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The GLE Of May 2, 1998: An Effect Of Disturbed Magnetosphere On Solar Cosmic Rays

O.A.Danilova[1], M.I.Tyasto[1], E.V.Vashenyuk[2], B.B.Gvozdevsky[2], H.Kananen[3], P.Tanskanen[4]

[1]*St-Petersburg Filial of IZMIRAN, Russian Academy of Sciences, 191023 St.-Petersburg, Russia*

[2]*Polar Geophysical Institute Russian Academy of Sciences, Apatity, Murmansk region 184200, Russia*

[3]*SGO, Oulu unit, Linnanmaa, FIN-90570 Oulu, Finland*

[4]*University of Oulu, Oulu, Dept.of Physical Sciences, Linnanmaa, Finland, FIN-90570 Oulu, Finland*

Abstract

The GLE of May 2, 1998 occurred during disturbed interplanetary and magnetospheric conditions. The very complicated picture of the increase effects at different neutron monitor stations has been analyzed using the results of asymptotic direction calculations. The Tsyganenko 89 geomagnetic field model has been used in these calculations to reveal the primary solar proton anisotropy characteristics as well as possible disturbed magnetosphere effect on the observed ground level enhancements.

1 Introduction

The Ground-Level Enhancement of May 2, 1998 was caused by parent flare 3B/X1.1 with heliocoordinates S15W15. The soft X-ray burst start and maximum were observed by GOES-9 spacecraft at 13.31 and 13.42 UT correspondingly. The event occurred when a Forbush decrease of 5% and a geomagnetic storm (Kp>7) were in progress. The IMF direction (θ: –53°, Φ: 23°) measured by Wind spacecraft differed markedly from the classical “garden hose” direction. The combining effect of the strong solar proton anisotropy, unusual IMF direction and the magnetospheric disturbance created a rather complicated picture of the ground level enhancement at different neutron monitor (NM) stations. The data obtained by these stations were compared with asymptotic acceptance cones calculated using the Tsyganenko 89 (T89) geomagnetic field model to obtain the primary solar proton characteristics as well as possible magnetospheric effects on the observed intensity profiles.

2 Neutron Monitor Observations

Fig.1 shows intensity profiles for the May 2, 1998 GLE event at a number of high-latitude neutron monitors. Fig. 1a shows the very short-lived impulselike intensity profile observed by the neutron monitor in Oulu contrasted with nearly absence of any increase at the neighboring station in Apatity**.** The smooth intensity profiles observed with neutron monitors at South Pole and Thule (Fig. 1b) show a coincidence of the intensity curves at these nearly antipodal stations. Fig.1c shows the intensity profiles at the Goose Bay, Oulu and South Pole stations. Oulu and South Pole demonstrate an example of prompt and delayed solar proton profiles (Vashenyuk et al.1997) which were registered separately by these stations. At the same time, Goose Bay NM detected both these components simultaneously, showing an intensity profile resembling the sum of the prompt and delayed components (Fig.1c). Fig.1d shows the increase profiles at the Tixie and South Pole stations. The increase at Tixie started half an hour later than the one at South Pole. After 15 UT the intensities at both stations became equal, notwithstanding statistical fluctuations. Similar delayed increase is seen in the neighboring station Yakutsk.

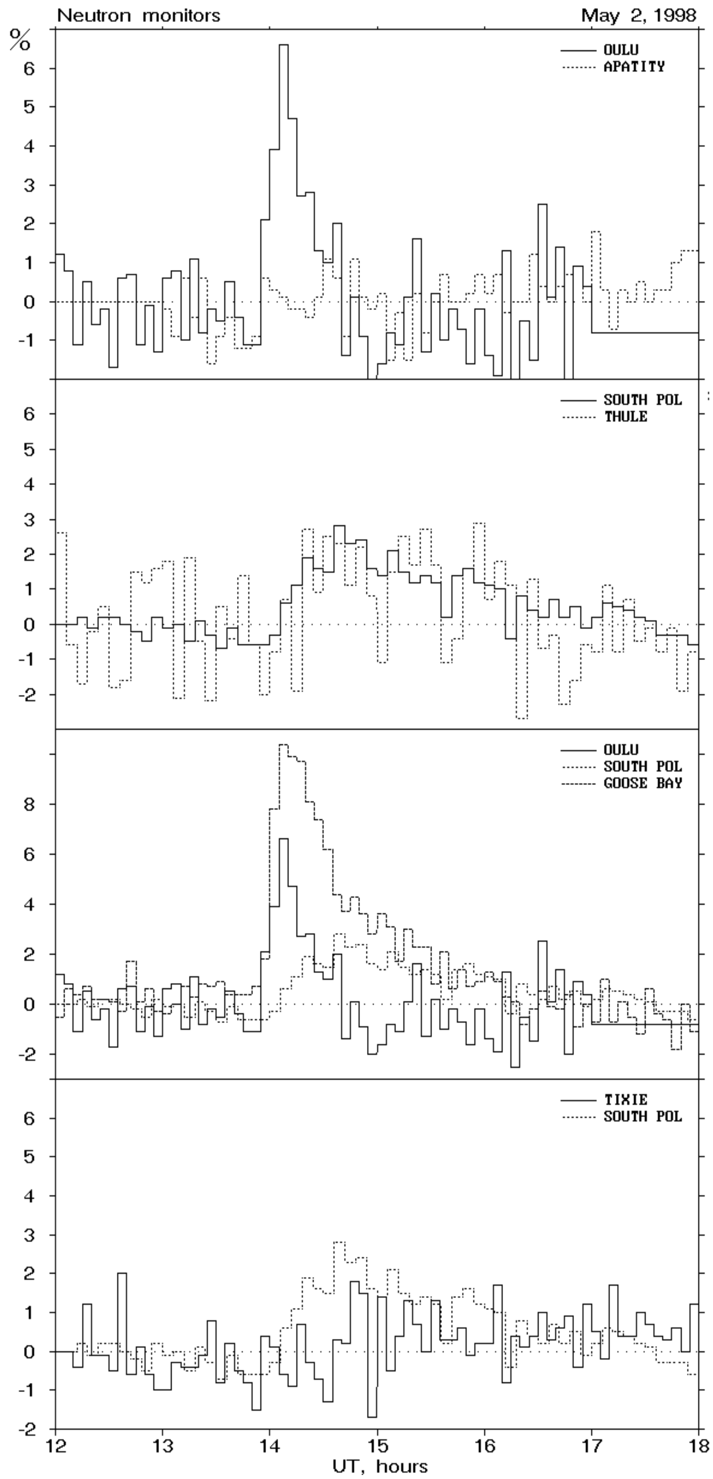

Fig. 1. Increase profiles at different neutron monitor stations during the May 2, 1998 GLE.

Table 1 summarizes the amplitudes of the increases at all neutron monitor stations studied, including those considered in Fig.1 The stations are numbered in order of their cutoff rigidities. The maximum enhancements are indicated in the two columns depending on whether the maximum occurred during the early phase (14.00-14.30 UT) or the later phase (14.30-15.00 UT). **It is remarkable that only three**

stations (Goose Bay, Oulu and Newark) showed intensity maxima during the initial phase of the event.

3 Anisotropy Effects

Fig. 2 shows the asymptotic cones calculated in GSE coordinates for stations used in this study. Details of these calculations can be found in Danilova et.al. (1997) The directions IMF vector are indicated by the symbols **+** and **x**. The equal pitch angle grid is drawn in steps of 30°. Judging from the prompt increase at the Goose Bay the direct solar cosmic ray flux was coming from the direction marked by **+** (Fig.2). The Tixie NM as well as Yakutsk (not shown) registered only backward flux from the direction marked by **x**.

Table 1.

Neutron monitor Station	R, GV	Increase, percent	
		14.00-14.30 UT	14.30-15.00 UT
McMurdo	0.0		1.2
Thule	0.0		3.1
South Pole	0.09		4.1
Inuvik	0.16		3.1
Tixie Bay	0.45		3.3
Goose Bay	0.60	10.4	
Apatity	0.60		1.4
Oulu	0.77	6.6	
Yakutsk	1.63		4.1
Newark	2.02	2.8	
Moscow	2.39		2.6

The initial impulse-like increase was highly anisotropic as only Goose Bay and Oulu were able to register it. The overlapping of the low-rigidity parts of the South Pole and Thule asymptotic cones can explain the coincidence of the intensity profiles at these stations (Fig.1b). They both registered equal direct and reverse solar cosmic ray fluxes. The asymptotic cone of Apatity could accept radiation only from the antisun direction and with great pitch angles. That could explain the low response of the station during this GLE. According to Fig. 2 also Oulu with nearly the same asymptotic cone of acceptance should not have registered the direct solar cosmic ray flux..

However, one cannot exclude the possibility that during very disturbed geomagnetic conditions the real asymptotic cone for the Oulu station could have differred from calculated one.

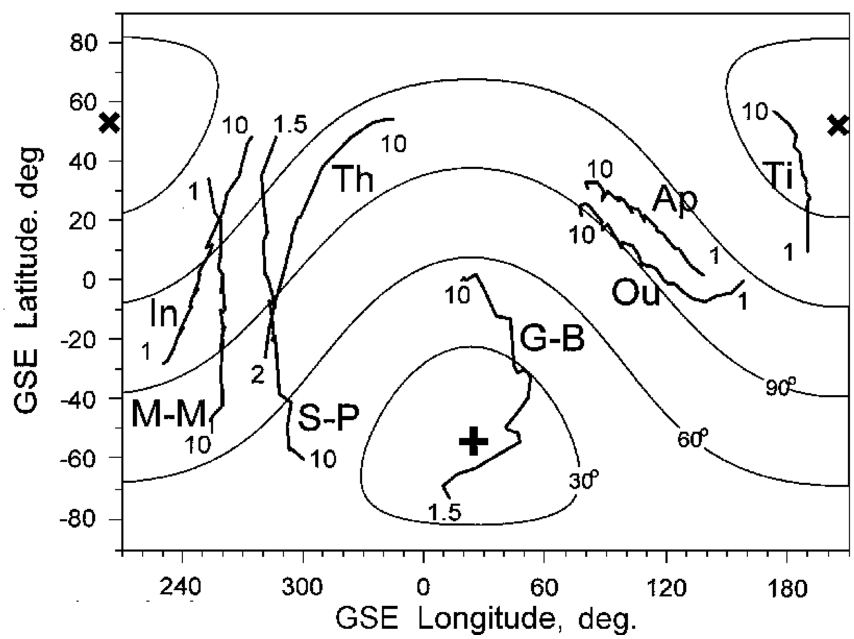

Fig. 2. Asymptotic cones for NM stations: Inuvik, McMurdo, Thule, South Pole, Goose Bay, Oulu, Apatity, Tixie for 14 UT 2.05.1998. Crosses denote the IMF direction.

4 Discussion And Conclusions

The unusual IMF direction, bidirectional solar proton anisotropy, geomagnetic disturbance, and as a consequence, the complicated distribution of the increases registered by the NM stations was the result of the CME inside which the Earth stayed since early May 2 (Skoug et.al. 1999, Wimmer-Schweingruber et.al., 1999) A CME-associated Forbush effect began on May 1 as seen in Fig.1. Influence of distorted IMF and geomagnetic disturbances on asymptotic cones of acceptance were discussed by Cramp et al.(1997), and Flueckiger et al.(1990). In our case one should note the two component structure of the relativistic solar proton flux. The first prompt component (impulselike profile of Oulu, Fig.1a) and the delayed profiles of South Pole and Thule (Fig.1b) look like the "coherent peak" followed by the "diffusion wake" of Earl (1976). The bidirectional anisotropy observed after 14.30UT could be related to the arrival of the backward solar proton flux in the looplike structure of IMF, which is often present inside a flare ejecta. If the source of the delayed component on the Sun has great angular dimensions, the particles can be injected into both ends of the loop forming the bidirectional anisotropy (Richardson et al., 1991). As applied to the May 2, 1998 event the great transients encompassing the Sun as observed from SOHO spacecraft do not rule out such possibility (Belov et al., 1999).The striking difference in responses of Apatity and Oulu NM's to relativistic solar protons during the event seems to be purely a magnetospheric effect. The contribution of quasitrapped particles drifting azimuthally more than 100 degrees inside the magnetosphere (Shumilov et al., 1993) could not be sufficient. Because of magnetic storm during the GLE and great negative Bz component of IMF (about –10nT) the dayside magnetopause should be close to the Earth. In extreme cases this distance may diminish from 10 to 4 R_E (Beering et al., 1991). This is also the equatorial distance of the field line connected to Oulu. Thus, the anisotropic solar proton flux coming along the IMF from below the ecliptic plane up to the dayside magnetopause could directly reach the Oulu. station The geomagnetic field lines connected to this station should not have been far from the dayside magnetopause. For Kp > 7 the field lines connected to Apatity are open. The border between the open and closed field lines in that case is between Apatity and Oulu. Apatity station whose field lines were open at the moment could not have accepted the upward directed anisotropic solar proton flux.

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