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MAGNETIC SUBSTORMS IN DEPENDENCE OF LARGE-SCALE STRUCTURE OF THE SOLAR WIND

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Abstract. The aim of our work is to study a possible influence of the solar wind large-scale structure on the substorm appearance. The substorms have been studied basing on the data obtained from SuperMAG and IMAGE networks. Three types of substorms have been considered: two types of the substorms observed at the geomagnetic latitudes higher ~ 70° CGC ("polar" and "expanded" substorms) and the supersubstorms (substorms with SML index < - 2500 nT). Different solar wind types were determined by OMNI data base and the catalog of the large-scale solar wind phenomena. Six basic solar wind types were considered: the high speed streams from coronal holes (FAST); the interplanetary manifestations of coronal mass ejections: the magnetic clouds (MC) or EJECTA; the regions of compressed plasma before these streams – CIR and SHEATH; the slow solar wind (SLOW) streams. It is shown that the distribution of these 3 types of substorms on the different solar wind streams is almost opposite. "Expanded" substorms are observed during FAST streams, in plasma compression regions (CIR and SHEATH) and sometimes during EJECTA observed against the background of FAST streams."Polar" substorms are observed during SLOW streams and EJECTA that occur against the background of a slow stream and sometimes at the end or the beginning of a FAST. Supersubstorms (SSS) were associated with SHEATH, MC, EJECTA and they almost did not observe during FAST and SLOW streams. Thus, the impact of the different solar wind large-scale structure controls the ground-based substorm type appearance.

Introduction

It is known that solar wind is not inhomogeneous, there are different streams and structures [1], [2], [3]. The complex large-scale structures of the solar wind can be divided into three main types: (i) Slow solar wind. It is the slow flux of solar plasma above the coronal streamers, with the velocity ~ 300-450 km/s. (ii) Quasistationary high speed streams over coronal holes (velocity ~600-1000 km/s). There are recurrent streams with the period of appearance 27 days. These streams responsible for recurrent geomagnetic disturbances. (iii) Interplanetary Coronal mass ejections (CME), which are sources of sporadic high-speed streams and sporadic geomagnetic activity. Moreover, certain solar wind type can be considered as a driver of geomagnetic activity. Because certain type of the solar wind is characterized by different plasma and field parameters and within certain solar wind type values of these parameters vary only slightly.

At the present time different classifications of the solar wind types were developed; one of these is the catalog of large-scale solar wind phenomena [4]. The purpose of our work is the study of the influence of different types of the solar wind on the geomagnetic disturbances, namely on magnetic substorms.

Data

We defined the solar wind types using the catalog of the large-scale solar wind phenomena (*ftp://ftp.iki.rssi.ru/omni/*) and the OMNI data base. In this catalog there were 3 quasistationary, 5 disturbed types of the solar wind and shock waves are distinguished: 1) heliospheric current sheet (HCS); 2) slow plasma flows above streamers (SLOW); 3) high speed streams over polar coronal holes (FAST); 4) and 5) coronal mass ejections, which consists from body of CME – magnetic cloud (MC) or EJECTA- and the plasma compression region on their front (SHEATH); 6) a plasma compression region before the fast stream (CIR);7) and 8) direct and reverse shock waves (IS and ISa). In our work we were considered first 6 these types of the solar wind, but HCS was considered not as separated type, it included in the SLOW type.

The substorm intensity is measured usually by AE, AL, AU indices of geomagnetic activity. However, in our work we used the SML index, which calculated by using the data from all SuperMAG system station, because we considered very intense substorms (supersubstorms), which develop in wide area, from lower to high geomagnetic latitudes.

To study the high- latitudinal substorm dynamic, we used the magnetic data of the IMAGE network, from 57° to 75° of the geomagnetic latitudes. Note that the westward electrojet may be not inhomogeneous, and the concept of the electrojet "center" (the location of most intense current) was often used for the determination of the latitudinal location of the electrojet. We used this concept for the determination of the location of maximal latitude, which was registered by polar expansion of westward electrojet. Accordingly, high-latitude magnetic substorms were identified using the data from the IMAGE meridian chains TAR–NAL (Tartu (TAR), CGC lat. = 54.47°; Ny Ålesund (NAL), CGC lat. =

75.25°) for 1995, 1996, 1999, and 2000 years. For these four years there were over 400 events of high-latitude substorms selected and analyzed.

Results

The aim of our work is to consider three special types of substorms, which are only recently identified: extremely intense substorms [5], [6] and substorms observed at very high latitudes [7], [8]. We analyzed three special types of magnetic substorms:

1) First type represents extremely intense substorms (supersubstorms - SSS) which are typically observed at auroral latitudes. There are substorms, when SML or AL indices reach very high negative values (< -2500 nT). The study of the SSS events was based on the data from magnetic ground-based observations of the SuperMAG network and Scandinavian IMAGE network.

2) The second type represents the “substorms on the contracted oval” or “polar” substorms which were observed under quiet geomagnetic conditions, when the auroral oval is compressed and shifted poleward of the location of those stations from which standard magnetic activity indices are calculated. Fig. 1 presents some magnetic stations, which correspond to the location of “contracted”, “extended” and “normal” auroral oval. It is seen that “polar” substorms are substorms, which are registered only at the magnetic latitudes over 70 degrees in the absence of disturbances at the lower latitudes.

3) The third type represents the “substorms on the extended auroral oval” or “expanded” substorms, which were observed under disturbed geomagnetic conditions. These type of substorm starts at the latitudes of the auroral zone and then moves poleward. Namely, the substorm onset was observed at latitudes from 54 to 66 degrees of geomagnetic latitudes. In the maximal phase of the substorm, the “center” of the westward electrojet is observed at very high geomagnetic latitudes (above 75 degrees), at the LYR or NAL station. Fig. 1 presents some magnetic stations, which correspond to the location of “contracted”, “extended” and “normal” auroral oval.

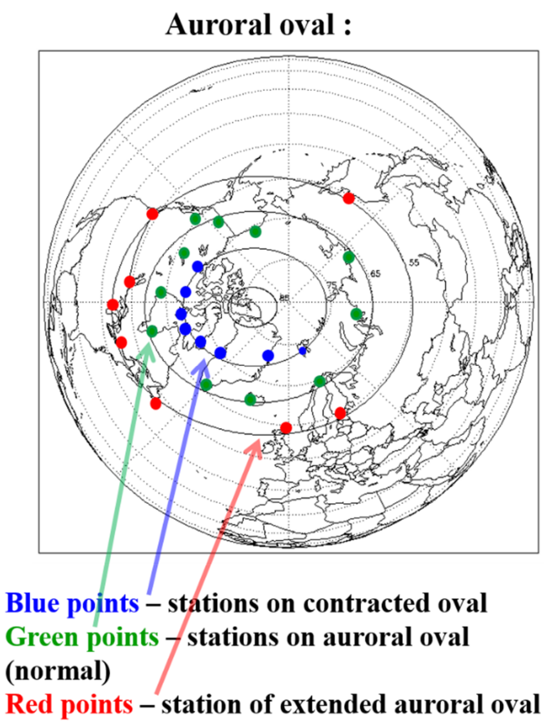

Figure 1. The map of some magnetic stations, which correspond to the location of “contracted”, “extended” and “normal” auroral oval.

Some examples of supersubstorms, “polar” and “expanded” substorms collected from–SuperMAG and IMAGE stations have been presented in our previous works [8, 9]. The objective of this work is to systematize the previously obtained results and to reveal the connection between supersubstorms (SSS), “polar” and “expanded” substorms and the large-scale solar wind structure.

We performed the comparative analysis of the distribution of substorms on the solar wind types. The occurrence of SSS events, “polar” and “expanded” substorms was compared with the simultaneous observations of different types of the solar wind. The comparative histograms of the supersubstorms distribution by the solar wind types shown in Fig. 2. It is shown that the distributions of these three types of substorms differ sharply, the observation conditions are almost opposite.

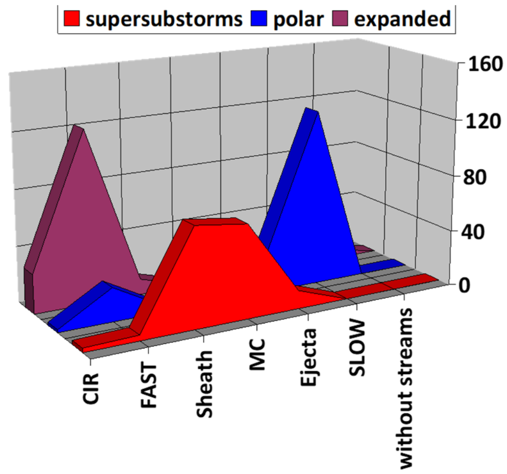

Figure 2. Histograms of distribution of "expanded" (*burgundy color*), "polar" (*blue color*) and supersubstorms (*red color*) by solar wind type. The number of events is plotted along the vertical axis.

It is seen that supersubstorms are observed: (i) mainly during solar wind magnetic clouds and SHEATH region (plasma compression region before MC/Ejecta); (ii) only sometimes they may be observed during Ejecta; (iii) very seldom SSS can be observed during FAST and CIR region (plasma compression region before FAST).

The "polar" substorms are observed: (i) mainly during SLOW solar wind streams; (ii) at the end of high-speed streams (FAST); (iii) sometimes during Ejecta. But it was only during Ejecta against to background of the SLOW stream; (iiii) not observed – during magnetic clouds.

It is seen that the "expanded" substorms are observed: (i) mainly during high-speed streams (FAST); (ii) during two regions of plasma compression – CIR and SHEATH; (iii) sometimes during Ejecta. But during these Ejecta which were observed against the background of a high speed stream (FAST); (iiii) only few events are registered during SLOW streams; (iiiii) only few events are registered without certain types of the solar wind.

Conclusions

The comparative analysis shown that under different space weather conditions different types of substorms are observed:

- The supersubstorms were observed during SHEATH and MC, namely during interplanetary manifestations of coronal mass ejections.
- The "expanded" substorms were registered during high-speed streams from coronal holes and compressed plasma region (Sheath and CIR).
- The "polar' substorms were observed during slow streams and Ejecta which were associated with slow stream, also at the end of high speed streams, when solar wind velocity decrease from high to low values.

Thus, 3 types of substorms appear under different solar wind types and we can suppose, that they reflect different sources. But this question is open yet.

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