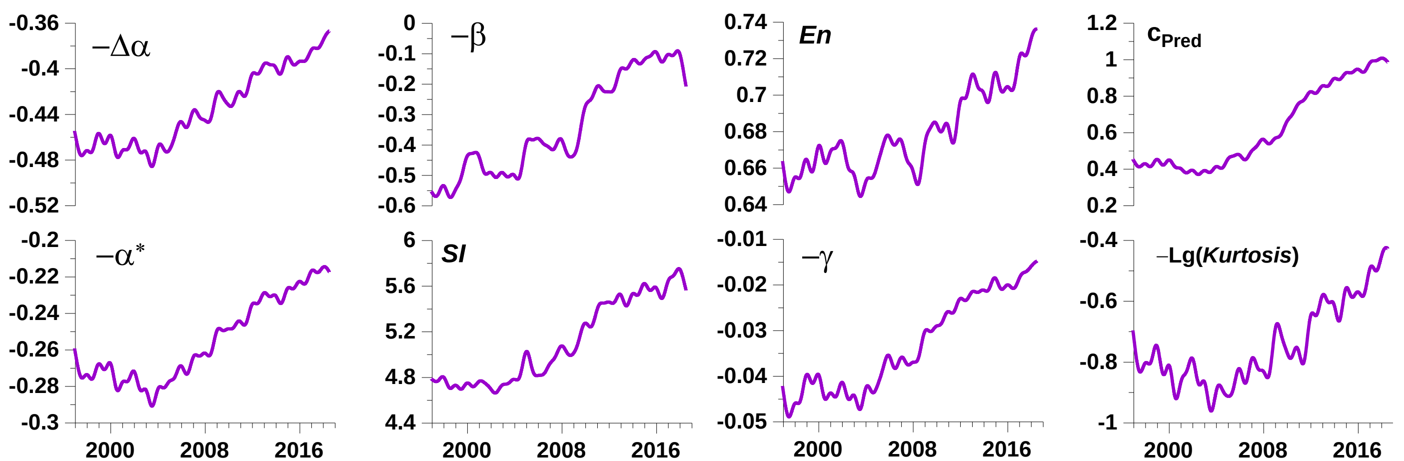
First principal components for each of 8 parts of worldwide broad-band seismic network calculated from daily median values of seismic noise multifractal singularity spectrum support width $\Delta\alpha$, generalized Hurst exponent α^* and multi-scale wavelet-based normalized entropy *En* within moving time window of the length 365 days.



Blue line - evolution of robust multiple correlation coefficient between principal components of daily median values of 3 seismic noise properties from 8 parts of global seismic network within moving time window of the length 365 days.

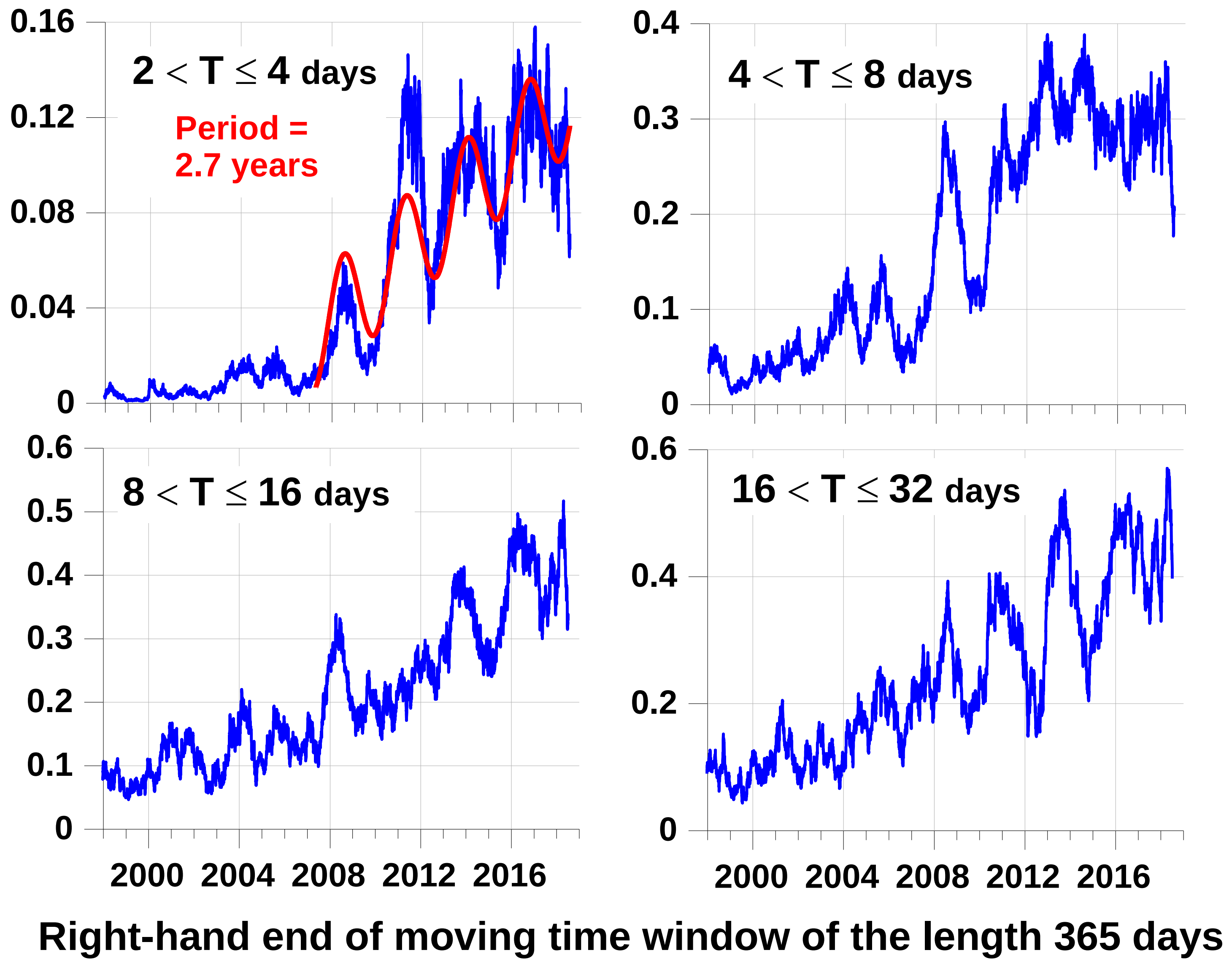
Red line - harmonic oscillation with period 960 days (~ 2.6 years) found from minimizing of residual variance.

The period 2.6 years is very close to the period 2.4 years of LOD variations.



Trends of daily median values of seismic noise properties from all stations of global network.

Wavelet-based robust coherence measures for variations of principal components of daily median values of 3 seismic noise properties from 8 parts of global seismic network within moving time window of the length 365 days for the first 4 detail levels, Haar wavelet.



Strongest earthquakes, , from the beginning of 20th century Source: https://earthquake.usgs.gov/earthquakes/search/							
Date	Magnitude	Latitude	Longitude	Date	Magnitude	Latitude	Longitude
1906.01.31	8.8	0.955	-79.369	1963.10.13	8.5	44.872	149.483
1922.11.11	8.5	-28.293	-69.852	1964.03.28	9.2	60.908	-147.339
1923.02.03	8.4	54.486	160.472	1965.02.04	8.7	51.251	178.715
1933.03.02	8.4	39.209	144.59	**2001.06.23**	8.4	-16.265	-73.641
1938.02.01	8.5	-5.045	131.614	**2004.12.26**	9.1	3.295	95.982
1946.04.01	8.6	53.492	-162.832	**2005.03.28**	8.6	2.085	97.108
1950.08.15	8.6	28.363	96.445	**2007.09.12**	8.4	-4.438	101.367
1952.11.04	9	52.623	159.779	**2010.02.27**	8.8	-36.122	-72.898
1957.03.09	8.6	51.499	-175.626	**2011.03.11**	9.1	38.297	142.373
1960.05.22	9.5	-38.143	-73.407	**2012.04.11**	8.6	2.327	93.063

Conclusion

A comparison of the anomalies of the averaged properties of seismic noise and periodicity of evolution of their multiple correlation coefficient on global broadband seismic networks allows us to propose the hypothesis that maximums of the non-stationarity (the irregularity) of the Earth's rotation is reflected in the synchronization of the properties of seismic noise and can be a trigger for the intensification of the strongest earthquakes since the end of 2004.

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