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INFLUENCE OF SLOPE OF THE SOLAR WIND INHOMOGENEITY FRONT ON PROPERTIES OF LONGPERIOD PULSATIONS DURING SSC

Yu.Yu. Klibanova[1,2], V.V. Mishin[1], B. Tsegmed[1,3], A.V. Moiseyev[4]

[1]*Institute of Solar-Terrestrial Physics SB RAS, Irkutsk*
[2]*The A.A. Ezhevsky Irkutsky State Agrarian University, Irkutsk*
[3]*Institute of Astronomy and Geophysics of the Academy of Sciences of Mongolia, Ulan Bator, Mongolia*
[4]*The Yu. G. Shafer Institute of Cosmophysical Research and Aeronomy SB RAS, Yakutsk*

Abstract. We study long-period geomagnetic pulsations caused by the arrival of the solar wind (SW) inhomogeneity front during the 14 July 2012 magnetospheric storm commencement from data of the ACE, WIND, THEMIS satellites, as well as ground stations, located at the low, mid and high latitudes. It is shown that the propagation direction of pulsations corresponds to the excitation mechanism by the front impact on the magnetopause, and the shift from the noon meridian of sector of waves running away is determined by an azimuth angle of the front inclination. A change in the polarization direction in longitude and latitude is observed. The rather high frequency of observed global pulsations f = 4.4 mHz is caused by the compression of the subsolar magnetopause to L = 6.7 and is not associated with SW fluctuations.

Introduction

The literature has accumulated extensive experience in the study of the basic mechanisms of the long-period geomagnetic pulsations generation in the frequency range (1.67 - 25 mHz) due to the SW inhomogeneity front impact that caused the magnetospheric storm sudden commencement (Ssc) [*Pudovkin et al.,* 1976, *Nishida* 1980; *Korotova and Sibeck*, 1994, *Rae et al.*, 2005]. To date, access to the data of the global network of ground-based magnetometers, widely spaced on the surface of the Earth with high temporal resolution, allows us to carry out a more detailed analysis of the properties of the impulsive (lasting several periods) long-period geomagnetic pulsations during Ssc.

The impact of the SW inhomogeneity front on the magnetosphere excites surface waves on its boundary, observed on the Earth in a form of rapidly decaying train of longperiod geomagnetic pulsations. Their propagation in the azimuth direction comes from the contact area of the magnetopause with: 1) the IMF plane [*Korotova et al.*, 2002], when the SW pressure is homogeneous on the front, or 2) the front in the presence of Pd inhomogeneity on it [*Mishin et al.*, 2013]. Activation of the substorm activity affects the propagation direction of waves, the distribution of their amplitude and polarization [*Mishin et al.*, 2013; *Klibanova et al.*, 2014].

The aim of this work is a detailed analysis of geomagnetic pulsations during the 14 July 2012 storm Ssc from the 1 s and 10 s geomagnetic data of ground stations located on not only high, but also the mid and low latitudes in a wide range of longitudes.

Observations

We analyze the 14 July 2012 event. Ssc was recorded at 18.09 UT according to Geomagnetic Indices Bulletin NGDC USA. Fig. 1 shows variations of the SW parameters and IMF. The time of the SW inhomogeneity front registration by the WIND satellite is shifted to match with the time of the sharp change of the geomagnetic field on ground- based stations, caused by the front. The SW dynamic pressure Pd changes from 1 to 6 nPa, the velocity component Vx - from 391 to 580 km/s, the IMF By - from 5.3 to 13.5 nT and the IMF Bz - from - 4 to - 9 nT.

Geomagnetic activity index reached a value of 1311 nT. Ground-based observations show that the geomagnetic pulsations begin at 18.09 UT (from data of the station DAWS (07 MLT)). The azimuth angle of the front plane inclination (measured counterclockwise from the direction of the x-axis in the plane (x, y) of the GSE system (ie from the Sun) is equal to φ = 92.5° from data of satellites WIND and ACE (X_{GSE} ≈ 230

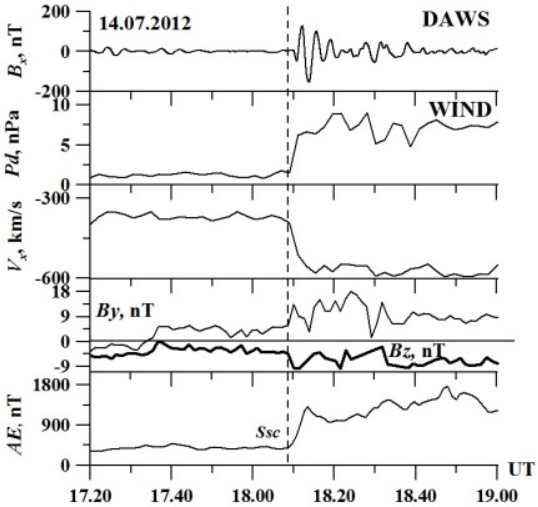

Figure 1. Variations of the IMF and the SW parameters at WIND (X_{GSE} = 205 R_E, Y_{GSE} = - 61 R_E, Z_{GSE} = - 12 R_E), and AE index.

R_E); and to φ = 88° at the orbit of the THEMIS satellites ($X_{GSE} \approx 42\ R_E$) (see. Fig. 4). The arrival of the inhomogeneity front has caused a sharp displacement toward the Earth of the magnetopause nose (its subsolar point) [*Shue et al.* 1998] before Ssc it was at x= 10.3 R_E from the Earth, and after the impact - at the x = 6.7 R_E.

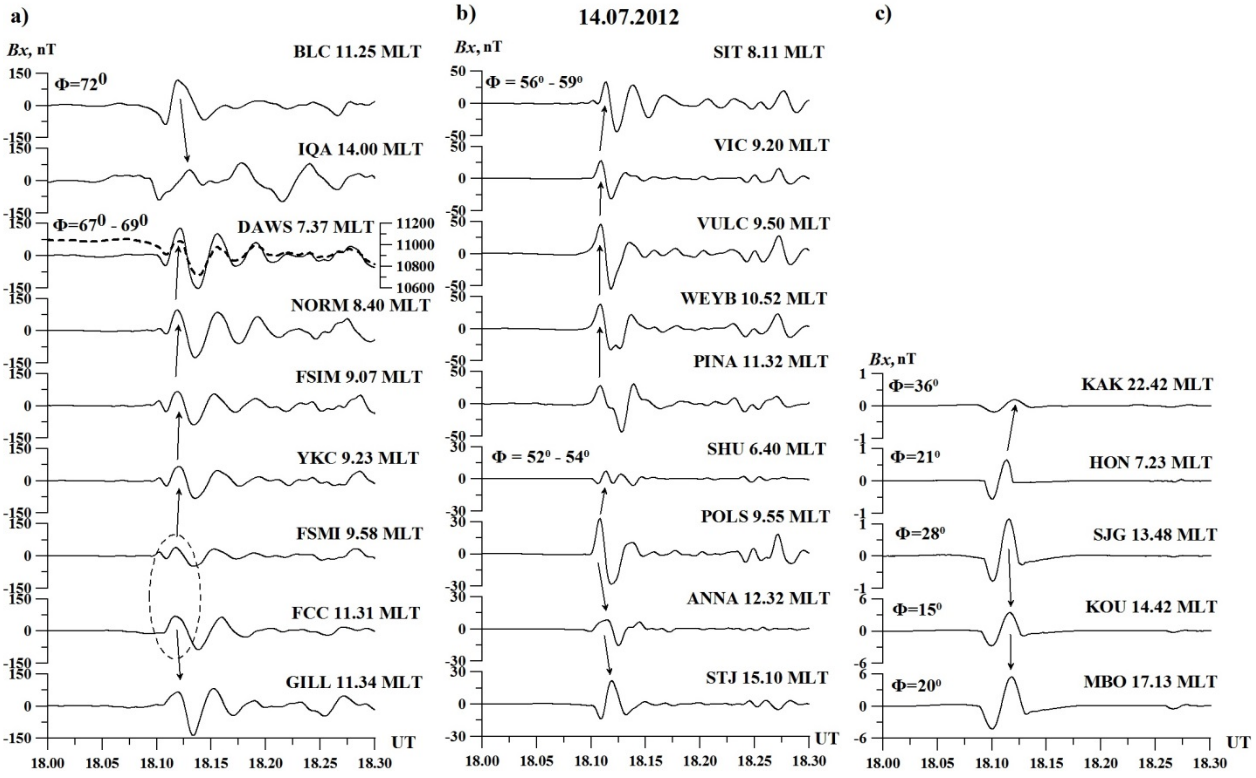

Figure 2. The Bx- component variations from data of: **a)** high-latitude parallels (Φ = 72° and Φ = 67° – 69°) – ground-based observatories of the CANMOS and CARISMA Canadian networks; **b)** the mid-latitude parallels (Φ = 56° - 59° and Φ = 52° – 54°) - of the CANMOS, CARISMA networks and US ground observatories; **c)** the low-latitude parallel of US and Japan ground stations. Black arrows show the propagation direction of geomagnetic pulsations. Dotted oval denotes the alleged area of divergence (running away) of geomagnetic pulsations.

Fig. 2 shows the results of our analysis of the long-period geomagnetic pulsations propagation at the high, middle and low latitudes in the azimuthal direction. Absolute value of the Bx component of geomagnetic pulsations is shown in Fig. 2a. At the high-parallel Φ = 72° (above the projection of the magnetopause) near noon irregular pulsations move from station BLC (11.25 MLT, *A* = 190 nT) to IQA (14.00 MLT, *A* = 70 nT) with a velocity of 14 km/s (Figure 2a). At the parallel Φ = 67° - 69° (right within the magnetopause projection) pulsations propagate from FSMI (9.58 MLT, A = 62 nT) to the morning station DAWS (7.37 MLT, A = 144 nT) at a speed of 50 km/s, and from FCC (11.31 MLT) to the nearnoon station GILL (11.34 MLT, A = 108 NT) at a speed of 6 km/s. Fig. 2a shows highlighted oval area of divergence pulsations, which is located between the stations FSMI and FCC. At the parallel Φ = 56° - 59° (close to the projection of the contact area of the front with daytime magnetopause) pulsations propagate from PINA (11.32 MLT, A = 32 nT). After the 3 seconds they were observed at the station WEYB (10.52 MLT), then through 4 s at stations VULC (9.50 MLT, A = 45 nT) and VIC (9.25 MLT, A = 28 nT), and by 33 s - at the morning station SIT (8.11 MLT) (Fig. 2b, upper panel). At the midlatitude parallel Φ = 52° - 54° (Fig. 2b, bottom panel) pulsations run from POLS (9.55 MLT, A = 32 nT) to dawn (SHU, 6.40 MLT) at a speed of 100 km/s, and to dusk (ANNA,12.32 MLT, A = 20 nT) at a speed of 70 km/s, and then to STJ (15.10 MLT, A = 22 nT).

At low latitudes (Φ = 15° - 28°, Fig. 2c) pulsations in the afternoon sector propagate duskward from SJG (13.48 MLT, A = 1 nT) to KOU (14.42 MLT, A = 3.5 nT) and further to MBO (17.13 MLT). On the dawn side waves propagated from HON (7.23 MLT, A = 0.8 nT) nightward to KAK (2.46 MLT) at a speed of 140 km/s.

Pulsations with a stable polarization were observed for 3.5 - 4 min. Fig. 3 shows the behavior of the polarization at the high, middle and low latitudes in the dawn, pre- and afternoon MLT sectors (dotted circle with the up arrow - the counterclockwise direction of the polarization vector, the solid circle with the down arrow – the clockwise polarization). The vertical dotted lines indicate the (9.20 - 11.30) MLT area (sector) of the divergence of waves. The polarization is directed: counterclockwise before noon and clockwise - afternoon. At the high-latitude parallels Φ = 67° - 69° and Φ = 56° - 59° polarization is counterclockwise before the sector of pulsations divergence, then there is a change of the direction of the polarization vector rotation. At the mid- latitude parallel Φ = 52°-54° in the morning, the polarization is counterclockwise in the divergence sector, and afternoon the polarization is clockwise. At low latitudes before noon the polarization is clockwise and afternoon - counterclockwise.

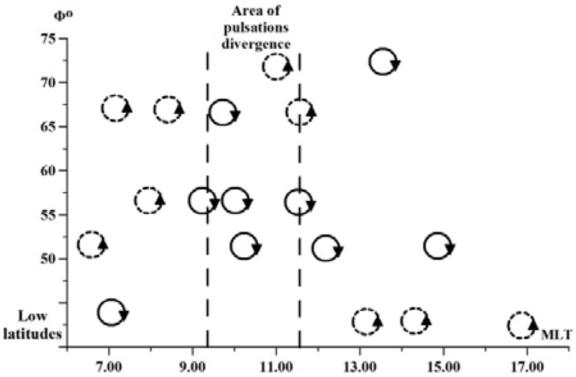

Figure 3. Rotation direction of the polarization vector of the geomagnetic field horizontal component (in the plane x, y)

The spectral analysis of magnetic field oscillations in the solar wind and on the Earth (Fig. 5). In the SW the two peaks of spectral power (according to the satellite ACE (X_{GSE} = 247 R_E, Y_{GSE} = 25 R_E, Z_{GSE} = 18 R_E)) are found at frequencies: f = 2.9 mHz and f = 4.7 mHz. All ground stations registered two peaks at the frequencies: f = 2.9 mHz and 4.4 mHz. At stations located within the projection of the magnetopause (L ~ 6.7) the peak with a maximum spectral power is observed at a frequency f = 4.4 mHz. At the low-latitude stations (L ~ 1), there are two peaks with a maximum spectral power at frequencies: f = 2.9 mHz and f = 4 mHz .

Discussion

On the dayside magnetosphere during Ssc, the arrival of the SW inhomogeneity front excites waves propagating on the magnetopause in both (to dawn and dusk) directions from the area of contact (Fig. 4).

Displacement of the pulsations running away sector from the noon meridian is determined by the azimuthal angle of the front, not by the IMF orientation. The sector boundaries are identified from the change of direction of the azimuthal velocity and polarization rotation, as well as the distribution of the pulsation amplitude. At all latitudes the polarization direction changes inside the sector of divergence of pulsations. Such a change in the polarization direction corresponds to the running away of oscillations from both sides of the sector typical for more quiet events [*Mishin et al.*, 2013]. Moreover, the direction of the polarization vector rotation is observed to be: left at high and middle latitudes before noon, and right- at low latitudes. Changing of the polarization vector rotation with latitude is associated with the resonance peak at a frequency f = 4.4 mHz

Spectral analysis shows that the geomagnetic pulsations excited by the sharp Ssc front inside the magnetosphere, are not explicitly related to the SW fluctuations. These pulsations are global, their properties are explained by the excitation mechanism at the magnetopause by the storm front, and a sufficiently high frequency value (f = 4.4 mHz), mainly by the close distance from the Earth to the subsolar magnetopause.

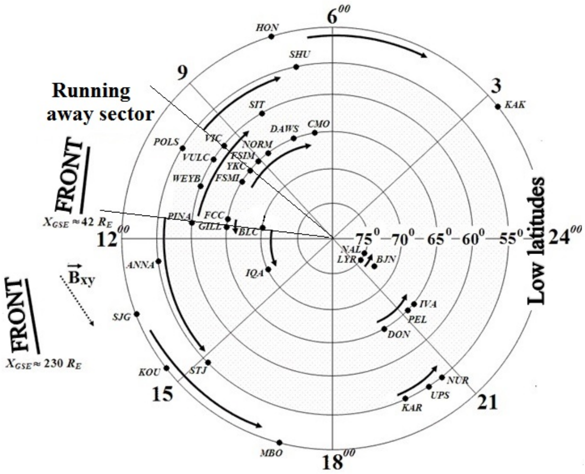

Figure 4. Directions in the plane (x, y) of the SW inhomogeneity front (thick line), the vector of IMF (dotted arrow) and the direction of propagation of geomagnetic pulsations (solid arrows) at high, middle and low latitudes.

Conclusions

1. It is shown that pulsations propagate from the dayside to the night through dawn and dusk sides from the boundaries of the (9.20-11.30) MLT pre-noon sector, with the opposite polarization direction. Position of the sector is determined relative to noon by the azimuthal angle of the front.
2. A change in the direction of rotation of the polarization vector of the geomagnetic field horizontal component (in the plane x, y) is reversed at the transition from middle to low/sub-auroral latitudes.
3. Strong compression of the dayside magnetosphere (L = 6.7) resulted in the observation at all latitudes, of a global, non-SW related oscillations, the frequency of which (f = 4.4 mHz) is increased compared with the weaker fronts.

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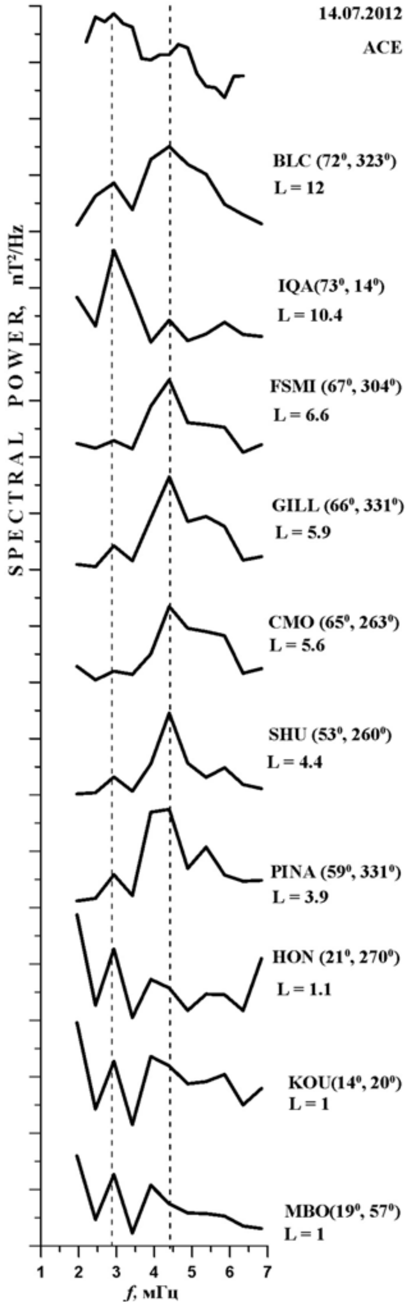

Figure 5. The spectral power of fluctuations in the SW (on the ACE satellite) and geomagnetic pulsations at high, middle and low latitudes.

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