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SOLAR WIND CONTROL OF THE HIGH-LATITUDE PROPAGATION OF THE SUBSTORM ELECTROGET

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Introduction

During the expansion phase of substorm the westward electrojet propagates poleward following the auroral expansion (*Akasofu*, 1968). Sometimes the electrojet propagates from the auroral zone (CGLat = 60-70°) up to very high latitudes (CGLat > 75-80°). *Sergeev et al.* (1979) and *Dmitrieva and Sergeev* (1984) showed that such "high-latitudinal" substorms occur under high-speed solar wind, and the latitude of the electrojet propagation is higher, when the solar wind velocity is larger. This finding was confirmed by *Weatherwax et al.* (1997) and *Gussenhoven* (1982), who considered high-latitude signatures of substorm in auroras and riometer absorption. *Sergeev et al.* (1979) showed that other solar wind parameters (density, value of the magnetic field and magnetic field components) do not show any deviations from those observed during "standard" substorms. *Dmitrieva and Sergeev* (1984) noted, however, that "high-latitudinal" substorms can appear under relatively low velocity, but in such rare cases the southward component of the interplanetary magnetic field is large. This fact is in agreement with result obtained by *Zverev et al.* (1975), who found that poleward expansion of the auroral bulge depends on the B_z-component. (Note, that these authors considered the substorms occurred at CGLat < 75°).

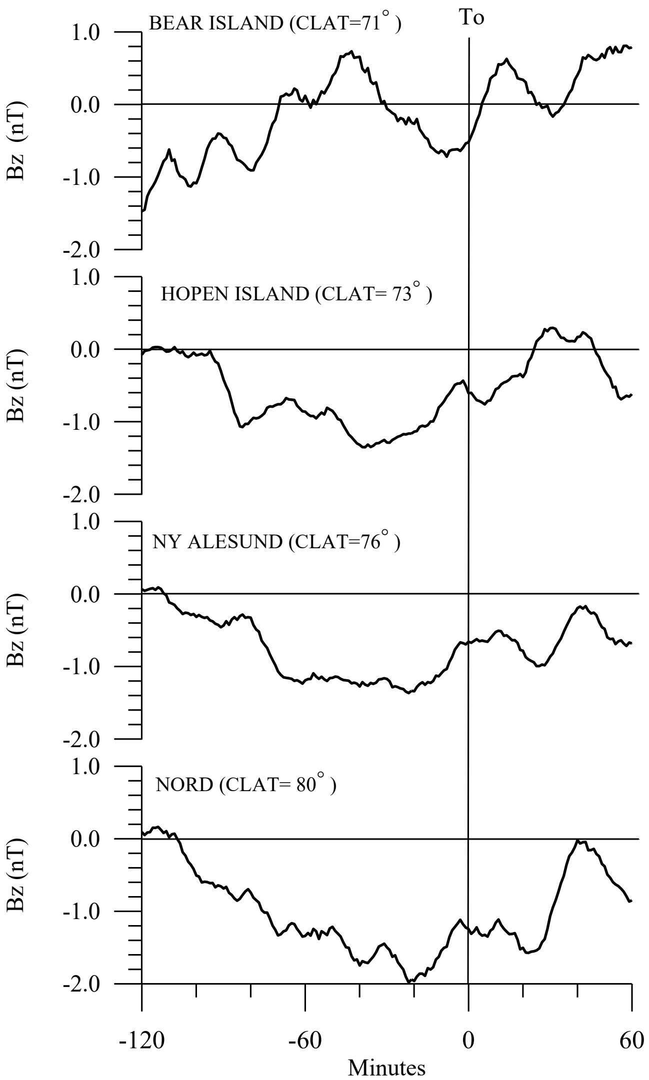

Figure 1. The average behavior of IMF B_z for four groups of events obtained by the superposition epoch method.

This report is devoted to further investigation of the conditions under which the substorms can propagate to very high latitudes.

Data and analysis

The data base used consists of substorm events occurred in 1995 in Scandinavian sector under solar wind velocity more than 550 km/s. For this year the solar wind plasma and magnetic field data were obtained from the Wind satellite observations. The data were taken from CDAWeb (http://cdaweb.gsfs.nasa.gov/cdaweb/istp_public/).

Among substorms occurred under conditions mentioned above four groups of events were selected. Group 1 (21 events) consisted of substorms, which started in auroral zone (Tromso station) and propagated not further than Bear Island station (CGLat = 71°). Group 2 (43 events) consisted of substorms, which propagated poleward of Bear Island, but not further than stations Hopen Island and Horsund (CGLat = 73°). Group 3 (56 events) consisted of substorms, which propagated poleward of Hopen, but not further than Longyearbyen and Ny Alesund (CGLat=75-76°). Group 4 (31 events) consisted of substorms, which propagated poleward of Longyearbyen and Ny Alesund and were detected in Nord (CGLat = 80°). Propagation of the westward electrojet was controlled by using the standard analysis of the meridional profiles of H- and Z-components of the ground magnetic field. The mentioned stations (all of them, excluding Nord, are beyong the IMAGE network) are suitable for the study because they are located on approximately the same magnetic meridian.

Dependence on B_z, V, and V*B_z

Taking the time of the electrojet appearance over the station (for groups 1-3) and the time of the magnetic bay onset in Nord as a zero-time reference (T_0), we considered the behaviour of B_z-component for each group (Fig. 1) obtained by the superposition epoch method. Averaging was done for every minute preceding T_0. From Fig. 1 one can conclude, that propagation to higher latitude requires longer interval of preceding negative B_z. Thus, for substorms of group 1 the interval is only ~0.5 hour (note, that it is comparable with typical growth phase duration), but for higher latitude stations it is 1-2 hours. Also, the averaged values of B_z are a little larger for the higher latitude substorms.

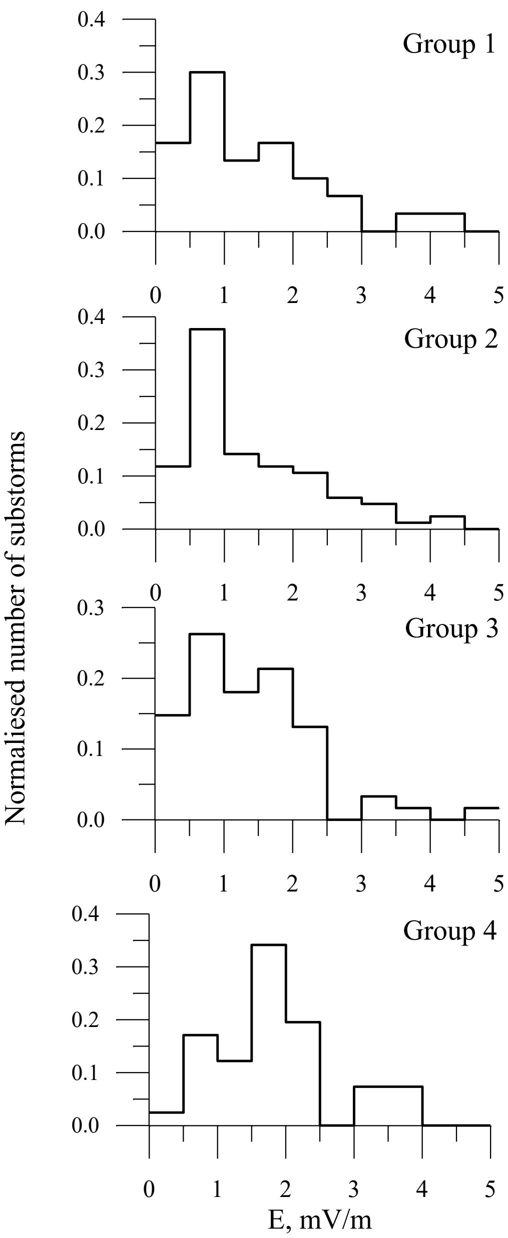

Figure 2. Normalized distribution of substorms in groups 1-4 in respect of the solar wind electric field

Although events have already been selected according to the condition V > 550 km/s (high-speed solar wind flow), they exhibit dependence on solar wind velocity. Average velocity for groups 1-4 is 633, 640, 653, 680 km/s, respectively. Such dependencies on B_z and V mean that there should be similar dependence on the dawn-to-dusk component of the solar wind electric field (E_y=-V*B_z). Fig. 2 shows how a normalized number of substorms for groups 1-4 depends on solar wind electric field. It is evident that substorms of group 4 appear during greater values of the electric field than others. This is stressed in Fig. 3 presenting the dependence of probability to observe the substorms at station Nord on E_y. Here E_y is average value of -V*B_z within 1.5-hour interval preceding the magnetic bay. When averaging, it was suggested that E_y = 0 if B_z>0. The probability is determined as a ratio of the number of substorms in group 4 and the total amount of substorms observed in auroral zone under the E_y values being within a certain interval. The probability exhibits a clear tendency to a growth as E_y increases. Figs. 2b and 2c shows the dependencies of the probability on B_s (southward directed component of the IMF) and V.

Discussion and conclusion

The dependence on E_y has a clear physical sense. Indeed, E_y is a measure of the dayside reconnection rate. Multiplied by the time of negative B_z, this value gives a gain of the magnetic flux in the tail lobes. Prolonged interval of negative B_z under large V and B_z results in extremely large supply of the magnetic energy, which may be released in form of the very intense substorm. According to the reconnection model, the substorms are the result of the reconnection in the magnetotail, and the auroral bulge area is proportional to the reconnected surplus of the tail-lobe magnetic flux. Evidently, the large supply of the magnetic flux should associate with the large-scale auroral bulge, and, in particular, with high-latitude location of its poleward edge.

The poleward propagation of the electrojet (and auroras) means the tailward retreat of the near-Earth neutral line. The tailward progression of the reconnection site simultaneous with poleward expansion of the substorm have been documented (e.g., *Hones*, 1992; *Angelopoulos et al.*, 1996).

As discussed by *Dmitrieva and Sergeev* (1984), the high-speed solar wind is the necessary but not sufficient condition for the high latitude substorm propagation. One can note that strong E_y (at least that measurable) is not sufficient condition too. Indeed, only half of the strong E_y cases are associated with the high-latitude substorms (Fig. 3). Probably, there are conditions in the plasma sheet, which can prevent or stimulate the substorm development farther to the tail. They could be, for example, the far-tail current sheet intensity and thickness, that is, parameters important for the reconnection process.

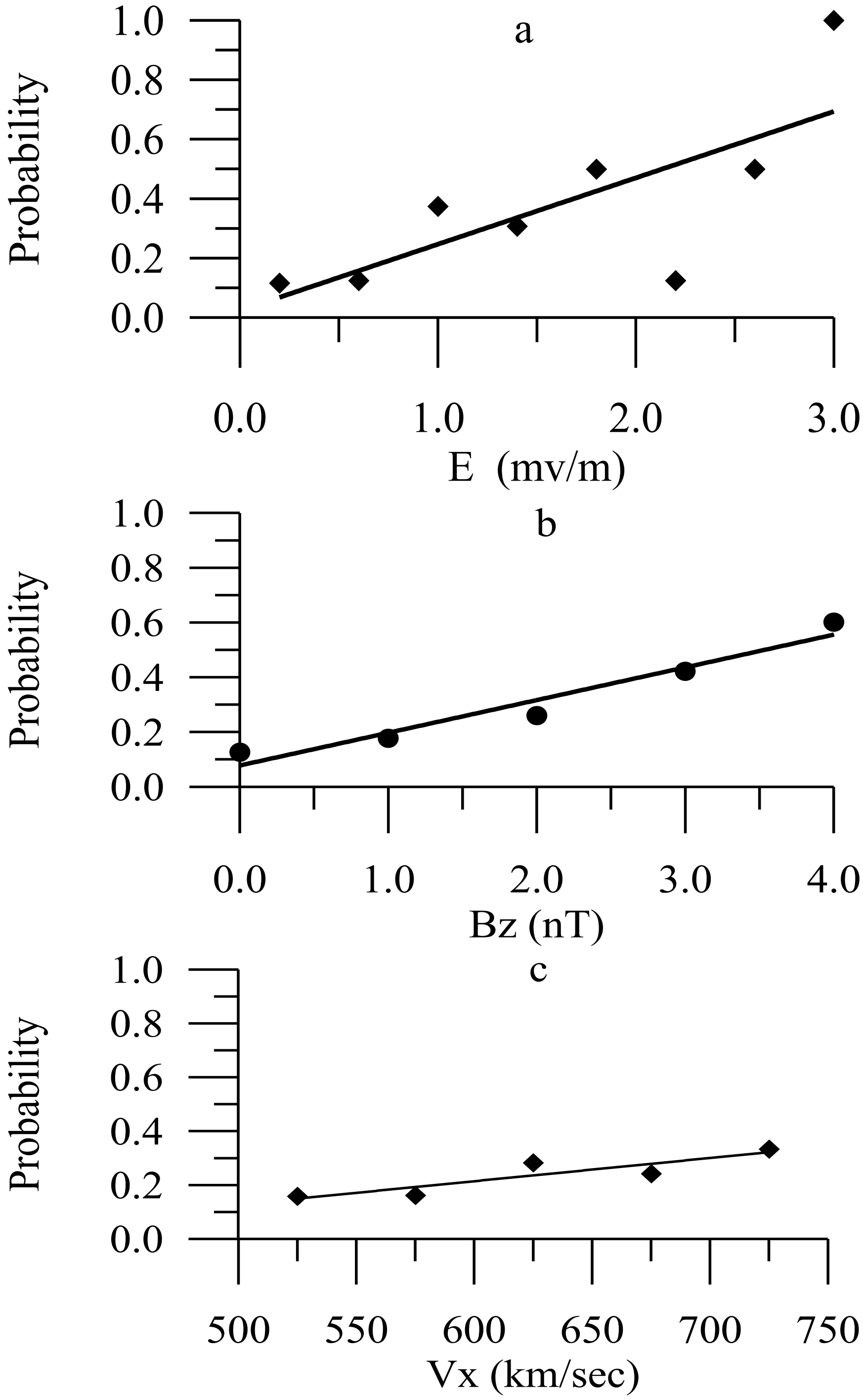

Figure 3. Probability of observation of the westward electrojet at station Nord.
a) Dependence on the solar wind electric field E_y; b) Dependence on B_s component of the interplanetary magnetic field; c) Dependence on the solar wind velocity.

Finally, we conclude that high-latitude propagation of the substorms is controlled not only by solar wind velocity but southward B_z, and, as sequence by the solar wind electric field $E_y = -V*B_z$.

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