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EFFECT OF AURORAL ELECTROJETS ON THE Dst-INDEX VARIATIONS DURING THE SUPER-MAGNETIC STORM ON OCTOBER 29-30, 2003

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1. Introduction

It is known that during magnetic storm there is a depression of the magnetic field at low latitudes, which is characterized by negative values of the Dst-index or SYM-H-index [1]. A magnetic storm is accompanied by substorm disturbances and strengthening of auroral electrojets. In this period, the intensity of auroral electrojets is known to increase with their centers shifted to lower latitudes.

For recent years, one of the urgent problems concerning magnetic storm nature has been to clarify storm-to-substorm relation. Traditionally, it was considered [2] that magnetic storm is a result of a series of substorms. According to this scenario, during substorm expansion there are injections of ions into the inner magnetosphere, which results in strengthening of the ring current and depression of the magnetic field. However, in recent years another point of view on the cause of magnetic storm depression has been put forward. Within this viewpoint, it is supposed that the basic source of the depression is an enhancement of magnetotail currents due to magnetic flux transfer from the dayside to the night side [3]. In this case, it is considered that substorm disturbances do not strengthen the Dst-variation but, on the contrary, weaken it because of tail current disruption during substorm expansion phase [3,4]. In papers [5,6] the data which are not consistent with this point of view are derived. Thus, the problem of storm-to-substorm relation remains debatable. The purpose of the present study is to clear up the effect of substorms and other geomagnetic disturbances on the Dst variations by analyzing the development of auroral electrojets during a super magnetic storm with Dst ~ - 400 nT.

2. Observations

For the analysis, geomagnetic data of the CPMN, IMAGE, MACCS, CANOPUS, Greenland Coast array projects with 1-20 sec resolution have been used. The spatial - temporal distribution of the intensity and dynamics of auroral electrojets has been studied. The data for October 29, 2003 and October 30, 2003 are presented in Figs. 1, 3, and in Figs. 2, 4, respectively. In all the Figures the SYM-H and Dst-index variations are given. In Figs. 1 and 3 the variations of IMF Bz-component, solar wind dynamic pressure (Pd) and westward ionospheric current intensity-J_{KA}, integrated over latitude for various meridian chains (the IMAGE, CANOPUS, Greenland Coast array) by a technique suggested in [7], and ΔH variations at the Chokurdakh station ($\Phi'\approx 64{,}7°$; $\lambda'\approx 212{,}12°$) of the CPMN chain are shown. Figs. 2 and 4 illustrate the dynamics of the situation in the meridian of the eastward (J_E) and westward (J_W) electrojets, obtained by the technique described in [7], in the course of magnetic storm development.

The onset of magnetic storm and sudden magnetic pulse SC took place on October 29, 2003 at 06.12 UT under negative values of Bz IMF and a sharp increase in Pd (Fig.1). As shown in [8], it results in strengthening of DP2 current system during the first ~30-40 min., followed by strengthening of the westward electrojet in all MLT sectors (Fig.1). As seen from Fig. 2, in the midnight sector (Canopus) the westward electrojet extended toward the pole from the latitudes $\Phi'\approx 63$ °. A simultaneous enhancement of the eastward electrojet at ~ 10 MLT (Fig.2, IMAGE) as well as in the evening sector at latitudes $\Phi'\leq 60$ ° (not shown) was observed. Probably, in this period, both DP2 current system and a substorm current wedge intensified.

For the first 40-60 min after SC onset, positive SYM-H variations (Fig.1) were observed, with no changes registered in Dst. Further, the SYM-H and Dst indices indicated a magnetic depression down to ~ - 200 nT (till ~ 11 UT), then (starting from ~ 12 UT) its relaxation to ~ -100 nT, followed by small changes in the field till ~ 18 UT. The data in Fig.2 (starting from 12 UT) show strengthening of the eastward electrojet in the evening sector and of the westward one – in the morning-to-day hours. That is, a two-vortical current system (of DP2-type) is observed. The centre of the eastward electrojet moves by ~ 9 degrees for ~ 4 hours, i.e. with the velocity ~2,2 ° per hour, which can be caused by the daily rotation of the station chain relative to the auroral oval. Starting from ~ 18 UT on October 29, 2003, after a turn of Bz IMF to the south (Fig.1), a sharp increase of negative values of Dst, persisting up to ~02UT on October 30, 2003 with the maximum amplitude of ~ -350 nT (Figs.1 and 3), is registered. This is accompanied by a sharp strengthening of the westward electrojet in all longitudinal sectors and in a wide latitudinal range from $\Phi'\leq 55$ ° up to $\Phi'\sim 73$ °, with the expansion of separate activations of the westward electrojets in the

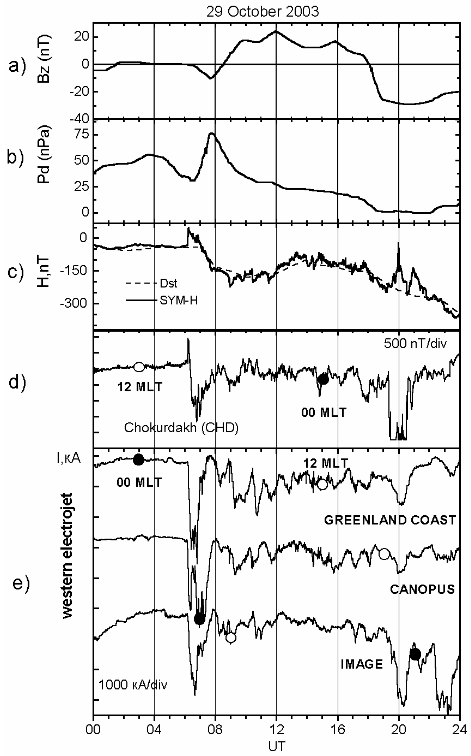

Fig.1 Variations of the IMF Bz (a), solar wind dynamical pressure Pd (b), SYM-H and Dst indices (c) with variations of ΔH in CHD (d), and intensity of the westward electrojet (J, kA) integrated over latitude in different MLT sectors (e) for magnetic storm on October 29, 2003

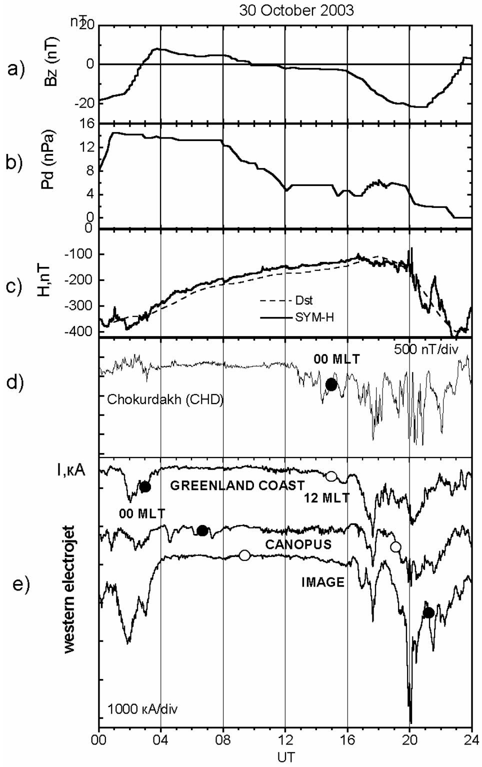

Fig.2. Same as in Fig.1 but for October 30, 2003.

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midnight-to-morning sector toward the pole (Figs. 2 and 4). Strengthening of the westward electrojet, as well as of the eastward one in the evening sector at latitudes Φ′≤ 60 °, (Fig. 4) resulted in a sharp reduction of negative values of the SYM-H as separate peaks (Figs.2 and 4), which were not observed in Dst variations. The probable reasons of SYM-H and Dst variations in this period were considered in [9]. After ~02 UT on October 30, 2003 a gradual decrease of negative values of SYM-H and Dst till ~ 17 UT were observed. In this period no geomagnetic disturbances were registered (Fig. 3). Rather small disturbances (500 nT) were observed near midnight after 12 UT as a strengthening of the westward electrojet (Fig. 3, CHD) and the eastward one in the afternoon sector (Fig. 4, IMAGE).

After 17 UT on October 30, 2003 a new sharp increase of negative values of Dst accompanied by an increase of negative values of the Bz IMF and strengthening of westward electrojet intensity at all MLTs with the maximum intensity in the midnight sector (Fig. 3, IMAGE) started. This was accompanied by strengthening of the eastward electrojet near the post-noon meridian (Fig. 4, CANOPUS). As well as in the event on October 29, 2003, the strengthening of electrojets resulted in sharp peaks of decrease of negative values of SYM-H, not manifested in Dst (Fig. 4). The westward electrojet shifted down to latitudes Φ′≤55 ° and was characterized by the expansion to the pole in the midnight sector during its separate activation (Fig.4).

After ~ 20 UT, the intensity of the westward electrojet at auroral latitudes gradually decreases (Fig.3), perhaps because of its centre displacement to the south and decrease of Bz IMF negative values. However, an increase in negative values of Dst persists till ~ 23 UT (Fig. 4), with the maximum amplitude being ~ - 400 nT.

3. Principal results and discussion

We have presented the data on the relation between the spatial - temporal dynamics of the auroral electrojets and Dst variations, which show that:

1. The sharpest variations in Dst strengthening correspond to the periods of negative Bz IMF and activation of substorm disturbances, i.e. to the enhanced intensity of the westward electrojet in all MLT sectors with the expansion of the electrojet to the pole in the nighttime ionosphere.
2. The attenuation of the Dst index (a decrease of its negative values) is accompanied by strengthening of auroral electrojets typical for convectional disturbances of the DP2 type.

3. The maximum negative values of Dst ~ -350-400 nT are observed during subsiding of substorm disturbance at the latitudes of auroral zone, displacement of westward electrojet centre down to latitudes $\Phi' \leq 55$ ° and growth of the southward Bz IMF.

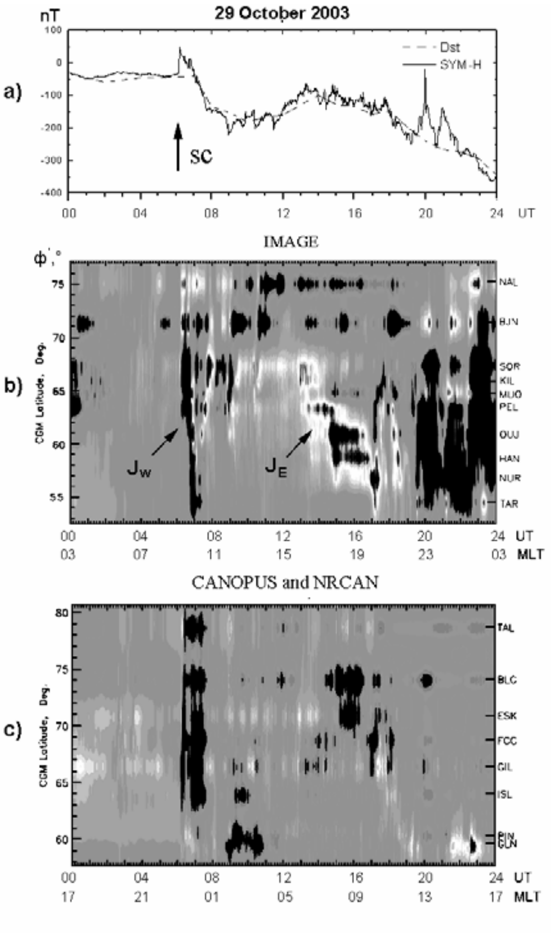

Fig.3. Variations of the SYM-H and Dst indices (a), and spatial-temporal dynamics of the westward (dark) and eastward (light) electrojets from the data on two meridians (b, c) during a magnetic storm on October, 29, 2003

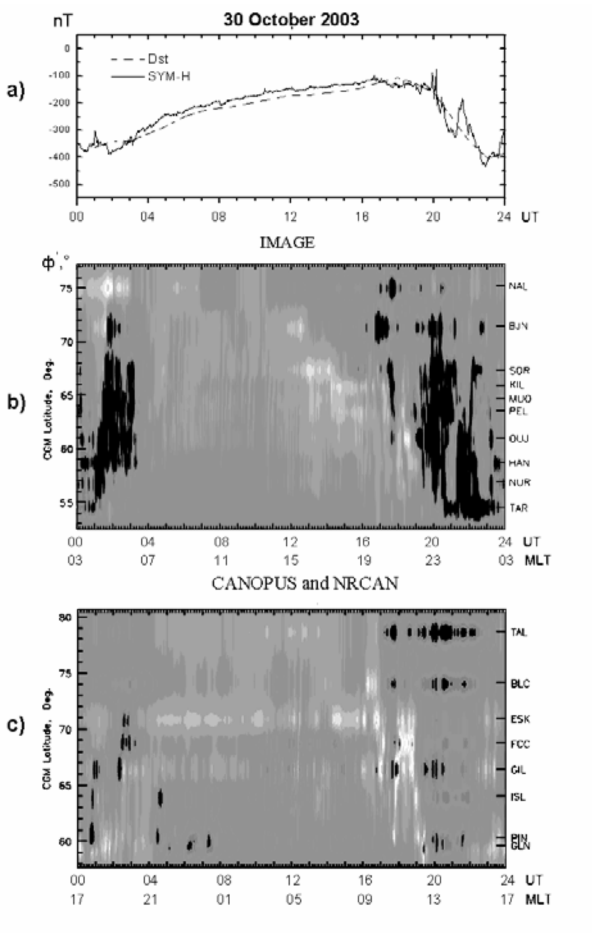

Fig.4. Same as in Fig. 3 but for October, 30, 2003.

The first and second results are in agreement with those obtained earlier in [2,3,10]. According to [2,3], a common reason for the increase of negative values of Dst and strengthening of substorm activity is an increase of negative values of Bz IMF, resulting in the displacement of precipitation area and auroral electrojet to lower latitudes. According to [10], the SYM-H variations depend on the type of disturbance, i.e. whether they are of substorm or non-substorm type. By our classification, the non-substorm disturbances correspond to those of DP2-type, which intensify when Pd is increased. The increase of Pd and DP2-disturbances result in strengthening of the eastward currents at low latitudes because of strengthening of the currents on the magnetopause and currents in the nighttime ionosphere closing the DP2 currents [11]. This effect should result in the reduction of negative values of the SYM-H and Dst.

The result 3 testifies that maximum negative values of Dst are only observed when the westward electrojet reaches the most southern location in latitude (Φ_S'), i.e. in the given event the westward electrojets shifted down to $\Phi_S' \leq 55$ ° ~ 2-3 hours later after the last onset of the substorm and at the maximum negative values of Bz IMF. This result is in agreement with the point of view that the main contribution to Dst variation is given by the ring current at latitudes $\Phi' \sim$ 10-30 ° with the maximum intensity in the evening sector [2] and by the westward ionospheric currents at these latitudes because of the influence on magnetic field variations of the westward auroral electrojet currents. The time of delay of Dst maximum relative to the onset of substorm can be determined by the time of convectional movement of particles to lower latitudes and the time of ion gradient drift from the midnight sector to the evening sector.

In model [3] it is suggested that strengthening of the magnetospheric tail current is caused by transfer of the magnetic flux, resulting from the reconnection of the geomagnetic field with the negative Bz IMF, from the dayside to the nightside. In this case, the delay of maximum Dst relative to maximum Bz IMF (Figs. 1 and 3) can be determined by the transfer time of magnetic field lines from the dayside to the nightside, which, according to [12,13], depends on the solar wind velocity as well as on convection velocity in the internal magnetosphere and electric field Ey in the solar wind. According to [13], the duration of substorm growth phase is equal to the transfer time of magnetic field lines from the dayside to the nightside. It varies from ~ 1,5-2 hours to ~ 0,5 hours for Ey increasing from ~ 1 to ~ 5 mV/m. For the magnetic storm considered (Bz IMF ~ -20-30 nT and Vsw ~ 800 km/s), the maximum values of Ey are greater than 10 mV/m, which corresponds to the transfer time significantly less than 0,5 hours. Thus, strengthening of the currents in the magnetospheric tail could not be the source of the depression of the magnetic field in the inner magnetosphere.

4. Conclusion

We conclude that our study on the relation of geomagnetic auroral disturbance variations with Dst variations supports the traditional point of view about the source of magnetic field depression at low latitudes, which is strengthening of the ring current, and also suggests a possible influence of the westward electrojet displaced to lower latitudes on the reduction of Dst.

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