"Physics of Auroral Phenomena", Proc. XIX Annual Seminar, Apatity, pp.41-44, 1996

Polar Geophysical Institute

THE RELATIONSHIP BETWEEN INTERPLANETARY AND MAGNETOSPHERIC DISTURBANCES ON DATA OF CORRELATED IMF, COSMIC RAYS AND GEOMAGNETIC MEASUREMENTS

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Abstract. The paper investigates the relationship between parameters of disturbed solar wind inside the interplanetary shock wave and the high-latitude geomagnetic activity. Data on correlated variations of the IMF, cosmic rays and geomagnetic field at stations of Scandinavian and Alaskan regions during the great heliospheric disturbance of October 19-21, 1989 have been analyzed. It is shown that cosmic ray fluctuations can be used as an indicator of the solar wind turbulence. Polarization of anomalously great IMF fluctuations in the post interplanetary shock region has been studied. The high correlation has been found between IMF Bz and geomagnetic variations on the day side what speaks for the existence of direct driven disturbance in the ionosphere.

1. Introduction

The paper deals with the IMF fluctuations in the frequency range $10^{-4} < f < 10^{-3}$ Hz and their link connection with fluctuations of cosmic rays (CR) and the geomagnetic field. IMF fluctuations in these frequency limits are the waves: Alfven, fast and slow magnetosonic and discontinuities of different kinds. Beside direct measurements the cosmic rays may be used as an indicator of IMF fluctuations. And as a parameter of magnetosphere-ionosphere disturbances the AE-index (auroral ionospheric electrojet index) usually has been used [1-4]. The delay time of separate magnetospheric disturbances in respect to those of the solar wind (parameters: ε , Bz, v*Bz, v^2*Bz, etc.) varies in the wide range from 5 to 60 min. [1,2]. A statistical analysis allows to distinguish two character delay times: 20 min and 1 hr [1]. These periods seem to correspond to two general ways of energy input from the solar wind to the ionosphere: 1) direct driven disturbances through direct energy input via reconnection at the dayside magnetopause (short delay) and 2) the energy input into the magnetosphere through the viscouslike interaction or other mechanisms with subsequent substorm activity [1-3]. In the latter case the 1 hour delay equals to an average substorm recurrency period [1-3]. At the same time, the correlation between the AE-index and IMF Bz component is rather poor [1]. The reason could be due to the fact that AE-index includes into itself geomagnetic variations both from the day and night sides which correspond to the mentioned above two ways of energy input from the solar wind into the ionosphere. In this paper an attempt is made to reveal the directly driven disturbances by means of a correlation analysis between different components of IMF and geomagnetic variations at the stations located in the midday sector. High time resolution data: 15-sec IMF vector data as measured on board the IMP-8 spacecraft, the 10 sec data of cosmic ray intensity as measured at the neutron monitor in Apatity, 1-min

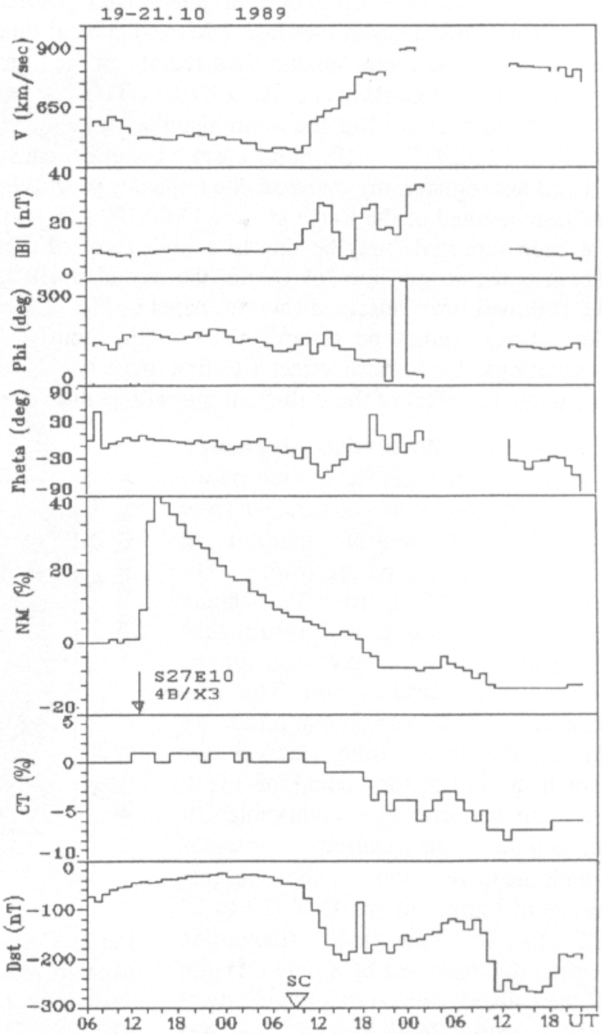

Fig.1. Interplanetary parameters (IMP-8), cosmic ray intensity: neutron monitor (NM) and muon cubical telescope (CT) in Apatity and Dst index variations during the great solar-terrestrial disturbance of October 19-21, 1989. Moments of the great solar flare on October 19, 12.32 UT and an SC at 9.15 UT 20.10 are indicated. Note the impulselike positive increase in the Dst-index at the moment of the second shock arrival at 17 UT 20.10.

magnetometer data from the two meridional chains of stations: Scandinavian (EISCAT magnetometer chain) and Alaskan one have been analyzed for the period of very strong solar - terrestrial disturbance of the October 19-21, 1989.

2. Data analysis and results

Heliospheric disturbance of the 19-21 October, 1989. The large-scale interplanetary turbulence of October 19-21 was the most powerful in the 22nd solar activity cycle. The solar wind speed exceeded the value of 900 km/s and the Dst-index in the minimum was 270 nT. Disturbances of such a scale usually enclose the whole heliosphere.

Fig.1 shows from the top to bottom: hourly data of solar wind speed, IMF vector components, cosmic ray intensity from data of the neutron monitor (NM) and cubical muon telescope (CT) in Apatity, Dst-index. The source of this very complicated event was the flare activity on the Sun on October 18-19 [4]. Namely, as it is supposed in [4], the coronal eruption causing the SC at 09.15 UT, 20.10 was associated with a series of flares in the active region AR 5747 on October 18. But the main disturbance in the event was due to the powerful flare 4B/X13, S27E10, which began at 12.32 UT, 19.10. Solar cosmic ray effect caused by the flare was 38% as observed by the NM in Apatity. CT did not register any increase due to its low sensitivity to SCR having a soft energetic spectrum. The shock from the flare arrived at the Earth at near 17.00 UT as it was observed by the IMP-8 spacecraft [4]. Though the SC had not been reported (may be due to a high level of magnetic activity) the Dst-index showed a short impulselike increase just at the time (18 UT) of the second shock arrival. Right after the shock a highly fluctuating regime of the IMF had been observed (bottom panel of Fig. 2, where 15-sec data of |B| IMF i s shown). Note that these IMF fluctuations cannot be discovered from the hourly data (Fig. 1). Simultaneously with arrival of these IMF fluctuations the forbush effect (its first step) began as cosmic ray detectors (NM and CT, Fig.1) showed. The geomagnetic effect of these fluctuations will be discussed below.

Cosmic ray fluctuation dynamics. Fig. 2 shows the CR fluctuation power spectra dynamics as constructed from 10-s data of neutron monitor in Apatity during the period from 00 UT 20.10 to 18 UT 21.10. The 4-hours time intervals of data with 6-min shift along the time axis were used for the power spectra construction. The 15-s data of the IMF vector magnitude |B| during the same time interval are shown at the bottom panel of Fig.2. One can see that the remarkable CR fluctuation activization proceeds simultaneously with the highly turbulent regime of the IMF (17 to 23 UT 20.10). This IMF fluctuation regime was followed by a new increase of the IMF |B| (the source is unknown) with a regular field structure that was perhaps a reason for CR fluctuation damping. The next activization of CR fluctuations in the morning hours of 21.10 may signal about new strengthening of the IMF turbulence (the data of direct measurements are absent). The CR fluctuations ceased after 12 UT when the Earth entered a magnetic cloud [5] having a regular field structure [6]. The second step of the forbush-effect and the Dst-decrease which proceeded from 10 to 12 UT confirms the suggestion [5] about entering of the Earth into the magnetic cloud

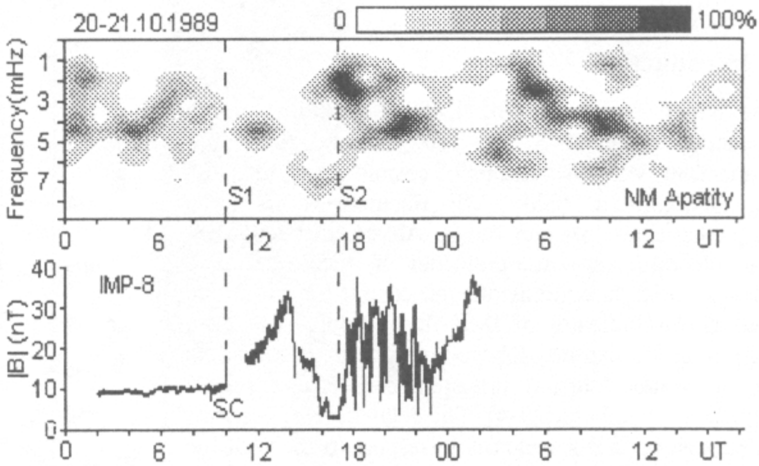

Fig.2. Cosmic ray fluctuation spectra dynamics on the data of the neutron monitor in Apatity (top) and the vector |B| IMF magnitude variations (bottom) during the period of disturbances on October 20-21, 1989. Dashed lines S1 and S2 denotes the time of arrival of the first and second shocks correspondingly.

On the character of CR interaction with the IMF turbulence. To determine the polarization of the IMF turbulence during the disturbed period 17-23 UT 20.10 and its effect on cosmic rays a special analysis was performed. The quantity Bo, which is the averaged over the period 17-23 UT IMF vector **B**, was calculated. Then components of the IMF vector: parallel and normal to the averaged value Bo were determined by formulae:

$\mathbf{B}_{\parallel}= (\mathbf{B}*\mathbf{Bo})/|\mathbf{Bo}|$; $\mathbf{B}_{\perp} =(\mathbf{B}^{\times}\mathbf{Bo})|/|\mathbf{Bo}|$.

$\mathbf{B}_{\parallel}$ corresponds to the magnetosonic mode and $\mathbf{B}_{\perp}$ to the Alfven one.

Fig. 3 shows fluctuation power spectra constructed from data of the neutron monitor and quantities $\mathbf{B}_{\parallel}$ and $\mathbf{B}_{\perp}$ for the whole disturbed period 1700 - 2300 UT. As one can see the most power of cosmic ray fluctuations is related to the magnetosonic mode ($\mathbf{B}_{\parallel}$) of the IMF turbulence, but contribution of the Alfven mode ($\mathbf{B}_{\perp}$) also is remarkable. It is known however that in the linear approximation limit the cosmic rays are influenced at most by the magnetosonic mode and the Alfven mode is relatively inefficient for the CR modulation [7]. In our case, the relative perturbances of the IMF (Fig.2) are very large: $\delta B>B$ and nonlinear processes should predominate. As a consequence, the spectral power of the IMF fluctuations and influenced by them those of CR weakly depend on polarization of disturbance.

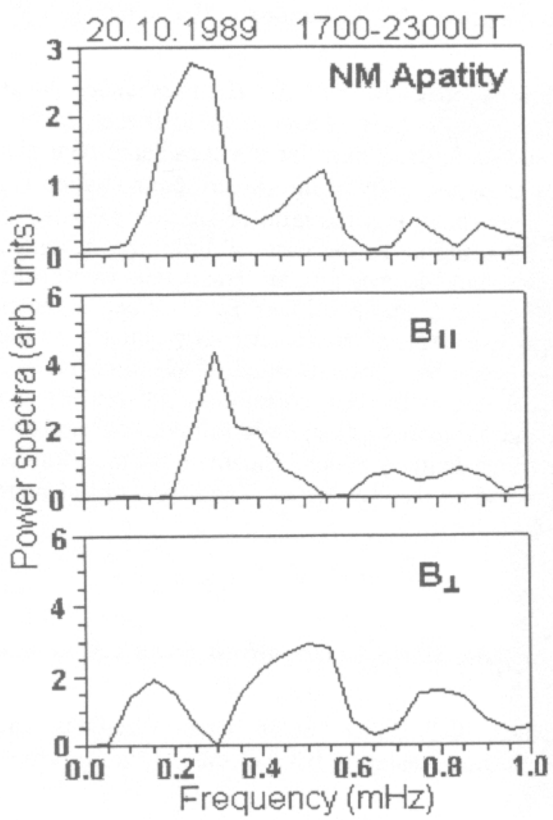

Fig.3. Fluctuation power spectra for the disturbed period of 17-23 UT 20.10.1989 calculated from the data of: cosmic ray intensity (neutron monitor in Apatity - upper panel); IMF components $B_{\parallel}$ and $B_{\perp}$ - parallel and normal to the mean IMF vector for the period of 17-23 UT 20.10.

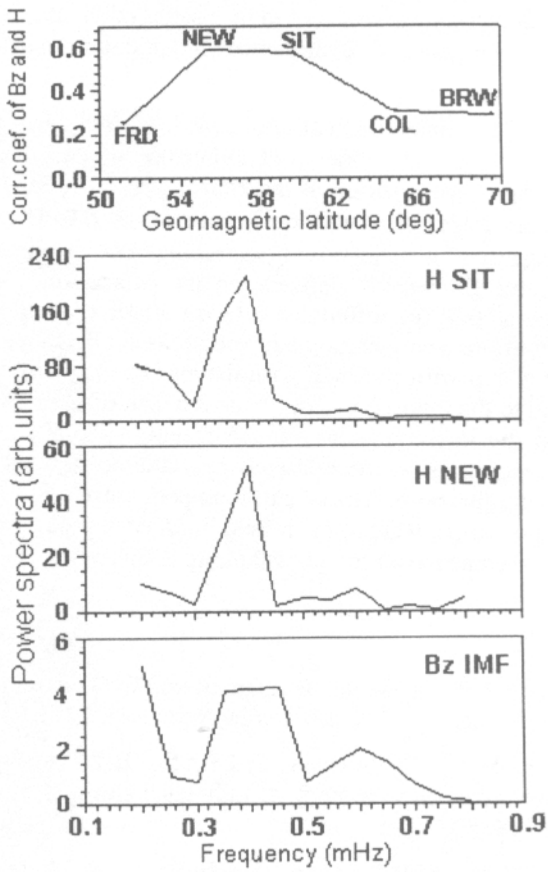

Fig.4. Top: A latitudinal section of correlation coefficient between the IMF Bz and the geomagnetic field H-component calculated for the disturbed period 17-23 UT for the meridional chain of stations: Frederiksburg, Newport, Sitka, College, and Barrow. Bottom: Fluctuation power spectra of the IMF Bz, and the geomagnetic H-component at the stations Newport and Sitka for the disturbed period 17-23 UT 20.10.

Geomagnetic Disturbances. The extraordinarily great IMF fluctuations in the period of 17-23 UT 20.10 and appropriately situated in the day sector the Alaskan meridional magnetometer station chain gave a chance to investigate the mechanism of a direct energy input into the ionosphere (direct driven disturbances). The statistical analysis was performed between different components of the IMF,ground based magnetic variations and different stations. Significant correlation coefficient (0.6) were obtained for the IMF Bz component and H-component at the stations Sitka and Newport. The raw data were previously filtered by band pass filter in the frequency range $0.3<f<0.5$ mHz. The results of this analysis for different stations in dependence on latitude are shown in Fig. 4. The high level of correlation speaks for the directly driven disturbances. The next evidence for that is the coincidence of peaks in the fluctuation power spectra of the Bz and H-component at these stations (Fig.4). The important parameter of physical processes responsible for the direct driven disturbances is a delay time of ionospheric disturbances in respect to ones in the solar wind. The cross-correlation analysis between H-component data of the stations Sitka and Newport with Bz gives for the considered period of 17-23 UT, 20.10 the delay time of ~9 min which is of the same order of magnitude with the period (20 min) for the direct energy input obtained in [1].

3. Summary and discussion

The performed analysis of the direct observations of the IMF and ground based variations of cosmic rays and the geomagnetic field allowed to reveal both the large and small scale structure of the great helispheric disturbance of October 29-21, 1989 and its relationship with geomagnetic variations. A complicated character of cosmic ray and geomagnetic variations was caused by a series of shocks, flare ejecta and their interaction created the very unusual structure of interplanetary disturbance, in particular the extraordinary grate IMF fluctuations in the period of 17-23 UT 20.10.

The study of correlated fluctuations of the IMF and CR in the frequency range $10^{-4} < f < 10^{-3}$ Hz gives an additional information about the solar wind turbulence. If perturbations of interplanetary plasma are small they can be expressed as a superposition of the known types of MHD-waves and static structures. For the considered event the nonlinear processes plays the important role, as $\delta B > B$ excludes an applicability of the linear approximation [8] for interpretation of polarization parameters. The results of our study shows that the ratio of spectral densities of the IMF and CR weakly depends on the polarization. This means, unlike to the case of little and moderate perturbations, that the difference between modes (Alfven, magnetosonic) becomes formal. The comparison of the IMF fluctuations and geomagnetic variations confirms the dependence of latter on the IMF Bz [1-3] and excludes the relationship with the IMF perturbations of magnetosonic type. Evidences of the direct energy input from the solar wind to the ionosphere "direct driven disturbances" in the day sector have been obtained. If this mechanism is related to the interconnection at the magnetospheric day side the fact of the best correlation between Bz and magnetic variations at the relatively low latitude stations Sitka and Newport (geomagnetic latitudes 54° and 48° correspondingly) becomes unclear. And poor correlation with the high latitude stations Barrow (70°) and College (65°) (Fig.4) which were at open field lines during the disturbed period on the October 20. The papers of last years [9] allow to come closer to understanding of this paradox.

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