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RESPONSES OF EARTHQUAKES ON JULY 17, 2006 IN THE LOWER IONOSPHERE

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Introduction

It is known that there is a connection between processes in the lithosphere of the Earth and disturbances in the atmosphere and the ionosphere. The seismic activity in the earth's crust is accompanied with both geodynamic processes and intensive hydrodynamic, electromagnetic and chemical influence of the earthquake focus on the atmosphere. As a result of such influence there are numerous abnormal changes of parameters of the environment and electromagnetic field.

Disturbances in the lower ionosphere at the heights of 60-85 km caused by the strong distant earthquakes are investigated by the method of partial reflections of HF-radio signals [Gokov et al., 2003]. At the same time amplification of the reflected signal from the large irregularity arising at the distance of 11000 km from the epicentre was observed. The wave caused by an earthquake propagates from the source and leads to the change of the atmosphere parameters. During earthquakes the conductivity of the ground layer of the atmosphere [Martynenko et al., 1994] can increase, which leads to disturbances in the lower ionosphere.

According to data of registration of the vertical components of the atmospheric Ez electric field in a seismically active region (Kamchatka) for the period of 1997-2002 Ez anomalies are found in daily variations. They are manifested mainly in bay decreases of the field 1 - 24 hours prior to an earthquake [Smirnov et al., 2003; Mikhaylov et al., 2002, 2004; Rulenko, 2003]. Before the earthquake on 18 September 1999 expansion of atmospheric noise spectra into the region of shorter periods and Ez reduction were observed [Mikhaylov et al., 2002]. The registered Ez disturbances in the atmosphere can be an integrated effect of the flux of pulse electromagnetic radiation (EMR) [Morgunov, 1998]. During an earthquake and prior to its beginning weak variable electromagnetic fields in the range of frequencies from units of hertz up to tens of kilohertz [Gokhberg et al., 1982, 1985; Nenovskiy and Boychev, 2004] can be excited.

The tendency of increase of the number of earthquakes after geomagnetic storms was noted. Usually the amplitude of magnetic field variations before an earthquake makes 1-10 nT. However, in the literature a number of observations of very strong disturbances of the geomagnetic field with duration of a few hours and even days [Frost et al., 2002] are mentioned.

The analysis of experimental data

In this paper the experimental data measured on the Kola peninsula and in Scandinavia to reveal responses of an earthquake were analyzed. A strong earthquake with magnitude of 7.7 took place on 17.07.2006 at 08:19:25 UT on the western coast of Indonesia (-9.33 ºS, 107.26 ºE) at the depth of 10 km under very quiet conditions in the geomagnetic field (∑Kp = 5). As a result of a powerful explosion a huge wave 5 meters high and even higher (tsunami) was generated which hit Pangandaran (islands of Java). The heights of the tsunami waves were measured by the Tsuji group (Earthquake Research Institute) and Fachrizal et al. (2006).

Figure 1 presents the changes of X components of the magnetic field on 17.07.2006 at observatories of Loparskaya (LOP) (68.63 ºN, 33.25 ºE), Ivalo (IVA) (68.55 ºN, 27.28 ºE) and Sodankyla (SOD) (67.42 ºN, 26.39 ºE).

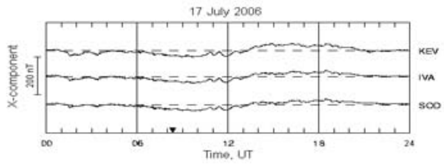


Fig. 1. Daily variations of the X-component of the geomagnetic field on July17, 2006 at the stations Kevo (KEV), Ivalo (IVA) and Sodankyla (SOD) (▼ - the time of beginning of the earthquake).

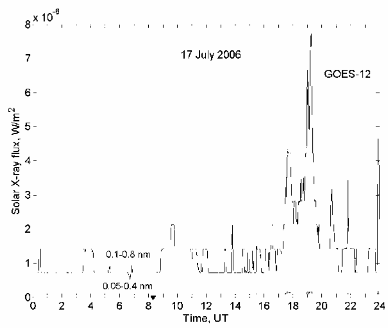


Fig. 2. The variations of the solar X-ray emission flux on July17, 2006 by data of the GOES-12 satellite (▼ - the time of beginning of the earthquake).

Observations of daily variations of solar X-ray radiation fluxes of the wave lengths of 0.05-0.4 nm and 0.1-0.8 nm on board the GOES-11 and GOES-12 geostationary satellites showed that on the considered day of July 17, 2006 the flux of X-ray was insignificant (fig. 2), except for small flares of the A class. The peak flux of the flare did not exceed $8 \cdot 10^{-8}$

W/m^2. Such a quiet period with rare flares of class A lasted from July 10 to 18. According to the riometer data kindly put at our disposal by J. Manninen, a researcher from the Sodankyla Geophysical Observatory, insignificant absorption of space radio emission < 0.61 dB (fig. 3) was observed on the frequency of 29.9 MHz with minute resolution in Ivalo (68.56 ºN, 27.29 ºE).

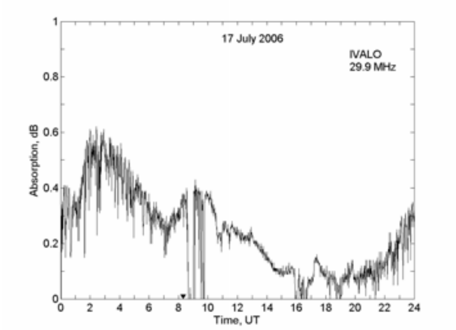


Fig. 3. The variations of the. riometer absorption at the frequency 29.9 MHz on July17, 2006 at the station Ivalo (▼ - the time of beginning of the earthquake).

Let us consider the experimental data obtained by the method of partial reflections at the observatory of Tumanny (69.0 ºN, 35.7 ºE). Figure 4 presents daily variations of amplitude of ordinary components on 16-18 July 2006 at height of 101 km. It can be seen in the figure that on July 17 before the beginning of the earthquake (08:19:25 UT) and after it sine wave fluctuations of amplitude with the period ~ 6 hours and 2 hours are observed, at that the size of the amplitude varies from 500-4700 mV and 1000-2000 mV respectively. In the daily variations of the amplitude of ordinary components on July 16 and 18 it is difficult to distinguish such clear repeating periods. Figure 5 presents the daily spectra of amplitudes. On the day of the earthquake the spectrum with the well manifested maximum is observed on July 17. On the next day after the earthquake on July 18 in the spectrum two basic maxima are observed approximately equal in size. We find the periods from the amplitude spectra of ordinary component amplitude fluctuations. Thus, we believe that fluctuations of the ordinary component amplitude of a signal with periods of a few hours are internal gravitational waves.

The amplitude of electron concentration fluctuations in Tumanny on July 17 at the height of 101 km before the beginning of earthquake at 7.96 UT decreases down to $2.8 \cdot 10^3$ cm^{-3} and then increases up to $2.2 \cdot 10^4$ sm^{-3} (9.0 UT). During these days there were registered sporadic layers (Es) of different types at the station of vertical sounding in Sodankyla (27.37 ºN, 26.63 ºE). In the morning of 16 and 18 July Es (such as h, c, r, a) and in the evening Es (type h and a) were observed.

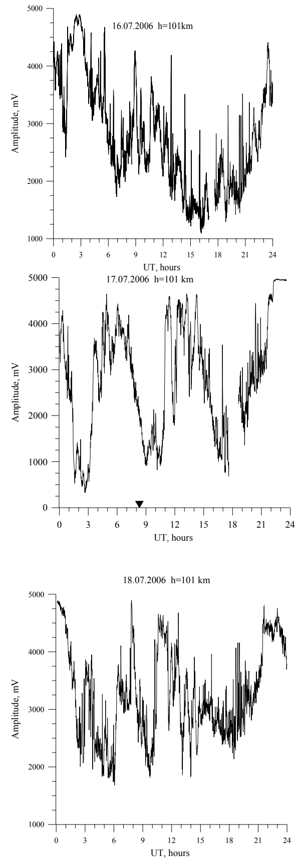


Fig. 4. Daily variations of the ordinary component of the wave at the height of 101 km in Tumanny, (▼ - the time of beginning of the earthquake).

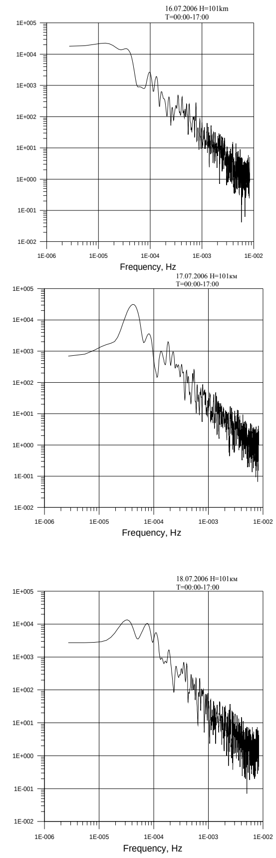
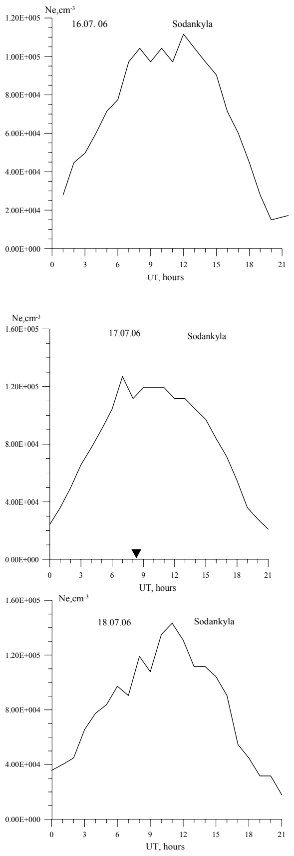


Fig. 5. The amplitude spectra at the height of 101 km.

On the day when the earthquake occurred, on 17 July, during the period from 0 UT up to 8 UT sporadic layers (type l, h, r) and at 14-23 UT (type h and a) were observed. Critical frequencies of sporadic layers foEs at the morning and evening time changed from 15-8 MHz up to 4 MHz. In the afternoon foEs changed from 2.7 MHz up to 3.8 MHz. Before the earthquake critical frequencies of a sporadic layer sharply decreased from 7.5 MHz up to 3.4 MHz. Frequency of penetration fbEs characterizes the electron density in the lower ionosphere and is a parameter of sporadic ionization in the ionosphere. The regular layer of the E region was observed at the height of 100 km at 0-21 UT. From ionospheric data of the Sodankyla observatory mean hour values foE and fbEs for calculation of electron concentration in the E region of the ionosphere were used (fig. 6). Before the earthquake on 17 July the electron concentration in Sodankyla and in Tumanny decreases abruptly. The profiles of electron concentration obtained by means of the method of partial reflections at 6.33 UT, 8.33 UT and 10.33 UT are presented in fig. 7. Profiles of electron concentration at 6.33 UT and 10.33 UT are similar in shape. At the moment of the earthquake the height of the maximum of electron concentration in the E region increased by 1.5 km and then at 10.33 UT it dropped 5 km down and other additional maxima appeared.



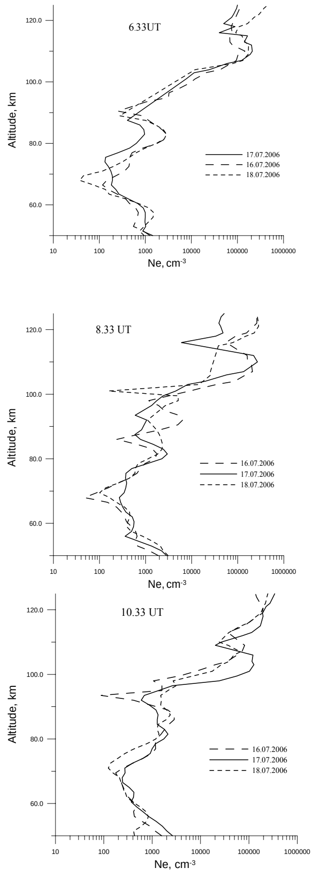


Fig.6. The electron concentration of the *E*-region in Sodankyla (at the height of 100 km).

Fig. 7. The profiles of electron concentration in Tumanny

Conclusions

Under undisturbed conditions the ionization in the lower ionosphere is created by the following usual sources: direct and scattered radiation of the Sun in lines L_α and L_β, X-ray radiation $\lambda = 0.05 - 10$ nm, galactic space rays and radiation in the range of 102.7-111.8 nm [Smirnova et al., 1984, 1988]. Radiation in the line L_α ($\lambda = 121.57$) is effective in the *D* region.

This radiation can be responsible for formation of the usual undisturbed D region by ionizing the nitrogen oxide. Radiation in the line L_β ($\lambda = 102.6$ nm) can give the contribution to electron concentration, basically, by means of ionization O_2. In our case, as mentioned above the X-ray radiation on 17 July 2006 was insignificant. The absorption of space radio emission according to the riometer data in Ivalo was insignificant either < 0.61 dB. The data of monitor in Oulu (65.05 ºN, 25.47 ºE) showed, that changes of hourly average values of space rays intensity to the monthly median value make 1-2 %. In the day time conditions ionization from the sunlight is rather high. In the twilight and during night periods (at the big zenith angles and at low ionization by scattered sunlight) their basic source is the precipitating high energy electrons, even under quiet conditions.

Mikhaylov et al. [2003] showed, that in the ground atmosphere internal gravitational waves have seismogravitational nature in spectra of the Ez electric field. From the analysis of atmospheric noise spectra and power spectra of the Ez electric field, measured simultaneously in Kamchatka, Mikhaylov et al [2004] found some similarity of spectra in shape, on the eve of the earthquake. It testifies about the penetration of internal gravitational waves up to heights (~80-120 km) of the lower ionosphere. From the analysis of experimental data we are making a conclusion that fluctuations of the amplitude of ordinary components of signal with the periods of a few hours, could have been caused by internal gravitational waves. The such periods are characteristic for internal gravitational waves registered by hydroxyl emissions at the height of 90 km in Yakutsk [Atlasov et al 1978].

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