Proc. NIPR Symp. Upper Atmos. Phys., **10**, 135–141, 1997

NIGHTSIDE SUBAURORAL FIELD-ALIGNED CURRENT SYSTEM DURING GREAT MAGNETIC STORMS (EXTENDED ABSTRACT)

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Why we did this work

It is well known that the equatorward edge of the auroral oval expands toward lower latitudes during disturbed geomagnetic conditions with the equatorward expansion depending on the geomagnetic disturbance; in the magnetotail, this equatorward movement is associated with the earthward intrusion of plasma sheet particles. On the other hand, it is also well known that what we call ring current that effects the ground level geomagnetic field at middle and low latitudes, develops drastically during magnetic storms. Although the details of ring current formation are still far from clear, the cause is mostly attributable to the enhanced energetic particles trapped in the Earth's magnetosphere. Thus, it is expected that during great magnetic storms the interaction between the plasma sheet and the ring current region plays an important role in the dynamics of the inner magnetosphere. Our first intention of this study was to investigate such dynamical process by making use of low-altitude polar-orbiting satellite data, namely, low-altitude diagnosis of the storm-time inner magnetosphere. As a result, we found a very interesting phenomenon, that is, "subauroral field-aligned current system" that appears on the equatorward side of the main body of the plasma sheet. We describe it briefly in this abstract.

How we did this work

First we selected five magnetic storms such that the *Dst* index decreased lower than -100 nT. Then, using magnetic field and precipitating particle data obtained by DMSP-F7 satellite (a sunsynchronous orbit in the prenoon-premidnight meridian at an altitude of 835 km), we have investigated the relationship between field-aligned currents (FACs) and ion precipitation from the plasma sheet. The reason why we focused on ion precipitation is that in the inner magnetosphere the plasma pressure is carried mostly by ions and the plasma pressure gradient plays a crucial role in the generation of region 2 FACs. In fact, recent observation shows that region 2 FACs are collocated with the inner plasma sheet determined by ion precipitation. (Roughly speaking, the ion inner plasma sheet is at the traditional central plasma sheet, or CPS, but differs substantially in that it is determined from ions.) Therefore, using the ion precipitation pattern as the marker of source region of FACs, we can definitely identify the region 2 FAC system at the Harang

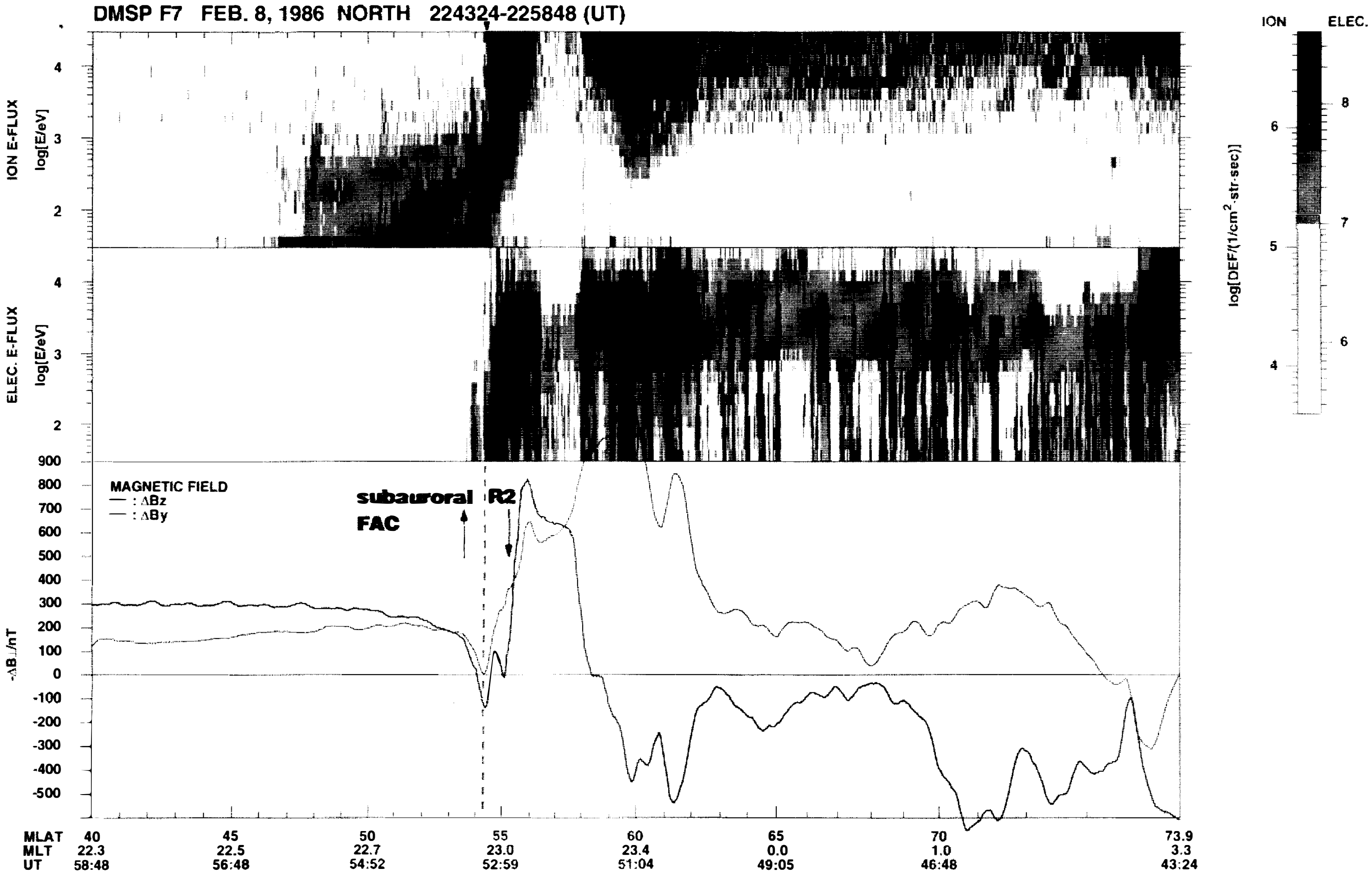

Fig. 1. Energy versus time spectrograms of precipitating ions (top panel) and electrons (middle panel), and transverse magnetic field disturbances (bottom panel) in cross-track (positive eastward, thick line) and along-track (positive northward, thin line) components, observed by the DMSP-F7 satellite in the northern hemisphere pass "b" in Fig. 2. The triangle at the top and the dashed line in the bottom panel show the inner edge of ion plasma sheet determined by the flux drop-off of above-10-keV ions. Downward and Upward arrows denote, respectively, the field-aligned current flowing into and away from the ionosphere. Magnetic latitude (MLAT) and magnetic local time (MLT) are given in eccentric dipole coordinate system.

discontinuity sector even with multiple current sheets. Once the origin of FACs is determined, it is possible to find the spatial structure of FACs straightforward.

We will illustrate this method by giving an example. Figure 1 demonstrates an example of what we call energy-*versus*-time spectrogram of precipitation ions (top) and electrons (middle) in the energy range 30 eV to 30 keV observed by the DMSP-F7 satellite in the northern hemisphere. Lower latitudes are to the left. At the equatorward boundary of ion precipitation ($\approx 55^\circ$ MLAT), we can discern a strong energy flux of ions in the energy range more than 1 keV. This is the main body of plasma sheet ions that have been conveyed from the magnetotail and energized during the inward motion. We call this ion precipitation "inner plasma sheet" following our recent nomenclature. Although the general definition of high latitude limit of inner plasma sheet is difficult to quantify, its low-latitude limit can be clearly defined by its flux drop off. In this paper, we tentatively define the inner edge of ion plasma sheet by the drop off of the above-10-keV flux in its linear profile (not shown here). The inner edge of ion plasma sheet thus determined is shown by the filled triangle at the top of Fig. 1. The bottom panel of Fig. 1 shows the cross-track (positive eastward, thick line) and along-track (positive northward, thin line) components of transverse magnetic field disturbance simultaneously observed by the DMSP-F7 satellite. In this format, positive slope in cross-track component indicates the presence of FAC into the ionosphere. Here we focus only on the cross-track component. The inner edge of the plasma sheet determined above is also shown by vertical dashed line for reference. By comparing ion precipitation and magnetic field disturbance, we can see the inner plasma sheet is associated with FAC into the ionosphere (the downward arrow). Conversely, we can identify the FAC indicated by the downward arrow is the evening-type region 2 current that occurred at 2300 MLT (magnetic local time). Thus, we can use the ion precipitation in discriminating region 2 FACs.

What we found

Figure 2 shows *AE* (top) and *Dst* (bottom) indices during a great magnetic storm in February 1986. The storm had a minimum *Dst* of -312 nT on February 9. The filled triangles and vertical lines in Fig. 2 indicate the DMSP-F7 passes when "subauroral FACs" were observed. Figure 1 demonstrated above is the observation in the pass "b" in Fig. 2. Returning to Fig. 1, we can discern a FAC away from the ionosphere (the upward arrow) that occurs equatorward of the evening-type region 2 FAC system. This is the FAC that we have newly found in this study. We call this current system "subauroral FAC system", because it appears on the equatorward side of the main body of the plasma sheet. Figure 3 demonstrates another example of subauroral FACs; it was observed in the southern hemisphere pass "a" in Fig. 2. The format of Fig. 3 is the same as that of Fig. 1, except that the sign of transverse magnetic disturbance (bottom panel) is reversed for the comparison with Fig. 1 observed in the northern hemisphere. In the same way as Fig. 1, positive slope in cross-track component indicates the presence of FAC into the ionosphere. Again, from the comparison of FACs and ion precipitation, we can conclude that the FAC associated with the inner plasma sheet is the evening-type region 2 current occurring

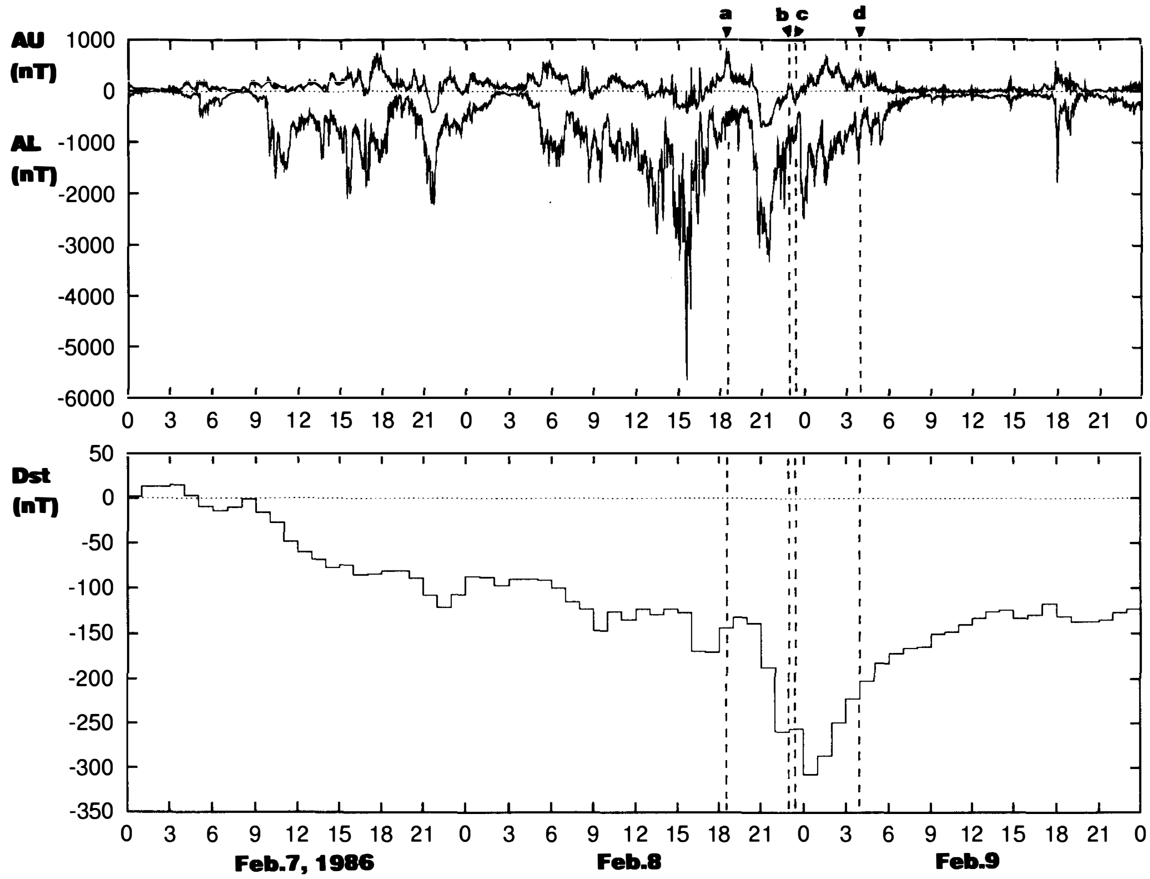

Fig. 2. AE (top panel) and Dst (bottom panel) indices during a great magnetic storm in February 1986. The triangles at the top and the vertical dashed lines in the panels indicate the DMSP-F7 passes when subauroral FAC system was definitely observed.

in the 2000 MLT region, and the FAC flowing away from the ionosphere and occurring further equatorward of the region 2 current is the subauroral FAC that we have just described in Fig. 1. Subauroral FACs similar to Figs. 1 and 3 were also observed in the passes "c" and "d" in Fig. 2, and also found in another magnetic storm event on November 15–17, 1984.

Upper panel of Fig. 4 shows traditional picture of large-scale FAC system in the nightside auroral oval. Spatial structure in the so-called Harang discontinuity sector has been expressed simply by three-sheet pattern as first advocated by IIJIMA and POTEMRA (1976). However, this picture is oversimplified and the actual FAC system in the Harang discontinuity sector is highly variable and complicated. What we found in this paper is an appearance of extraordinary large-scale FAC flowing away from the ionosphere and located just equatorward of and adjacent to the eveningside region 2 FACs (lower panel of Fig. 4). The current system exhibits as though the morningside region 2 current system has extended toward eveningside domain intruding further equatorward of the eveningside region 2 current system, sometimes up to 2000 MLT.

What we think our finding means

It is believed that most part of region 2 currents are generated by the

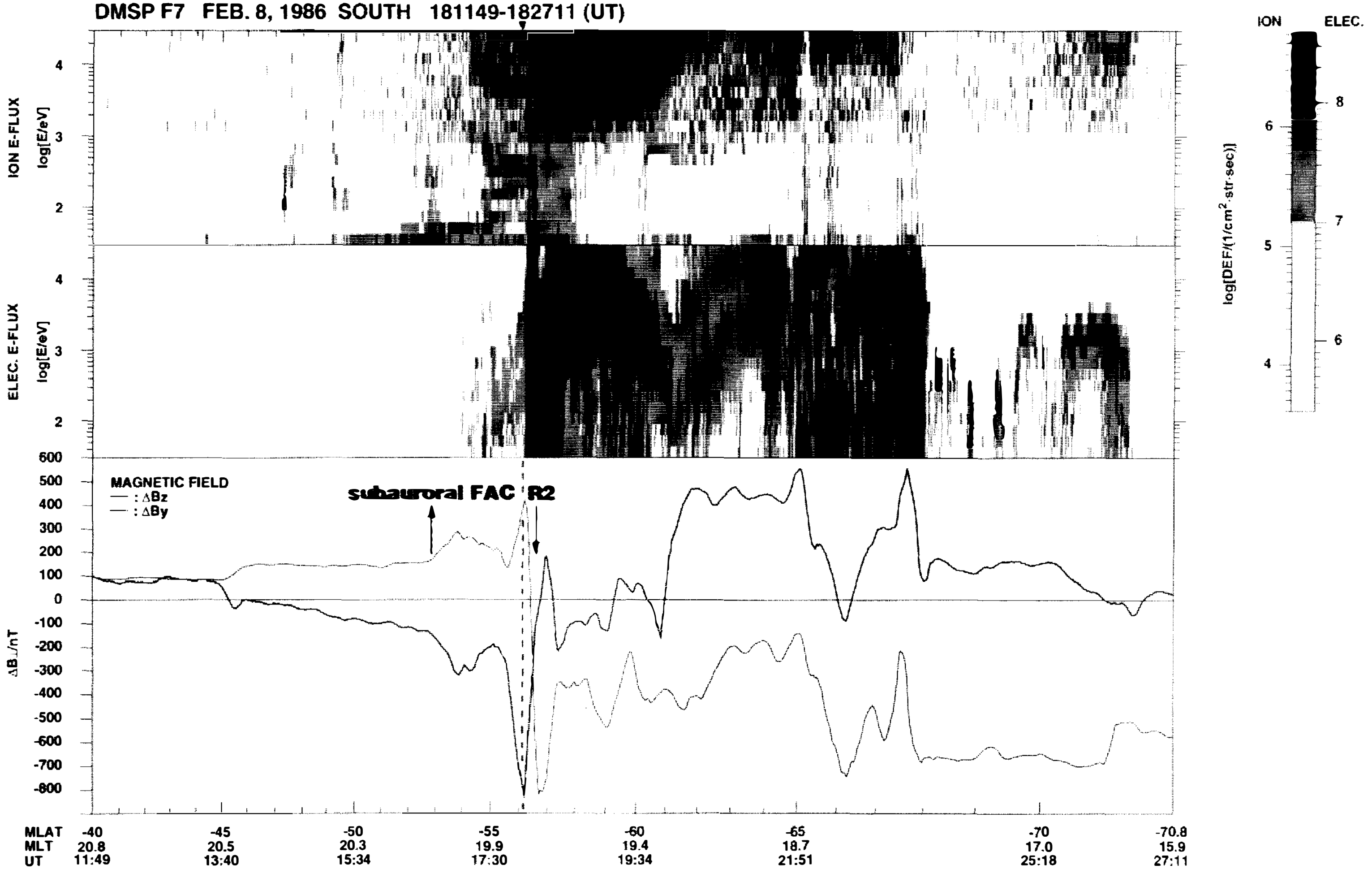

Fig. 3. Energy versus time spectrograms of precipitating ions (top panel) and electrons (middle panel), and transverse magnetic field disturbances (bottom panel) in cross-track (positive westward, thick line) and along-track (positive southward, thin line) components, observed by the DMSP-F7 satellite in the southern hemisphere pass "a" in Fig. 2. Except for the reversed sign in transverse magnetic field disturbance, the format is the same as that in Fig. 1. The triangle at the top and the vertical dashed line in the bottom panel show the inner edge of ion plasma sheet. The arrows in the bottom panel denote field-aligned currents and their flow directions.

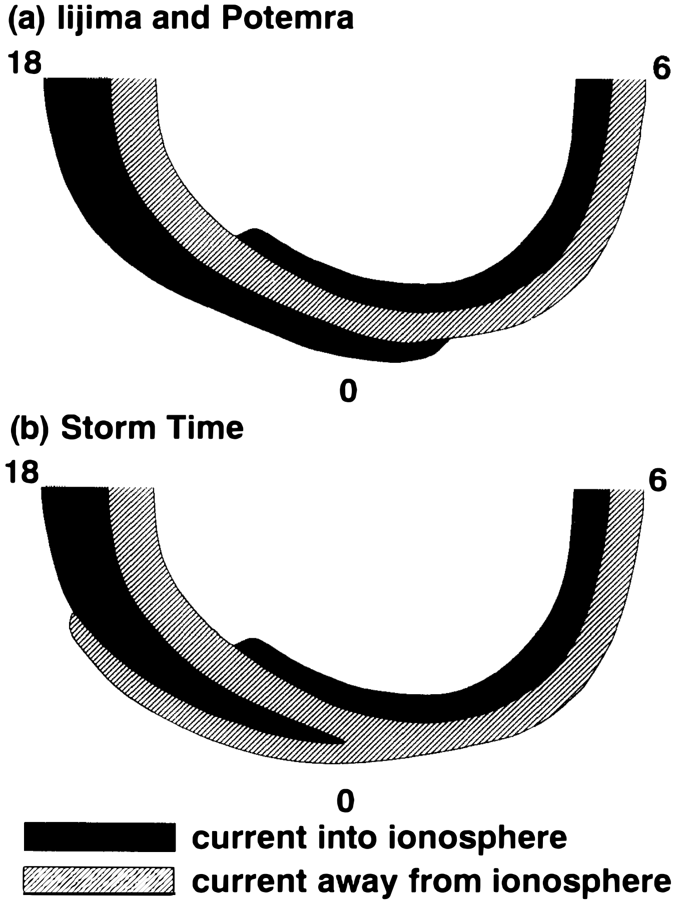

Fig. 4. Simplified pattern of large-scale FACs (field-aligned currents) on the nightside: (a) traditional three-region pattern advocated by IIJIMA and POTEMRA (1976) and (b) appearance of subauroral FAC system during great magnetic storms.

divergence of azimuthal perpendicular current in the magnetospheric equatorial plane, that is, earthward pressure gradient in the main body of ion inner plasma sheet plays an essential role for causing region 2 FACs. However, the subauroral FAC determined here occurs on the earthward side of the inner edge of ion plasma sheet, where the radial component of pressure gradient is suggested to be tailward since ion flux drops at the inner edge of the plasma sheet by its definition. This fact suggests to us the possibility of radial source current in the magnetotail. Indeed, some of the examples of subauroral FACs that we encountered, were associated with magnetic filed disturbances characteristic of the coupling with the region 2 FAC. Figure 5 schematically depicts our idea on the cause of subauroral FACs. During great magnetic storms, more ions are conveyed from the magnetotail rather than from the flankside due to the enhanced dawn-dusk electric field. Ions injected from the magnetotail are deflected duskward during the earthward transport. Recent computer simulation suggests (BOSQUED *et al.*, 1994) some of the injected ions are strongly accelerated duskward owing to the non-adiabatic motion in the transition region from tail-like to dipolar field; as a consequence, high pressure region will be formed in the duskside of inner magnetosphere resulting in highly

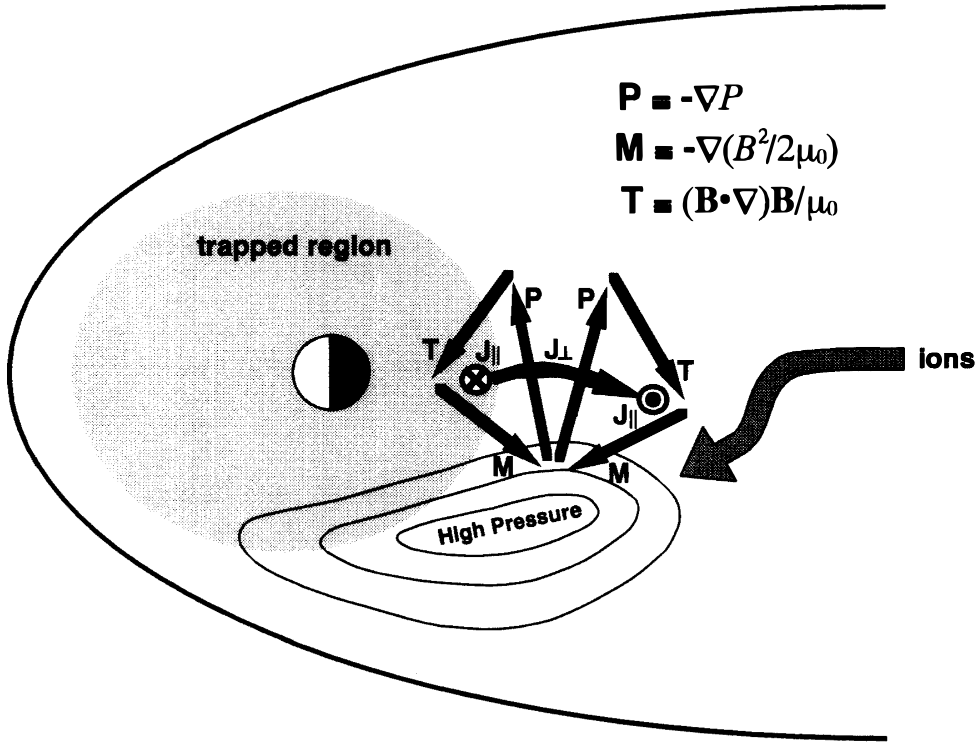

Fig. 5. Stress balance in the inner magnetosphere (equatorial cross-section) that causes subauroral field-aligned current system during great magnetic storms.

dawn-dusk asymmetric pressure contours in the equatorial plane as shown in Fig. 5. Under such circumstances, not only radial pressure gradient but also azimuthal pressure gradient becomes dominant in the near midnight region. And if the triangle vectorial relationship between plasma pressure force (**P**), magnetic pressure force (**M**), and magnetic tangential stress (**T**) is retained as depicted in Fig. 5, region 2 and subauroral FACs are generated in pair via radial source current. We infer that this stress balance will produce subauroral FAC system during great magnetic storms.

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(Received May 7, 1996; Revised manuscript accepted July 18, 1996)