"Physics of Auroral Phenomena", Proc. XXXII Annual Seminar, Apatity, pp. 181 - 184, 2009

Polar Geophysical Institute

RESPONSES TO THE EARTHQUAKES IN THE LOWER HIGH-LATITUDE IONOSPHERE

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Abstract. Experimental data measured by a partial reflections radar in the Kola Peninsula at the observatory Tumanny (69.0°N, 35.7°E) in the course of the period from May till August 2006 were analyzed with the purpose of finding out of ionospheric responses to earthquakes. For this period in the region of the Island Java there were 40 strong earthquakes with magnitudes of 5.8 to 7.7 on the Richter scale, which were fixed also by the seismic stations located in the Kola Peninsula and Scandinavia. The earthquakes took place under different geophysical conditions. For the analysis we have chosen earthquakes which took place under the quiet geomagnetic field and at small (background) solar flares.

1. Introduction

Earlier we considered in detail two strong earthquakes on 17 July 2006 and on 26 May 2006 which took place in one region at the same depth of 10 km under the quiet geomagnetic field and at small solar flares of the A-class. The first earthquake with the magnitude 7.7 took place on 17 July 2006 at 08:19:25 UT at the western coast of Indonesia (9.33°S, 107.26°E) under the very quiet geomagnetic field (∑Kp = 5.7). Another strong earthquake with the magnitude 6.2 took place on 26 May 2006 at 22:53:59 UT in the southern hemisphere on the Island Java, Indonesia (7.94°S, 110.32°E) under the quiet geomagnetic field (∑Kp = 6.3). From the analysis of experimental data of partial reflections and vertical sounding of the ionosphere we have found the general behavior of changes of the high-latitude ionosphere parameters. Reaction of the ionosphere to these strong earthquakes under the quiet geomagnetic field and at small solar flares was showed in parameters of the lower ionosphere [Sergeeva et al., 2007; 2008; 2009a, b].

In this work we have considered changes of high-latitude ionosphere parameters which were caused by strong earthquakes in the Atlantic Ocean.

2. Analysis of experimental data

For finding effects in the ionosphere, caused by lithospheric processes at the final phase of preparation of earthquakes, we chose earthquakes taken place under the quiet geomagnetic field and at weak solar flares. Such conditions are necessary to decrease amount of different sources which can cause disturbances in the ionosphere. 10 strong earthquakes were observed under such circumstances.

At first we consider experimental data for the earthquake on 09 June 2006. The earthquake with the magnitude 5.9 took place at 23:17:26 UT in the southern hemisphere in the region of the Islands of Prince Edward in the Atlantic Ocean (47.38°S, 32.29°E) on the depth of 10 km under the weakly disturbed geomagnetic field (∑Kp=17.3). In Figure 1 magnetograms of the observatory Loparskaya (68.63°N, 33.25°E) for the 9-10 June are shown. The geomagnetic field on 9 and 10 June can be considered as quiet (∑Kp = 17.3 and 15.7, accordingly).

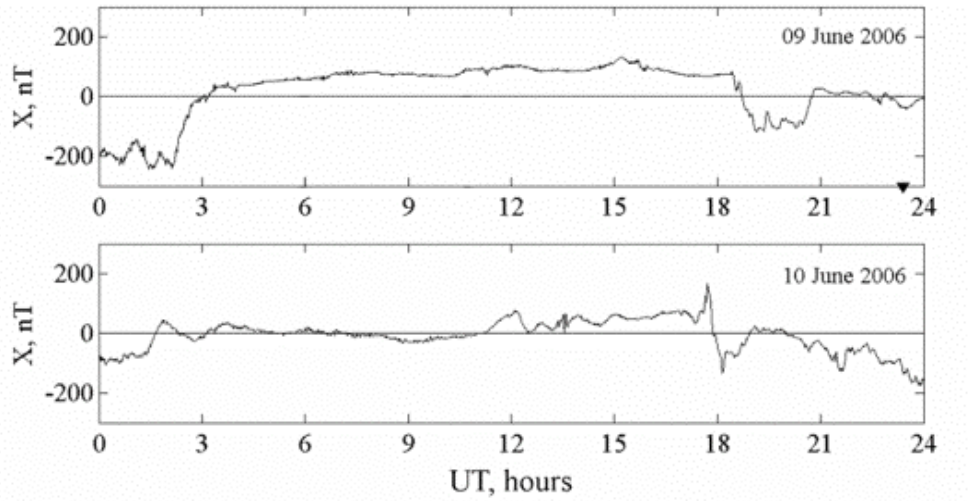

Figure 1. Daily variations of the X component of the geomagnetic field on 9 and 10 June 2006 at the observatory Loparskaya (▼ - time of the earthquake beginning).

Fluxes of solar electrons and protons, as well as the interplanetary magnetic field, had not noticeable changes. The fluxes of solar X-rays, registered on the satellites GOES-10 and GOES-12, were typical for quiet days. Solar activity was up to standard background of the A-class and only on 10 June from 16:30 UT till 17:00 UT in the long-wave spectrum of X-ray radiation one weak flare of the B-class was observed. Riometric absorption at the frequency of 29.9 MHz at the observatory Ivalo (68.55°N, 27.28°E) on 9 June from 0 UT till 4 UT was weak and then decreased up to background. Weak absorption was observed on 9 June after 22 UT till 8 UT and on 10 June after 19 UT. The experimental data of partial reflections were obtained in the Kola Peninsula at the observatory Tumanny. Data of vertical sounding of the ionosphere were obtained in Finland at the observatory Sodankylä (67.37°N, 26.63°E). In Figure 2 daily variations of the ordinary component amplitude of partial-reflected signal and spectra of the amplitudes on 9 and 10 June 2006 at the height of 101 km at the observatory Tumanny are shown.

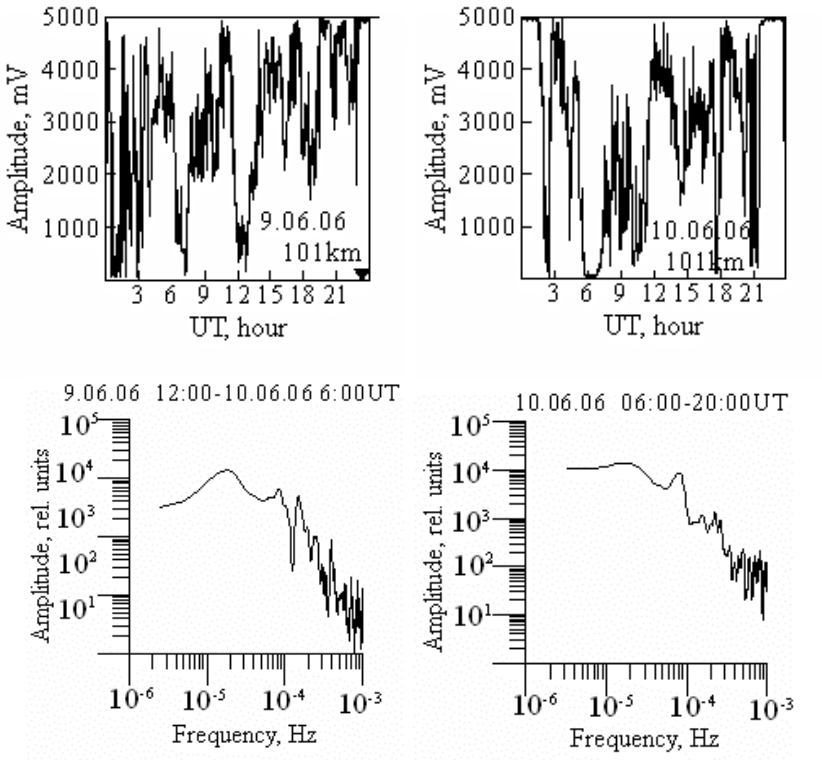

Figure 2. Daily variations of ordinary component amplitude (top) and spectra of amplitudes (bottom) on 9 and 10 June 2006 at the observatory Tumanny (▼ - time of the earthquake beginning).

From Figure 2 it is seen that after the earthquake on 10 June the maximum of the spectrum of amplitudes broke up to some maxima, as it was at other earthquakes. Before the beginning of the earthquake on 9 June 2006 the amplitude of ordinary component variation of wave at the height of the E-layer changed from 1500 mV up to 5000 mV. After the earthquake on 10 June 2006 the amplitude of ordinary component variation of wave has increased from 140 mV up to 5000 mV. In the spectrum of ordinary component amplitude of the partial-reflected signal on 9 June 2006, together with tidal atmospheric waves with the period of 11 hours, also internal gravity waves with the period of 2-6 hours were observed. On 10 June 2006, the next day after the earthquake, tidal atmospheric waves with the periods of 20 and 8 hours were observed.

In Figure 3 daily variations of the frequency fmin and spectra of amplitudes with the hour resolution on 9-10 June 2006 are submitted. Full absorption of waves in the ionosphere was observed on 8 June 2006 at 0-2 LT, 5 LT, 7-8 LT, 10-11 LT. In the day of the earthquake on 9 June 2006 full absorption of waves was observed at 3-4 LT. Variations of fmin at the vertical sounding station Sodankylä began after 12 LT on 8 June 2006. The periods of variations before the earthquake and after the beginning of the earthquake were 3-5 hours.

Another earthquake with the magnitude 6.0 took place on 18 June 2006 at 18:28:02 UT in the northern hemisphere in the region of Northern Mid-Atlantic ridge (33.03°N, 39.7°W) on the depth of 9.6 km. The earthquake was under the quiet geomagnetic field ($\sum Kp = 10.7$) and at small solar flares of the A-class. On 17 and 18 June satellites GOES fixed on their orbits the fluxes of X-ray radiation which are typical for quiet conditions.

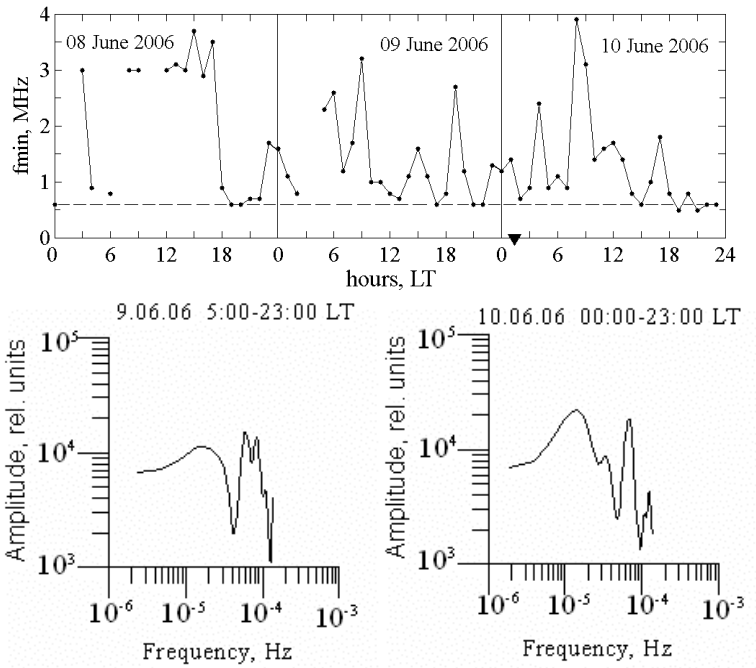

Figure 3. Daily variations of the frequency fmin and spectra of amplitudes on 9-10 June 2006 (▼- time of the earthquake beginning) LT=UT+2 hours.

At the same time, fluxes of electrons and protons, and also the magnetic field, differed from the quiet course from 04 till 12 UT. On 19 June parameters of solar wind and X-ray radiation were quiet too. Riometric absorption at high-latitude stations on 18 June was increased from 5 till 12 UT. The maximal value in 4 dB was observed at 8-9 UT. At another time absorption was small, not more than 1 dB (Fig. 4). The specified behavior of riometric absorption was connected with changes of solar wind parameters. The next day on 19 June riometric absorption behaviour was entirely quiet and can be considered as not disturbed.

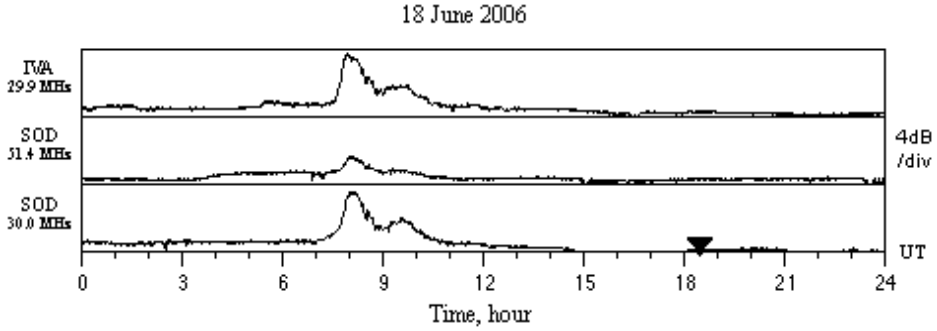

Figure 4. The riometric absorption on 18 June 2006 at stations Ivalo and Sodankylä (Finland) (▼ - time of the earthquake beginning).

In Figure 5 daily variations of ordinary component amplitude of partial-reflected signal and spectra of amplitudes at the height 101 km on 18 and 19 June 2006 are submitted. From the Figure it is seen that after the earthquake, on 19 June, the maximum broke up to several maxima, as well as during other earthquakes. Before the beginning of earthquake on 18 June 2006 the ordinary component amplitude of the wave at the height of the E-layer changed from 10 mV up to 5000 mV. After the earthquake, on 19 June 2006, the amplitude of fluctuations of the ordinary component of the wave changed from 1500 mV up to 5000 mV. In the day of the earthquake on 18 June 2006 in the spectrum of ordinary component amplitude of partial-reflected signal, together with tidal atmospheric waves with the period of 11 hours, internal gravity waves with the periods of 2-6 hours were also observed. On 19 June 2006 in the maximum of the spectrum of ordinary component amplitude of partial-reflected signal tidal atmospheric waves with the period of 11 hours were observed.

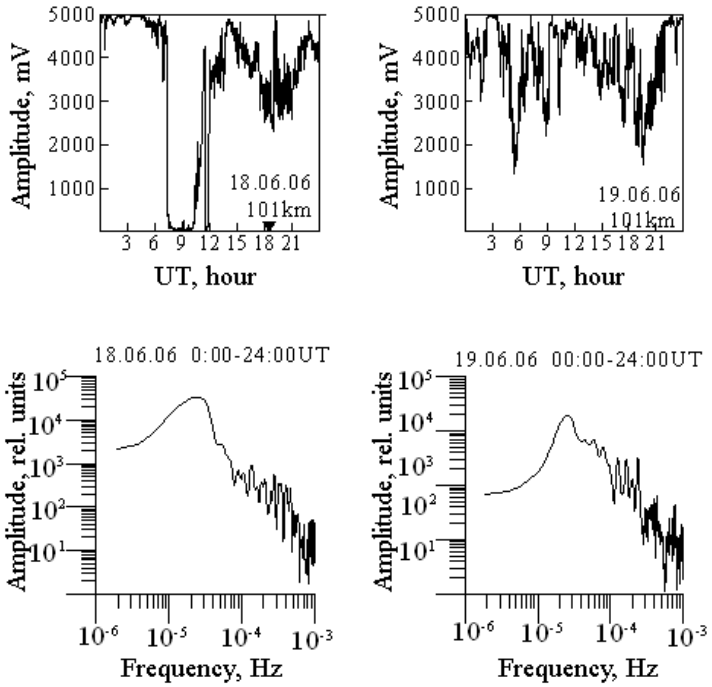

Figure 5. Daily variations of ordinary component amplitude of partial-reflected signal and spectra of amplitudes at the height 101 km on 18 and 19 June 2006 (▼ - time of the earthquake beginning).

From the analysis of experimental data we have found that there were similar regularities in changes of parameters of seismo-ionospheric disturbances as they were during other earthquakes [Sergeeva et al., 2007; 2008; 2009a, b]. We have also analyzed spectra of the ordinary component amplitude of the partial-reflected signal under quiet conditions in the geomagnetic field and at small solar flares on the days when there were no strong earthquakes. During the considered period from May till August 2006 it was only twice: on 12 June (∑Kp = 6.3) and on 17 June 2006 (∑Kp = 16.7). The solar activity on 12 June 2006 was weak with the A-class flares. The weak B-class flare was observed on 17 June at 10 UT. In the main maximum of the spectrum of ordinary component amplitude of partial-reflected signal on 12 June and on 17 June only tidal atmospheric waves with the different periods of 18, 12 and 8 hours were observed. It is proved that the amplitude fluctuations of the ordinary component of the partially reflected signal with the periods of some hours are caused by internal gravity waves related to the earthquakes.

3. Conclusions

Thus, we have come to the following conclusions:

1. Under quiet conditions in the geomagnetic field and at small solar flares in the days of earthquakes amplitude fluctuations of the ordinary component of partial-reflected signal and fmin with the periods of several hours are caused by internal gravity waves which are connected with earthquakes.
2. In the days of strong earthquakes in spectra of ordinary component amplitude of partial-reflected signal, together with tidal atmospheric waves of different periods, also internal gravity waves with the periods of 2-6 hours are observed.

References

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