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# *DPY* currents in the cusp/cleft region: A crucial role of southward interplanetary magnetic field

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**Abstract.** Geomagnetic variations observed at the meridional chain of stations in Greenland during 1982–1992 are utilized for the study of relationships between occurrence of azimuthal currents in the dayside cusp/cleft region and changes in the interplanetary magnetic field (IMF) $B_y$ and $B_z$ components. Events were selected for analysis if (1) the Greenland West Coast stations were located near magnetic noon $\sim$ 1400 UT and (2) the absolute values of the IMF $B_z$ were less than $B_y$. Sixteen events were selected under these conditions. The analysis shows that intensive azimuthal currents develop in the cusp/cleft region in association with the southward IMF despite the fact that the IMF $B_y$ component had the same orientation during the few previous hours. The direction of these currents (westward or eastward) is specified by the sign of the $B_y$ component (negative or positive, respectively). If the IMF $B_y$ is not zero but $B_z$ is mainly northward, no significant currents are observed in the cusp/cleft region at all. As a result, because magnetic substorms usually follow extended periods of southward $B_z$, the dayside cusp/cleft magnetic perturbations often precede substorm activity in the midnight sector of the auroral zone. This can simply be a connection between the dayside cusp/cleft and nighttime auroral electrojets and therefore could be used as the dayside substorm precursors.

## Introduction

Magnetic disturbances caused by the azimuthal component $B_y$ of the interplanetary magnetic field (IMF) are the most prominent near noon. They are caused by the eastward (westward) ionospheric currents developed in the northern polar region when the IMF $B_y$ component is positive (negative); these currents flow in the opposite directions in the southern hemisphere for the same sign of $B_y$ [*Mansurov*, 1969; *Svalgaard*, 1973]. To explain this Svalgaard–Mansurov effect, *Leontyev and Lyatsky* [1974] suggested an analytical model of the dayside ionospheric convection, in which the electric field (responsible for the convection flow in the cusp region) drives Pedersen currents that diverge into and out of the ionosphere as two sheets of oppositely flowing field-aligned currents (FAC) located at the low- and high-latitude boundaries of the cusp. These current sheets can be identified as the region 1 currents and the cusp field-aligned currents in the statistical FAC pattern obtained by *Iijima and Potemra* [1976].

Subsequent examination of the polar cap magnetic variations [e.g., *Friis-Christensen and Wilhjelm,* 1975; *Kuznetsov and Troshichev,* 1977; *Levitin et al.*, 1982] revealed the existence of a large-scale $B_y$-dependent ionospheric current system which is similar to the Leontyev and Lyatsky analytical model. Then *Wilhjelm et al.* [1978] examined the relationship between ionospheric and field-aligned currents in the dayside cusp region and made it clear that the ionospheric Hall currents in the vicinity of the cusp are really located between two sheets of field-aligned currents. Because of the strong dependence of these three-dimensional current system on the IMF $B_y$ component strength and direction, the authors suggested that the ionospheric portion of this current system be named *DPY.*

Using the Sondrestrom incoherent scatter radar observations, *Clauer et al.* [1984] have shown that direction of the plasma flow in the cusp region corresponds



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to changes in the IMF $B_y$ component in agreement with the Svalgaard–Mansurov effect: the convection is westward (eastward) in the northern hemisphere for $B_y > 0$ ($B_y < 0$). *Banks et al.* [1984] and *Clauer and Friis-Christensen* [1988] suggested that the cleft current system be separated into two components: *DPY* and *DPZ* which are associated with the IMF $B_y$ and $B_z$ components, respectively.

To explain some features in the cusp/cleft convection affected by the IMF $B_y$ component, a few different FAC configurations have been proposed. *Erlandson et al.* [1988] suggested the placement of the specific $B_y$-affected current sheet poleward of the region 1 currents, similar to the analytical model by *Leontyev and Lyatsky* [1974] and the original scheme obtained by *Iijima and Potemra* [1976]. *Saunders* [1992] and *Yamauchi et al.* [1993] suggested the FAC pattern resembling the model developed by *McDiarmid et al.* [1979] where the cusp field-aligned currents are considered as an extension of the region 1 currents to the dayside sector under the influence of the IMF $B_y$. *Taguchi et al.* [1993] and *Ohtani et al.* [1995] suggested the placement of two separate current sheets poleward of region 1 in which the FAC direction is determined by the sign of IMF $B_y$. The transient convection, controlled by both, the azimuthal and southward IMF, is an another special feature of the cusp region [*Stauning et al.*, 1994, 1995; *Clauer et al.*, 1995; *Papitashvili et al.*, 1995; *Weiss et al.*, 1995].

Discovery of the dayside auroral intensification which precedes substorms in aurora [*Lui et al.*, 1987; *Murphree and Cogger*, 1992] inspired a new interest to the relationships between the *DPY* currents and substorm activity. For example, *Belehaki and Rostoker* [1996] examined possible connection between the *DPY* currents and the dayside portion of the auroral electrojets and concluded that the *DPY* are not isolated currents but should be considered as a part of the auroral electrojet (it AE) system. *Troshichev et al.* [1996] discovered that intensification of the westward currents in the afternoon sector of the cleft region precedes or accompanies the magnetic substorm development in the nighttime auroral zone.

It is clear that the diversity of the current and convection patterns proposed to relate to the IMF $B_y$ in the cusp/cleft region indicate the complexity and ambiguity of the problem. In this paper we further examine the relationships between steady *DPY* currents in the northern cusp/cleft region and the IMF $B_y$ and $B_z$ components to understand better the role of $B_z$ in generation of the *DPY* currents. We also briefly address the problem of the substorm activity precursors in the dayside magnetic perturbations.

## Experimental Data and Method of Study

Magnetic data from the meridional chain of stations along the Greenland West Coast for 1982–1992 were inspected (Table 1). Events were selected for analysis if (1) the Greenland West Coast stations were located near magnetic noon ($\sim$ 1400 UT) and (2) the absolute values of the IMF $B_z$ were less than $B_y$. The latter condition was applied to reduce the distorting influence of the *DP2* currents on the cusp/cleft magnetic disturbances. Sixteen events listed in Table 2 were selected for further analysis.

Distributions of the ionospheric equivalent currents along the meridional chain of magnetometers were calculated from the $\Delta H$ and $\Delta Z$ component variations for every one-minute interval using the technique developed by *Kotikov et al.* [1987]. The test calculations show that this method realistically reproduces a meridional profile of the ionospheric currents with a resolution from 100 to 60 km depending on the current intensity. *Kotikov et al.* [1991] present the technique's description along with the analysis of its resolving power and calculation errors.

Figures 1–6 show the space-time maps of the equivalent currents where the solid contours represent westward currents and the dashed line contours – eastward currents. Magnetic activity during examined events is determined by the *AE* index available from the World Data Center C2 (Kyoto, Japan). Thick arrows on Figures 1–6 show time of the sharp increase in geomagnetic

**Table 1.** West Greenland Magnetometer Array

| Station | IAGA | Geographic | | Corrected Geomagnetic | | MLT Noon, |
|---|---|---|---|---|---|---|
| Name | Code | Latitude | Longitude | Latitude | Longitude | UT |
| Thule | THL | 77.5 | 290.8 | 85.6 | 34.3 | 1450 |
| Savissivik | SVS | 76.0 | 294.9 | 83.9 | 36.5 | 1440 |
| Kullorssuaq | KUV | 74.6 | 302.8 | 81.4 | 45.0 | 1402 |
| Upernavik | UPN | 72.8 | 303.8 | 79.7 | 42.4 | 1414 |
| Umanaq | UMQ | 70.7 | 307.9 | 77.1 | 44.2 | 1405 |
| Godhavn | GDH | 69.2 | 306.5 | 76.0 | 40.5 | 1421 |
| Attu | ATU | 67.9 | 306.4 | 74.8 | 39.1 | 1427 |
| Sondre Stromfjord | STF | 67.0 | 309.3 | 73.4 | 41.8 | 1415 |
| Sukkertoppen | SKT | 65.4 | 307.1 | 72.3 | 37.9 | 1432 |
| Godthab | GHB | 64.2 | 308.3 | 70.8 | 38.6 | 1430 |
| Frederikshab | FHB | 62.0 | 310.3 | 68.3 | 39.6 | 1425 |
| Narssarssuaq | NAQ | 61.2 | 314.6 | 66.6 | 43.9 | 1405 |

**Table 2.** List of the Selected Events, the IMF $B_z$ and $B_y$ Components Strength and Direction, and Parameters of the *DPY* Ionospheric Equivalent Currents

| Date | UT | IMF $B_z$ Change | IMF $B_y$ Change | *DPY* Current Parameters | | |
|---|---|---|---|---|---|---|
| | | | | Time | Invariant Latitude | Direction |
| *1982* | | | | | | |
| May 28 | 1100–1700 | 0/-7 | -3/-9 | 1130–1700 | 75–78 | W |
| *1986* | | | | | | |
| April 1 | 1600–1800 | 0/ 2 | 0/ 2 | – | – | – |
| | 1800–2000 | 0/-2 | 0/-3 | 1900–2100 | 75–77 | W |
| | 2000–2200 | 0/ 4 | -2/ 0 | – | – | – |
| April 3 | 1600–1800 | 0/-2 | 0/-2 | 1615–1815 | 77–79 | W |
| | 1800–2000 | 0/ 3 | 0/ 3 | – | – | – |
| May 7 | 1400–1900 | -1/-3 | -1/-3 | 1500–1900 | 77–79 | W |
| May 31 | 1500–2100 | 0/-3 | -8/-1 | 1600–2100 | 76–78 | W |
| June 12 | 1100–1500 | 0/ 3 | -1/-4 | – | – | – |
| August 7 | 1300–1700 | -1/ 4 | -2/-4 | – | – | – |
| *1987* | | | | | | |
| May 10 | 1000–1100 | -5/ 4 | -4/ 5 | 1030–1300 | 73–76 | W |
| | 1100–1200 | 4/ 0 | 5/ 2 | – | 71–76 | W |
| | 1200–1300 | 0/-7 | 2/-3 | – | 75–77 | W |
| | 1300–1700 | 4/ 6 | 4/ 4 | – | – | – |
| | 1500–1700 | 0/-2 | 2/ 6 | 1500–1700 | 72–77 | E |
| June 5 | 1200–1300 | -3/ 1 | 2/ 4 | – | – | – |
| | 1300–1700 | -2/-6 | 2/ 6 | 1330–1700 | 73–75 | E |
| July 23 | 1200–1500 | -2/ 1 | -5/-6 | – | – | – |
| | 1500–1800 | -3/-4 | -1/-6 | 1600–1800 | 77–79 | W |
| July 25 | 1300–1400 | 3/ 4 | -4/-6 | – | – | – |
| | 1400–1700 | 0/-2 | -6/-8 | 1430–1700 | 76–79 | W |
| August 3 | 0800–1000 | 4/ 0 | 10/ 8 | – | – | – |
| | 0900–1200 | -1/-5 | 5/-1 | 0945–1130 | 76–78 | E |
| August 8 | 1200–1700 | -2/-3 | 4/ 6 | 1200–1500 | 77–80 | E |
| August 29 | 1400–1500 | 1/ 2 | -6/-7 | – | – | – |
| | 1500–1800 | -2/-4 | -6/-3 | 1530–1745 | 76–79 | W |
| *1988* | | | | | | |
| June 24 | 1000–1100 | 4/ 5 | 2/ 3 | – | – | – |
| | 1100–1400 | 0/-7 | 3/ 6 | 1145–1400 | 74–77 | E |
| *1992* | | | | | | |
| January 29 | 1400–1600 | -3/ 0 | -4/-6 | 1400–1600 | 78–82 | W |
| | 1600–1800 | 1/ 4 | -4/-5 | – | – | – |
| | 1800–1900 | -2/-3 | -5/-6 | 1800–1900 | 79–81 | W |

activity, that is, the beginning of the substorm expansion phase.

## Results of the Analysis

Figures 1 and 2 show two examples of the equivalent current developments obtained from the Greenland West Coast data when magnetic substorms occur under the conditions of prolonged negative IMF $B_y$. On July 25, 1987 (Figure 1), the IMF $B_y$ was negative during the entire day but westward currents in the cleft region (at corrected geomagnetic latitudes $\Phi = 75° - 79°$) intensify only after 1430 UT, following the southward turn of the IMF $B_z$ component. Eastward currents appear equatorward of the cusp/cleft region. The substorm occurred at 1615 UT with $\sim$ 1.5 hour delay relative to the corresponding southward turn of $B_z$ and intensification of the cusp/cleft westward electrojet.

A similar situation occurs on August 29, 1987 (Figure 2), when intense westward currents develop in the cusp/cleft region only at 1530 UT in association with a sharp decrease of the southward IMF and despite the fact that $B_y$ was largely negative during few previous hours. The substorm in the midnight auroral zone occurred with a half-an-hour delay from the westward current intensification.

Figures 3 and 4 show examples with the eastward equivalent currents in the cusp/cleft region. In the case of August 3, 1987 (Figure 3), the IMF $B_y$ was positive since 0715 UT, but the eastward electrojet in the cusp/cleft region develops only at 0945 UT in association with the southward turn of $B_z$. The substorm occurred 15 min later. On June 24, 1988, two bursts of intensive eastward currents are seen in the cusp/cleft region at 1140 and 1240 UT. They evidently follow (with an approximately 20 min delay) the corre-

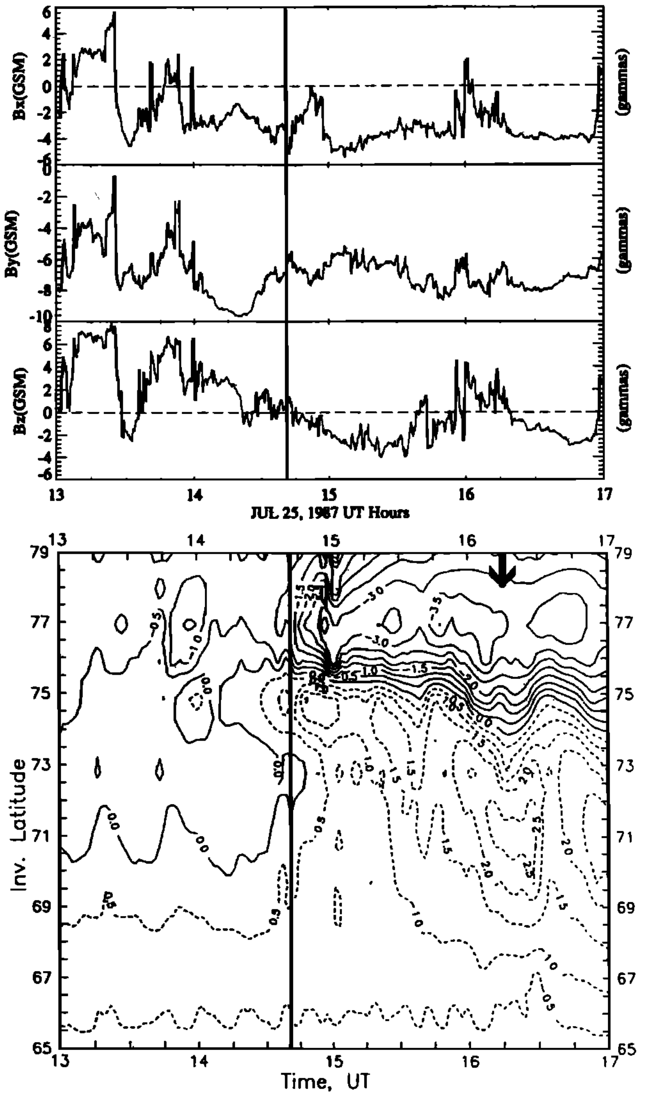

**Figure 1.** The IMP 8 interplanetary magnetic field on July 25, 1987 (top: negative $B_y$ and southward $B_z$) and distribution of ionospheric equivalent currents derived from the Greenland West Cost magnetometer data (bottom: westward currents are drawn by solid contours; eastward currents, by dashed lines). The vertical solid line shows the time instance when the IMF $B_z$ component turns southward. The thick arrow indicates the follow-on substorm onset according to the $AE$ index data.

sponding southward turns of IMF $B_z$. In both cases the westward currents are seen equatorward of the eastward electrojet in the cusp/cleft region.

Figures 5 and 6 show another situation when the negative IMF $B_y$ is accompanied by mainly positive $B_z$. In both cases, June 12 and August 7, 1986, no significant currents appear in the cusp/cleft region at all though the IMF $B_y$ was negative quite a long time. During these events the substorms occurred at 1200 and 1500 UT, respectively, but the corresponding $AE$ index does not exceed 200 nT in both cases.

We find that the behavior of the dayside cusp/cleft electrojets shown on Figures 1–6 are common for all 16 examined events. As seen from Table 2, the eastward or westward currents in the cusp/cleft region appear when the IMF $B_z$ turns southward. A single exception is the May 10, 1987, event when the westward current is observed at 1100–1200 UT when $B_z = +4$ nT. However, note that this event was preceded (at 1000–1100 UT) and then followed (at 1200–1300 UT) by the periods of strong negative $B_z$ (−5 and −7 nT, respectively).

The direction of observed $DPY$ currents was determined by the sign of azimuthal IMF component for all examined events: eastward $DPY$ currents are developed during $B_y > 0$, and westward currents, during $B_y < 0$ again with the exception at 1100-1200 UT on May 10, 1987. The displacement of $DPY$ currents is likely controlled by the southward IMF component strength: the currents are located at $\Phi = 75° - 79°$ for $B_z > -3$ nT, and at $\Phi = 73° - 76°$ for $B_z < -3$ nT. Sometime currents, directed in the opposite direction to $DPY$, appear equatorward of the $DPY$ electrojets. This allows us to

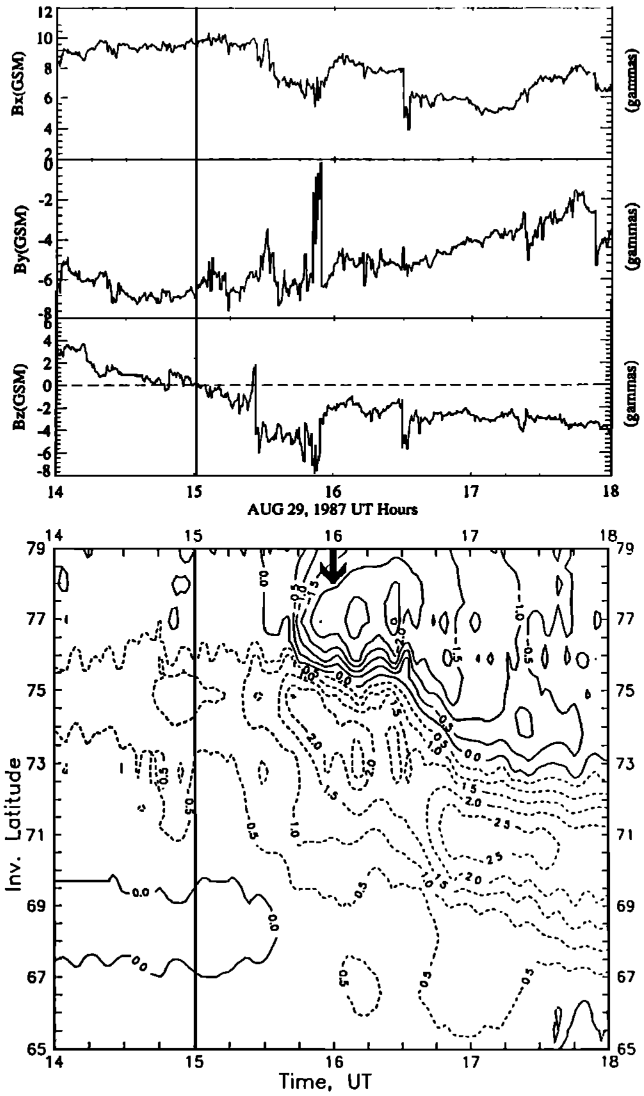

**Figure 2.** The same as in Figure 1 but for August 29, 1987 (negative $B_y$ and southward $B_z$).

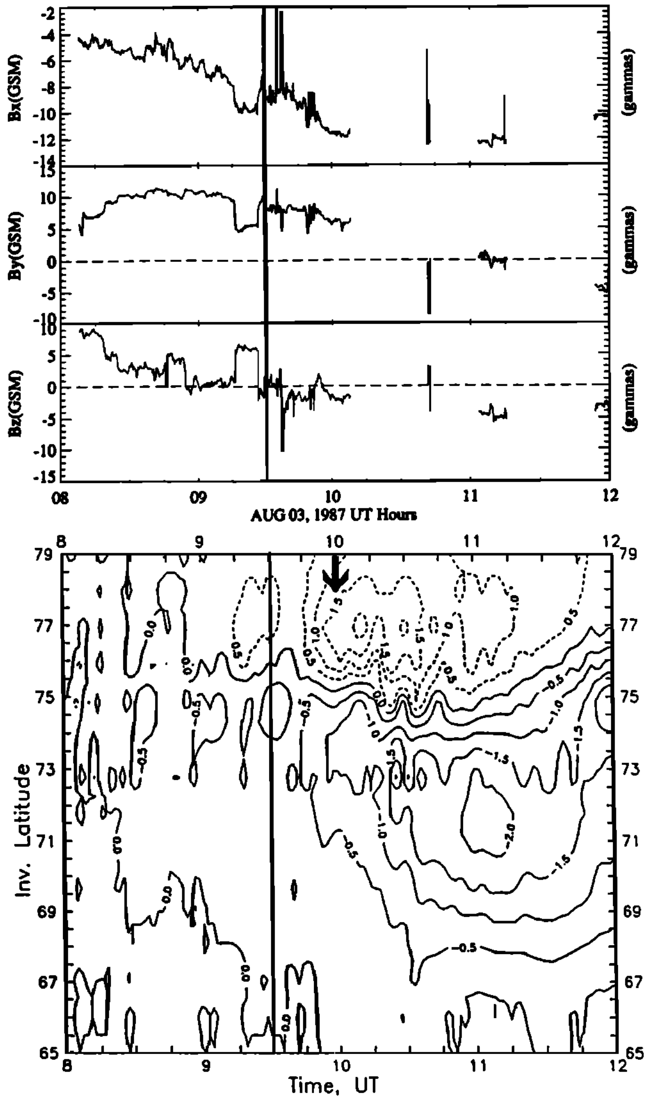


**Figure 3.** The same as in Figure 1 but for August 3, 1987 (positive $B_y$ and southward $B_z$).

conclude that, in agreement with the results obtained by *Belehaki and Rostoker* [1996], the *DPY* current system derived in this analysis consists of two antiparallel currents developing simultaneously in the cusp/cleft region and equatorward of that region.

## Discussion

**Source of *DPY* currents.** The results presented here show that the *DPY* currents in the cusp/cleft region (at latitudes $\Phi = 78° - 80°$) develop only when the IMF $B_z$ component is oriented southward. Therefore we can conclude that their appearance is controlled by the IMF $B_z$, but the current direction is still specified by the $B_y$ component orientation. This conclusion contradicts with the widely accepted opinion that the *DPY* currents appear in the cusp/cleft region irrespective of the IMF $B_z$. However, we note that this opinion is mainly based on the results obtained from the plasma drift measurements made by incoherent scatter radars and the FACs derived from satellite observations in the cusp regions [e.g., *Clauer and Friis-Christensen*, 1988; *Newell et al.*, 1989; *Taguchi et al.*, 1993]. Our results are obtained from the analysis of ground-based magnetometer data. Two reasons can be drawn to account for this discrepancy: the displacement of *DPY* currents poleward and a decrease of the current intensity below the certain threshold of the ground magnetometer sensitivity.

Indeed, we probably do not see the corresponding *DPY* currents during northward IMF because of their displacement to higher latitudes, that is, beyond of the magnetometer "field-of-view." Unfortunately, there are no data from magnetometers between Upernavik ($\Phi$ = 79.7°) and Thule ($\Phi$ = 85.6°) for the cases we examined. Nevertheless, no evidences of the *DPY*-like currents were found examining the Thule magnetograms for the northward IMF conditions. We do

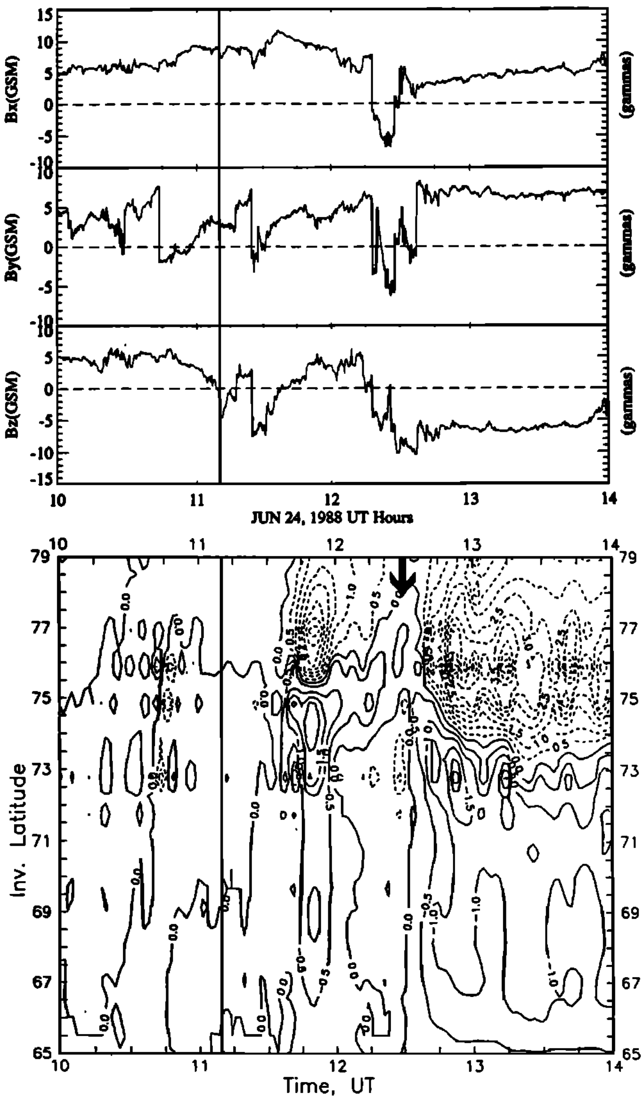


**Figure 4.** The same as in Figure 1 but for June 24, 1988 (positive $B_y$ and southward $B_z$).

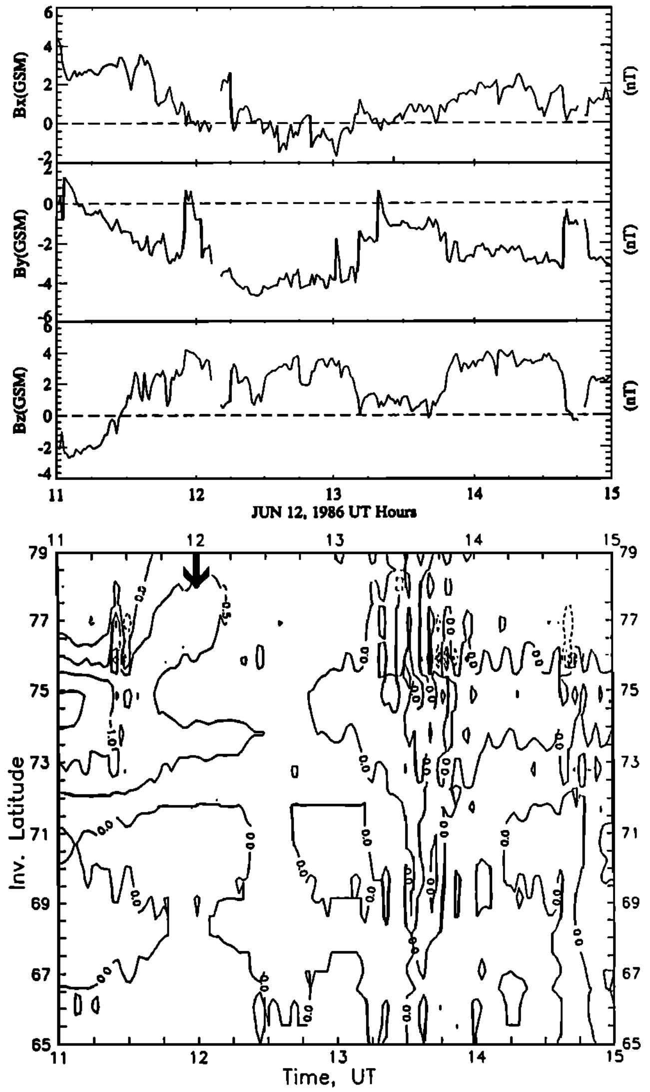


**Figure 5.** The same as in Figure 1 but for June 12, 1986 (negative $B_y$ and northward $B_z$).

not see even any tendency towards the displacement of *DPY* currents to higher latitudes while the IMF $B_z$ component turns from south to north. However, the equatorward (poleward) displacement of *DPY* currents in connection with an increase (decrease) of the southward IMF is seen in Figures 2 and 3 if the 20–30 min time delay is taken into account according to *Clauer and Friis-Christensen* [1988]. It implies that the *DPY* currents are sharply reduced rather than displaced when the IMF turns northward.

To our knowledge, there are no experimental data providing evidences that the *DPY* currents move poleward when $B_z > 0$, but there are data indicating their significant reduction during these conditions. For example, the geomagnetic data collected by *Stauning et al.* [1994] from the Greenland magnetometer chain include stations Kullorsuaq ($\Phi = 81.4°$) and Savissivik ($\Phi = 83.9°$). The authors show that *DPY* currents still remain within a narrow latitude interval (usually at $\Phi < 80°$ for the events when the southward $B_z$ is small or $B_z > 0$. Therefore we can expect that precipitating particles (which ensure the field-aligned currents in the cusp/cleft region) are also limited to a latitudinally narrow region. For example, the airborne all-sky imager data [*Weiss et al.*, 1995] show that the enhanced 630.0-nm auroral emission produced by the magnetosheath electron precipitation during northward IMF appears within the zonally elongated regions at latitudes lower than $\Phi = 80°$.

*Belehaki and Rostoker* [1996], who inspected magnetic variation data from the CANOPUS magnetometer array in the north central Canada (24 events, mainly for the IMF $B_z < 0$ conditions), chose not to present events with $B_z > 0$ because the *DPY* currents appeared to be quite weak for the cases they examined. According to these authors, the westward *DPY* currents are located at invariant latitudes $77° - 83°$ for $B_y < 0$, but these currents occur during IMF $B_z < 0$ (if $B_z$ is taken in

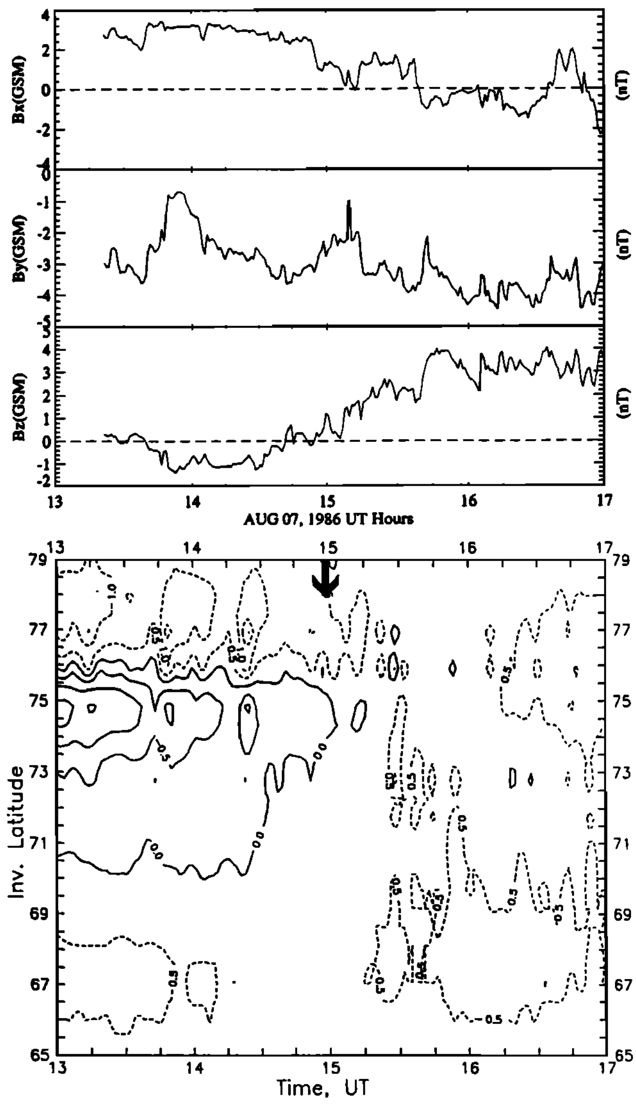


**Figure 6.** The same as in Figure 1 but for August 7, 1986 (negative $B_y$ and mainly northward $B_z$).

GSM coordinates). Therefore we can come to the conclusion that *DPY* currents for $B_z > 0$ are weak and appear only in a latitudinally narrow region. Taking into account a resolving power of the applied Kotikov's technique, we can also conclude that the *DPY* currents having a latitudinal width $\leq 0.5°$ are incapable to ensure a noticeable magnetic effect at the Earth's surface.

It is widely accepted that *DPY* currents are associated with the existence of two FAC sheets flowing at the low- and high-latitude boundaries of the cusp/cleft region. It was suggested that the low-latitude boundary of the cusp region coincides with the boundary between closed and open magnetic field lines [e.g., *Bythrow et al.,* 1988; *Kremser and Lundin,* 1990; *Newell et al.,* 1991; *de la Beaujardiere et al.,* 1993]. The region 1 field-aligned currents (located in the vicinity of this boundary) flow in general along the closed magnetic field lines, but they can also flow partially along the open field lines [*de la Beaujardiere et al.,* 1993; *Lu et al.,* 1995]. In contrast, the field-aligned currents coinciding with the mantle precipitation are always generated on the open field lines poleward from the cusp [*Bythrow et al.,* 1988; *Erlandson et al.,* 1988]. Disposition of these two FAC sheets is consistent with the theoretical notion that the merging site is located poleward of the cusp for the northward IMF and equatorward for the southward IMF [*Dungey,* 1963; *Crooker,* 1979]. It is evident that the strong IMF $B_y$ component affects significantly both the poleward or equatorward merging sites.

**The $B_y$-driven ionospheric transient events in the cusp/cleft region.** Both the auroral and ionospheric transient events are observed in the cusp region and the influence of the IMF $B_z$ is especially pronounced in these cases. If the IMF $B_y$ is modulated by the long-period pulsations of significant amplitude on the background of steady southward IMF, the cusp/cleft current jet may work against the large-scale current system producing the antisunward-like convection pattern [e.g., *Stauning et al.,* 1994, 1995]. The ionospheric perturbations (which reproduce variations of $B_y$) occur first at the cusp latitudes and then progress in the polar cap. If the IMF $B_y$ component is modulated by nearly periodic signal ($\sim$ 25 min) and $B_z$ is strongly negative, the latitudinally narrow and longitudinally limited convection perturbation is observed propagating poleward [*Clauer et al.,* 1995; *Papitashvili et al.,* 1995]. If the IMF $B_z$ is small or positive, the $B_y$ component variations are reflected by the latitudinally narrow convection flow which keeps its position within the cusp [*Stauning et al.,* 1994; *Weiss et al.,* 1995].

The structure of the local field-aligned currents responsible for the transient ionospheric events is evidently similar to the FAC pattern which generates the large-scale *DPY* currents: there are two FAC sheets with oppositely directed currents specified by the IMF azimuthal component [*Stauning et al.,* 1994, 1995]. The FAC sheets appear close to the dayside auroral oval and can drift poleward under influence of the southward $B_z$ but with a displacement towards dusk or dawn depending on the sign of IMF $B_y$. Sources of these transient current sheets and their relation to the region 1 and cusp/mantle current systems remain unclear.

It seems that the results reviewed above indicate some regular behavior and can be briefly summarized as the following:

1. If the IMF $B_z$ is southward and $B_y$ is stable, the steady *DPY* currents (i.e., dayside electrojets) develop during conditions $|B_y| > |B_z|$.
2. If $B_z$ is strongly negative and $B_y$ is strongly modulated, the transient ionospheric perturbations develop producing the $B_y$ variations and progressing poleward during conditions $|B_z| > |B_y|$.
3. If $B_z$ is positive, only narrow current jets can be observed within the cusp latitude boundaries during conditions $|B_y| > |B_z|$.
4. If $B_z$ is positive, there are no currents at all in the cusp/cleft region during conditions $|B_z| > |B_y|$.

**Dayside magnetic disturbance precursors to substorm activity.** A close check of the relationships between the cleft azimuthal currents, IMF parameters, and *AE* index variations, undertaken in this study, shows that the *DPY* currents in the cusp/cleft region (the dayside electrojets) are only observed if the IMF $B_z$ component is southward. This supports the results obtained by *Troshichev et al.* [1996] that intensification of westward currents in the cleft afternoon sector precedes or accompanies the magnetospheric substorm expansion in the midnight auroral zone. Indeed, the substorm expansion phase is preceded, as a rule, by the growth phase (e.g., during extended period of southward IMF).

The southward turn of the IMF $B_z$ marked in Figures 1–4 by a vertical solid line increases the energy input into the magnetosphere and leads to a growth of the directly-driven electrojets and an energy storage in the magnetospheric tail. At the same time, the southward IMF can promote generation of the *DPY* currents if the IMF $B_y$ is nonzero. The impulsive release of the energy stored in the tail gives rise to an expansion phase (e.g., the appearance of the substorm current wedge in the midnight auroral zone); we mark this time instance in figures by a heavy vertical arrow. Although the onsets of the expansion phase were roughly determined from *AE* index, it is evident that the onsets are delayed from the southward turn of the IMF $B_z$ and a development of the corresponding *DPY* currents. If the energy release is large enough, the substorm can start even if the IMF becomes northward, but in these cases we do not see a substorm growth phase as well as the magnetic precursors in the cusp/cleft region (for example, as in Figures 5 and 6).

These results are also consistent with the concept suggested by *Rostoker* [1980] and discussed later by *Papitashvili and Popov* [1982] and *Belehaki and Rostoker* [1996]. The authors of the latter study concluded that the *DPY* currents do not belong to an isolated current system but relate to the redistribution of currents in the directly-driven auroral electrojets. If this conclusion is correct, then the *DPY* currents (1) appear almost exclusively during the southward IMF conditions when the directly-driven auroral electrojets develop (i.e., during the substorm growth phase), and (2) precede the main substorm activity (e.g., the substorm expansion phase) in the nightside region of the polar cap. These features of the *DPY* currents are found by *Troshichev et al.* [1996] and firmly confirmed in this study.

## Conclusion

Magnetic data from the meridional chain of stations in Greenland are analyzed for 16 selected substorms when the chain was in the noon sector and absolute values of $B_z$ were less than that of $B_y$. The results of the analysis show that the *DPY* currents in the cusp/cleft region (at corrected geomagnetic latitudes $75° - 79°$) develop only under the conditions of southward IMF, although the current direction is specified by the sign of the IMF azimuthal component. When the IMF $B_y$ component is not zero and the $B_z$ is mainly positive, no significant currents are observed in the cusp/cleft region at all. Dependence of the *DPY* current occurrence on the southward IMF provides an evident and logical explanation for the dayside magnetic perturbations preceding the nighttime substorm activity.

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The comment of one referee noting that *AL* index begins to increase before the time instance marked by a thick arrow on Figure 1 is gratefully acknowledged, but we identified the substorm occurences by the sharp increase in *AE* index.

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