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ON THE REACTION OF THE POLAR LOWER IONOSPHERE TO THE CATASTROPHIC EARTHQUAKE IN THE SOUTH-EAST ASIA ON DECEMBER 26, 2004

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Abstract. Using data of the partial reflection technique, the behavior of electron concentration in the D-region of the polar ionosphere during a strong earthquake on December 26, 2004 has been investigated. At the distance of about 7000 km from the source of the event, wave disturbances in the auroral D-region were found, which spatial and temporal characteristics were determined.

Introduction

Investigation of wave disturbances in the ionosphere, which are related to seismic activity, is a topical task. Earlier it was established [Birfeld, 1973] that under quiet and moderately disturbed solar-magnetic conditions, seismo-ionospheric disturbances distinctly manifest in the polar regions at long distances from the source of earthquakes.

At the end of December 2004, a series of powerful underwater earthquakes was recorded. The strongest earthquake from the series occurred on December 26 at 00:59 UT at the distance of 250 km from the western coast of the northern part of the Indonesian island of Sumatra and caused a giant tsunami. The earthquake epicentre had coordinates (3.3° N, 95.8° E), magnitude M = 9.0, depth h = 30 km (http://earthquake.usgs.gov/ eqithenews/2004/usslav/). In the next hours, shocks with M = 5.4-7.1 were recorded.

In the present paper, the preliminary results of seismo-ionospheric effect investigations in the auroral zone, based on the analysis of the partial reflection technique, are presented. The technique is one of the complex methods of the quantitative study of structure and dynamics of the lower ionosphere. The characteristics and pattern of the measuring complex of partial reflections are presented in the paper [Tereshchenko et. al., 2003]. The technique of measurements and data treatment are described in [Belikovich et. al., 2004].

Results of measurements and analysis

On December, 26, 2004 there were 34 earthquakes with magnitude M = 5.4-9.0. The diagram of the events considered is presented in Fig. 1.

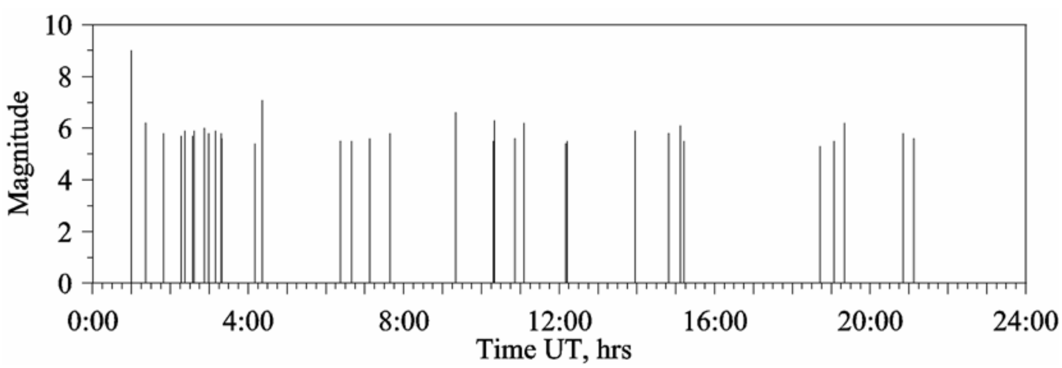

Fig. 1. Graph of Earthquakes in the South-East Asia on 26 December 2004.

The times of event occurrence is shown on the x-axis, while the magnitude is presented on the y-axis. It should be noted that the shocks with the magnitude M of 5.3-6.2 continued on the next days.

In Fig. 2 the altitude-temporal distribution of electron concentration in Tumanny on December 24 and 26, 2004, is shown. The data were obtained with a 15-min time averaging. One can clearly see that there is a well-pronounced increase in the electron concentration in the lower ionosphere during strong earthquakes as compared to the control measurements made on December 24.

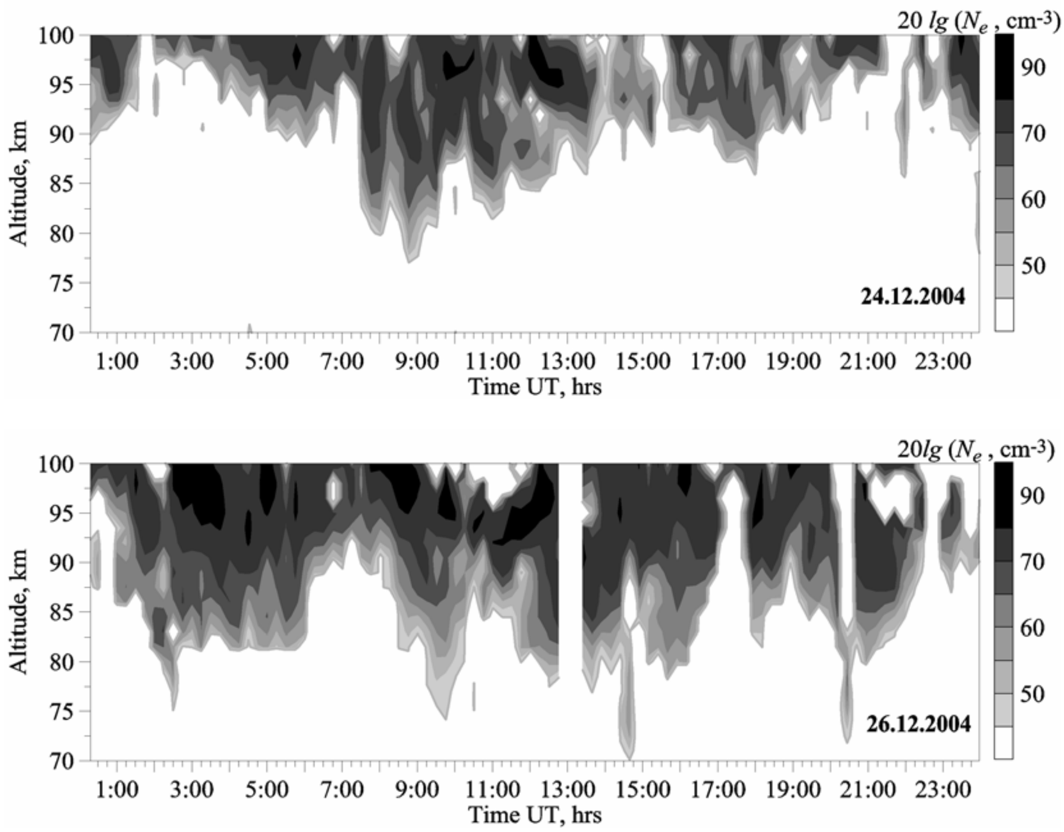

Fig. 2. Time-altitude distribution of the electron density for 24 December 2004 and 26 December 2004

To evaluate the characteristics of the wave disturbances, which are generated or amplified in the polar ionosphere after earthquakes, we will consider the behavior of electron concentration during the events at fixed altitudes, which sample, obtained for the altitude of 90.5 km for two days, is presented in Fig. 3. Solar-geomagnetic conditions during the days considered were rather quiet, i.e. there were no strong substorms or strong flares on the Sun. From the analysis of the data referred to the altitudes of 80-96 km, it was found that about 15-20 minutes after a strong earthquake, there started a noticeable increase in electron concentration $N_{e,}$ reaching the values greater than the electron concentration on the previous days.

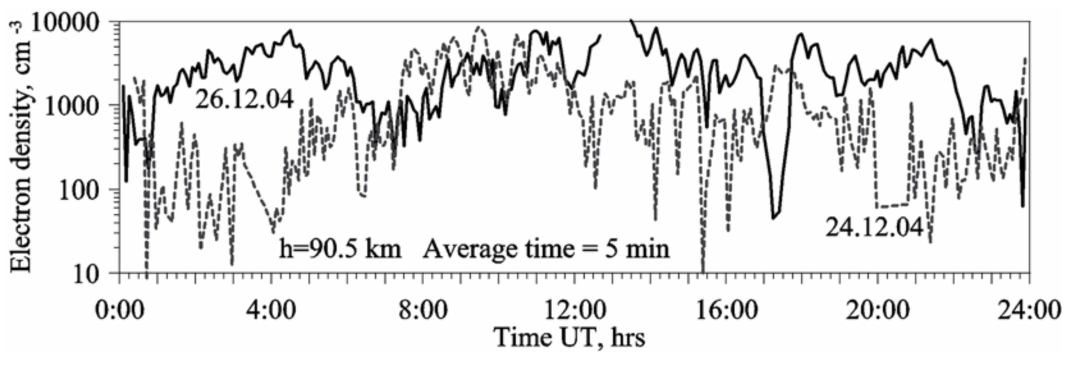

Fig. 3. Electron density as a function of time at the chosen height.

The observed splashes in the temporal variations of electron concentration permit to evaluate the velocity of propagation of wave disturbances at the altitudes considered. In the analysis of natural disturbances at one point, we deal with a series of events observed by one facility. The maxima, i.e. the fluctuations of charged particles in a local plane of the ionosphere, are interpreted as a sequence of longitudinal waves, which are caused by an earthquake and spread in the neutral atmosphere. The effective horizontal propagation velocity of different components of disturbances can be found by timing disturbance maxima appearance from different earthquake shocks.

The first noticeable maximum was observed at 1:40, the second one – at 1:55, the third one – at 2:04 and the fourth one – at 2:09 UT. Considering that the disturbances are coming from the earthquake center along the ionosphere in the plane of a big circle arch, their velocities can be estimated as about 2.8, 2.0, 1.8 and 1.4 km/s, respectively. A comparison of observations of electron concentration fluctuations (Fig. 3) with the data on the earthquakes (Fig. 1) also permits to find wave disturbances, which propagate with the velocity of 300 – 400 m/s.

The wave disturbances observed in the lower ionosphere by the partial reflection technique persist at any time of the day and in all seasons. Their spectrum has periods from several minutes to several hours and even a day, and horizontal velocities vary from several hundred of m/s to several km/s. The broad range of disturbance parameters can be explained by the processes of different nature, which take place in different regions of the ionosphere. The spectral structure of the wave disturbances from the earthquakes is practically the same as for the background, there is only an increase of fluctuation amplitude in this case.

The periods of acoustic-gravitational waves at a given altitude in the ionosphere can be found from the dynamic spectrum of fluctuations of reflection amplitudes or electron concentration. Spectral analysis of fluctuations of electron concentration indicates the presence of oscillations with the periods of 2-4, 6, 8, 9, 12 and 17 minutes (Fig. 4).

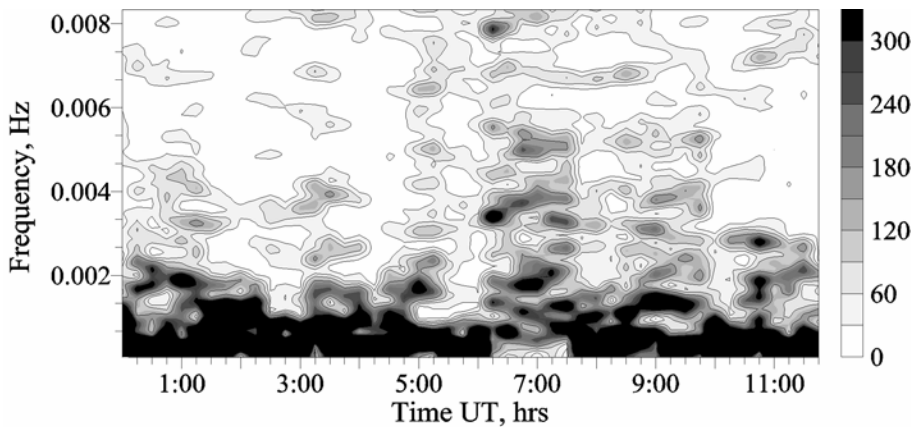

Fig. 4. Dynamic spectrum of the electron density fluctuations, h= 90.5 km, 26.12.2004.

From the analysis of given spectra it follows that after an earthquake the waves with a big period arrive first at the region of observation. The obtained periods and velocities of atmospheric waves do not contradict the measurements gained by the partial reflection technique during the investigation of remote earthquake influence on the middle-latitude lower ionosphere [Gokov and Tyrnov, 1997; Gokov, 2001].

In the paper [Birfeld, 1973] it is suggested that one of the cause-to-effect relations can be due to acoustic wave effect, which is strongest at high latitudes. During the propagation of acoustic waves, a part of their energy is captured by the waveguides: one of them is formed by the temperature minima associated with the tropopause and mesopause (mesospheric), the second one – by the regular altitude anisotropy of ionospheric conductivity at the heights of 80-120 km (thermospheric). This predetermines the propagation of acoustic energy in the ionosphere over large distance with producing ionospheric disturbances, which are especially strong and regular in the polar regions, as the charged particles under the influence of an acoustic wave tend to move almost perpendicularly to the geomagnetic field.

According to our data, the propagation velocity of the acoustic-gravitational waves mentioned above is 0.3 – 0.9 km/s, with the periods equal to 2 – 6 minutes. It should be noted that the type of ionospheric disturbances is related to the observed drop of electron concentration at the altitude registered.

The acoustic waves in the ionosphere can transform to the plasma-acoustic waves, with the horizontal velocity of propagation up to 1.3 – 2.2 km/s [Wickersham, 1966].

During earthquakes, the elastic Rayleigh waves are generated, which propagate over the Earth's surface with the velocity of 3.5 km/s [Egorov et. al., 1990]. The waves transform to long-period acoustic waves propagating upwards and manifesting with some delay in the variations of partial reflection amplitudes and electron concentration.

The increase in electron concentration associated with strong earthquakes can be referred to the penetration of high-energy electrons from the radiation belts, produced by a gyrotropic wave generated in the ionosphere under certain conditions [Gokov, 2001].

Conclusions

The variations of electron concentration in the D-region of the polar ionosphere in response to strong earthquakes in the South-East Asia have been explored experimentally using the partial reflection technique. Approximately one hour after the beginning of the strongest earthquakes, an increase in the electron concentration by factor 2-3 compared to the unperturbed values is detected, followed by a sufficient decrease in the concentration about 5 hours later. It is shown that the disturbances observed in the lower ionosphere during strong earthquakes can be explained by the arrival of long-period acoustic, plasma-acoustic and acoustic-gravitational waves to the investigated region and by the generation of gyrotropic waves.

From the observations, the disturbances of 5-20 min duration with the oscillation periods of 2-4, 6, 8-9, 12 and 17 min are revealed. Evidently, these periods correspond to the three groups of apparent velocities: 0.3-0.4, 1.4-1.8 and 2.0-2.8 km/s.

We note that the above conclusions are preliminary and need to be verified.

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