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WAVE DISTURBANCES IN THE LOWER IONOSPHERE DURING THE EARTHQUAKES ON AUGUST 2006

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Abstract. The experimental data, measured by a partial reflections radar in the Kola Peninsula at observatory Tumanny (69.0ºN, 35.7ºE) and vertical sounding of the ionosphere at observatory Sodankyla (67.37º N, 26.63º E) were analyzed with the purpose of the reason finding out ionospheric responses to earthquakes on August 2006. The strong earthquakes were fixed by seismic stations, located in the Kola Peninsula and Scandinavia. Earlier, we have chosen ten the strong earthquakes, which took place under quiet geomagnetic field and at small (background) solar flares. In this study we have considered earthquakes which have occurred under other geophysical conditions in the Pacific and Indian Oceans.

1. Introduction

Earthquakes influence on the ionosphere has been investigated more than 50 years with aim to find precursors of the earthquakes on ionosphere parameters. The forecasts of the strong earthquakes are necessary at present.

The ionosphere represents the dynamic environment influenced by different disturbances. Mainly they come from the Sun, but some of them come from the lithosphere of the Earth.

Earlier, we have considered in detail ten strong earthquakes, which took place at the western seaside of the Indonesia, near island Java, in region of island Sumatra, at Island of the king Eduard in Atlantic Ocean and at New Zealand. Under the quiet geomagnetic field and at small solar flares the reaction of the high- latitude ionosphere to these strong earthquakes was seen basically in parameters of the lower ionosphere (Sergeeva N.G et al., 2007; 2008; 2009 a; 2009 c). We have also analyzed spectra of the ordinary component amplitude of the partial-reflected signal under the quiet geomagnetic field and at small solar flares on the days, when there were no strong earthquakes. In spectra of the ordinary component amplitude of partial-reflected signal only tidal atmospheric waves with the different periods were observed. It is proof that at days of the earthquakes the discovered internal gravity waves with the periods of some hours are connected with earthquakes (Sergeeva et al., 2009b).

The purpose of this work is a finding of the general regularities in changes parameters of seismo-ionospheric disturbances in high-latitude ionosphere, caused by strong earthquakes on August 7 and 11, 2006. The earthquake on August 7 took place under very disturbed geomagnetic field and at weak solar flares of A- class. Another earthquake on August 11 took place under the quiet geomagnetic field and at several solar flares of B- class and C-class.

2. The analysis of experimental data

The considered day on August 7 was strongly disturbed (∑Kp =32.3). Index of disturbance Kp= 5.7 existed at 9-12 UT, that is classified as magnetic storm (Kp > 5). At the following days the geomagnetic activity decreased and on August 8 was already weakly. In figure 1 the magnetograms of the X- component of the geomagnetic field, measured at magnetic stations Soroya (70.54ºN, 22.22ºE) and Pello (66.90ºN, 24.08ºE) are submitted.

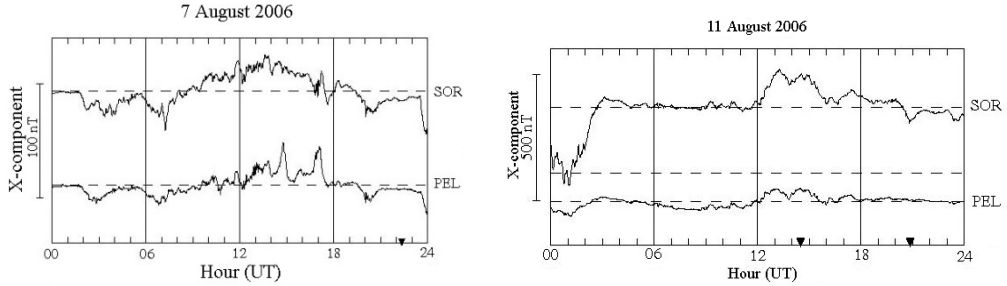

Fig. 1. Magnetograms of the X- component of the geomagnetic field on August 7 and 11, 2006 at stations Soroya (SOR) and Pello (PEL), (▼-time of the earthquakes beginning).

First earthquake on August 11 took place under small positive bay of the geomagnetic field (125 nT). The weak solar flares of A-class on August 7 were observed (fig.2 from the left). The solar activity increased gradually. In the following days on August 8 and 9 the solar flares of B- class began to appear. Solar flares of B-class and C-class were observed during on August 11 (fig.2 to the right). For August 7- 9 the variations of the particles of solar wind (the protons with energy > 1 MeV and electrons with energy > 2 MeV) were registered by satellites GOES-10 and GOES-12. Herewith, the fluxes of electrons on August 8 were increased on one order during several days, including

on August 11. Weak variations of the interplanetary magnetic field were observed also, particularly in first half of day on August 7.

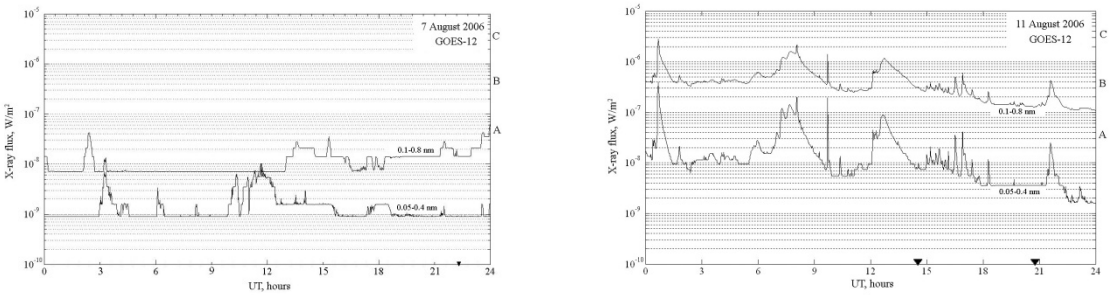

Fig. 2. The variations of the solar X-ray emission fluxes on August 7 and 11, 2006 by of the GOES-12 satellite. (▼-time of the earthquakes beginning).

The riometric absorption at the frequency 29.9 MHz at stations Ivalo (68.55º N, 27.28º E) and Sodankyla (67.37º N, 26.63º E) on August 7, 8 in the first half of the day were increased till 2.5 dB and 4.5 dB, accordingly.

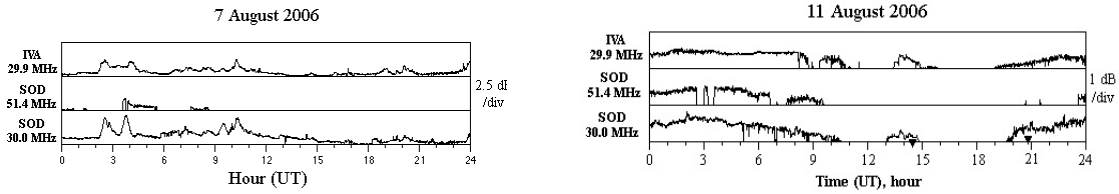

Fig. 3. The variations of riometer absorption at the frequency 29.9 MHz on August 7 and 11, 2006 at stations Ivalo (IVA) and Sodankyla (SOD). (▼-time of the earthquakes beginning).

The geomagnetic field (Kp =10.3) on August 11, 2006 can be considered as quiet. The solar activity reach maximum value, when three flares of C-class appeared. Then solar activity began to decrease. The interplanetary magnetic field was practically quiet. Riometer absorption at the frequency 29.9 MHz at stations Ivalo and Sodankyla on August 11 was weak, slowly changing and does not exceed 0.5 dB. The strong earthquake with the magnitude of 6.7 on the Richter scale took place on 7.08.2006 at 22:18:55 UT northward from island Vanuatu, in the Pacific Ocean (-15.80 ° S, 167.79 ° E) on the depth of 150 km under very disturbed geomagnetic field (Kp=32.3) and at weak solar flash of A-class.

Two strong earthquakes have occurred on 11.08.2006. The first earthquake with the magnitude of 6.1 on the Richter scale took place at 14:30:40 UT on 150 km to south-west from Tokyo (18.54 ºN, -101.05 ºE). The epicenter of the earthquake was situated on the depth of 56 km under bottom of the Pacific Ocean. The second strong earthquake with the magnitude of 6.2 on the Richter scale took place at 20:54:14 UT in region island Sumatra (2.40 ºN, 96.35 º E) on the depth of 22 km. The experimental data of partial-reflected signal were obtained in the Kola Peninsula at the observatory Tumanny (69.0ºN, 35.7º E). In fig.4 daily spectra of the ordinary component amplitude of partial-reflected signal on August 07 and 11 at height of 101 km at the observatory Tumanny are shown.

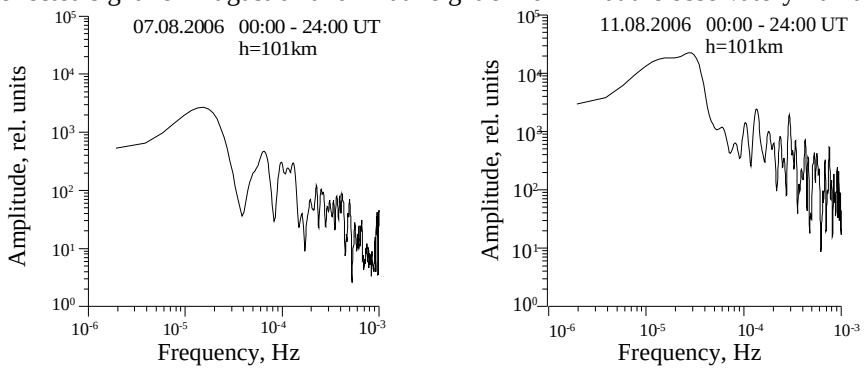

Fig. 4. Daily spectra of ordinary component amplitude of partial-reflected signal on August 7 and 11 at Tumanny.

On day of the earthquake on August 7 in spectrum of the ordinary component amplitude of partial-reflected signal, together with tidal atmospheric waves with the period of 18 hours, also internal gravity waves with the periods of 2-4 hours were observed. At day of the earthquake on August 11 in main maximum of the spectrum of the ordinary component amplitude of partial-reflected signal along with tidal atmospheric wave with periods of 18, 10 hours and internal gravity waves with periods of 3-5 hours were observed. On 11.08.2006 the spectrum of ordinary component amplitude of partial-reflected signal is broader, than spectrum of the amplitudes on August 7.

In figure 5 daily variations of least frequency of reflection fmin with the hour resolution on August 7-9 and 10-12, 2006 are submitted. The fluctuations of the amplitude of the least frequency fmin on August 7 at station of the vertical sounding of the ionosphere at Sodankyla increased till 3 MHz before beginning of the earthquakes and after it. On August 11 the fluctuations of the amplitude least frequency of fmin increased till 1.5 MHz before beginning of first earthquake. Full absorption of waves (B) in the ionosphere was observed on August 8 at 6 LT, 10-12 LT, 14 LT.

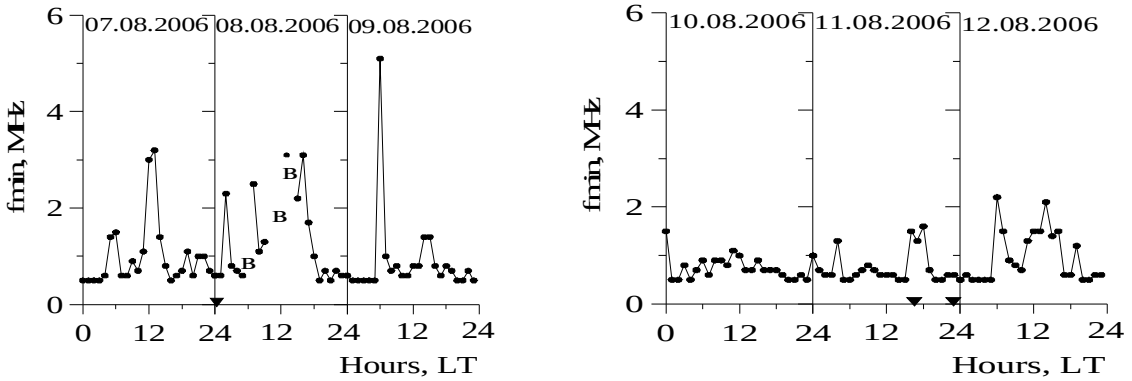

Fig. 5. Daily variations least frequency fmin on August 7-9 and 10-12, time LT=UT+2 hours (▼-time of the earthquakes beginning).

Daily spectra amplitudes of the least frequency fmin in days of the earthquakes on August 7 and 11, 2006 are submitted in figure 6. In spectrum of the amplitudes of the fluctuations of the least frequency of reflection (fmin) on 7.08 the tidal atmospheric waves since periods of 16 and 11 hours were observed along with internal gravity waves since periods of 2-4 hours. On 11.08 under high solar activity in spectrum of the fluctuations fmin amplitudes together with tidal atmospheric waves with the periods of 8 hours, also internal gravity waves periods of 2-4 hours were observed.

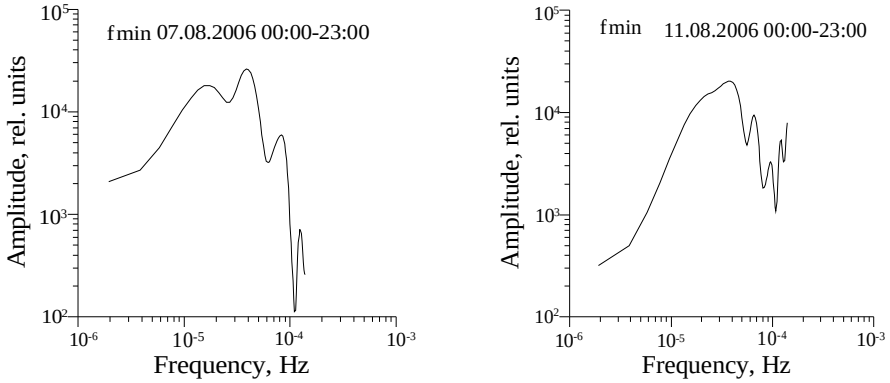

Fig. 6. Daily spectra amplitudes of the least frequency fmin on August 7 and 11, 2006.

The similar fluctuations of critical frequency foEs amplitudes of sporadic layer were observed. In spectra of the amplitudes foEs in the evening and morning on7.08. and 11.08.2006, together with tidal atmospheric waves with periods of 15, 11 hours, also internal gravity waves periods of 2-6 hours were observed (fig.7).

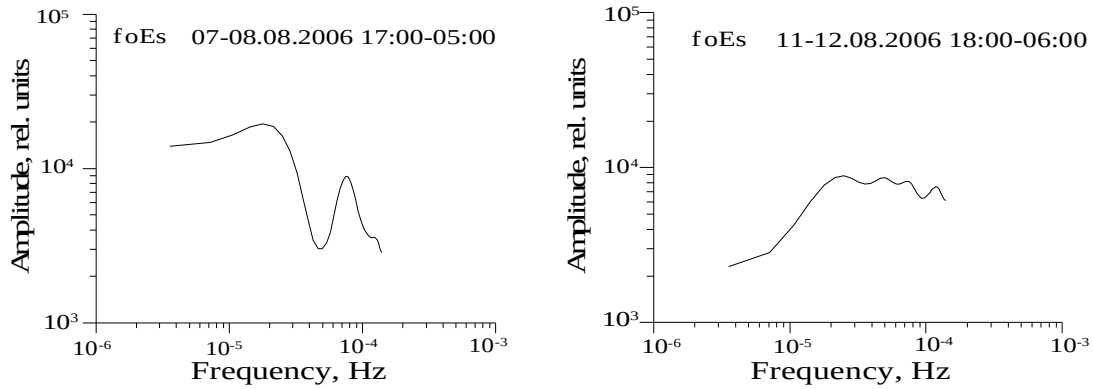

Fig. 7. Spectra of the amplitudes of sporadic layer foEs in the evening and morning on 7.08. and 11.08.2006. Time LT=UT+2 hours.

3. Discussion

In the day-time the conditions of ionization from the sunlight is rather high. High-energy precipitating electrons are main source of ionization in the twilight and during night, even under quiet conditions. The electrons with energy of ten keV liberally are penetrated at heights of 60-80 km. The fluxes of electrons increased from ten till hundreds times under disturbed conditions. (Danilov et. al., 2002). As it was mentionned already, on very disturbed day August 7 the flux of solar x-ray was weak (the flares of A-class). Riometeric absorption at frequency 29.9 MHz at observatories Ivalo and Sodankyla increased till 2.5 dB in the first half of day. The typical dependence of the least frequency fmin with index of disturbances Kp is observed in this day. The value fmin grows with growing of the magnetic activity. This means, that ionization in the lower ionosphere is caused by energy electrons, which precipitate from tail magnetosphere (Danilov, 2002). Two strong earthquakes took place on August 11, 2006 under quiet geomagnetic field and high solar activity. Riometeric absorption at frequency 29.9 MHz at observatories Ivalo and Sodankyla on August, 11 was weak, slowly changing and does not exceed 0.5 dB. During day solar flares of B-class and flares C-class were observed. The solar radiation of 102.7- 111.8 nm and electrons, entering in ionosphere can be by source of variations fmin in midday. Analysis of the experimental data has shown that, it is necessary to take into account additional sources of the disturbances in lower ionosphere.

4. Summary

From the analysis of experimental data we summarize our results as follows.

• In day of the earthquake on August 7 the auroral absorption increased under very disturbed geomagnetic field.

• On days of the earthquakes in the daily spectra of ordinary component of a partly-reflected signal, of the least frequency of reflection (fmin), of critical frequency of the sporadic layer (foEs), together with tidal atmospheric waves with various periods, also internal gravity waves with the periods of 2-6 hours were observed.

• The daily spectrum of amplitudes of the ordinary component of a partly-reflected signal, on August 11 is broader, than spectrum on August 7.

• The wave fluctuations of the amplitudes of the ordinary component of partly-reflected signal and the other parameters of the lower ionosphere with periods of several hours were caused by internal gravity waves, connected with earthquakes.

Acknowledgments. The experimental data of partial-reflected signal were obtained in the Kola Peninsula at observatory Tumanny (69.0ºN, 35.7º E). Data of vertical sounding of the ionosphere were measured in Finland at observatory Sodankyla (67.37 º N, 26.63 º E).

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