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DISPLAY OF MAGNETO-GRAVITY WAVES CAUSED BY POLAR INSTABILITY IN TRAVELLING IONOSPHERIC DISTURBANCES

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Abstract. Existence of magneto-gravity waves (MGW) caused by substorm activity can produce a travelling ionospheric disturbances (TID) which velocities exceed sound. For MGW detection experimental data of oblique impulse ionospheric sounding for decameter range radio waves have been used. Mid-latitude and subauroral paths Inskip (England) – Rostov-on-Don, Cyprus – Rostov-on-Don, Norilsk – Rostov-on-Don and Irkutsk – Rostov-on-Don within weak geomagnetic disturbance condition are considered. Time delays between AE index of polar electrojets intensity and maximum observed frequency (MOF) for all paths are established. Among received time shifts 5-10 min values are marked. Such small delays answer to high-velocity disturbances which propagate faster then usual AGW. These cases can be connected to MGW propagation. Studying of index AE and registered MOF spectral structures for high correlation cases at small time delay shows a good agreement of spectrum features. At the same time a good agreement of spectral features for index AE and geomagnetic field horizontal components disturbances on ground magnetic stations takes place. According to calculated MGW dispersion curves their frequencies are equal to $\omega \approx (1-2)\cdot 10^{-4}$ Hz.

1. Introduction

As probable sources of wave generation in ionosphere, including travelling ionospheric disturbances (TID), auroral electojets are considered frequently. According to current opinion disturbances from auroral region propagate to mid and low latitudes by acoustic-gravity waves (AGW) [Hocke and Schlegel, 1996]. However there are explanation complexity of large-scale AGW propagation with high velocities (more then 1300 $m\cdot s^{-1}$) [Sorokin and Fedorovich, 1982]. Account of magnetic field and gravity combined effect in hydrodynamics equations is executed in [McLellan and Winterberg, 1968]. It means that also in ionosphere can propagate so-called magneto-gravity waves (MGW). Velocities of such waves are greater then AGW velocities but lower than MGD wave velocities [Sorokin and Fedorovich, 1982]. The closeness of gravitational waves spectra and spectra of geomagnetic field variations is the additional reason for more stringent account of magnetic field influence. Thus, probably the role of geomagnetic field was in essence underestimated for low-frequency wave propagation in partially ionized plasma. In present work the opportunity of MGW propagation from auroral region to mid and low latitudes is considered. For this purpose connection between auroral disturbances (index AE) and TID at oblique sounding paths (determined by MOF variations) by methods of the correlation and spectral analysis is studied.

2. The correlation analysis of connection between MOF and AE

Auroral electrojets influence on mid-latitude TID was considered by analysis of MOF disturbances registered on oblique sounding paths Inskip – Rostov-on-Don, Cyprus – Rostov-on-Don, Norilsk – Rostov-on-Don and Irkutsk – Rostov-on-Don in December 2006 and March 2007. For only TID studying, subtraction of diurnal MOF variation of original values by approximation on each path is made. Also selection only a day time MOF interval according to LT is carried out.

Auroral disturbances propagation time from electrojets to reflection points of each path is determined by linear correlations calculation between MOF and index AE. Linear correlations are calculated with time shifts of MOF values relative to AE. Time shifts are realized with 5 minute step from day time MOF interval beginning. Changes of correlation coefficient R absolute values for linear correlation MOF and index AE depending on time delay for each path are shown on Fig. 1. Markers make note of peaks with high correlation coefficient for time delays corresponding to common times of AGW propagation and also peaks with the minimal time delay 5-10 min. The estimated propagation velocities of auroral disturbances for small time delays (5-15 min) make about 2000-5000 $m\cdot s^{-1}$. They considerably exceed AGW propagation velocities. Such cases can be connected to MGW propagation.

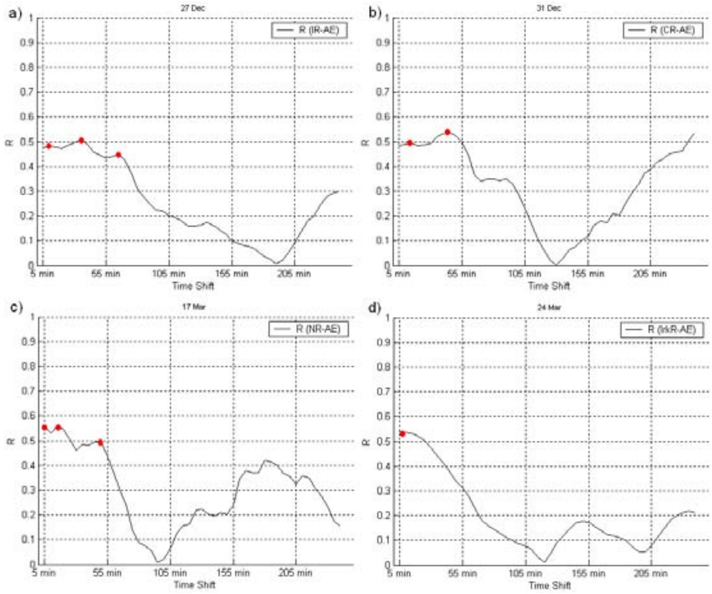

Fig. 1. Changes of correlation coefficient R absolute values between MOF and index AE for paths Inskip – Rostov-on-Don (a), Cyprus – Rostov-on-Don (b), Norilsk – Rostov-on-Don (c) and Irkutsk – Rostov-on-Don (d) depending on time delay MOF relative to AE. Markers make note of increased correlation cases.

3. The comparative spectral analysis TID and index AE

Research of AGW and MGW manifestation in TID is possible by comparative spectral analysis. For 5-15 min time delays with corresponds to increased correlation, dynamic spectra for MOF and index AE are calculated in December 2006 and March 2007. On Fig. 2 index AE and MOF spectrograms comparison on each oblique sounding path is shown. According to Fig. 2 for each path coincidence of spectral features is observed. It can be an evidence of high propagation velocities for auroral disturbances with propagates from auroral region to reflection points. Such cases are probably connected to MGW wave propagation.

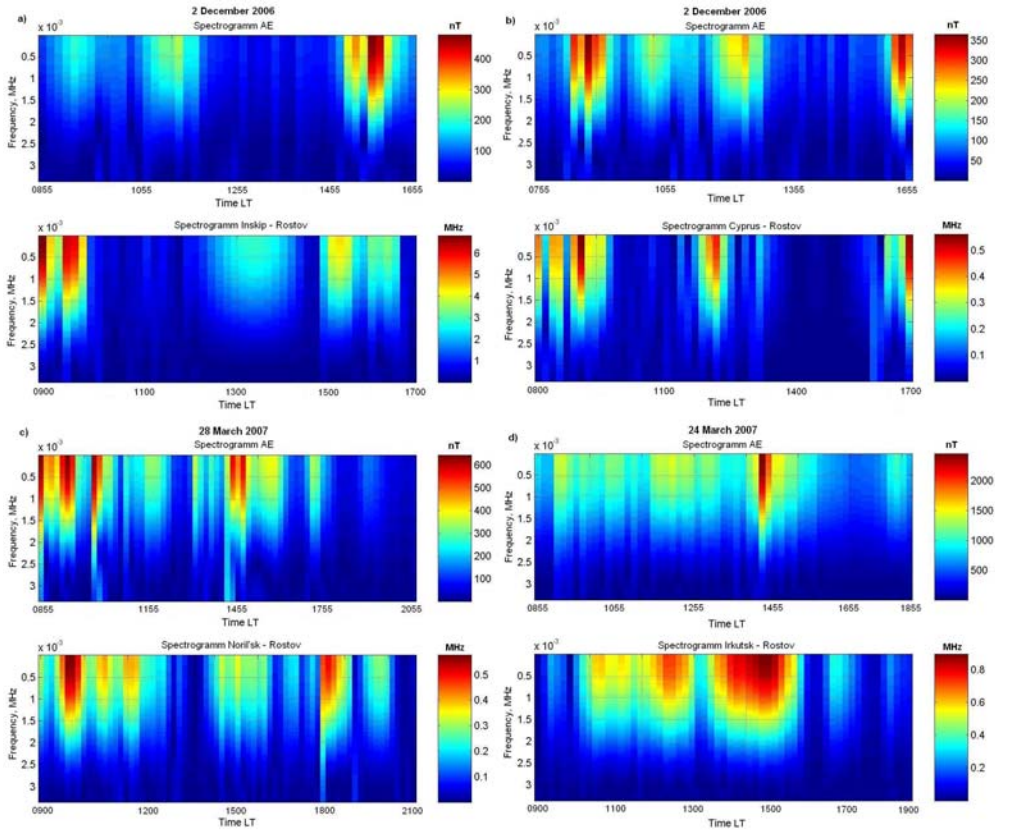

Fig. 2. MOF spectrograms with 5 min time delay relative to index AE for paths: a) Inskip – Rostov-on-Don; b) Cyprus – Rostov-on-Don; c) Norilsk – Rostov-on-Don; d) Irkutsk – Rostov-on-Don.

MGW propagation from auroral region can cause not only density disturbances which registered in MOF changes on oblique sounding paths, but also magnetic field disturbance. Therefore its propagation can be registered in magnetogram on ground magnetic stations. For the analysis three magnetic stations Nurmijarvi (60.508 N, 24.655 E), Belsk (51.837 N, 20.792 E), Surlari (44.68 N, 26.253 E) have been selected. Each of submitted magnetic stations presumably is on a way of MGW propagation from auroral region. On Fig. 3 comparison of index AE spectrograms and geomagnetic field horizontal components spectrograms, cleared from a Sq-variation, for stations Nurmijarvi, Belsk, Surlari on December 2006, 6 is shown. Obtained results show a good agreement of dynamic spectrum AE spectral features and H-component dynamic spectra for these ground magnetic stations. It allows assuming MGW propagation from auroral region to mid latitudes in this case.

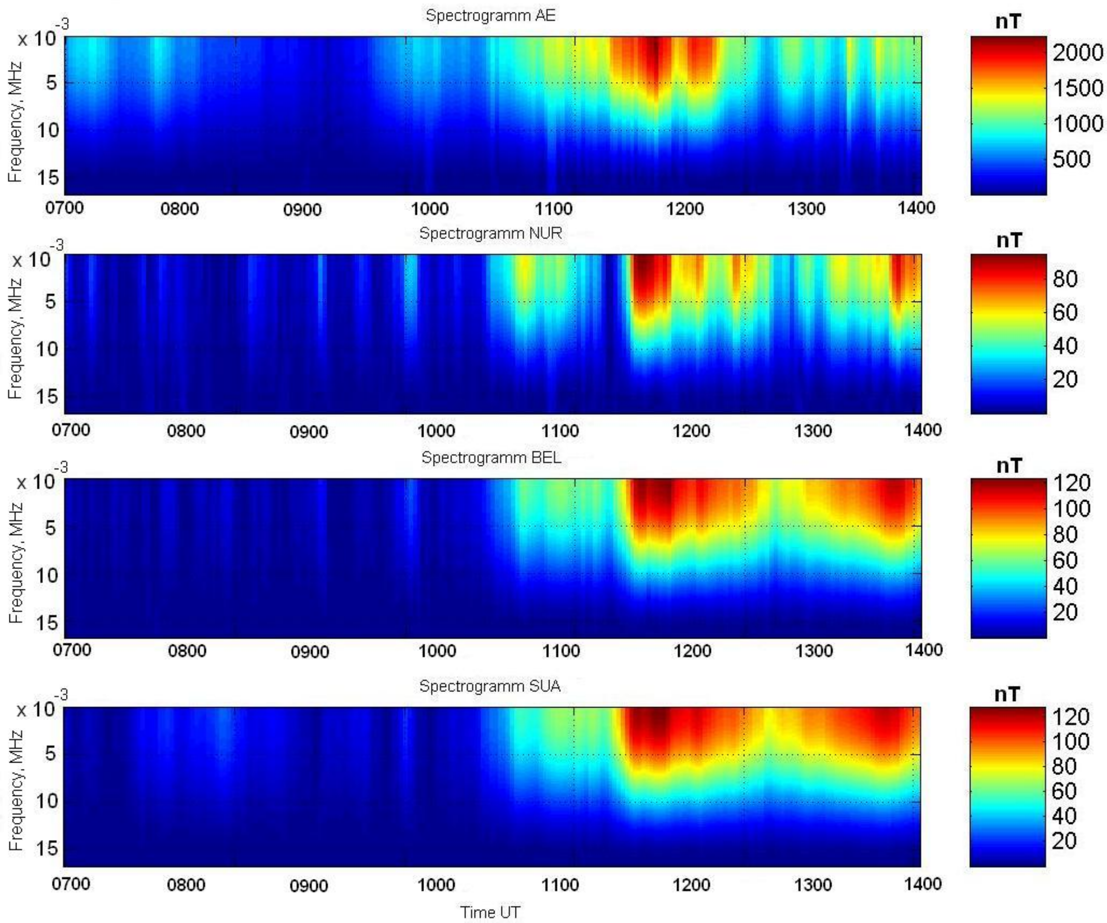

Fig. 3. AE index and geomagnetic field H-component spectrograms for stations Nurmijarvi (NUR), Belsk (BEL), Surlari (SUA) on December 2006, 6

4. Detection of MGW characteristic frequencies by dispersion curves

Geomagnetic field role in low-frequency waves propagation in ionosphere as partially ionized plasma environment is connect to strongly account of ponderomotive force on a par with gradient of pressure and gravity. Within the framework of such magnetohydrodynamic approach the dispersion equation for MGW [McLellan and Winterberg, 1968] is received. On its basis the estimation of propagated wave frequencies with experimentally established velocities in ionosphere at the altitude 250 km is executed. This estimation gives the values which co-ordinate with characteristic frequencies marked on MOF spectrograms. For one's turn an estimation of MGW velocity at the 250 km altitude received by analytical expressions correspond to experimentally received propagation velocities for small time delays. Thus, founded out characteristic frequencies and velocity values for wave propagation in ionosphere do not contradict to MGW existence.

5. Conclusions

- Time shifts between index AE and MOF with marked high correlation for considered paths are determined. Among received time shift values the cases 5-10 min answering to increased propagation speed (2000 - 5000 $m \cdot s^{-1}$) of auroral disturbances are marked. These velocities are great in comparison with usual AGW velocities for investigated paths. Such cases can be connected to MGW propagation.

- Studying of index AE and registered MOF spectral structure at 5-10 min time shifts for increased correlation cases shows a good agreement of spectra features. It can be an evidence of auroral disturbances propagation to lower latitudes with increased velocities in comparison with AGW.
- Comparison of index AE spectrograms with magnetic field horizontal component spectrograms on three ground stations, with are close to reflection points of Inskip – Rostov-on-Don and Cyprus – Rostov-on-Don paths shows a good agreement of spectral features. It can be an evidence of MGW propagation from auroral source to reflection points of ionospheric oblique sounding paths.
- According to received dispersion MGW curves, propagation of disturbances with frequencies $\omega \approx (1-2) \cdot 10^{-4}$ Hz and velocities 2000-5000 $m \cdot s^{-1}$ is possible. Experimental and theoretical estimations of MGW propagation velocities in ionosphere for a case of horizontal propagation give values of one order.

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