Short-term EQ precursors in paramaters of natural ULF/ELF electromagnetic emissions, detected from the data of Karimshino observatory (Kamchatka, Russia)

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Abstract

Magnetic field fluctuations were continiously registered at complex Geophysical Observatory Karimshimo (Kamchatka, Russia) for about eight years from 2000 to 2008 in the frequency range 0.003-40 Hz. For the first time long-term continuous observations with high data quality and low level of industrial interference were carried out in the region of high seismicity.

The parameters of natural emissions before earthquakes and seismically-quiet background are systematically analyzed to reveal seismo-electromagnetic phenomena and, first of all, short-term EQ precursors. As a result, two statistically significant seismo-electromagnetic phenomena are found that can be used for short-term earthquake forecast:

- depression of the magnetic field variations, caused by the absorption of radiation in the ionosphere in the range of 0.01- 0.1 Hz during 1-5 days before earthquakes;
- the emission in the frequency range from a few hertz to several tens of hertz also 1-5 days before an EQ.

Statistical analysis has confirmed the reliability of both effects. The dependence of presursor parameters on magnitude, depth and localization of future earthquakes make them good candidates for short-term EQ forecast.

The continuation of observations at Kamchatka and its developnent to multipoint network is necessary to make possible predicting of future eqrthquakes including precise timing and localization, and this will be the best memory to Oleg Molchanov, who passed away this summer.

Oleg Molchanov, 1940-2011

Observational data

<u>**Site Karimshino (KRM) was founded in 1999**</u>

Location Lat=52.827 N,
Long=158.132 E
L=2.1

Data Acquisition System

24- bits resolution ADC

150 Hz - sampling frequency, GPS sinc

3-component search coil 0,003 –40 Hz

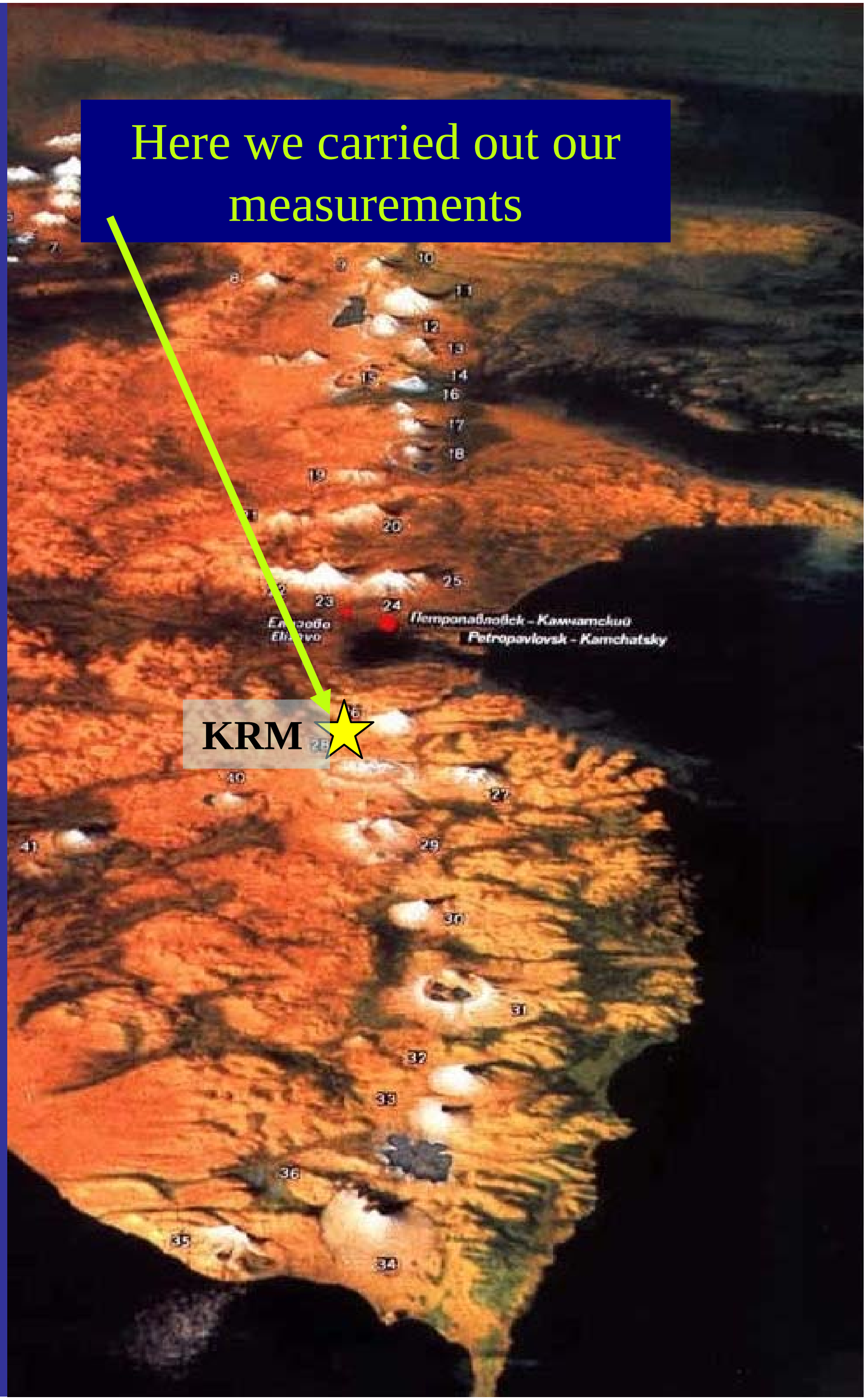
3- component seismometer

Acoustic seismometer

Telluric fields receiver

Meteo station

VLF receiver (in Petropavlovsk-Kamchatskyi)



Seismoelectromagnetic signals in ULF-ELF range. Physical background and observation facilities at Karimshino.

- The frequency range between the geomagnetic pulsations and Schumann resonance because of low natural level;
- High quality data and low interference is necessary at the first stage to search for a possible precursor
- At the next stage, for known precursor portrait, the technique can be extended to not ideal conditions with higher level of interference.

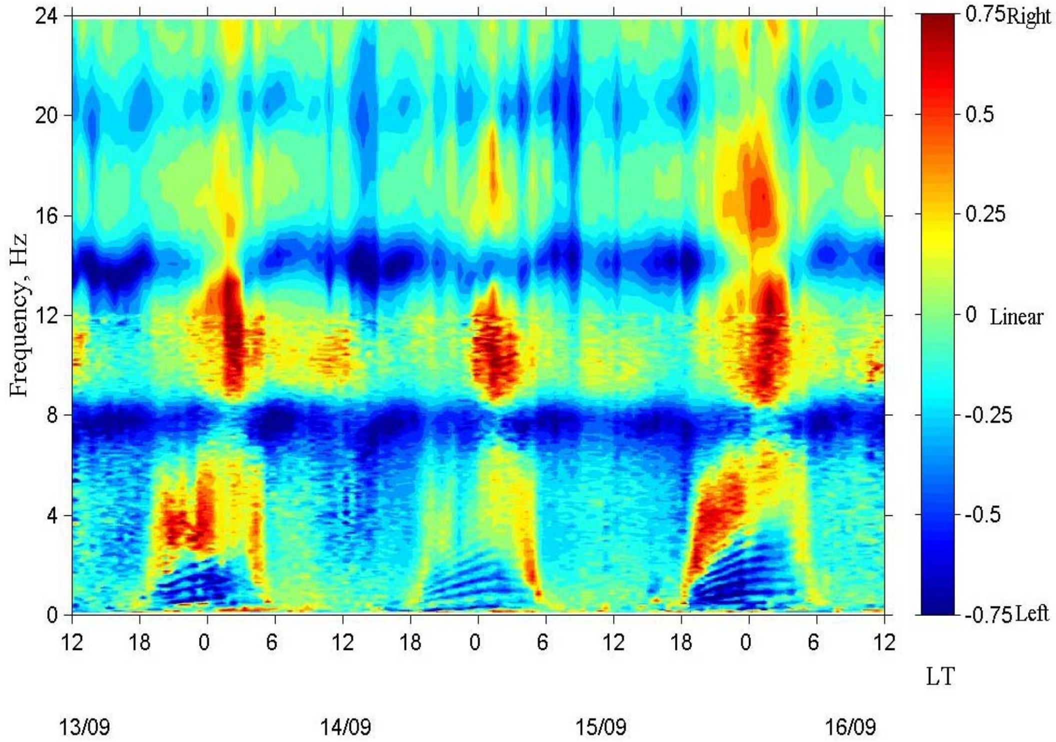


Fig.1 Magnetic field polarization , F = 0.1 - 24 Hz

An example of polarisation spectra in Karimshino

Data Processing

- Preliminary routine data processing includes substituting interpolated data for short (several points) instrumental peaks and data gaps, excluding of intervals that cannot be corrected, filtration and decimation to the 50 Hz sampling frequency.
- Power spectral densities (PSD) are calculated for the horizontal components: meridional (P_{hh}) and azimuthal (P_{dd}), together with the cross-spectra of the horizontal components P_{hd}.
- Field depression is calculated as a sum of inverse spectral power of horizontal components in the vicinity of local midnight
- $D=1/P_{hh}+1/P_{dd}$
- Seismic index Ks is defined as

$$Ks = (1 + R^{-Ms/2})^{-2.33} \times 10^{0.75Ms} / 10R$$

Depression. Technique

- A depression of ULF power around local midnight is registered several days before strong isolated earthquakes. The relative depression is

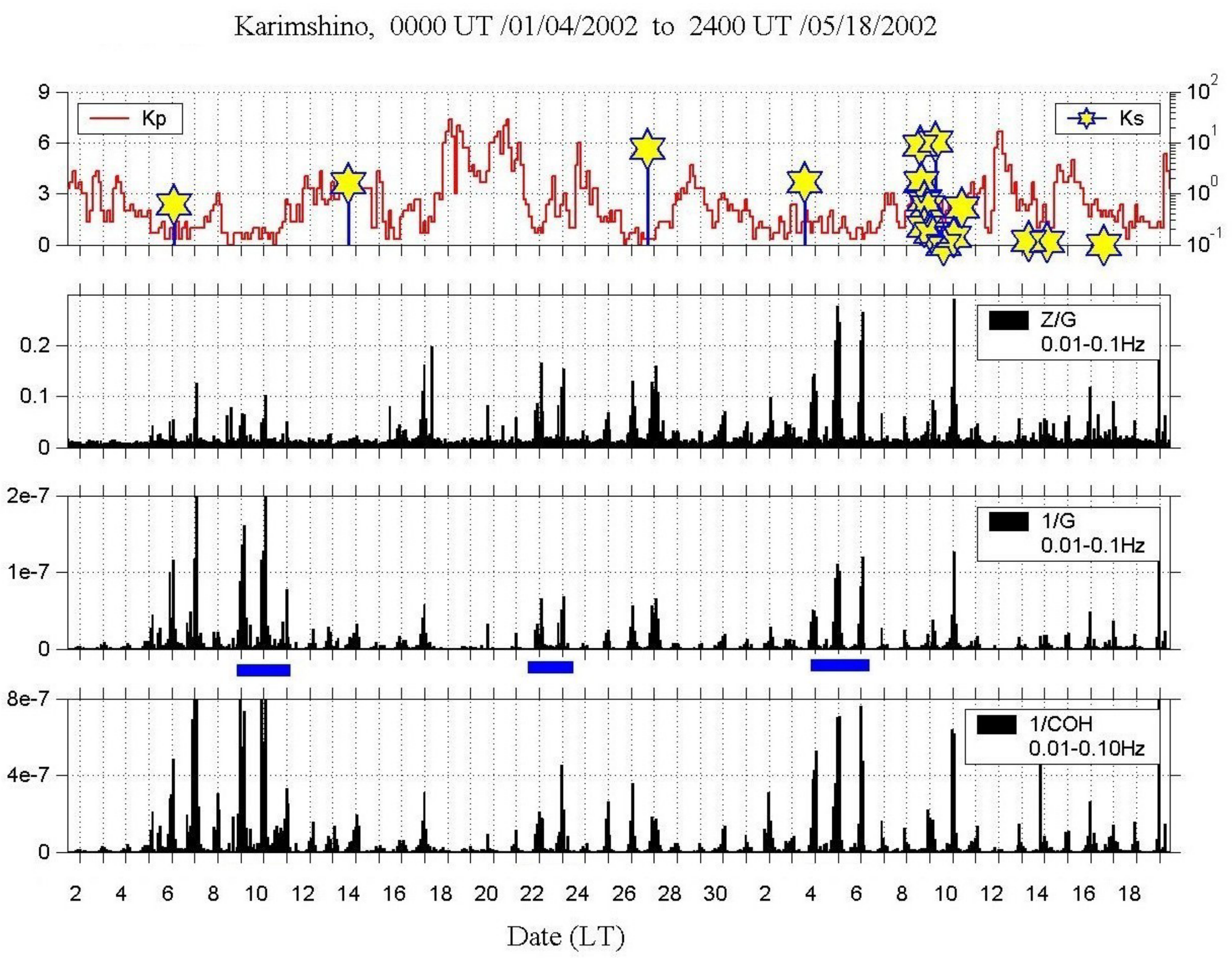
$$\delta D = (1/G \; - \; <1/G>)/<1/G>$$

and the absolute depression is found as a sum of inversed values of spectral power densities of horizontal components

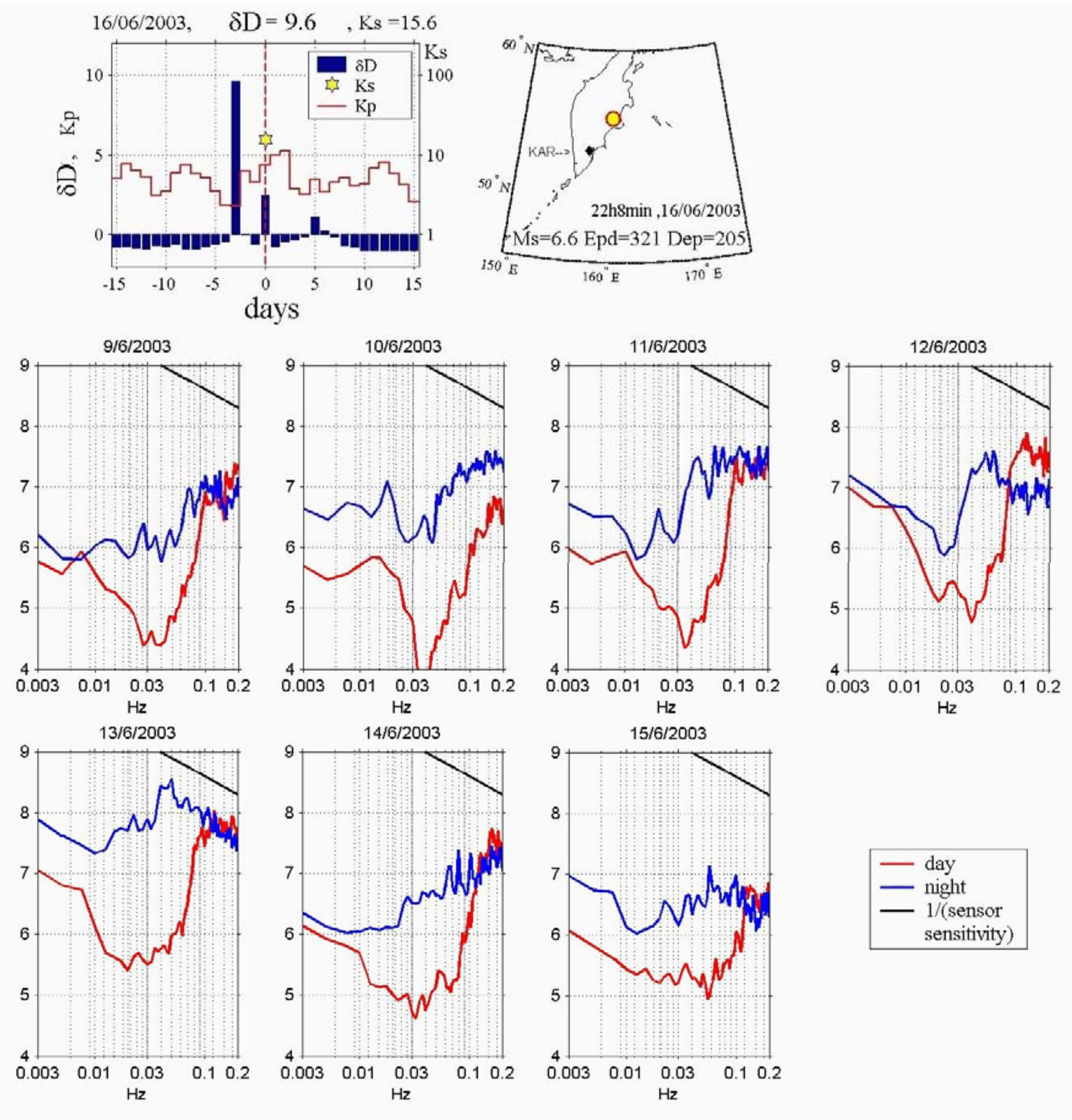
$$1/G = 1/P_{hh} + 1/P_{dd}$$

Here *P*hh, *P*dd are mean spectral densities of H and D components averaged in 1 hour interval around a local midnight, $<1/G>$ is the depression, estimated in a month sliding window.

Depression. Example. April-May, 2002

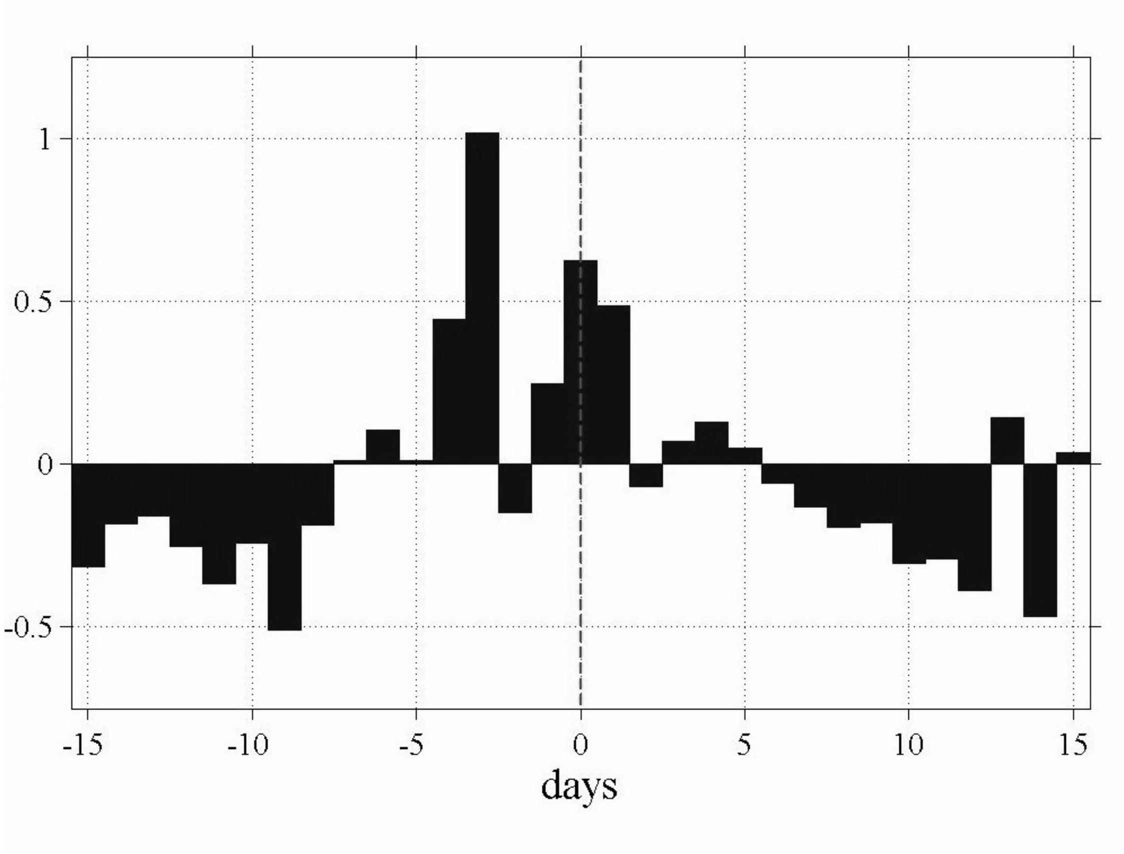


Depression. Evolution before the EQ



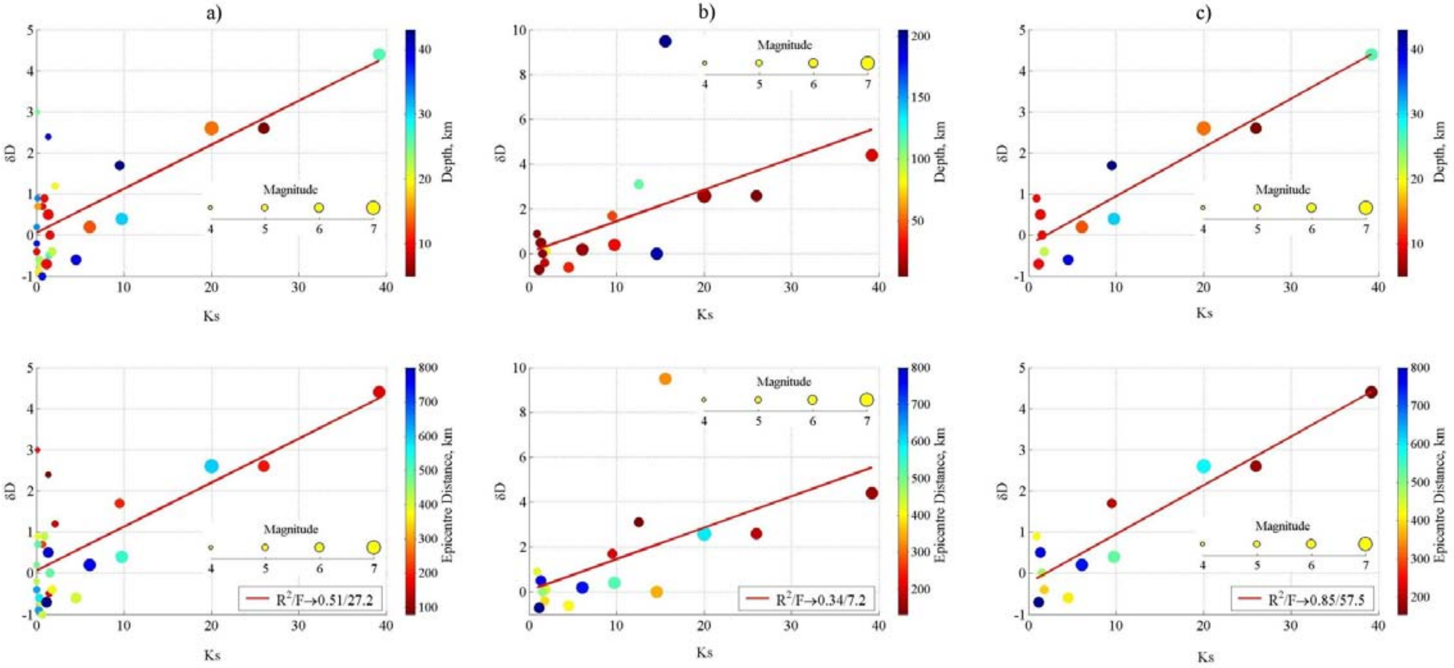
Depression spectra for local noon (red) and midnight (blue). Maximum night-time depression occurs on June 13 night, 3 days before the EQ. The effect is maximal in the frequency range 0.02-0.05 Hz.

Depression. Statistics



Time variation of δD averaged over all the EQs during 4 years, estimated with the SPE method.

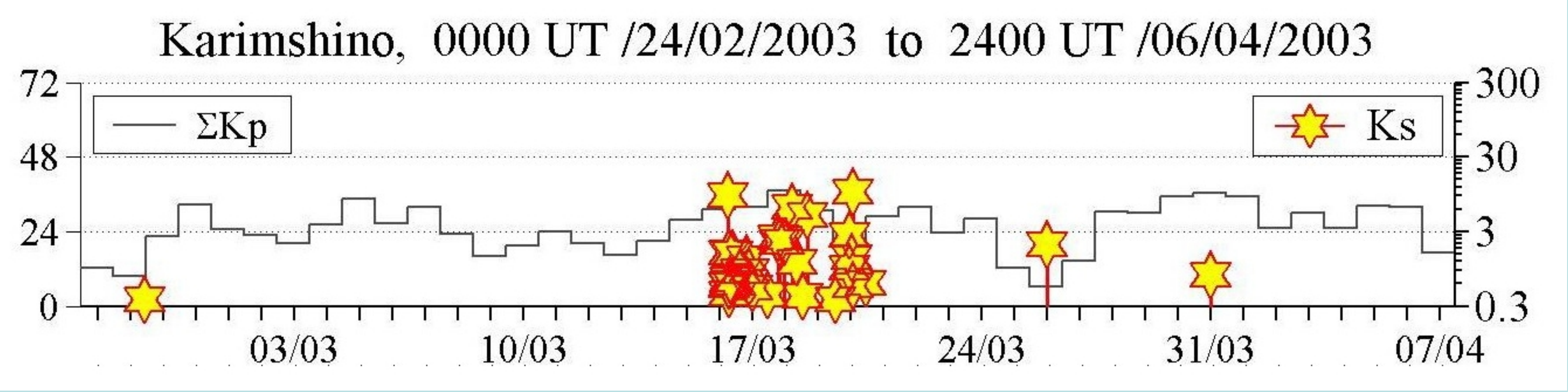
Validity of the depression effect as an EQ precursor



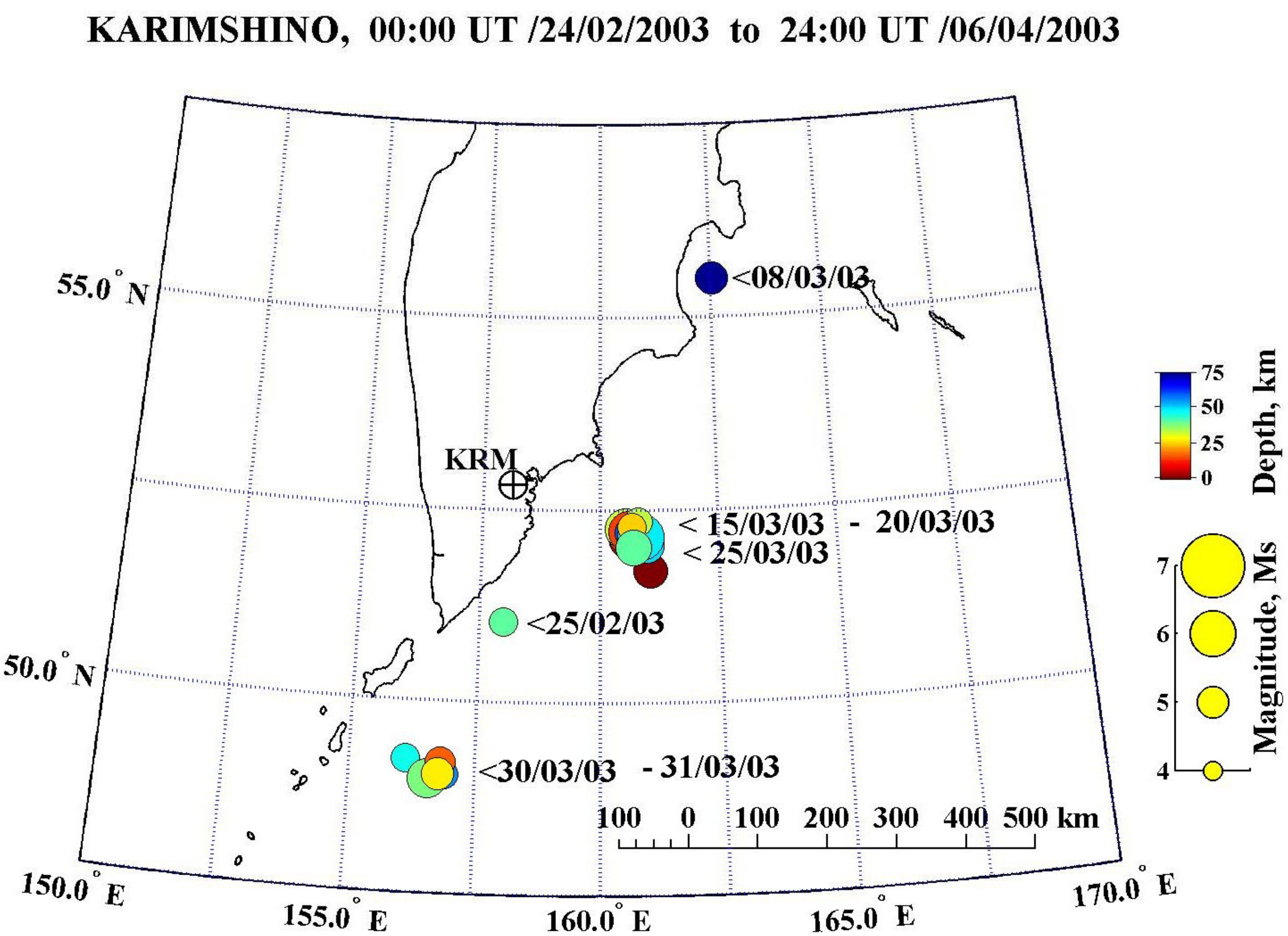
- Three features of the depression effect makes it a good candidate precursor (Molchanov and Schekotov, 20??):
- Time stationarity of the effect – it is clearly seen for 3 of 4 years with the same 3-days leading
- Locality – cross testing for depression and EQ-s in Kamchatka and Japan showed no depression at Kamchatka from Japanese EQ-s and vice versa
- Linear dependence δD on local Ks index

Preseismic ELF emission. Technique

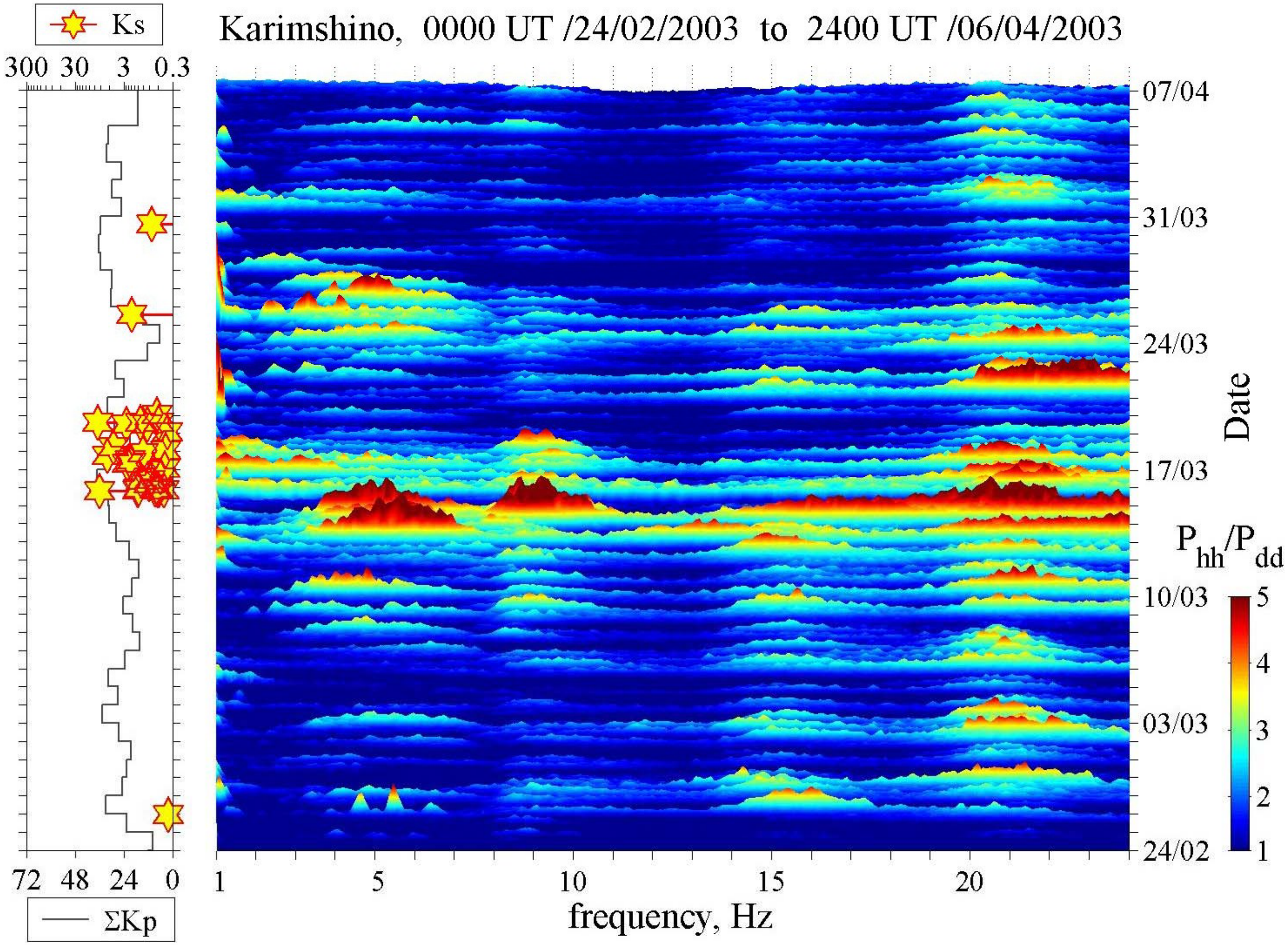
- The second seismoelectromagnetic effect, found with Kamchatka data, is the specific ELF activation 3-4 days before an EQ.
- For detailed consideration we select a period with duration of about 1.5 month around the seismic swarm in the middle of March, 2003.
- The first half of the interval is seismically absolutely quiet, and the second one starts with the Ms=5.9 shock on March, 15. This earthquake is the first in the EQ series with slowly decreasing intensity. The second peak in seismic activity corresponds to Ms=6 EQ registered on March, 19. Epicenters of almost all strong earthquakes lie to the East of the observational point in the sea.



Earthquakes. 24/02/2003-06/04/2003

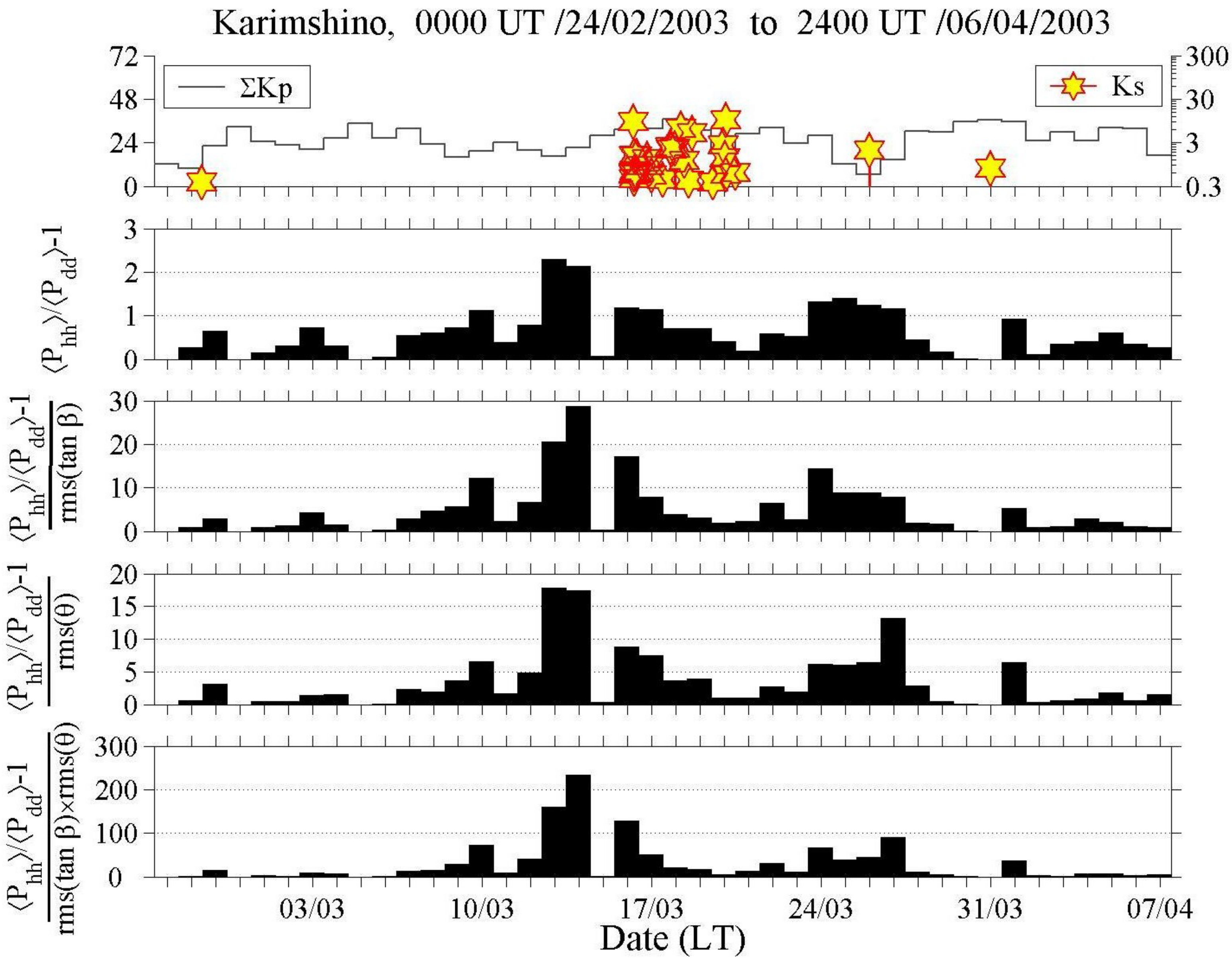


Phh/Pdd , seismic and geomagnetic activity



An emission occurs in wide frequency range. especially between harmonics of Schumann resonances and below the first Schuman in the range 4-6 Hz

What is a most effective parameter?

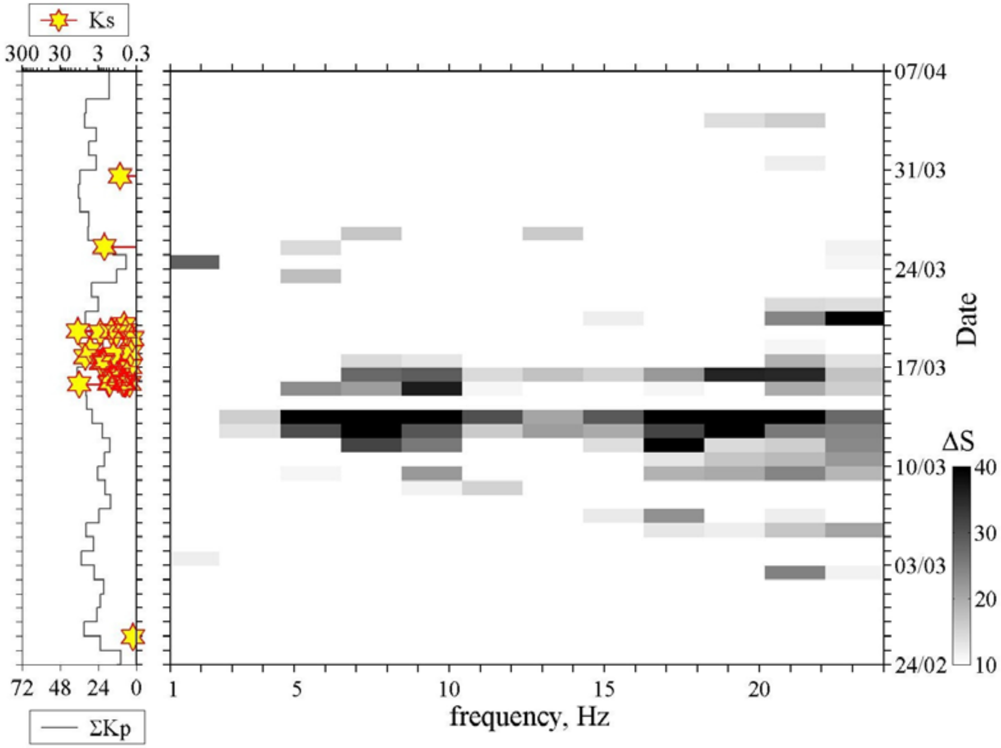


We find that the best for detection of the effect is the parameter

$$\Delta S = \frac{\dfrac{P_{hh}}{P_{dd}} - 1}{rms(tg\beta)}$$

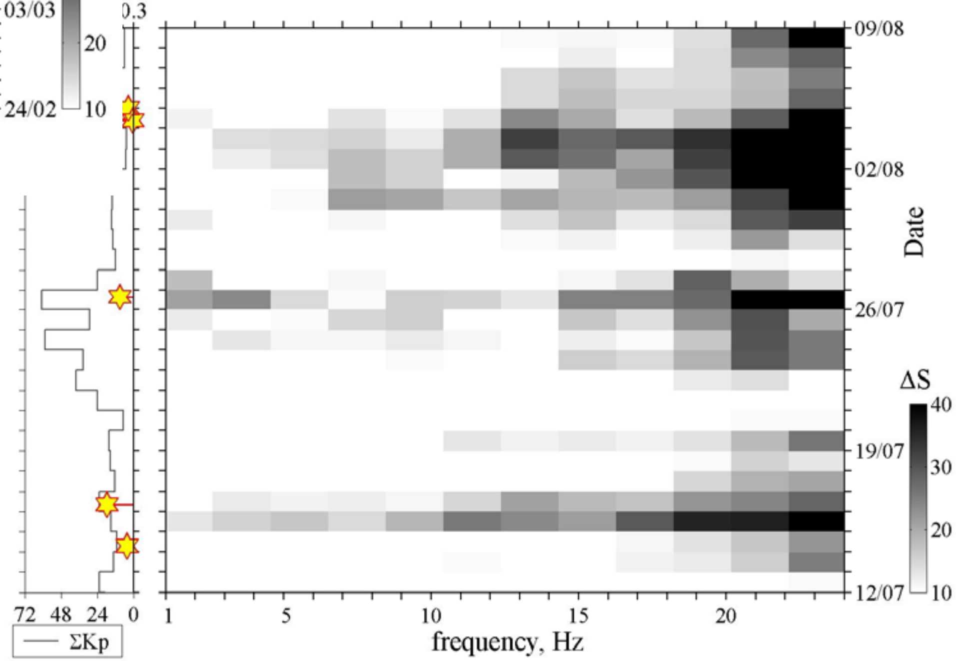
ΔS values are averaged both in frequency domain(δF=~2 Hz) and in time domain (δt = 10 hours each night).

More events



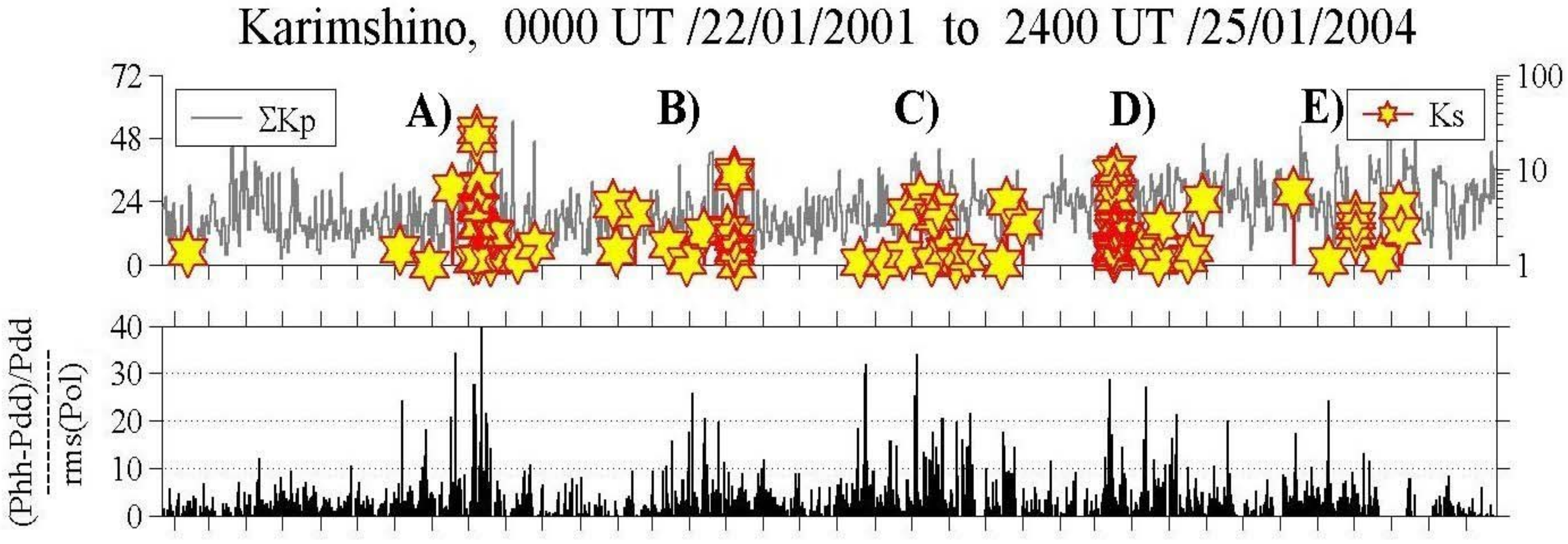
24/02/2003 - 06/04/3003

Clear ELF activations are seen for EQ-s during both intervals



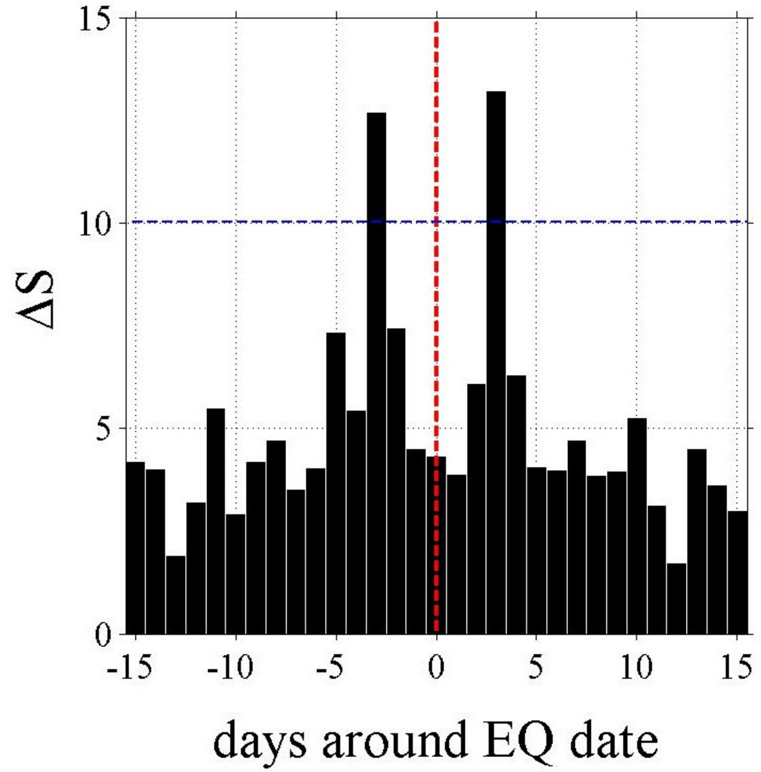
12/07/2004 - 08/08/2004

Comparison of seismic activity and parameter ΔS in the frequency range 4-6 Hz during 3 years .



ΔS peaks precede all five periods of seismic activation labeled from A to E.

The averaged ΔS variations, SPE results for 4 years of observations



Testing earthquake forecast hypothesis

There is a special terminology in order to estimate the precursor efficiency. We present the definitions following to Console (2001):

Target volume Vt is a volume in 3-D space (time and 2 coordinates of the Earth surface) determined by time of observation and geographical area of observation. Each earthquake with preconditioned magnitude threshold or *target event* is depicted as a point in the volume *Vt.*

Alarm volume Va is a volume in which an EQ related to that precursor or a set of precursors is expected.

success(S) if an EQ occurs in the alarm volume,

failure of predicting if an EQ occurs outside of alarm volume

false alarm - an alarm that is not associated to any EQ

If NS, NA and NE are the number of success, the number of alarms and the total number of EQs in the target volume then commonly considered parameters in earthquake prediction evaluation are the following:

Success rate = NS/NA is the rate at which precursors are foolowed by target events in the alarm volume.

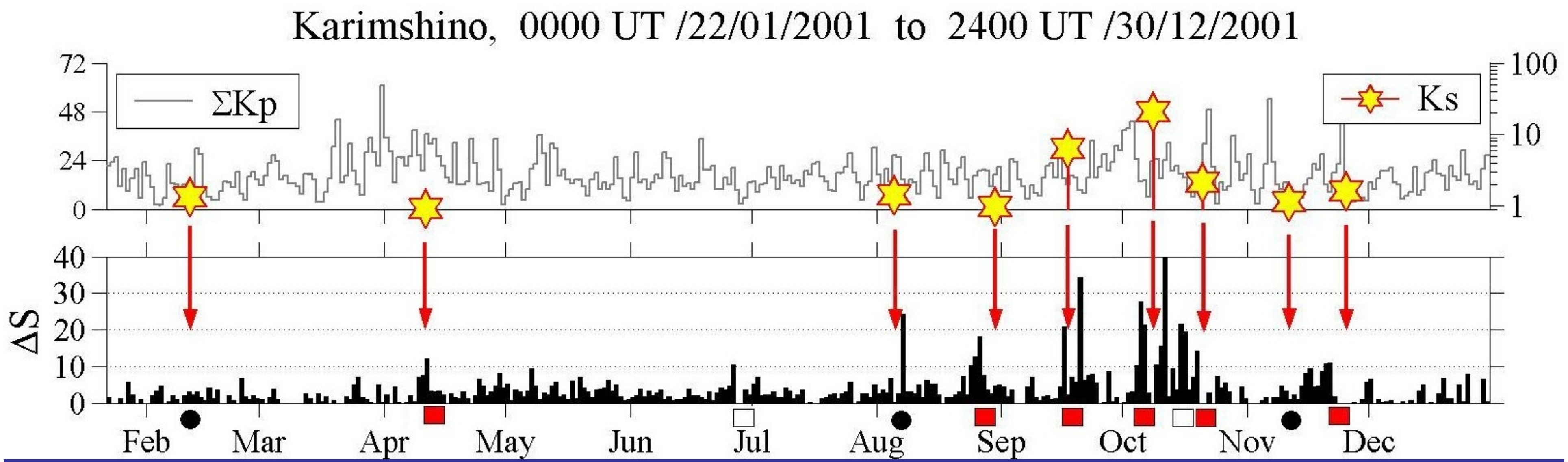
False alarm rate = 1 - NS/NA is the rate at which precursors are not followed by target events.

Alarm rate = NS/NE is the rate at which target events are preceded by precursors.

Failure rate = 1- NS/NE

Probability gain PG = [NS/(NAVa)]/[NE/Vt] is the ratio between the rate at which target events occur in the alarm volume and the average rate at which target events occur over the whole target volume.

In general, a method of prediction can be considered significant if it achieves a *PG* value greater than one (Console, 2001).



Upper panel: Ks≥1 (yellow stars) , ΣKp daily indices during observation period from January 22, 2001 to December 30, 2001(observation period 1). Lower panel: Δs. Alarm intervals are shown by squares below the horizontal axis, red square is for success but empty square is for false alarm. Estimation of prediction values for different observation periods are summarized in the Table

Observation period, T_e	N_E	N_A	N_S	Success rate	Alarm rate	PG
1. 343 days	9	8	6	0.85	0.88	6.47
2. 364 days	15	14	7	0.50	0.47	2.45
3. 264 days	10	13	3	0.23	0.30	1.22
Total, 971 days	34	34	16	0.47	0.47	2.68

Discussion and conclusion

- Geomagnetic data of Complex geophysical observatory in Kamchatka are unique due to combination of high data quality, low interference and moderate seismicity.
- The effect of depression of ULF geomagnetic fluctuations at local midnight occurs 1-5 days before essential nearby earthquakes. The depression effect demonstrates long-term stationarity, locality and nearly linear dependence on local density of seismic energy. The effect can be attributed to the ionospheric disturbances, leading to higher screening of ULF waves.
- Preseismic ELF emission is seen 3-4 days before a forthcoming EQ and is seen at frequencies about several Hz below 1-st Schumann harmonic and between subsequent harmonics. It is expressed clearly in polarization parameters and may be attributed to the redistribution of local atmospheric sources.
- Continuation and development of observations at Kamchatka to the multipoint network are necessary.