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RESPONSES TO THE EARTHQUAKE ON 26 MAY 2006 IN THE LOWER HIGH-LATITUDE IONOSPHERE

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Abstract. The strong earthquake with magnitude 6.2 occurred on 26 May 2006 at 22:53:59 UT in the southern hemisphere at the island Java, Indonesia (7.94º S, 110.32º E) is considered. The analysis of experimental data shown that for the strong earthquakes on 26 May 2006 and 17 July 2006 at the quiet geomagnetic field and at small flares of the class A the reaction of the high-latitude ionosphere was seen basically in parameters of the lower ionosphere. At the moment of the beginning of the earthquakes and later in amplitude spectra of the ordinary components of partially-reflected signal the internal gravity waves with the periods of some hours were observed, which are related to the earthquakes.

Introduction

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. The authors are interested in the processes in the Earth's crust at the stage of preparation of earthquakes and their influence on the high-latitude lower ionosphere. In the work we have considered effects in the ionosphere caused by the lithosphere processes taken place at the final phase of earthquakes' preparation. For the purpose we have analyzed experimental ionospheric data during earthquakes taken place under quiet conditions in the geomagnetic field. It is necessary to note that behaviour of the ionosphere depends on the features occurring in the Earth's crust: magnitude value, depth and location of the epicenter of an earthquake, types of stratum, etc. They are individual for each concrete earthquake. Earlier, in detail we considered the strong earthquake with magnitude 7.7, which took place on 17 July 2006 at 08:19:25 UT at the western coast of Indonesia (9.33ºS, 107.26ºE) on the depth of 10 km under the quiet geomagnetic field ($\sum Kp = 5.7$).

In the work experimental data of partial reflections radar (Tumanny, Russia; 69.0°N, 35.7°E) and vertical sounding of the ionosphere (Sodankyla, Finland, 67.41°N, 26.39°E) have been analyzed during another strong earthquake on 26 May 2006 under the quiet geomagnetic field ($\sum Kp = 6.3$). Both earthquakes (26 May 2006 and 17 July 2006) took place during periods, when in the high-latitude ionosphere the polar day was (when the night ionosphere was lighted).

The analysis of experimental data

The strong earthquake with magnitude 6.2 took place on 26 May 2006 at 22:53:59 UT in the southern hemisphere near the island Java, Indonesia (7.94ºS, 110.32ºE) on the depth of 10 km. Within several days before the earthquake the geomagnetic field was quiet. The sum of Kp for previous days steadily decreased: on 22 May - ($\sum Kp = 15.3$), on 23 May - ($\sum Kp = 9.0$), on 24 May - ($\sum Kp = 6.7$), on 25 May - ($\sum Kp = 6.7$). The day on 26 May 2006 was quiet ($\sum Kp = 6.3$) too. In Figure 1 for this day magnetograms of observatories Loparskaya (LOP, 68.63°N, 33.25°E), Ivalo (IVA, 68.55°N, 27.28°E) and Sodankyla (SOD, 67.37°N, 26.63°E) are shown. The records show typical quiet solar-diurnal variations of the geomagnetic field. The next day the geomagnetic field was more quiet: $\sum Kp = 3.3$. In previous days on 24 and 25 May two moderate earthquakes were: on 24 May 2006 at 10:11:08 UT near the north coast of Irian Jaya (2.23°S, 139.20°E, magnitude 5.5) and on 25 May 2006 at 20:48:06 UT near to the coast of Peru (17.99°S, 71.04°W, magnitude 5.7).

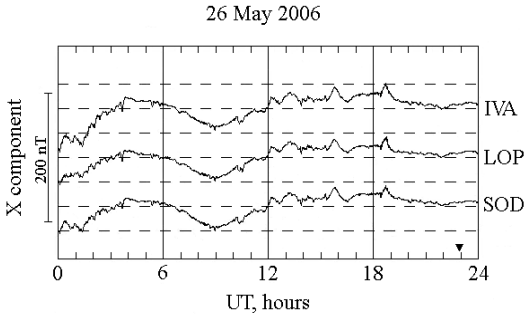

Fig. 1. Daily variations of the X component of the geomagnetic field on 26 May 2006 at the stations Loparskaya (LOP), Ivalo (IVA) and Sodankyla (SOD), (▼ – the time of beginning of the earthquake).

In Figure 2 the flow of solar X rays registered on 26 May 2006 on the satellite GOES-10 is shown. It is seen that only weak A-class solar flares were on the Sun within all the day. For previous days solar activity was also weak, some B-class solar flares were observed.

In Figure 3 riometric absorption measured in the observatory Ivalo has been shown. It is seen that during the considered day the intensity of space radio emission did not experience considerable changes and was at the background level. Experimental data of partial reflections and vertical sounding of the ionosphere were received on the Kola Peninsula at the observatory Tumanny (69.0ºN, 35.7ºE) and in Scandinavia at the observatory Sodankyla (67.37ºN, 26.63ºE).

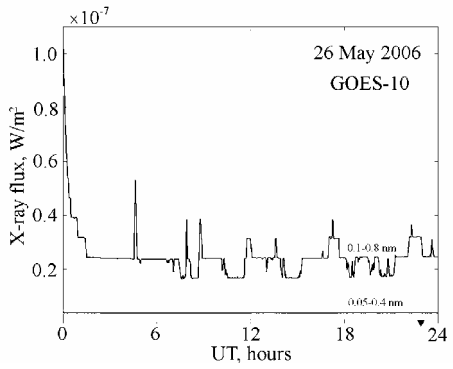

Fig. 2. The variations of the solar X-ray emission flux on 26 May 2006 by data of the GOES-10 satellite (▼ - the time of beginning of the earthquake).

Before the beginning of the earthquake on 26 May 2006 the change of ordinary component amplitude of sounding waves at the height of E layer (101 km) were from 2400 mV up to 5000 mV. Just after the earthquake on 27 May 2006 variation of amplitude decreased.

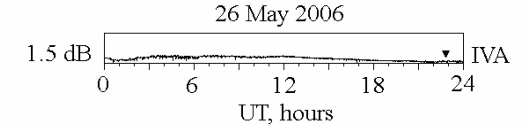

Fig. 3. The variations of the riometer absorption at the frequency 29.9 MHz on 26 May 2006 at the station Ivalo (▼ - the time of beginning of the earthquake).

The received spectra of ordinary component amplitude of partially reflected signals for considered days are submitted in Figure 4. From the figures it is seen that after the earthquake the maximum broke up to some maxima. The fluctuation periods of amplitude prior to the beginning of the earthquake on 26 May 2006 were 2-6 hours. After the earthquake on 27 May 2006 the periods of 1-4 hours are observed.

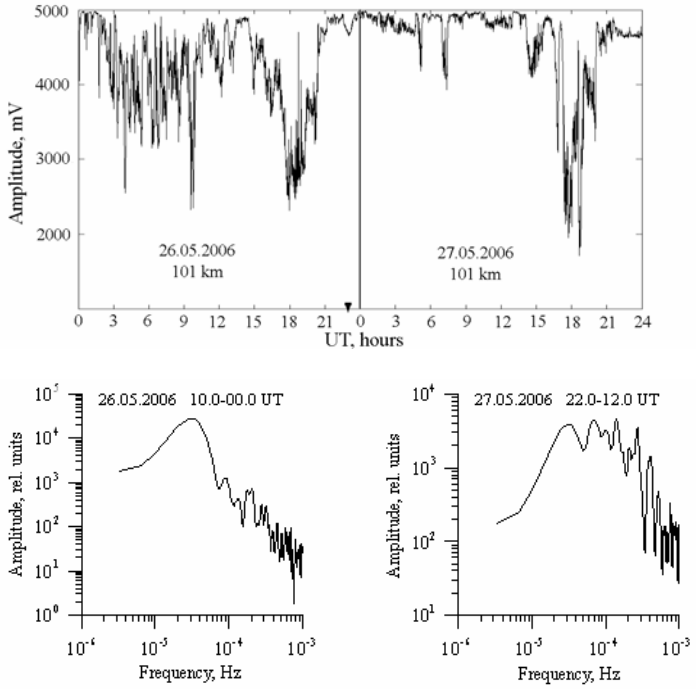

Fig. 4. Daily variations of the ordinary component of the wave (top) and amplitude spectra (bottom) on 26 May 2006 at the height of 101 km at Tumanny (▼ - the time of beginning of the earthquake).

In Figure 5 for 25-27 May daily changes of fmin and spectra of amplitudes with the hour resolution are submitted (ionospheric data of the observatory Sodankyla were given in local time. The local time = UT+2h). Fluctuations of fmin amplitudes at the station of vertical sounding at Sodankyla began two days prior to the beginning of the earthquake on 26 May 2006. It is probably that in the figure we can see influence of the earthquakes taken place on 24 and 25 May. Just prior to the beginning of another earthquake of 17 July 2006 fluctuations of fmin amplitudes were during twenty hours. As it can be seen from the spectra of fmin amplitudes the periods of the fluctuations prior to the beginning of the earthquake and after it were 2-5 hours (on 25 May 2006 and on 27 May 2006). For the day of the earthquake on 26 May 2006 the periods of fluctuations have increased (2-6 hours). In Figure 6 (top) daily variations of ordinary component amplitude on 16-18 July 2006 at the height of 101 km are submitted. From the figure it is seen that on 17 July, before the beginning of the earthquake (08:19:25 UT) and after, wave fluctuations of the amplitude with the period 3-6 hours were observed, thus the size of the amplitude changed from 500 mV up to 4700 mV. On 16 and 18 July the repeating periods in daily variations of ordinary component amplitude were not present.

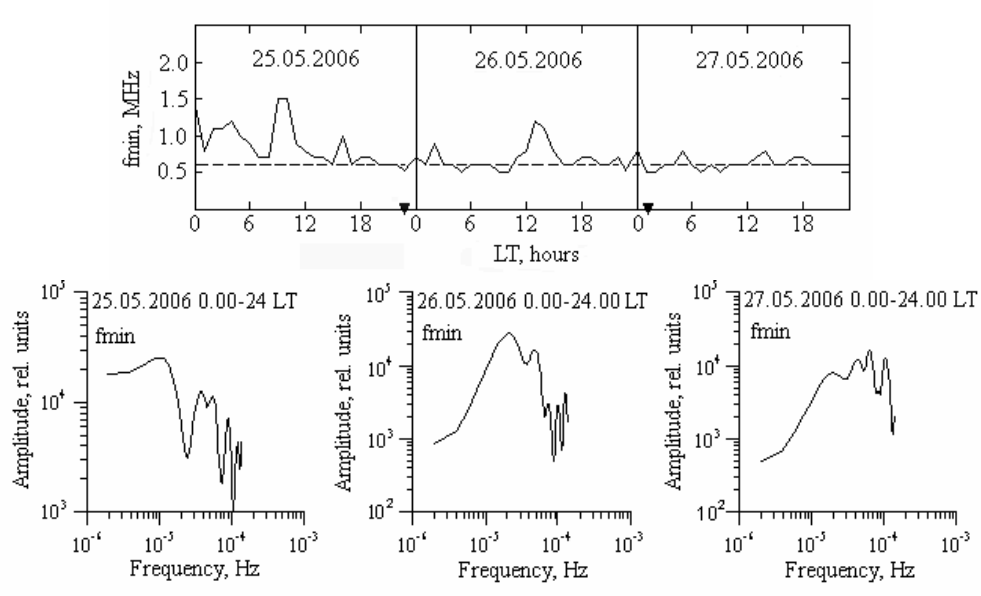

Fig. 5. Daily variations of fmin (top) and amplitude spectra (bottom) on 26 May 2006 at Sodankyla (▼ - the time of beginning of the earthquake. Local time = UT+2h).

In Figure 6 (bottom) daily spectra of the amplitude are submitted. On 17 July, the day of the earthquake, the spectrum with the well-expressed maximum was observed. On 18 July, the next day after the earthquake, in the spectrum two basic maxima approximately equal to each other. From the amplitude spectra of ordinary component fluctuations we found periods of the fluctuations. On 17 July periods of the fluctuations increased up to 3-6 hours in comparison with 16 July when periods of 2-3 hours were observed.

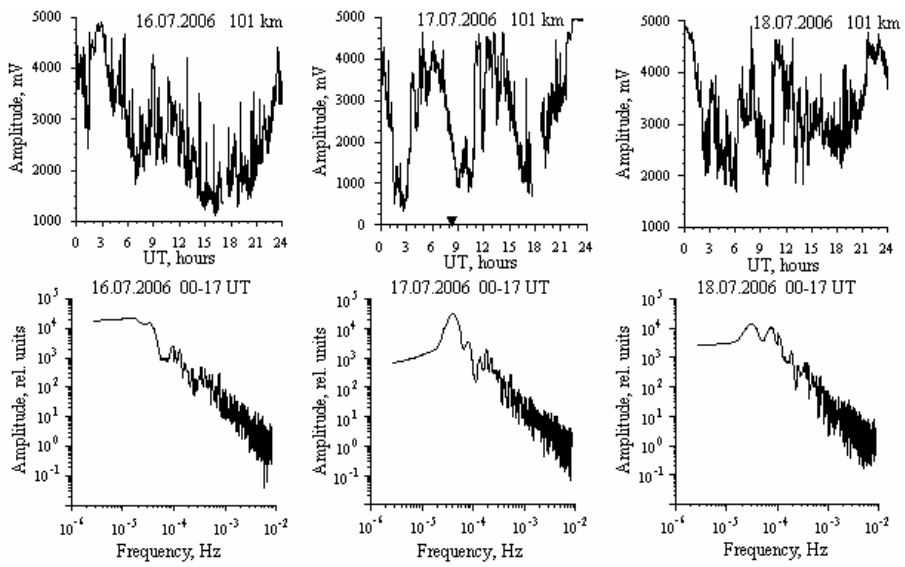

Fig. 6. Daily variations of the ordinary component of the wave (top) and amplitude spectra (bottom) on 17 July 2006 at the height of 101 km at Tumanny (▼ - the time of beginning of the earthquake).

In Figure 7 (top) for the 16-18 July daily changes of the least frequency (fmin) with the resolution of 10 minutes are submitted. In this figure fluctuations during twenty hours prior to the beginning of the earthquake (on 16 July 2006 from 14.00 LT) are visible. Before the earthquake on 17 July 2006 amplitude of fluctuations has increased from about 1.0 MHz up to 2.2 MHz. For the spectrum of fmin the periods of fluctuations are 3-6 hours (Fig.7, bottom) [see also, Sergeeva et al., 2007, 2008].

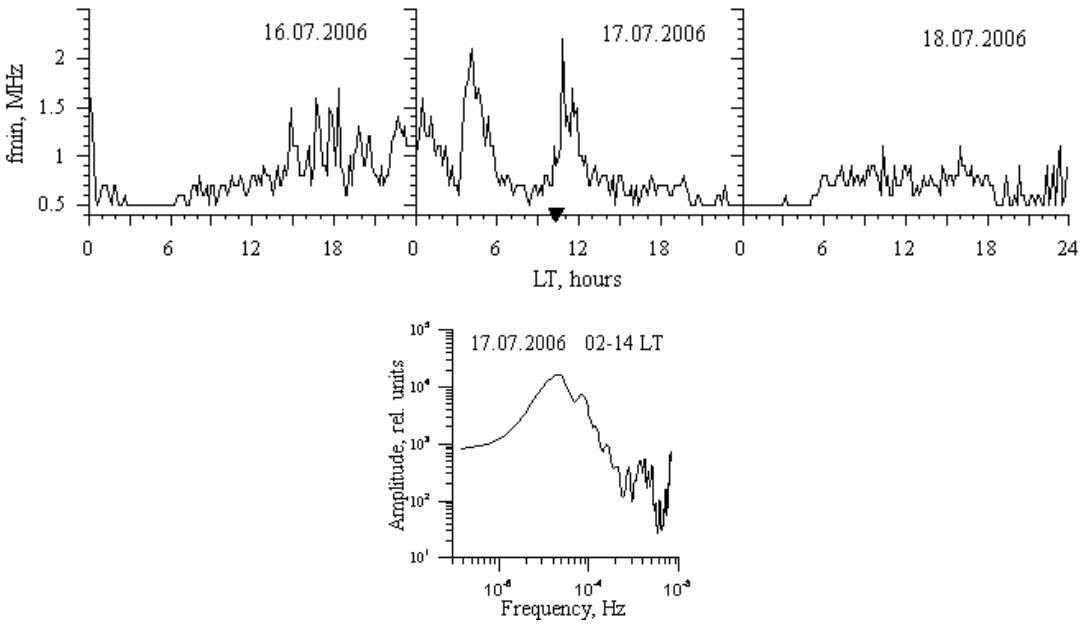

Fig. 7. Daily variations of fmin (top) and amplitude spectra (bottom) on 16-18 July 2006 at Sodankyla (▼ - the time of beginning of the earthquake. Local time = UT+2h).

Mikhailov et al. [2002, 2003] have shown, that before an earthquake internal gravity waves in spectra of the electric field Ez have seismic and gravity nature. From the analysis of the atmospheric noises spectra and the spectra of the electric field Ez power measured simultaneously at Kamchatka, Mikhailov et al. [2004] have found that there is some similarity of the spectra forms on the eve of earthquakes. It testifies that internal gravity waves penetrate up to heights (~80-120 km) of the lower ionosphere. Thus, the variations of ordinary component amplitude with the periods of some hours at the heights of the E layer are internal gravity waves connected to earthquakes. Our results presented above adjust with the results of Mikhailov et al.

Conclusions

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

1. Under quiet conditions in the geomagnetic field and at small A-class solar flares the reaction of the high-latitude ionosphere to strong earthquakes was seen basically in parameters of the lower ionosphere.
2. From the considered experimental data received by the method of partial reflections for the quiet days of 26 May 2006 and 17 July 2006 at the moments of the beginning of the earthquakes and after them, in spectra of amplitude of ordinary component the internal gravity waves with the periods of some hours connected with earthquakes were observed.

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