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IONOSPHERIC AND GEOMAGNETIC DISTURBANCES ON THE BACKGROUND OF SUBSTORM PROCESSES

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Introduction

One of the main reasons for the occurrence of geomagnetic disturbances associated with the magnetospheric storms and substorms development are magnetic clouds of the Solar wind. In the magnetic clouds (MC) structure the sheath and the body of the cloud are distinguished [1]. The sheath in front of the cloud is a compression region that occurs when it moves in a slower Solar wind. This is a dense and hot turbulent region with strong fluctuations of the Interplanetary magnetic field (IMF) components which have MHD character. Low-frequency MHD disturbances can be transferred from the cloud sheath to the Earth's magnetosphere from the night side through the "Substorm Current Wedge" current system, which includes the magnetosphere tail currents, field-aligned currents and the westward electrojet. This current system appears in the disturbed magnetosphere during magnetosphere substorm explosive phase and connects its active regions with the high-latitude ionosphere. The resulting electrojet instability can generate low-frequency MHD disturbances in the ionosphere and geomagnetic field.

This work is devoted to the search for night-time synchronous ionospheric and geomagnetic MHD disturbances on the background of significant substorm activity. The study was carried out for intense substorms intervals caused by MC turbulent sheath which follow the shock waves. In this paper we are supposed that low-frequency MHD night disturbances in geomagnetic field and ionosphere occurring on the substorm background are caused by out-magnetospheric wave agent located in the near-Earth space.

Used data and research methods

The generation possibility of night MHD disturbances in the ionosphere and geomagnetic field by turbulent MC sheath phenomena is demonstrated on seven clouds events with shock waves: 10.08.2000, 20.03.2003, 03.08.2000, 06.11.2000, 14.06.2005, 18.02.1999, 04.05.2010. All events cause the magnetospheric substorms development. For the detection of ionosphere-geomagnetic MHD disturbances the TEC data from GPS stations and the geomagnetic field H-component values at magnetic observatories located in the LT night sector were used. The analysis of the out-magnetospheric disturbance is based on the Solar wind data (proton concentration, velocity) and the Interplanetary magnetic field (Bx, By, Bz components). Wave phenomena were studied during a two-hour interval after the shock wave registration on the spacecraft. Substorm activity estimated by the AL index values was always observed at these intervals.

The characteristic periods and appearance times of out- and intramagnetospheric MHD disturbances were established using the wavelet-analysis method with a 4-order Daubechies basic function.

Out-magnetospheric MHD disturbance

For 7 examined MC events a spectral analysis of low-frequency MHD disturbances in the Solar wind parameters and in the interplanetary magnetic field components is carried out at intervals corresponding to the Earth passage through their sheaths. As an example, we consider the MC with a shock wave registered on November 6, 2000 and caused a sequence of intense substorms. At the examined time interval ALmax ~ -1300 nT. The registration time of a shock wave on a spacecraft is 09.40 UT. Fig. 1 (a) shows the wavelet spectra of Interplanetary magnetic field components (Bx, By, Bz), the Solar wind proton concentration (N) and its velocity (V). Spectral analysis of the Solar wind and Interplanetary magnetic field parameters shows the presence of synchronous low-frequency oscillations of the Earth ionospheric plasma and magnetic field with periods of 15 to 30 minutes as the spacecraft passes through a shock wave (interval 9.40 - 10.20 UT). This area is highlighted in Fig. 1 (a) by a rectangle. In the MC sheath (after 10.30) UT synchronous magnetic disturbances are recorded in all IMF components with periods of 25-30 minutes and Solar wind concentration with periods of 15-20 minutes.

Ionosphere-magnetospheric MHD disturbances

The analysis of ionospheric and magnetic wavelet spectra showed the presence of simultaneous disturbances in the ionosphere and geomagnetic field with periods from 15 to 30 minutes for all considered events. As an example, Fig.

1 (b) shows wavelet spectra of TEC variations for Holberg (50.6 N, 128.4 W, L = 2.87) and Mammoth Lakes (37.6 N, 119 W, L = 1.84) GPS stations and geomagnetic field H-components for Sitka (57.1 N, 135.3 W, L = 3.8), Victoria (48.5 N, 123.4 W, L = 2.7) and Tucson (32.2 N, 111 W, L = 1.66) magnetic stations for the event on November 6, 2000 in the interval from 09.20 to 12.00 UT. According to the presented results, simultaneous maxima of TEC and geomagnetic field spectra take place. The region of the shock wave passage from 09.20 to 10.10 UT is indicated in Fig. 2 by a black rectangle. After 10.20 UT rectangles are allocated to the regions of synchronous disturbances of ionospheric plasma and geomagnetic field horizontal components. These intervals correspond to the Earth passage through the turbulent MC sheath.

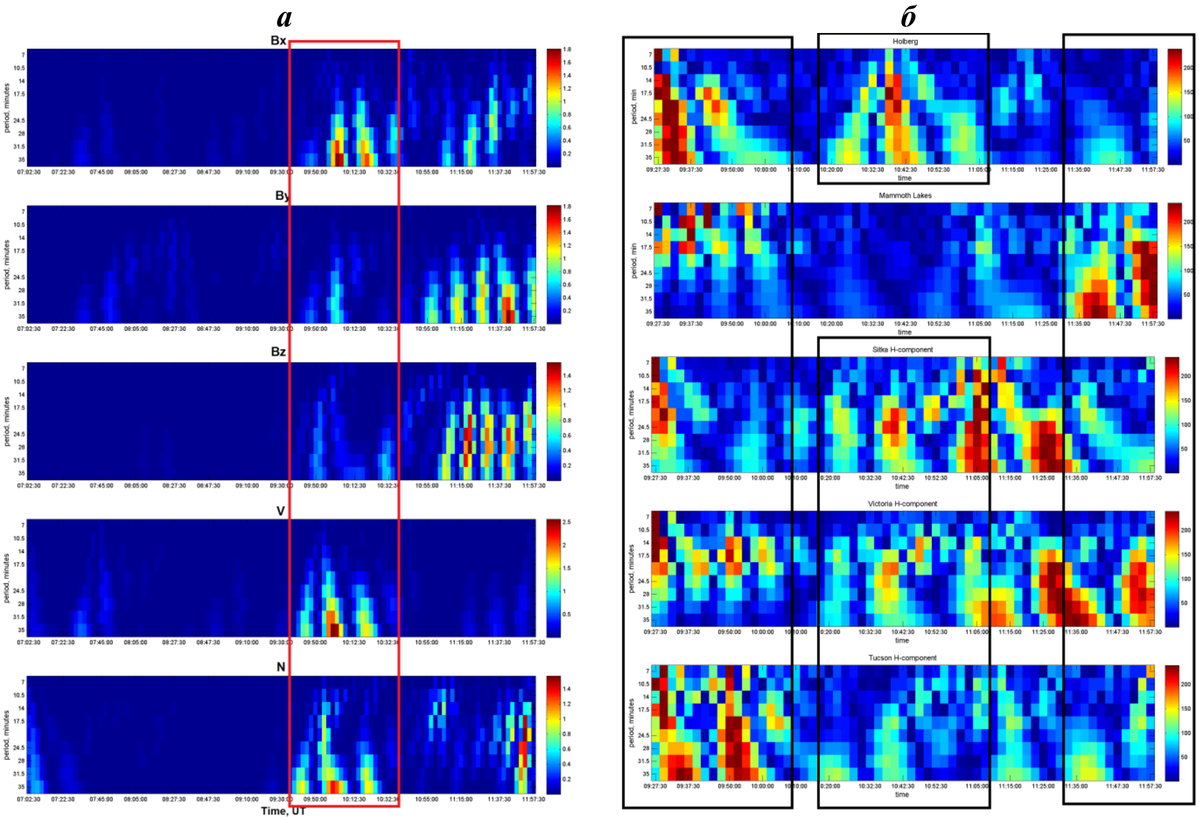

Figure 1. (***a***) Wavelet spectra of Bx, By and Bz IMF components, the Solar wind proton concentration and its velocity for the event on November 6, 2000; (***b***) Wavelet spectra of TEC for stations Holberg (50.6° N, 128.4° E, L = 2.87), Mammoth Lakes (37.6° N, 119° E, L = 1.84) and geomagnetic field H-components for stations Sitka (57.1° N, 135.3° W, L = 3.8), Victoria (48.5° N, 123.4° W, L = 2.7), Tucson (32.2° N, 111° W, L = 1.66) for the event of November 6, 2000.

Thus, synchronous ionospheric and geomagnetic disturbances were recorded during the period of MC sheath effect on the magnetosphere which may indicate their common MHD nature. The period interval of detected MHD wave disturbances is 10-35 minutes. This indicates a causal relationship between turbulent disturbances in the MC sheath with MHD disturbances appearance in the ionosphere-magnetospheric system. The validity of this statement was verified by an investigation of the ionosphere-magnetospheric disturbance for the time interval preceding the shock wave recorded at 09.40 UT on November 6, 2000. The duration of the analyzed interval was of the order of an hour and during this period no substorm activity was recorded (AL < -100 nT). Fig. 2 (a) shows the wavelet spectra of IMF components, the Solar wind concentration and velocity. In considered frequency range disturbances are observed for all parameters. Fig. 2 (b) demonstrates the spectral features of disturbances at terrestrial ionospheric and magnetic stations. Comparison of registration times for plasma and geomagnetic disturbances shows that there is no synchronicity between them.

It can be concluded that MHD disturbances in near-Earth space is almost always present. These disturbances however do not penetrate into the ionosphere-magnetospheric system in the substorm absence. In regions associated with magnetic clouds (shock wave and sheath), MHD disturbances are more intense and simultaneously conditions for the substorm sequence development are created. On the Earth during these periods exactly intense synchronous disturbances of the ionospheric plasma and the geomagnetic field are recorded.

Conclusions and discussion

In this paper, a parallel analysis of low-frequency ionospheric, geomagnetic, and near-earth MHD disturbances at the background of substorm activity intervals is carried out. The sequences of intense substorms in all the considered cases were caused by magnetic clouds turbulent sheaths following their shock waves. The spectral composition of the Solar wind and Interplanetary magnetic field parameters showed the presence of intense low-frequency MHD oscillations with periods of 10-35 minutes during the passage of the terrestrial magnetosphere, both through the shock wave and the cloud sheath. At the same intervals, the synchronous spectral maxima in ionospheric and geomagnetic disturbances with periods of 10 to 35 minutes were found for all events of magnetic clouds by comparing the spectral patterns of TEC and geomagnetic field horizontal component variations. The synchronism of geomagnetic and ionospheric disturbances indicates their common MHD nature. The results obtained are consistent with the conclusions of our earlier work [2].

Thus, we suppose penetration possibility to MHD oscillations from the Solar wind into the magnetosphere-ionosphere system from the night side through the tail of the magnetosphere. According to considered physical model, the disturbed and magnetized Solar wind influence on geomagnetic tail of the magnetosphere and it helps to transfer these vibrations to the westward electrojet (AL), which is part of the three-dimensional Substorm current wedge system. The active electrojet, in turn, can be the source of the detected low-frequency MHD disturbances.

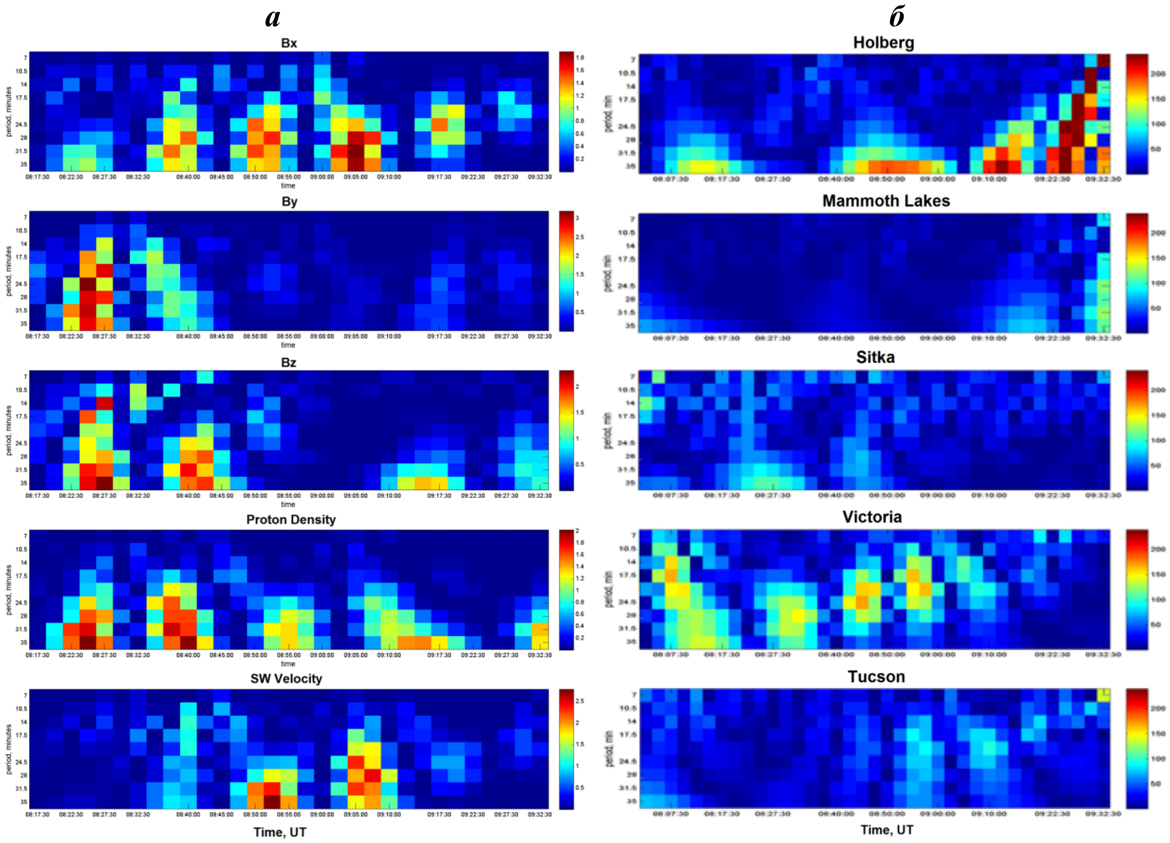

Figure 2. (***a***) Wavelet spectra of Bx, By and Bz IMF components, the Solar wind proton concentration and its velocity; (***b***) Wavelet spectra of TEC for Holberg (50.6° N, 128.4° E, L = 2.87), Mammoth Lakes (37.6° N, 119° E, L = 1.84) stations and geomagnetic field H-components for stations Sitka (57.1° N, 135.3° W, L = 3.8), Victoria (48.5° N, 123.4° W, L = 2.7), Tucson (32.2° N, 111° W, L = 1.66) for the event on November 6, 2000, the time interval of 08.10 - 09.30 UT.

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