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DETECTION OF MAGNETOGRAVITY WAVES BY IONOSPHERIC F2 LAYER DATA AND MAGNETIC OBSERVATIONS DURING HIGH ENERGY GEOPHYSICAL EVENT

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Abstract

The appearance of magnetogravity waves (MGW) during development of two strong (over 6.5 on the Richter scale) earthquakes on the west coast of Indonesia and Turkey is revealed. For this aim the simultaneous disturbances of ionospheric layers F2, E, Es concentration and disturbances of geomagnetic field components are analyzed. The observed magnetogravitational activity was growing at two days before the earthquakes and two days after them. During the days of earthquakes MGW were not observed but it was noted the passage of acoustic-gravity waves. The possibility of MGW existence in the equatorial ionosphere has been confirmed by analysis of the corresponding dispersion relations. These relations were obtained on the base of magnetohydrodynamical equations for finite conductivity ionospheric space.

Introduction

The disturbances of ionospheric layers ionization are often associated with wave phenomena accompanying high energy geophysical events (earthquakes, tsunamis , the instability of the auroral electrojet , etc.). In recent work the questions of wave disturbances generation and transfer in the ionosphere are mainly restricted by the different spatial scales acoustic-gravity waves (AGW) [*Hocke et al.*, 1996; *Vlasov et al.*, 2011]. However the existence of ionized component in the atmosphere creates the conditions for slow magnetohydrodynamic (MHD) waves propagation in this space which contains geomagnetic disturbances. The consideration of combined magnetic field and gravity influence causes to possibility of so-called magnetogravity waves (MGW) propagation in the ionosphere which velocities is higher than AGW but lower than MHD [*Sorokin and Fedorovich*, 1982; *Barkhatova et al.*, 2009; *Barkhatova et al*, 2012].

The magnetic disturbance strengthening may be caused by Cherenkov electron flow radiation from the source of future earthquake. This flow creates magnetic disturbances on the way from the source to ionosphere. In this case the duration of magnetic disturbances and their intensity determine the magnitude of a future earthquake [*Akhundov et al.*, 2004; *Guseinov et al.*, 2001]. Because of high conductivity of ionospheric plasma at F2 layer altitudes, such magnetic field disturbances associated with earthquake preparation can cause fluctuations of ionospheric plasma and in presence of gravity excite magnetogravitational activity.

In this paper the possibility of MGW formation from high-energy source (earthquake) in the middle- and low-latitude ionosphere is studied. For this aim the search of MGW is revealed on the base of simultaneous observations of the layers F2, E and Es concentration variations and magnetic observations during two strong earthquakes on the west coast of Indonesia and in Turkey with magnitude of at least 6.5 on the Richter scale. The possibility of MGW existence at height of ionospheric layer F2 the equatorial region is analytically performed under the condition of perpendicular direction of gravity force and geomagnetic field. Obtained dispersion relations of MGW propagating modes allow us to determine their specific parameters and compare them with the experimental observations.

The experimental data selection and processing

The data of ionospheric layers Es, E and F2 critical frequencies and geomagnetic field X, Y, Z components variations are analyzed in a period of two underground earthquakes July 17, 2006 and January 8, 2006. The time resolution of used data was 15 minutes. Coordinates of earthquake epicenter, time of earthquake start and parameters of selected stations are shown in Table 1. Epicentral distance to the stations did not exceed 1500 km.

The MGW search was performed within a time interval containing 3 days before the event, the day of event, and 3 days after them. The level of global geomagnetic activity during the study period was estimated from the planetary index Kp values. To avoid geomagnetic field disturbances which are not related to MGW propagation, the X, Y, Z component values for all considered stations have been cleared from the effects caused by ring current symmetric and asymmetric parts. To estimation of ionospheric disturbance level which is not related with periodic variations, the layers F2, E and Es critical frequencies were cleared from the daily variation. The detection of simultaneous plasma and magnetic disturbances caused by MGW propagation is performed on the base of spectral characteristics comparison for cleared data of critical frequencies and geomagnetic field in the range of $10^{-5} \div 10^{-3}$ Hz. The comparison was carried out for the intensity maxima of corresponding spectra.

Table 1

Earthquake date	Epicenter coordinates	Time of earthquake beginning, UT	Magnitude	Ionospheric stations	Magnetic stations
17.07.2006	9.33º S, 107.26º E	08:19	7.7	Learmonth (21.9º S, 114º E)	Learmonth (21.9º S, 114º E)
08.01.2006	36.30° N, 23.36° E	01:35	6.8	San Vito (40,6 N, 17,8 E)	Laquila (42.4 N, 13.3 E)

MGW detection on experimental data

The MGW detection is associated with the search for similar dynamic spectra features corresponding to simultaneously observed disturbances of ionospheric layers Es, E and F2 density and disturbances of X, Y, Z geomagnetic field components. At three days before the earthquake the number of concurrences in considered spectral peaks is not more than one. This may indicate a low level of magnetogravitational activity in this period. A similar situation is noted at three days after the earthquake. However at two days before the earthquake and two days after them a number of observed simultaneous disturbances markedly increased - there is up to five concurrences during the day.

Fig. 1 (left column) shows the dynamic spectra of ionospheric and magnetic parameters at two days before the earthquake (15 July). The arrows indicate the simultaneous spectral peaks of critical frequencies and geomagnetic field disturbances. At the day of the considered earthquakes simultaneous plasma and magnetic disturbances are absent what indicate a weakening of magnetogravitational activity.

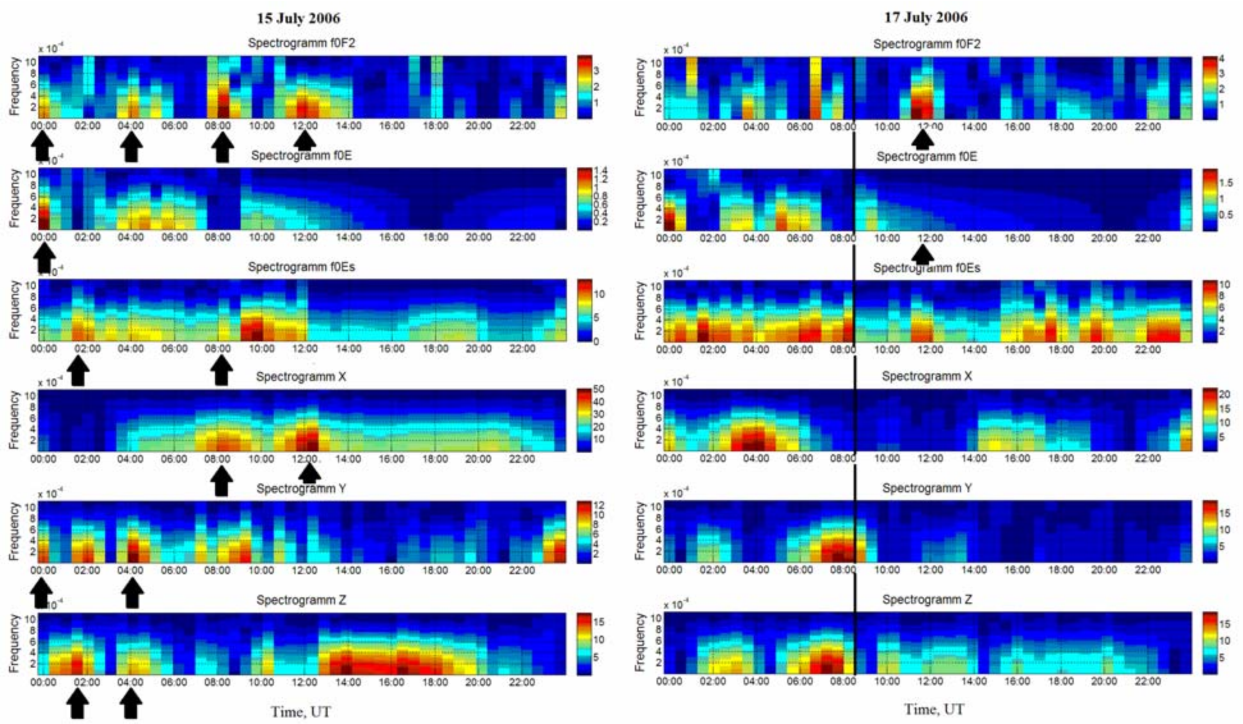

Fig. 1 Dynamic spectra at two days before the earthquake (July, 15) and at day of earthquake (July, 17). The three upper panels correspond to the dynamic spectra of critical frequencies layers F2, E and Es, the bottom three panels - the dynamic spectra of geomagnetic field X, Y, Z components. The horizontal axis represents time (UT), the vertical axis - the characteristic frequencies of plasma and magnetic disturbances. Arrows indicate the cases of MGW propagation. Vertical line indicates the start time of earthquake.

However there are other typical features associated with the immediate preparation and development of the earthquakes. It is marked the increase of critical frequency fluctuations intensity for sporadic Es layer during two hours before the earthquake on January, 8 and during 8 hours before the earthquake on July, 17. This feature is clearly showed at critical frequency dynamic spectra for Es layer (Fig. 1, right column, the third panel from the top). Vertical line in the figure indicates the start time of the earthquake. Another feature is the occurrence of synchronous critical frequencies disturbances for different layers associated with the passage of acoustic-gravity waves at days of earthquakes. For example, on July, 17 synchronous disturbance of critical frequencies F2 and Es layers is observed (Fig. 1, right column, second and third panels from the top).

Total number of simultaneous plasma and magnetic disturbances for each considered day is shown in Fig. 2. Thus, the analysis of the dynamic spectra during the study period showed that magnetogravitational activity increases markedly at two days before and two days after the earthquake. At other days of considered time intervals the level of magnetogravitational activity remains low.

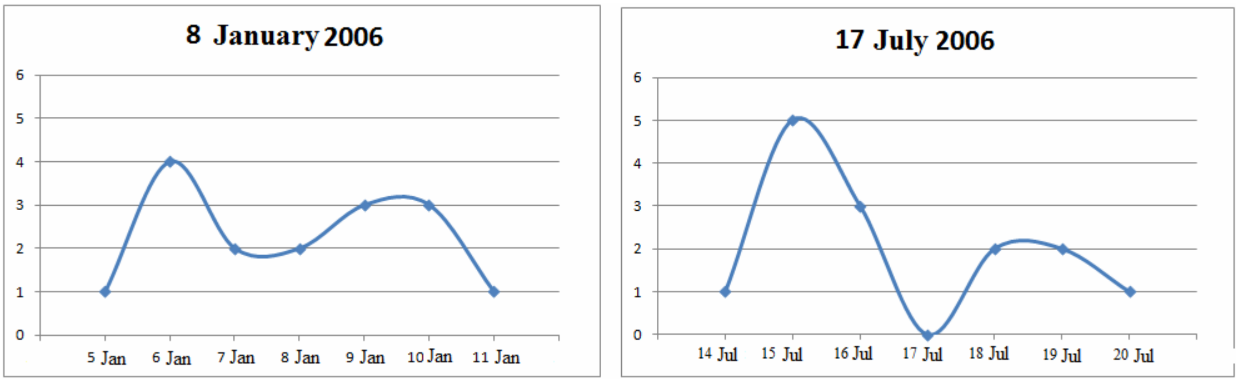

Fig. 2 The number of simultaneous plasma and magnetic disturbances.

MGW dispersion relations

The possibility of MGW propagation in the ionosphere with account of its finite conductivity was confirmed by analysis of solutions of the linearized MHD equations for the collective account of gravity and Ampere force. In these paper here the horizontal direction of the geomagnetic field is considered, which corresponds to the equatorial ionosphere region. Numerical calculations of the dispersion curves for the two propagating fast and one slow MGW modes are shown in Fig. 3. In these case the azimuth angle value is $\varphi = 45°$ and following parameters ionosphere are used: $T = 10^3$ K, $\gamma = 1.4$ – the adiabatic, $\beta = 0.02$, H=3*10^6 cm, $\mathbf{H}_0$ = 0.5 G, conductivity $\sigma=10^{10}$ s^{-1} and magnetic Reynolds number Re_m=3*10^2 [*Barkhatova et al.*, 2012] . The presence of three propagating modes confirms the possibility of MGW existence in the equatorial region in the conditions close to parameters of ionosphere F2 layer. Experimental analysis of dynamic spectra of magnetic and plasma disturbances in the earthquakes intervals was carried out in the frequency range of $2{\cdot}10^{-4} \div 10^{-3}$ Hz because of used data time resolution. According to analytical evaluation in this frequency range can be obtained all propagating MGW modes with wavelengths greater than 40 km.

Conclusions

The study revealed the MGW occurrence during strong (over 6.5 on the Richter scale) underground earthquake at January 8, 2006 and July 17, 2006. A significant increase of magnetogravitational activity is marked at two days before and two days after the earthquake. During earthquakes magnetogravitational waves are not observed but the passage of acoustic-gravity waves is noted.

Analysis of MGW dispersion relations confirms the possibility of this wave type propagation at ionosphere F2 layer height in the equatorial region, where the gravity force and geomagnetic field is almost perpendicular to each other. Three propagating MGW modes are analyzed with the establishment of specific propagation directions and frequency ranges for each mode.

Thus the results of experimental and analytical studies suggest the possibility of MGW appearence in the equatorial region of the ionosphere at intervals of high energy geophysical events. Detected magnetogravitational activity caused by preparation of strong underground earthquakes can be used to development of predicting methods for such large-scale events.

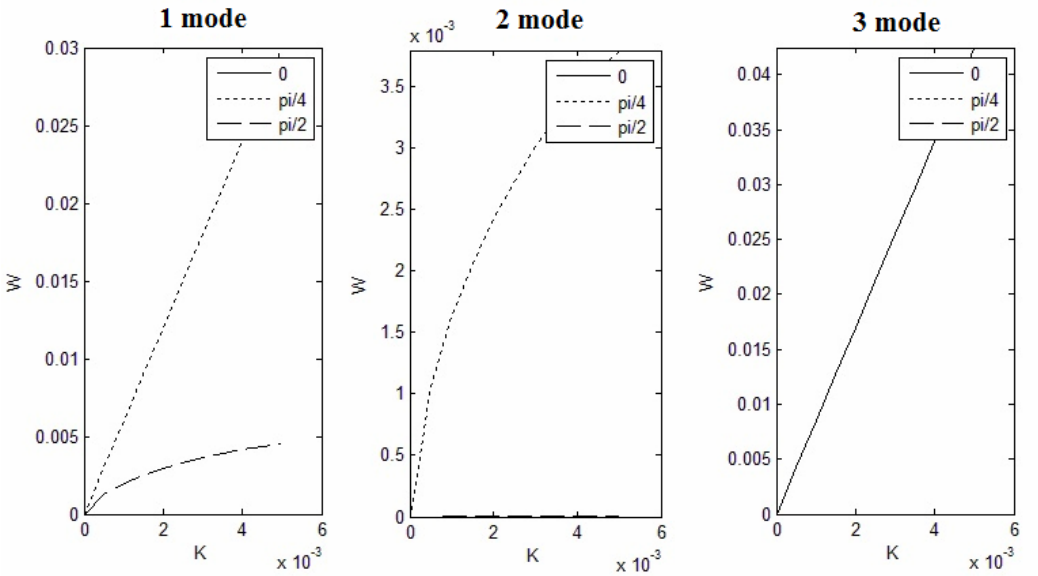

Fig. 3 The dispersion curves of the three propagating MGW modes SGA received for azimuthal angle $\varphi = 45°$. The solid line corresponds to the longitudinal MGW distribution (θ = 0°), small dash – oblique propagation (θ = 45°), a large dotted line - transverse propagation (θ = 90°).

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