



SYNCHRONIZATION OF GEOMAGNETIC AND IONOSPHERIC DISTURBANCES ON THE SUBSTORM PROCESS BACKGROUND

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Abstract. The phenomena accompanying the event of synchronous night-time ionospheric and geomagnetic disturbances, marked in globally magnetospecific quiet-time on the base of the mid-latitude Kazan station minute data, are analyzed. The dynamic and wavelet spectra comparison for studied disturbances showed coinciding features of the simultaneous disturbances for layer F2 critical frequency and H, D, Z geomagnetic field components. Therefore it was possible to assume their magnetosonic nature and establish the characteristic periods of observed magnetosonic ULF disturbances in the range of 35-50 minutes. The spatial analysis of noted magnetosonic disturbances with use of geomagnetic data obtained at stations located at different latitudes and longitudes toward to Kazan station demonstrated the isotropy of founded magnetosonic waves. This allows classifying them as fast magnetosonic disturbances. It is shown that the studied event occurs under substorm development conditions.

The causes establishment of intramagnetospheric magnetohydrodynamic (MHD) disturbance is an important goal of solar-terrestrial physics. The appearance of magnetosound disturbances in the magnetosphere-ionospheric medium is commonly associated with development of geomagnetic storm. MHD disturbances in the magnetosphere and ionospheric conductive layers can also be associated however with other high-energy processes. In studies [Barkhatova et al., 2009; Barkhatova et al., 2015], for example, magnetosound type waves, generated by an eastward electrojet and earthquakes of large magnitude were detected. At the same time in addition to geomagnetic field disturbances, synchronous disturbances in ionospheric conductive layer F2 in the ULF range were observed. The present study is devoted to the analysis of phenomena accompanying the event of synchronous night time ionospheric and geomagnetic disturbances, detected in the globally magneto-quiet time at the mid-latitude station Kazan (55.78° N, 49.01° E). The search of synchronous ionospheric and geomagnetic disturbances was performed on ionospheric vertical sounding data and data of geomagnetic field H, D, and Z components with a minute resolution for the interval September 1-4, 2014.

The coinciding features of F2 layer critical frequency and the geomagnetic field components simultaneous disturbances as a result of dynamic spectra and wavelet patterns comparison of studied disturbance for September 3, 2014 were found. For other days (1, 2 and 4 September) in the night time region (+ 3 GMT) there is no pronounced ionospheric disturbance. Fig. 1 shows the critical frequency foF2 and the geomagnetic field H component wavelet spectra for Kazan station, received for September 3, 2014 during the night time interval (00.00 to 02.00 UT). The black arrows show the maxima coincidence of ionospheric and geomagnetic field H component disturbances for the interval 01.17 - 01.55 UT. The best coincidence of considered disturbances was noted for periods from 15 to 30 minutes. The fact of simultaneous disturbances for foF2 and the geomagnetic field components coincide allow us to assume their magnetosound nature.

The question of relation for considered disturbances to SMS (slow magnetosound), more likely associated to geomagnetic field force line, or to an isotropic FMS (fast magnetosound) type can be solved by spatial analysis of disturbance wavelet spectra received at stations with different latitudes and longitudes from Kazan. The data of geomagnetic field H and D components were used at stations Sodankylä (67.37 N, 26.63 E), Port Alfred (46.43 S, 51.87 E), Hel (54.61 N, 18.82 E), San Fernando (36.67 N, 5.50 W). The coincidence of spectral maxima for Kazan station critical frequency and geomagnetic field H component at the magneto-conjugated observatory Port Alfred (southern hemisphere) for the analyzed frequency range is established for the studied time interval. This indicates the connection of studied wave phenomenon to the corresponding geomagnetic force line.

The comparison of the disturbance spectral features for the critical frequency over Kazan with disturbances of geomagnetic field H, D components at other stations located in a large latitudinal-longitude region also showed cases of analyzed spectral features coincidence. Such isotropic behavior for studied magnetosound waves makes it possible to classify them as fast magnetosound disturbances.

The search for a possible source of considered night time mid-latitude synchronous ionospheric and geomagnetic disturbances required the study of outer magnetospheric processes. During the case of foF2 disturbances in Kazan, disturbances of the interplanetary magnetic field Bz component (Bz IMF) were detected in the same frequency range. So it was established that the long-period oscillations of Bz IMF find their manifestation in the ionosphere and geomagnetic field components. Fig. 2 shows the wavelet spectra of the foF2 critical frequency at Kazan station (upper panel) and Bz IMF component for the considered time interval.

A study of time behavior for the Solar wind concentration shows that in the time period up to 00.45 UT (+3 GMT Kazan) its higher values are observed with a further decrease and reaching the minimum value at 01.00 UT. For the interval 01.00 - 02.00 UT, there is a general increase in the Solar wind velocity, which persists throughout the interval.

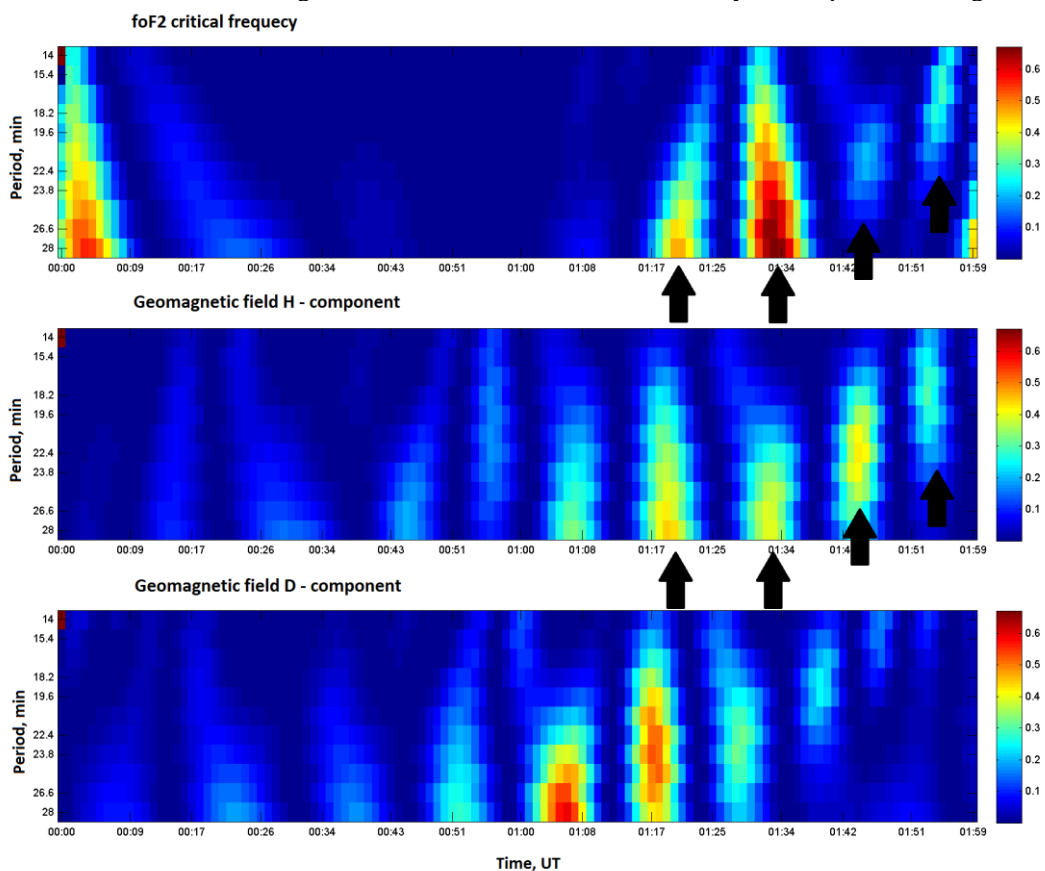


Figure 1. Wavelet spectra of F2 layer critical frequency (*the first panel from the top*) and geomagnetic field H component (*second panel*) for September 3, 2014. The black arrows indicate a correspondence between the spectra maximums for foF2 and the H component disturbances.

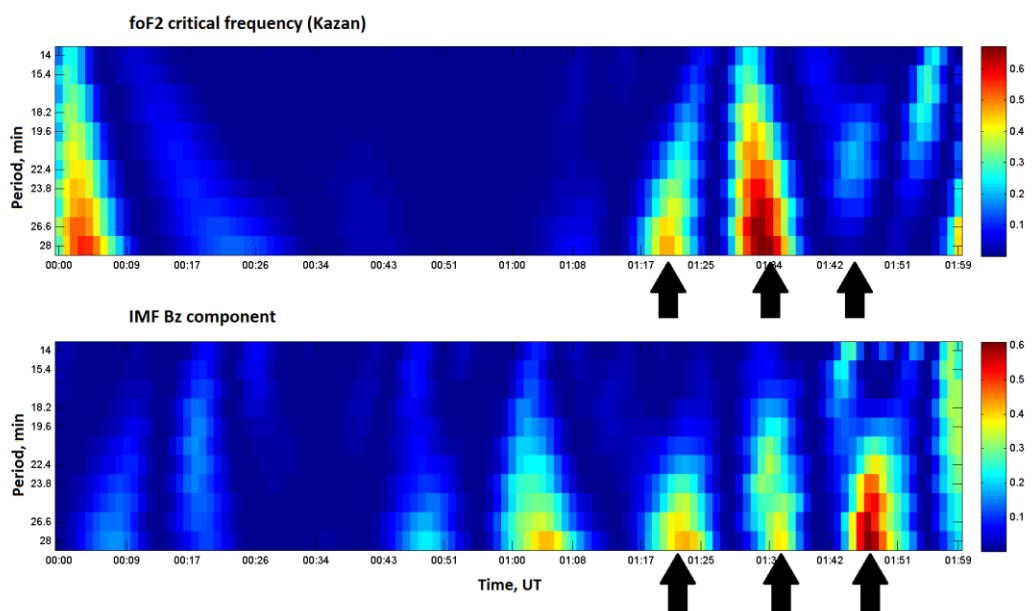


Figure 2. Wavelet spectra of the ionospheric layer F2 critical frequency and interplanetary magnetic field Bz component disturbances for September 3, 2014. The arrows indicate areas of the spectral singularities coincidence for foF2 critical frequency and IMF Bz component.

In addition, during ~ 01.00 UT, the values of IMF Bz component change from small negative to positive values. Such situation, according to [Barkhatov et al., 2017; Morley and Freeman, 2007], correspond to the substorm development. Note that the considered time interval corresponds to the night-time magnetosphere sector, within the westward electrojet (AL) is localized. Its dynamic shows that during this time there really is a bay-like disturbance preceded a non-disturbed period (AL ~ -20 nT). Fig. 3 shows the dynamics of the Solar wind parameters and the AL index. Black vertical lines indicate the coincidence of foF2 and geomagnetic field H component spectral features at Kazan station.

The performed results demonstrate the possibility of synchronous ionospheric and geomagnetic disturbances existence in the class of Pi3 pulsations (periods of 15-30 min) at medium latitudes for local nighttime in the global geomagnetic non-disturbed conditions. The magnetosound nature of observed disturbances is demonstrated by comparing of foF2 critical frequency over the Kazan station and geomagnetic field component spectral patterns over a large spatial region including high, middle and low latitudes. The revealed magnetosound disturbances can be generated by the instability of westward electrojet. At the same time, these electrojet participates in substorm process as an element of a large-scale three-dimensional current system - a substorm current wedge. During the substorm development, the extended magnetic force lines of geomagnetic tail are subjected to ULF vibration by disturbed magnetized Solar wind. It makes possible to explain such low frequencies of observed disturbances in comparison with resonant MHD oscillations under quiet conditions.

Thus, the noted synchronization of ionospheric and magnetic disturbances gives reason for believing that detected disturbances have a magnetosound nature and are associated with substorm activity.

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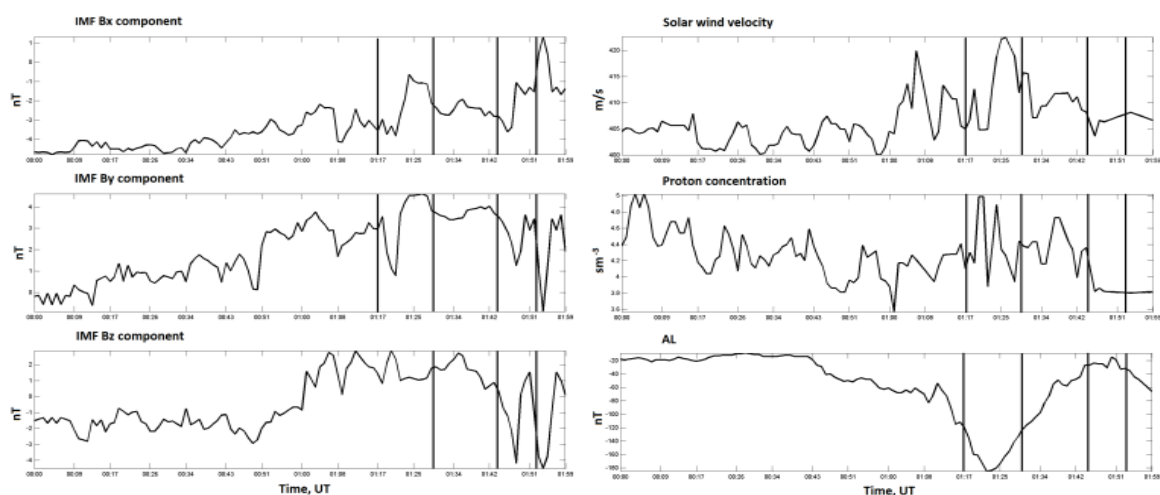


Figure 3. Interplanetary magnetic field component Bx, By, Bz plots (*left panel*), Solar wind velocity and concentration (*right panel*) for September 3, 2014. Vertical black lines indicate the coincidence of foF2 and H component spectral features at Kazan station.

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