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SEISMIC ACTIVITY IN KAMCHATKA AND THE PARAMETERS OF NATURAL ULF/ELF EMISSIONS

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Abstract

Spectral and polarization parameters of the natural ULF/ELF signal in a seismic region (Kamchatka, Russia) are statistically analyzed and a meaningful change in the signal polarization is found to occur several days prior powerful earthquakes (EQ). This effect can be caused by an extended thunderstorm activity in the EQ preparation zone due to either aerosol and gas emissions by an active fault or by the modification of the ionosphere by the preseismic AGW waves.

Introduction

A review of seismoelectromagnetic phenomena is given in the books by Hayakawa et al. (1994); Hayakawa et al., (1999); Hayakawa and Molchanov (2002). The most amazing results have been obtained in the ULF frequency range for nearby violent earthquakes (Fraser-Smith et al., 1990; Kopytenko et al.;1990; Molchanov et al., 1992). Numerous publications describe the effects at frequencies above hundred Hz (Hayakawa et al.,1994; Hayakawa et al., 1999; Hayakawa and Molchanov;2002). However, there are only few publications on seismoelectromagnetics in the frequency range 1-40 Hz (e.g. Ohta et al., 2006). All these papers deal with individual cases or present the statistical analysis of rather short time intervals. In this paper the results of more than 3 year continuous observations of natural magnetic field fluctuations in the frequency range 1-40 Hz are analyzed statistically and for individual earthquakes.

Measurements and data processing

Variations of the magnetic field have been measured at the Karymshino observatory (Lat=52.827 N, Long=158.132 E) since June, 2000 till now using a 3 component induction magnetometer in the frequency band 0.003 – 40 Гц, noise level 0.16*F^{-1} pT/$\sqrt{Hz}$ and conversion function 0.4*F V/(nT*Hz) in the frequency band F=0.003 - 4 Hz and 1.6 V/nT in the band F= 4 - 40 Hz. The sensors for the horizontal components H and D are oriented along the magnetic meridian and transversally to it, and the Z sensor is vertical.

Routine data processing includes correction of non-physical data and data gaps, filtration and decimation to the 50 Hz frequency, and calculation of power spectral densities (PSD) of the field components, and the cross-spectra of the horizontal components, with the frequency resolution ~0.2 Hz and time window 30 min. The parameters of the polarization ellipse are calculated following (Born and Wolf, 1964). The orientation angle θ is the angle that the principle axis of polarization ellipse makes with the H axis. The absolute value of the ellipticity (tan(β)) is the ratio of minor to major axis and its sign is determined by the sense of polarization, i.e. $\beta > 0$ or $\beta < 0$ as the polarization is right- or left-handed as measured when looking into the propagation wave. Small absolute values of averaged ellipticity do not necessarily correspond to the linear polarization if the dispersion is high. To analyze the degree of signal's linearity a parameter $R = a/b - 1$, where a and b are the big and small ellipse axis, respectively is used.

Seismic data are taken from the local seismic catalogue (http:// emsd.iks.ru) and for each earthquake the local seismic index Ks (Molchanov et al., 2003) is calculated. It gives an estimate of the earthquake seismic energy in the observational point as

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

where R is the distance from the observational point and Ms is the EQ magnitude. If earthquakes form series of foreshocks and aftershocks only the main shock is taken for the analysis. Geomagnetic activity is estimated with the daily ΣKp index.

Results

We illustrate the changes of the field parameters with the 1.5 month interval around the seismic swarm in March, 2003. The first half of the interval is absolutely quiet seismically, 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. Epicenters of almost all the earthquakes lie in the sea eastward from the observational point. The dynamical spectra of two horizontal components and H/D spectral ratio are shown in the lower panels of Fig.1. Ks and ΣKp indices are given in the upper panel.

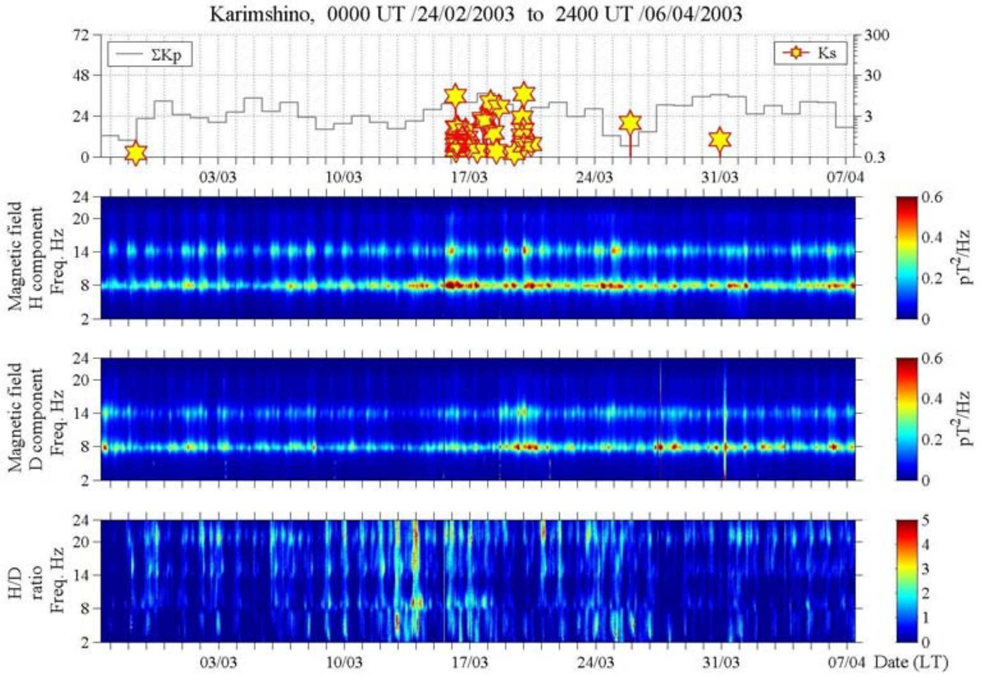

Fig.1. From top to bottom: ΣKp and Ks indices, dynamical spectra of H and D components and H/D spectral ratio.

The intervals of the enhanced H/D ratio start several days prior the earthquakes and last several days after them. A similar but weaker effect is seen in power spectra of the field components. The time correspondence of seismic activations and steep variations of the field parameters makes plausible the assumption about existence of an additional local source of ULF/ELF magnetic field fluctuations in the epicenter zone. The fact that the majority of the nearby earthquakes occur eastward from Karymshino results in the enhancement of the H/D ratio at the intervals of high seismic activity. In invariant parameters this effect is equivalent to a more linear signal and to the increased θ. The other effect of seismicity is a reduced daily standard deviation (rms) of signal's ellipticity and ellipse orientation. A combined parameter

$$\Delta S = (H/D-1)/\mathrm{rms}(tg\beta)$$

has proved to be the most sensitive to the seismic activity. The influence of individual earthquakes on ΔS is illustrated in Fig.2.

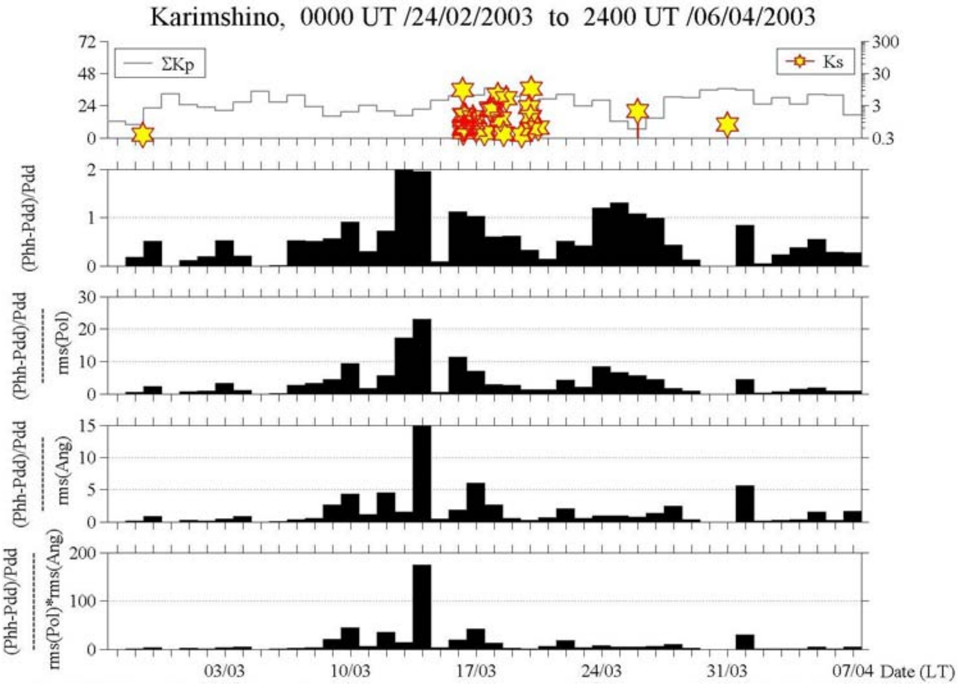

Fig.2. From top to bottom: Ks and ΣKp indices, H/D-1, ΔS=(H/D-1)/rms(tan(β)),(H/D-1)/rms(θ), ΔS/ rms(θ)

To suppress a possible parasite correlation between seismicity and the parameters of ULF/ELF emissions caused by seasonal variations the following technique is used. Seismic intervals (a central day ±10 days) are selected with an EQ of a sufficient Ks, magnitude and depth occurred during a central day. Besides, this central EQ is to be the main shock. The seismic intervals are distributed over months in a different way in comparison with the non-seismic intervals. Selecting only months where both types of intervals exist (for our case these are months numbered 1, 2, 3, 6, 8, 12) we form two arrays of seismic and non-seismic intervals with identical seasonal distributions. Then the field parameters are calculated for both sub-arrays and compared. This technique is similar to the routine Superposed Epoch (SPE) analysis with seasonal distribution taken into account. The results for the ellipse orientation angle θ and the parameter of the signal linearity *R* is shown in Fig.3.

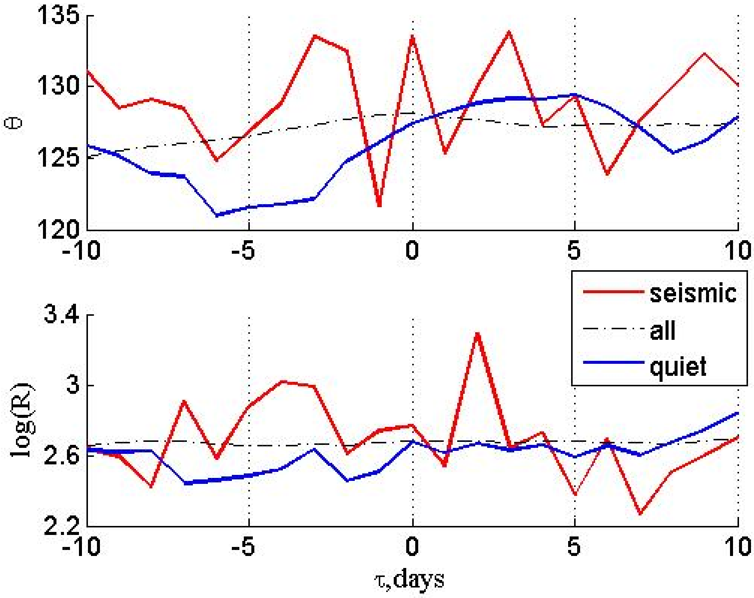

Fig.3. The results of SPE analysis for orientation angle θ and the parameter of the signal linearity R

The signal proves to be obviously more linear for seismic intervals. Day to day variations of polarization are also higher for seismic intervals and two main maxima are seen about three days prior and two days after the central EQ. By comparing *R* for seismic and non-seismic intervals with equal seasonal distribution we have shown that seasonal variation of ELF parameters and EQ non-homogeneous seasonal distribution cannot explain the change of ELF parameters in seismic periods. In the bottom panel the results for the angle of ellipse orientation θ are shown. Several days prior an EQ the polarization ellipse rotates 5-10 degrees towards the meridian from its undisturbed direction. These two effects result in the increase of H/D ratio before the earthquake.

Discussion

The parameters of natural ULF/ELF emissions in Kamchatka differ for seismic and non-seismic intervals. An additional signal occurs several days prior an EQ. The horizontal magnetic field of this additional signal is more linear and it is rotated towards the meridional direction in comparison with the non-seismic signals. The difference between seismic and non-seismic signals is seen more clearly in the polarization parameters than in the spectral power. The maximal effect is found at frequencies between Shumann resonanses, especially below the first Shumann resonance frequency. These features of the emissions associated seismo-related emission indicate its generation by nearby sources. The waveforms of the preseismic are similar to those registered by Fujinawa et al. (1999) and can be interpreted as cloud-to-cloud discharges.

The difference between the field parameters for the seismic and non-seismic intervals indicates the existence of additional sources of the ULF/ELF emissions in the vicinity of EQs. The fact that almost all the earthquakes near Karymshino take place in the sea makes impossible the mechanisms of active generation of such a signal in the Earth's crust or variation of crust conductivities. Thus, the only possible explanation is the generation or the spatial redistribution of lightning discharges in the EQ preparation zone. It can be explained by the acoustic emissions in a wide frequency range including AGW (10-60 min). The latter are known to modify ionospheric properties (Miyaki et al., 2002) and can be important for high altitude cloud-to cloud and sprite-like discharges. The other mechanisms can be the enhancement of thunderstorm activity in the EQ zone due to gas and aerosol emissions by the active fault.

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