ELECTROMAGNETIC AND PLASMA EFFECTS OF THE SEISMOLOGICAL ACTIVITY IN THE EARTH IONOSPHERE

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Abstract

Data from the low-orbiting satellite COSMOS-1809 were used to search for a correlation between seismic activity and increases in ELF/VLF emissions and plasma density fluctuations for different regions. The data of ~ 100 revolution of satellite were chosen for the analysis of ionospheric effects of this seismic activity. Analysis enables to draw the following conclusions. The electromagnetic emissions in the frequency range of 140-450 Hz are regularly observed within the L-shells with the root in the seismoactive zone. Near a zone of seismic activity ($\Delta\lambda=\pm6$) at the altitude ~ 950 km bursts of ELF radiation are observed at the frequencies f=140 and 450 Hz in the magnetic and electric components. The radiation excess above the background level can reach more than an order of magnitude. The radiation bursts are observed minutes to hours beforehand an earthquake and during several hours after it. The sizes of the disturbed region are usually ~400-600 km, and greater in the period of aftershock activity than during the earthquake development. The small-scale plasma irregularities dN_e/N_e ~ 3-8% with characteristic scales 4-10 km along the orbit has been revealed in geomagnetic field tubes connected with epicentral region in which seismogenic ELF emissions were observed simultaneously. The empirical models of distribution of ELF-emissions for different regions was constructed on the basis of statistical study of this measurements. For these regions amplitude-spatial distributions of siesmoelectromagnetic radiation were constructed both for electric and magnetic components and distributions of the signal (-to-) noise ratio were constructed as well. Analysis of seismogenic ELE/VLF radiation had shown that main signal characteristics (frequency, amplitude etc.) were sufficiently different for different seismoactive regions of the Earth. This fact is evidence of seismoelectromagnetic parameters dependence on physical-chemical properties of Earth's crust and lithospheric processes. Characteristic features of ELF/VLF radiation related to submarine earthquakes were exposed (radiation of higher frequences, up to 15 kHz, were observed). It is obvious in the present case that amplification of natural ELF/VLF radiation take place, because electromagnetic connection between lithosphere and ionosphere is absent.

1. Introduction

During recent decade some authors reliably showed basing on the satellite and ground-based data that there exist the litosphere-atmosphere-ionosphere interaction in the region of seismic activity during its increased levels. The mechanisms of such interaction are still poorly developed. However, we have all the foundations to suppose three main factors of the effect of the earthquake focus on the surrounding medium. This mechanical-chemical, acoustic and electromagnetic action the summary effect of which appeared at various stages of the earthquake development in the form of modifications of characteristics of electromagnetic waves and plasma in the ionosphere. There were experimentally revealed the following effects:

-increase of intensity of ELF-VLF-noises, formation of small-scale plasma irregularity and appearance of abnormal quasi-stationary electric field with the intensity 3÷7 mV/m above the earthquake focus;

-increase of intensity of the atmosphere emissions in the lines 6300 and 5577 A;

-variation of light ion density and plasma temperature.

A number of seismogeneous effects was revealed from the data of vertical ionosphere sounding from the ground-based and satellite observations in the regions of seismic activity as well as from measurements of the amplitude and phase of the SLW signals on the radio lines passing through the regions of seismic activity. All the mentioned above effects are preceding the earthquake and observed within time intervals from tens of minutes to several days before the earthquake onset and could be used as the perspective base for developing the method of short-period prognosis of the earthquakes. It should be remembered that these results were obtained from a limited number of measurements so they do not enable one to display the characteristic features which could be used as a ground for methods of identifying earthquake precursors. The most extensive results concerning studies of earthquake precursors from satellite data are obtained up to now on the basis of measurements of low-frequency electromagnetic emissions. These results gave rise to series of publications which proved convincingly that during earthquake preparation as well as in the period of aftershock activity the bursts of low-frequency emissions connected with preparation and development of earthquakes are observed in the earth ionosphere (Chmyrev et al., 1989, 1997; Isaev et al., 1997; Mikhaylova et al., 1991; Molchanov et al.,1993; Parrot and Lefeuvre 1995; Serebryakova et al.,1992). The results will be presented below of processing and analysis of telemetric information on the ELF emissions and ionospheric plasma parameters onboard "Cosmos-1809" above the different regions.

2. Brief description of experimental results

Measurements onboard "Cosmos-1809" satellite were carried out at the altitude of ~950 km. To measure the ELF-VLF emissions the five-band parallel spectrum analyzer was used with central frequencies f_0=140, 450, 800, 4500 and 15000 Hz and with the frequency bands $\Delta f = f_0/6$. For measuring the ionosphere plasma density Ne and its fluctuations dNe the capacity high-frequency impedance probe IZ-2 was used through which the quantities N_e and dN_e were determined by means of measuring a variation of the probe detector capacity depending on variations of the dielectric permittivity of the ionosphere at the generator frequency f=5.025 MHz.

After strong earthquake in Armenia on December 07, 1988 during almost three months aftershocks of various intensities were registered near the earthquake focus. In this connection, the instruments aboard "Cosmos-1809" were switched to the monitoring mode (ZAP-4) and operated in it during January-February, 1988 (During properly Spitak earthquake the satellite device was not switched in.). During that period a great number of weak earthquakes occured on the territory of Central Asia, Kazakhstan and Thian Shan.

The regime of satellite monitoring in this period enabled the selection of a great number of passages (above 50) near the foci of earthquakes ($\Delta\lambda=\pm6°$), in the temporal window of several hours either before an earthquake or after it. An example of the data is shown in Fig.1. This presents the distributions of the radiation intensity in the magnetic component at the frequencies f=140 and 450 Hz as well as the values of plasma density N_e and its variations dN_e over the zone of seismic activity ~3.4 hours beforehand the rather strong aftershock of the Spitak earthquake with energetic class E=8 on January 20, 1989.

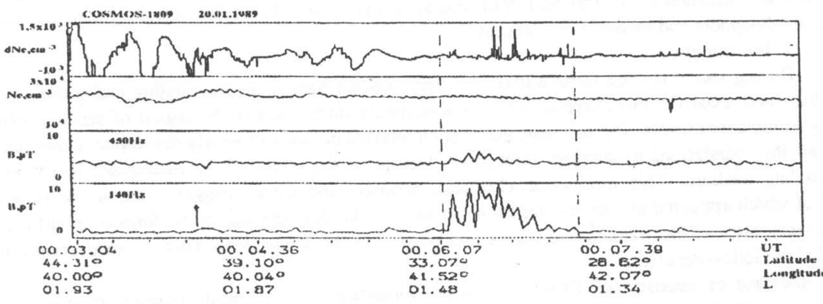

Fig.1. ELF emission intensity for the magnetic component B in the frequency channels 140 and 450 Hz, plasma density Ne and variations dNe over the Spitak seismic zone ~ 3.3 h before the shock on 20 January 1989.

The time instant 00.04.06 UT when the satellite crossed the geographic latitude of the earthquake focus, is marked with the vertical arrow. The measurements were carried out in the night-time sector at the conditions of the recovery phase of geomagnetic storm (Kp=30). As seen from Fig. 1, an intensity burst of electromagnetic radiation at frequency f=140 Hz (bottom panel) with amplitude of up to 10 pT was observed in the longitude range 41.6°<λ<42.0° i.e. approximately 2° to the West from the focus and in the latitude range 30°< φ <33.1°. A weaker increase of electromagnetic noise (up to 3 pT) was observed also at the frequency f=450 Hz. At higher frequencies no increase of the radiation level was registered. In the both channels the radiation maximum is located on the L-shell (L=1.42) which crosses the ionosphere lower boundary (h=100 km) above the earthquake center. The region of increased values of the radiation intensity is marked by vertical dotted lines in Fig. 1 and has the dimensions of ~450 km along the satellite orbit. One should note that both at the frequencies ~140 Hz and ~450 Hz a quasi-regular modulation of the intensity with the period 5-6 seconds is observed. In the disturbed region the small-scale dN_e fluctuations with characteristic spatial scales l=4-8 km and the magnitude dN_e/N_e up to 8% were also observed (upper panel in Fig.1). Also, in the channel of dNe measurements the fluctuations of plasma density of a larger scale (l~50 km) but lower in magnitude (dN_e~4-5%) were registered.

The other example of the seismo-ionospheric effects is presented in Fig.2 for the earthquake in Iran on 17.01.1989. The distribution of the radiation intensity in the electric and magnetic components in the channel 140 Hz are presented parallel with plasma density N_e and its variation dN_e over the focus 2.5 minutes before the shock on January 17, 1989. The time instant when the satellite crossed the latitude of the earthquake focus (23.29.00 UT) is marked with vertical arrow. The measurements were carried out in the night-time sector with the conditions of geomagnetic storm recovery phase at $K_p=3_0$. As is seen from Fig. 2, the intensity burst in the magnetic component of radiation at the frequency f=140 Hz (bottom panel) with amplitude up to 12 pT was observed in the longitude range $56° < \lambda < 57°$ i.e. approximately 1.0° to the West of the focus and in the latitude range $10° < \varphi < 17°$. A weaker increase of electromagnetic noise (up to 3 pT) was observed at the frequency f=450 Hz (not shown in Fig. 2). At higher frequencies no increase in the radiation level was registered. In contrast to the results of [Serebryakova et al., 1992] in this case the electric field oscillations with amplitude ~ 10 μV/m were also registered in the channel f_0=140 Hz. At higher frequencies no emissions in the electric component related to seismic activity were registered. The zone of increased values of the radiation intensity in the channel f=140 Hz is marked with vertical dotted lines in Fig. 2. The maximum in this case was located at the L-shell (L=1.1) corresponding to the earthquake focus projected onto the lower boundary of the ionosphere (h≈100 km). Note that in this region the small-scale fluctuations of plasma density dN_e with the characteristic scale l≈4 km and the amplitude dN_e/N_e = 3-5% (upper panel in Fig. 2) is coincident with the results of (Chmyrev et al., 1997). A generation mechanism of such plasma density inhomogeneities was developed in (Sorokin et al., 1998) A cavity with decreased plasma density N_e (the second panel) was registered in the disturbed zone. The density was decreased by ~10% as compared to the density value outside the zone boundaries. A similar result has been obtained only once from the ISIS-2 satellite data. The dimensions of the disturbed zone in the case under consideration were approximately 550 km.

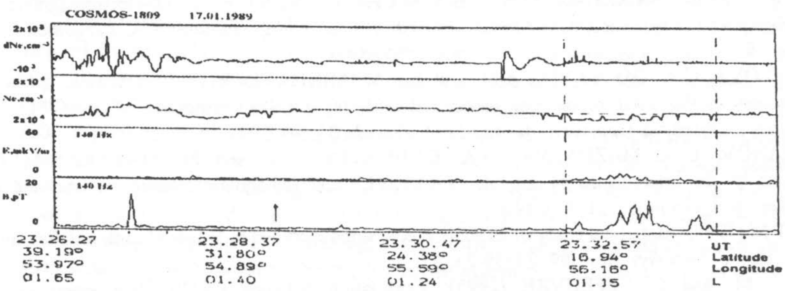

Fig.2 ELF emission intensity for the magnetic B and E components in the frequency channels 140 Hz, plasma density Ne and its variations dNe over the focus of Iran earthquake ~ 2.5 min before the shock on 17 January 1989.

3. Summary and Discussion

Detachment of seismoionospheric effects relative to background values from measurements onboard the near-earth satellites is a complicated problem since the ionosphere plasma paramcters, mechanisms of the field and radiation generation, onditions of propagation of various types of waves are to a considerable extent dependent on solar activity, geomagnetic disturbance level, season, local time etc. Besides, a great number of physical processes are developed in near-earth plasma resulting frequently in variations of ionosphere parameters similar to seismoionospheric effects, especially, in high-latitude zone. The most extensive results concerning studies of earthquake precursors from satellite data are obtained up to now on the basis of measurements of low-frequency electromagnetic emissions. These results gave rise to series of publications which proved convincingly that during earthquake preparation as well as in the period of aftershock activity the bursts of low-frequency emissions connected with preparation and development of earthquakes are observed in the earth ionosphere (Larkina et al., 1985; Chmyrev et al., 1989; Mikhaylova et al., 1991; Molchanov et al., 1993). In the work (Parrot, 1994) statistical studies were performed on the basis of analysis of the data on ELF/VLF emissions, registered onboard the OREOL-3 satellite for more than 300 earthquakes. In this paper the dependence was studied of the average amplitude of seismoelectromagnetic signal on a distance in latitude and longitude of the point of measurements. Besides, the dependence was studied of the signal amplitude on Δt, which is the time interval between the earthquake occurence and the moment of measurement in 24-hour time window. This approach enables the author to obtain a number of important results. For example, scisoelectromagnetic effects are the most pronounced at the frequencies below 800 Hz near the focus. Extension of disturbed region in latitude is considerably greater than in longitude. These conclusion agrees with the results of the papers (Parrot and Lefeuvre, 1985; Serebryakova et al., 1992; Chmyrev et al., 1997).

The results, presented in quoted works, proved the existence of low-frequency (ULF-VLF) emissions in the earth ionosphere, connected with seismic processes. A number of ground-based experiments on measurements of ULF-VLF emissions during periods of preparation and development of earthquakes also demonstrated the presence of low-frequency emissions in a wide range of frequencies, connected with seismic sources (Gokhberg et al, 1988).

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