Map of Pseudo-F-statistics of seismic noise parameters as an indicator of current seismic danger in Japan

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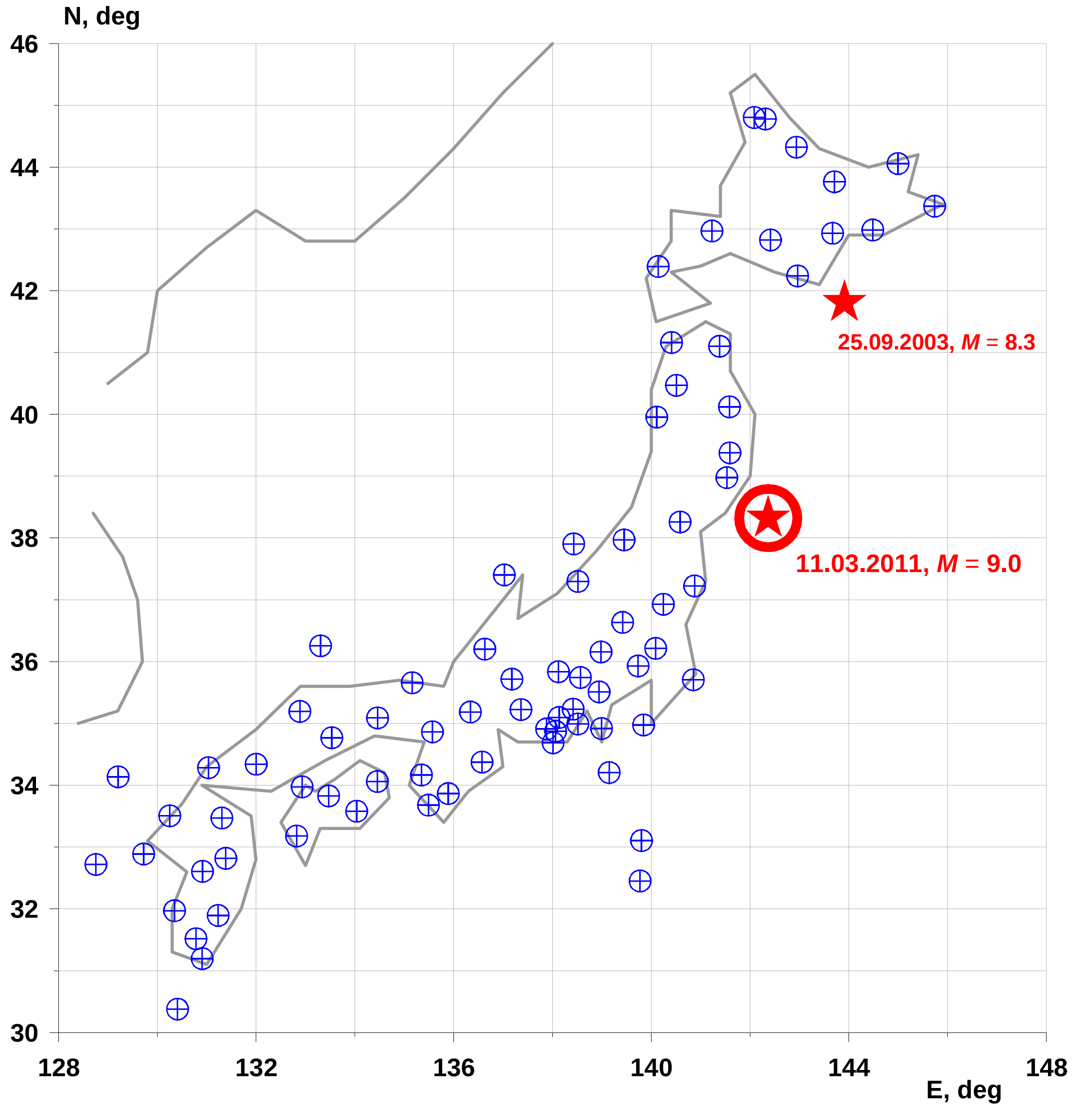
http://meetingorganizer.copernicus.org/EGU2016/EGU2016-3316.pdf

Positions of 78 seismic stations of broadband network F-net in Japan
History of registration: 1997 – 2016.



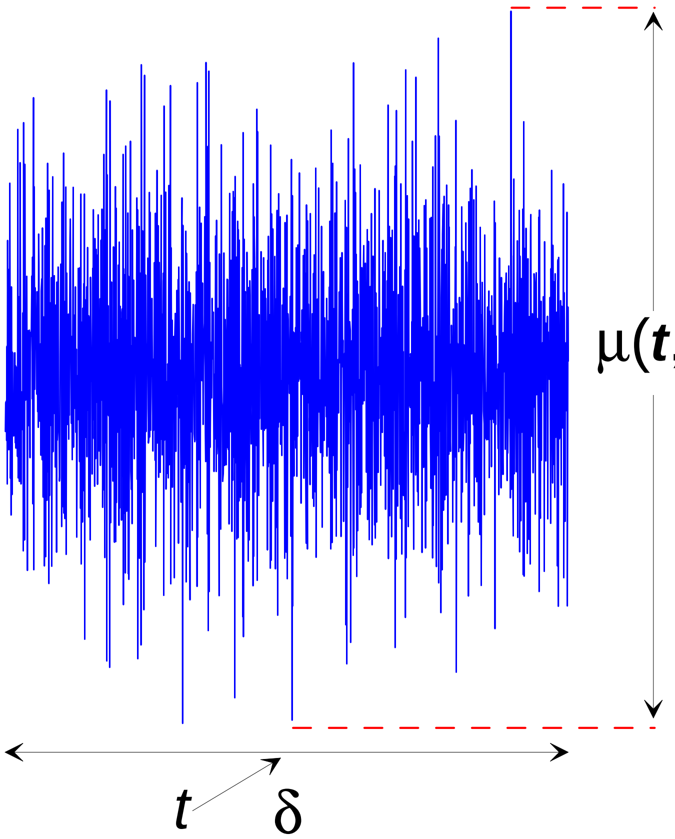
I acknowledge to seismic noise data source:

Broadband Seismic Network Laboratory,
Earthquake and Volcano Data Center,
Earthquake and Volcano Research Unit,
Monitoring and Forecast Research Department,
National Research Institute for Earth Science
and Disaster Prevention.
3-1 Tennodai, Tsukuba City, Ibaraki Prefecture,
305-0006, JAPAN

http://www.fnet.bosai.go.jp/top.php

Multi-fractal singularity spectrum

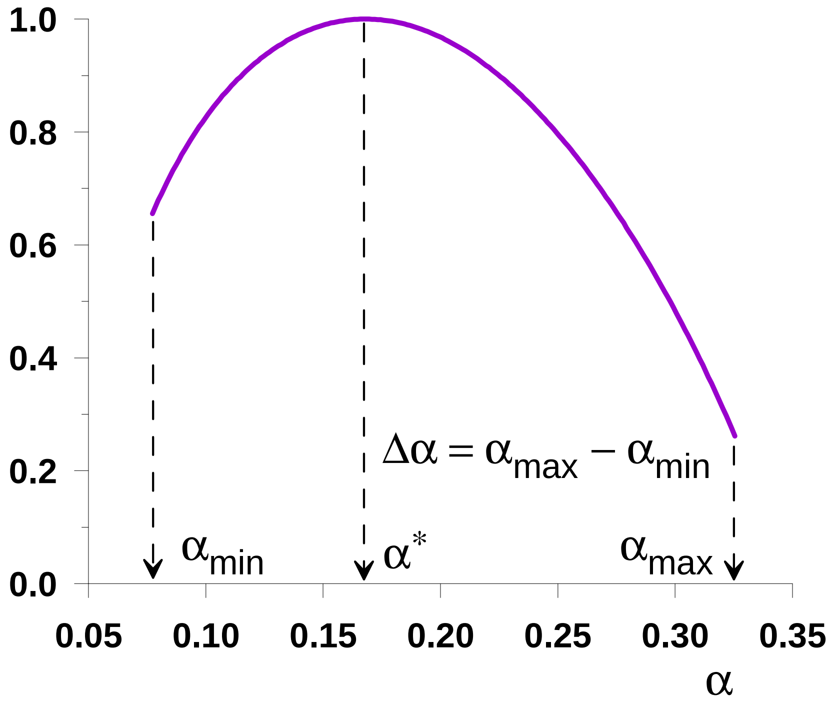
Measure of the random signal variability at the time interval [$t - \delta/2, t + \delta/2$]



$$\mu(t,\delta) \sim \delta^{h(t)}, \quad \delta \to 0$$

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 $h(t) = \alpha$



Minimum normalized entropy of squared orthogonal wavelet coefficients distribution

Minimum normalized entropy:

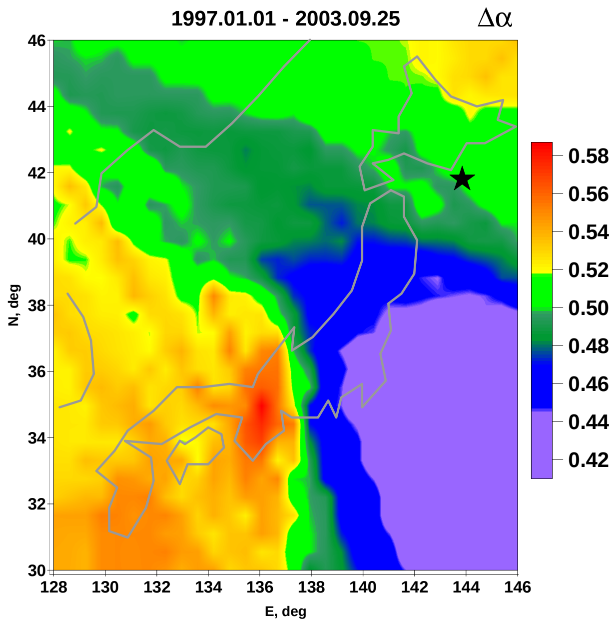
$$En = -\sum_{k=1}^{N} p_k \cdot \log(p_k) / \log(N) \;\rightarrow\; \min$$

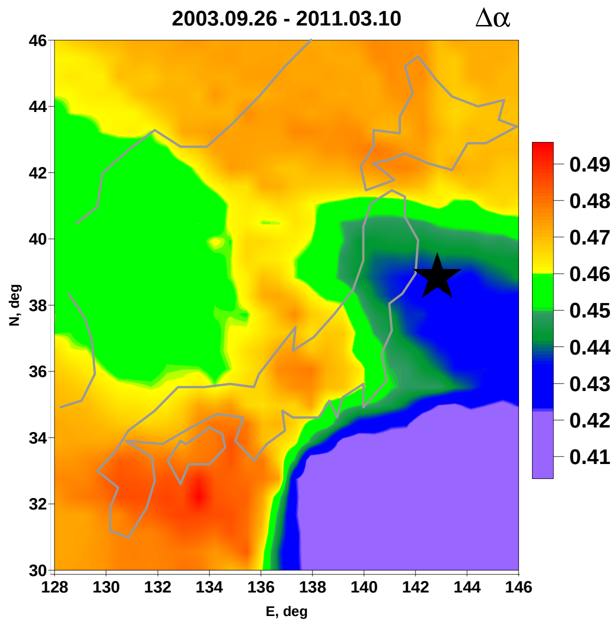
$$0 \le En \le 1, \qquad p_k = c_k^2 / \sum_{j=1}^{N} c_j^2,$$

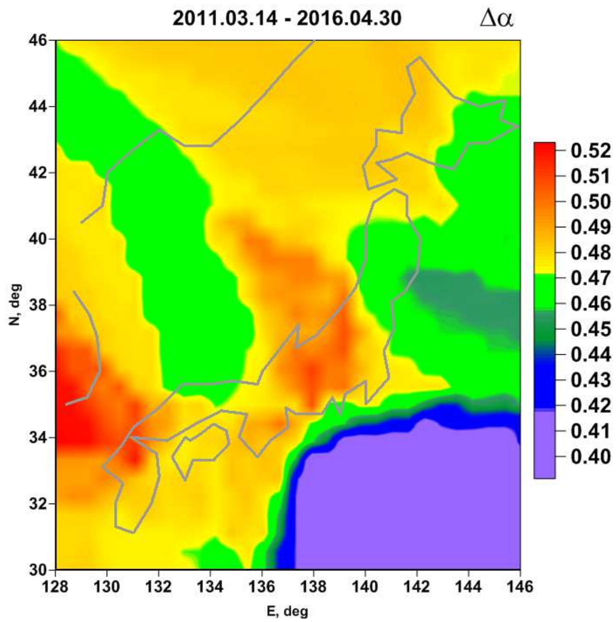
c_j - orthogonal wavelet coefficients,

minimum is taken by wavelets from Daubechies family.

Maps of multi-fractal singularity spectra support width $\Delta\alpha$.
Low $\Delta\alpha$ values ("blue and violet regions") indicate synchronization and danger.







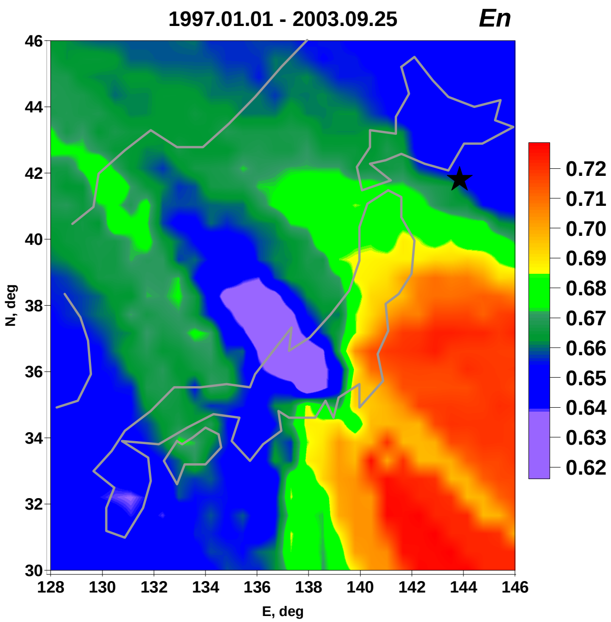
From the beginning of 1997 up to 25 of Sept 2003: the area of future seismic catastrophe is characterized by relatively low $\Delta\alpha$ and it is not split into North and South parts.

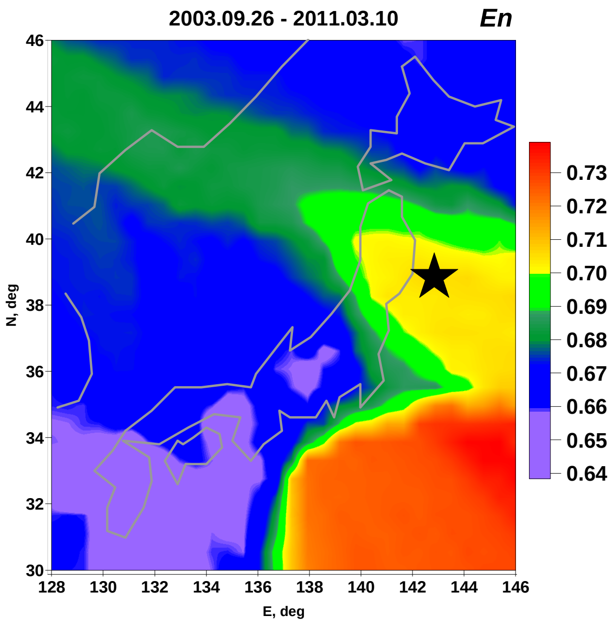
From 26 of Sept 2003 up to 10 of March 2011: the area of future seismic catastrophe is characterized by relatively low $\Delta\alpha$ and the previous area of low $\Delta\alpha$ values is split into North and South parts.

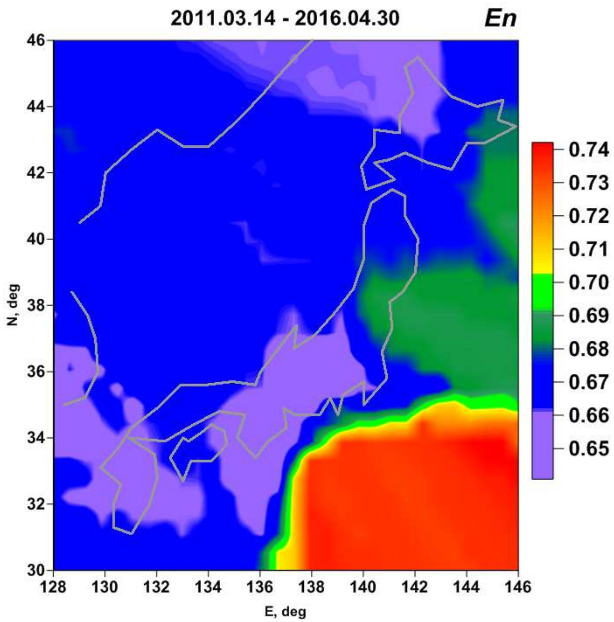
From 14 of March 2011 up to 30 of April 2016: the North part of the relatively low $\Delta\alpha$ values before 25.09.2003 was realized as the area of Great Japan Earthquake 11 of March 2011, M=9.0, whereas the South part is still characterized by low $\Delta\alpha$ values.

Details: Lyubushin, A. (2012) Prognostic properties of low-frequency seismic noise. Natural Science, 4, 659-666. doi: 10.4236/ns.2012.428087. http://www.scirp.org/journal/PaperInformation.aspx?paperID=21656

Maps of low-frequency seismic noise <u>wavelet-based normalized entropy</u>, i.e. normalized entropy of the noise waveforms squared wavelet coefficients for the “best” orthogonal wavelet which is found for each station within each daily time window from the minimum of entropy.





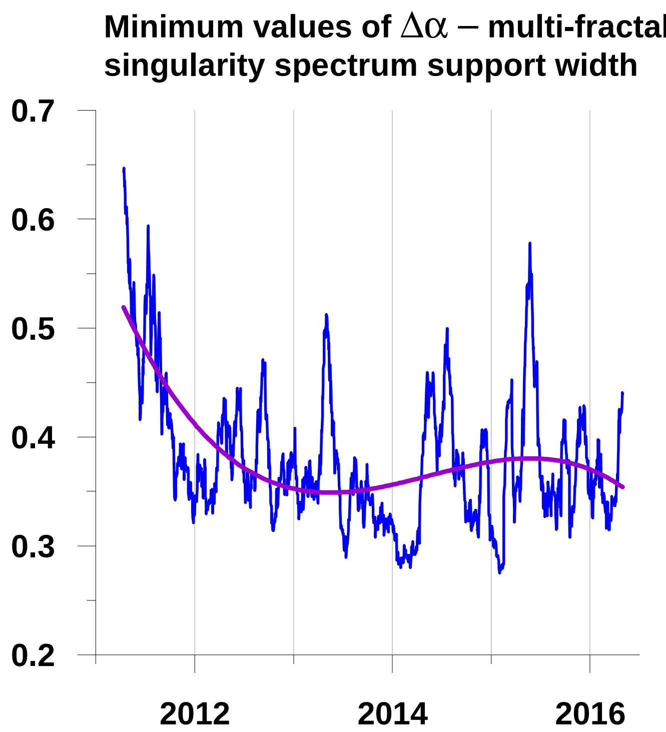


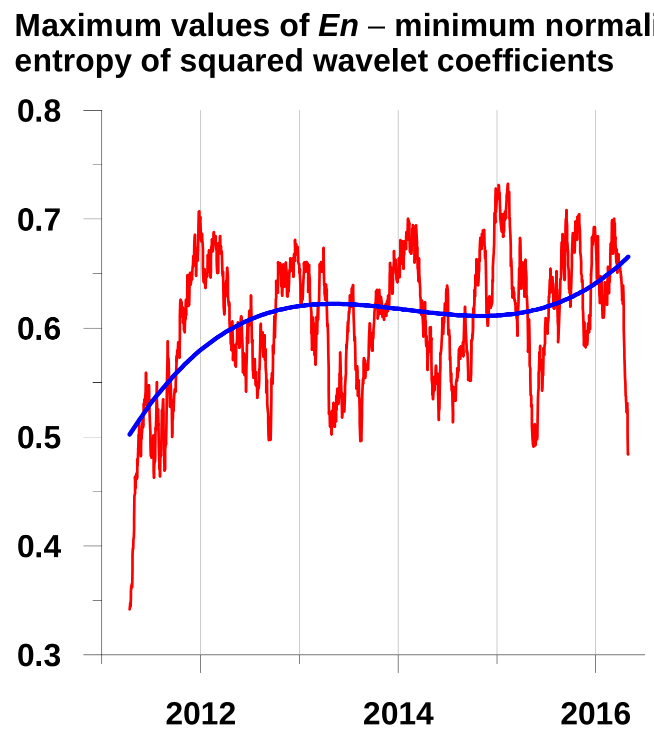
From the beginning of 1997 up to 25 of Sept 2003: the area of future seismic catastrophe is characterized by relatively high values of normalized entropy and it is not split into North and South parts.

From 26 of Sept 2003 up to 10 of March 2011: the area of future seismic catastrophe is characterized by relatively high values of normalized entropy and the previous area of high entropy values is split into North and South parts.

From 14 of March 2011 up to 30 of April 2016: the North part of the relatively high values of normalized entropy before 25.09.2003 was realized as the area of Great Japan Earthquake 11 of March 2011, M=9.0, whereas the South part is still characterized by high entropy values.

Natural fluctuations of seismic danger in Japan after March 11, 2011, according to low-frequency seismic noise properties, estimates within moving time window of the length 30 days





Minimum values of Δα indicate dangerous time intervals

Maximum values of *En* indicate dangerous time intervals

Correlation = –0.82

Clustering of seismic noise daily median parameters

Let $\xi = (\Delta\alpha, \alpha^*, \alpha_{\min}, En)$ be median of microseism statistics which are computed each day using information from all stations;

ξ_t $-4D$ vector in the current 1 years time window, $t = 1,\dots,N = 365$ days

$<\xi_k> = \sum_{t=1}^{N} \xi_{t,k} / N, \quad s_k^2 = \sum_{t=1}^{N} (\xi_{t,k} - <\xi_k>)^2 / (N-1)$ – mean values and st.dev.

Normalization (+ winsorization) of each component of ξ_t within each 1-years window :

$\zeta_{t,k} = (\xi_{t,k} - <\xi_k>) / s_k, \; k = 1,\dots,4.$ Transition from $4D$ vectors ζ_t to $3D$ vectors η_t of first principal components by projection of vectors ζ_t to the cov.matrix eigenvectors

$\Gamma_r, r = 1,\dots,q$ – splitting of N vectors η_t within 1-years windows to q clusters; $2 \le q \le 40$

$z_0 = \sum_{t=1}^{N} \eta_t / N$ – mean vector of the whole 1-years cloud of the principal components;

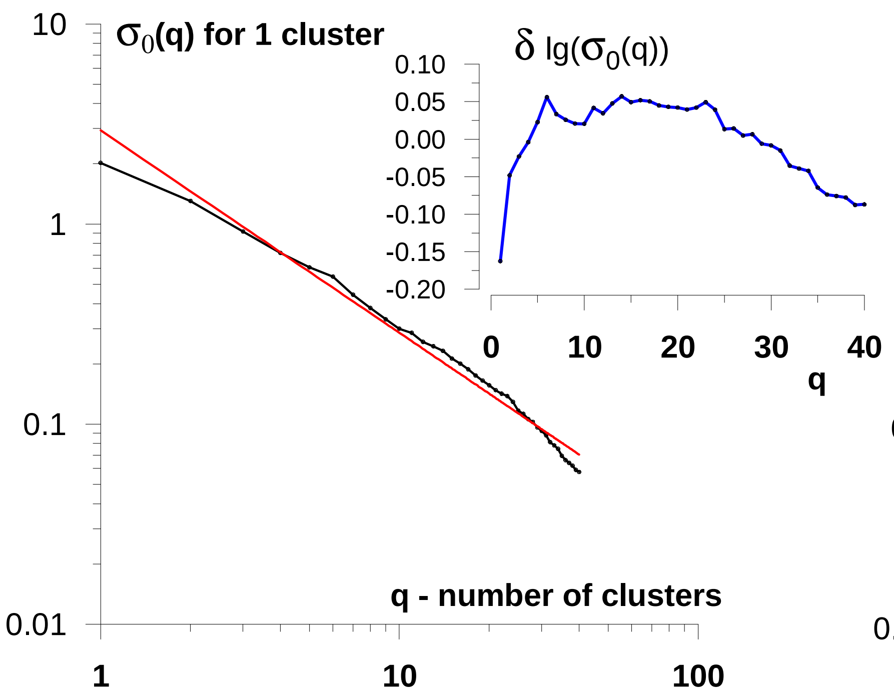
$z_r = \sum_{\eta_t \in \Gamma_r} \eta_t / n_r$ – mean vector of the cluster Γ_r; $\sum_{r=1}^{q} n_r = N$

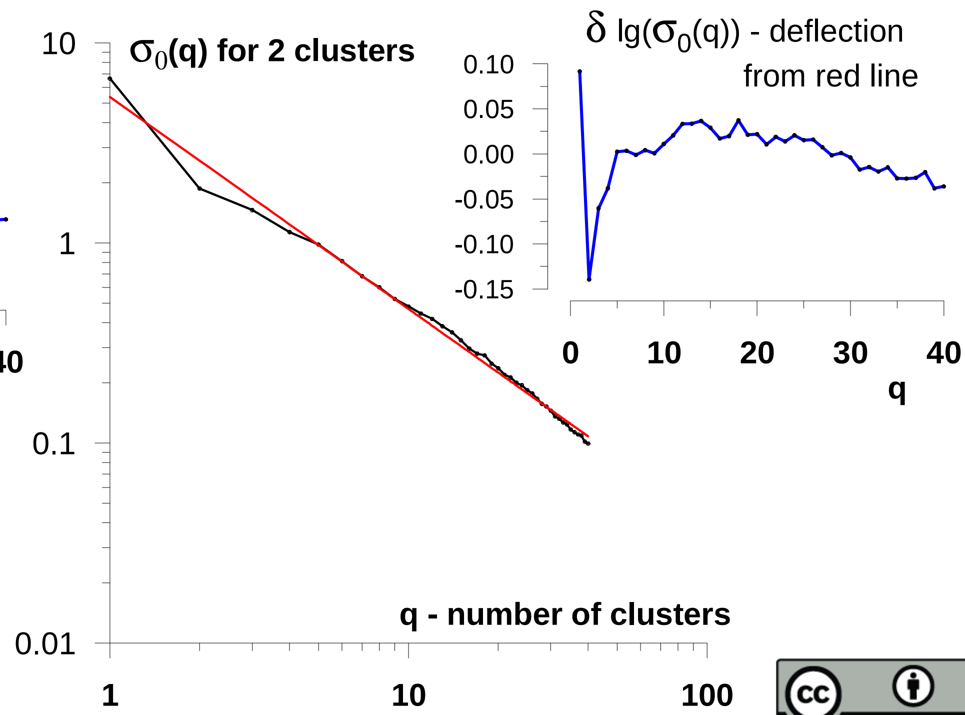
$$PFS(q) = \frac{\sigma_1^2}{\sigma_0^2}, \quad \sigma_0^2(q) = \frac{\sum_{r=1}^{q} \sum_{\eta_t \in \Gamma_r} |\eta_t - z_r|^2}{N-q}, \quad \sigma_1^2(q) = \frac{\sum_{r=1}^{q} \nu_r \cdot |z_r - z_0|^2}{q-1}, \quad \nu_r = \frac{n_r}{N}$$

Cases of 1 or 2 clusters are distinguished by the existence of break point of the dependence $\sigma_0(q)$ at q=2.

$$\text{Let } q_0 = \arg\max_{2 \le q \le 40} PFS(q); \quad \text{if } q_0 > 2 \text{ then } q^* = q_0$$

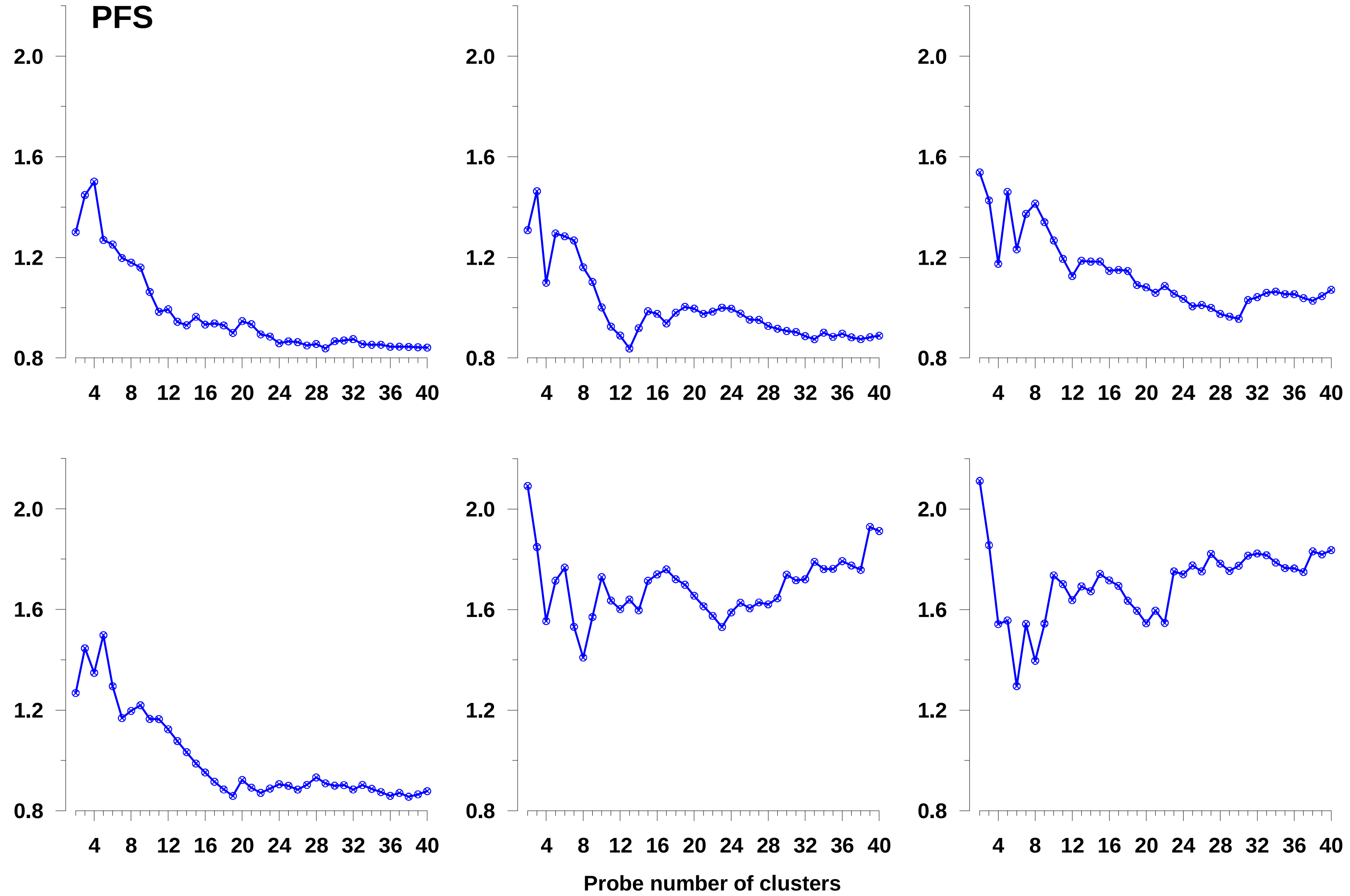
$$\text{else if } \frac{\delta \log(\sigma_0^2(1))}{\max\limits_{2 \le q \le 40} \delta \log(\sigma_0^2(q))} \le 1 \text{ then } q^* = 1 \text{ else } q^* = 2$$

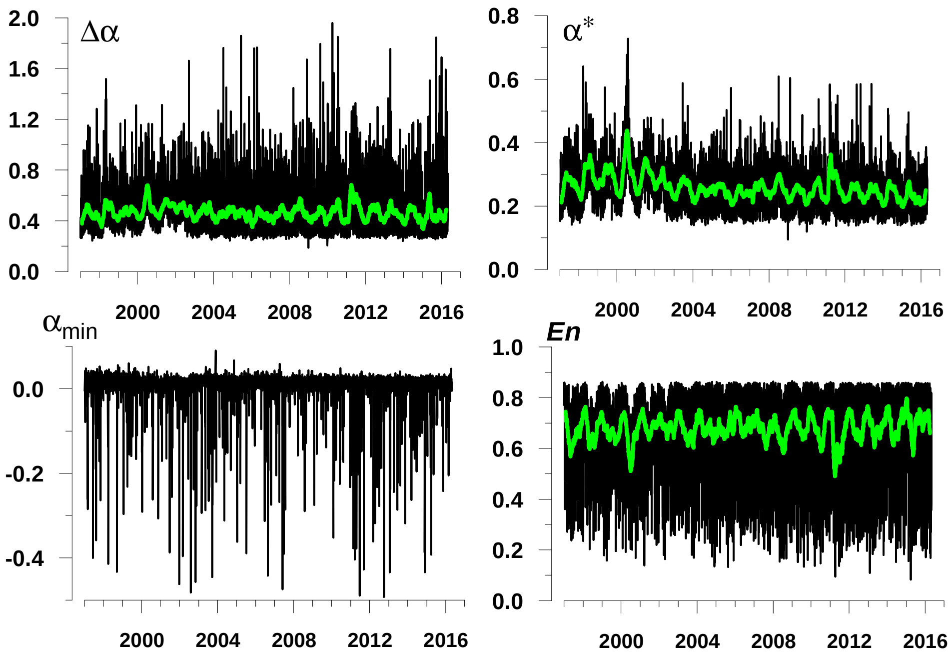




Examples of pseudo-F-statistics within different time windows of the length 365 days in dependence on probe number of clusters from 2 up to 40

Details of calculating pseudo-F values:
Lyubushin, A. (2013) How soon would the next mega-earthquake occur in Japan? Natural Science, Vol.5, No.8A1, 1-7. doi: 10.4236/ns.2013.58A1001. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=35770

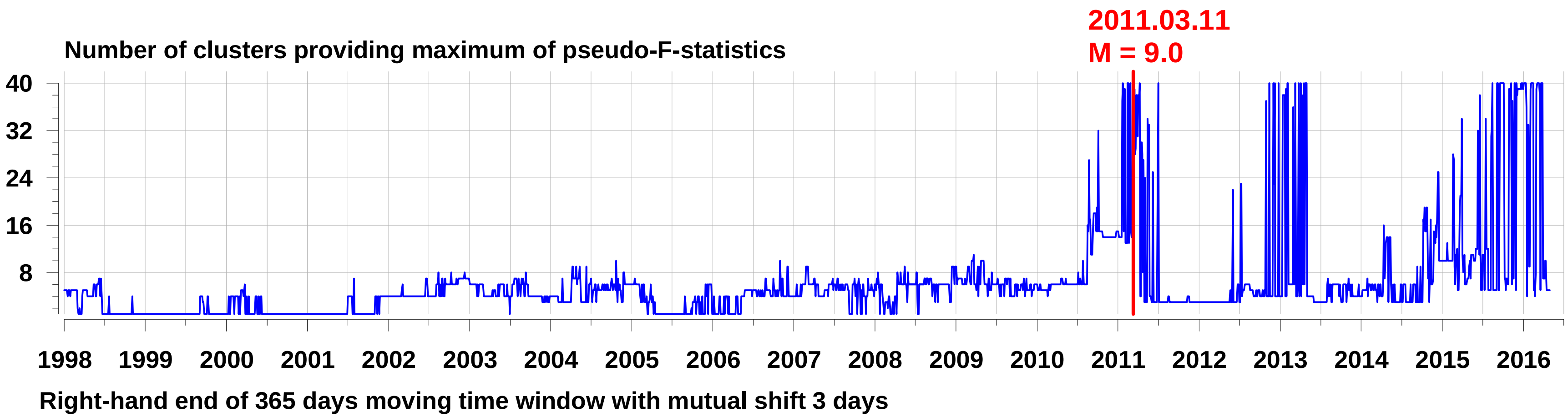




1997 – 30 April 2016

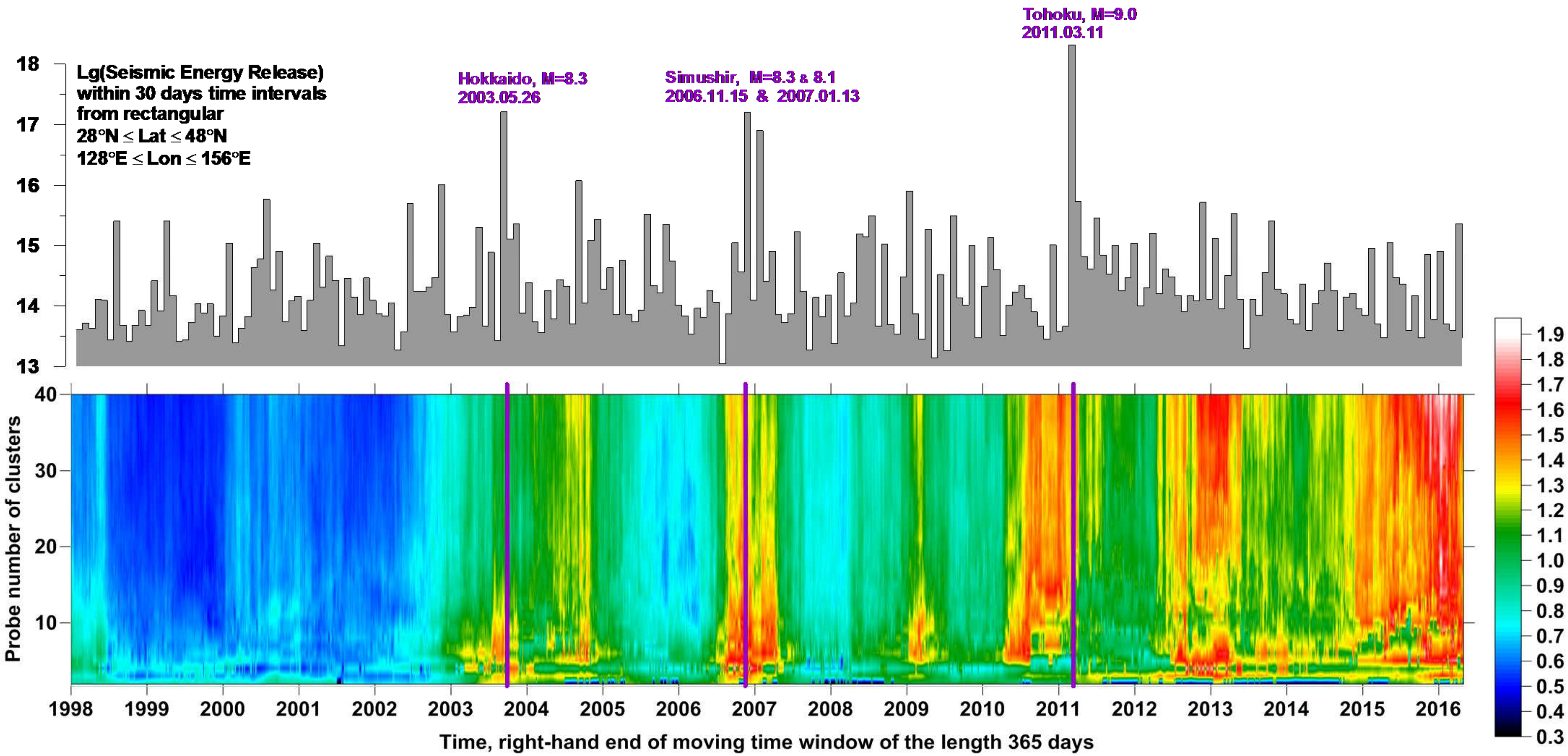
Median values of 4 daily parameters of seismic noise from Japan broadband seismic network F-net:
$\Delta\alpha$, α^*, α_{min} - multifractal singularity spectra parameters;
***En* - minimum normalized entropy of squared wavelet-coeffcients**
Green lines - running average within 57 days moving time window.

Clusterization of 3 first principal components of medians of 4 daily seismic noise parameters within moving windows of the length 365 days with mutual shift 3 days.
Preliminary normalization & winsorization $\pm 4\sigma$ within each window.



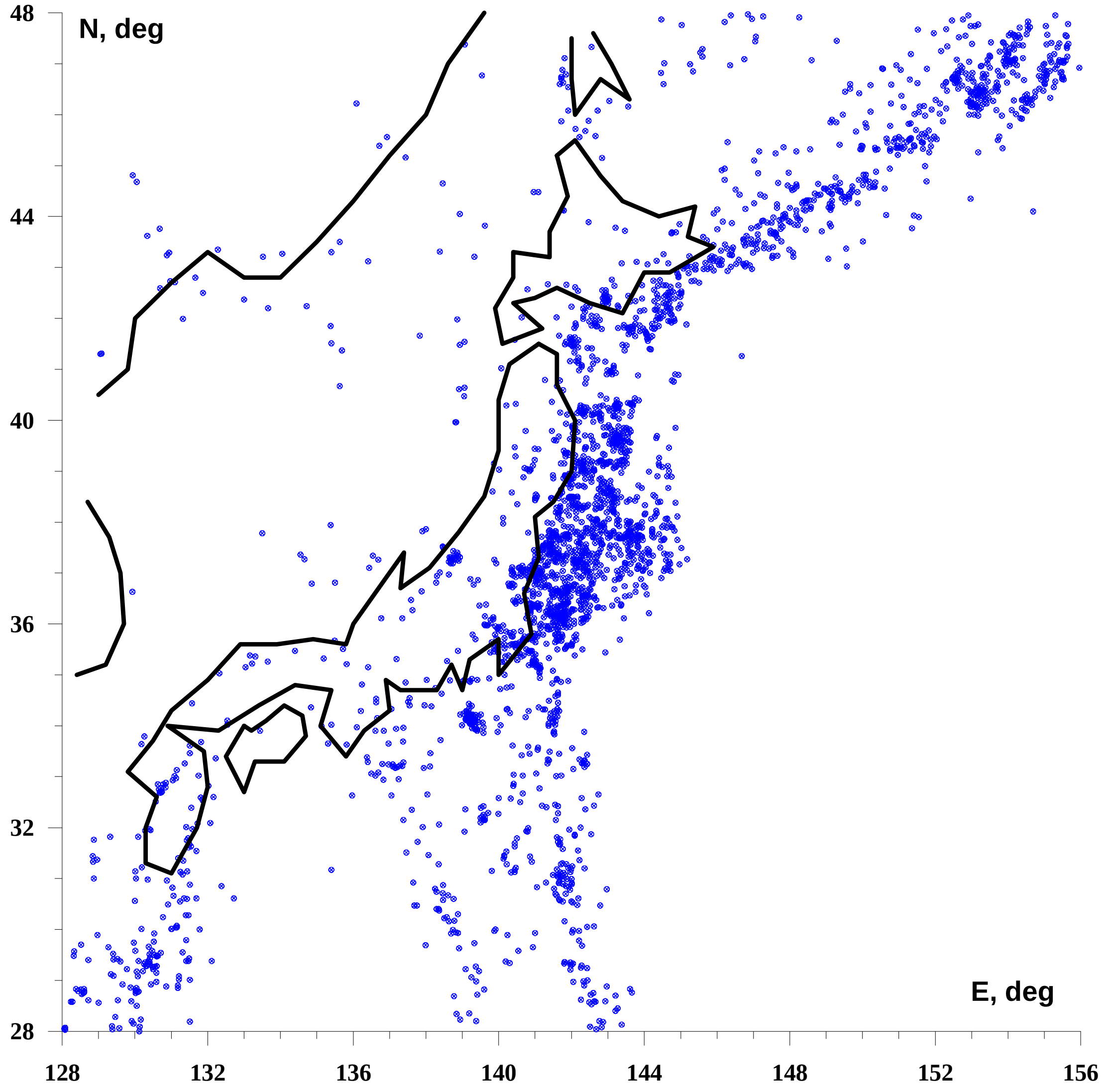
Pseudo-F-statistics map as an estimate of current seismic danger

Clustering of principal components of median values of 4 parameters of daily seismic noise waveforms: minimum normalized entropy of squared orthogonal wavelet coefficients, minimum Holder-Lipschitz exponent, singularity spectrum support width and generalized Hurst exponent within moving time window of the length 365 days with mutual shift 3 days.

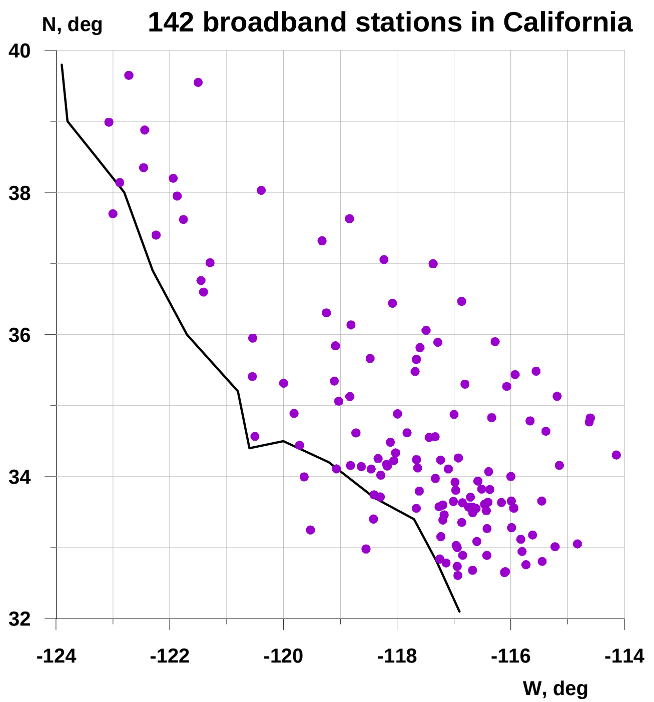


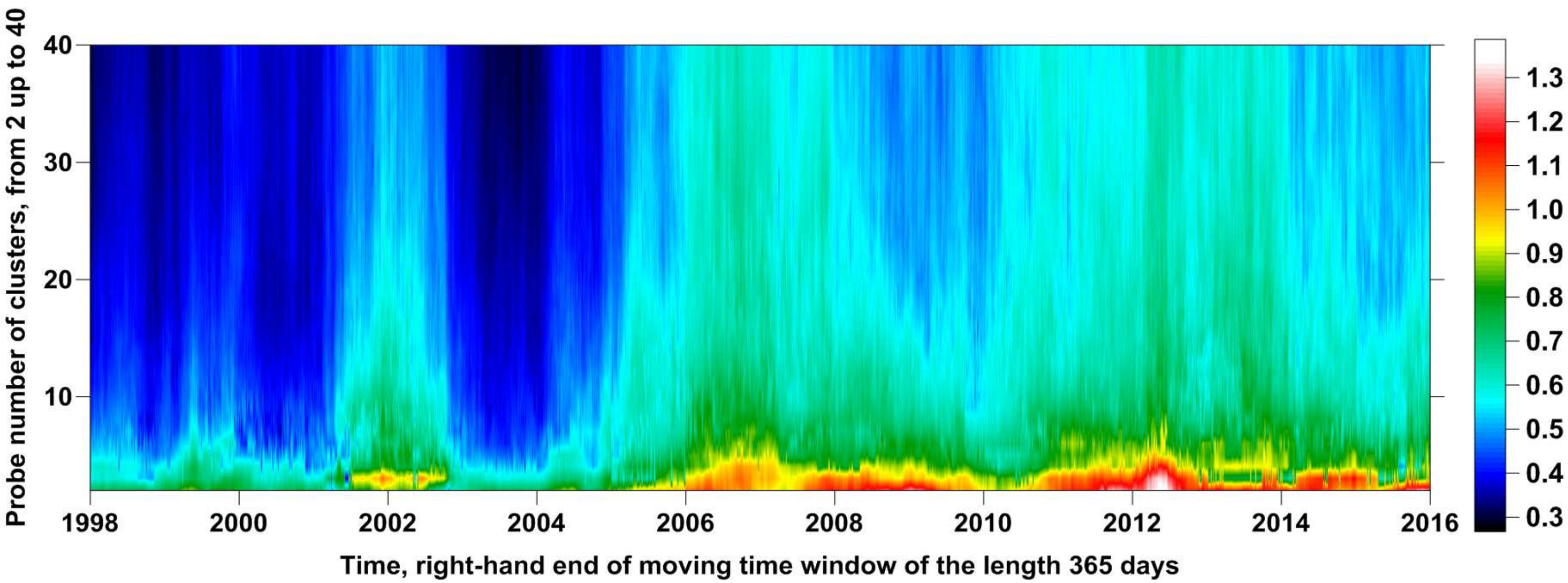
Seismicity at the vicinity of broad-band seismic network F-net in Japan

Epicenters of earthquakes M ≥ 5, since the beginning of 1997



Comparison with pseudo-F-map in California, 1997-2015





Conclusions.

Pseudo-F-map for clustering of low-frequency seismic noise properties "feels" preparing strong seismic events at the vicinity of broad-band seismic network in the form of relatively high values of pseudo-F statistics (PFS) and chaotic regime of changing the best number of clusters.

This form of precursors was observed before Tohoku mega-earthquake on March 11, 2011.

Starting from the middle of 2015 the high PFS values and chaotic regime of best number of clusters variations were returned. This could be interpreted as the increasing of the danger of the next mega-EQ in Japan in the region of Nankai Trough at the first half of 2016.