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SUBSTORM INTENSIFICATION FROM THEMIS SATELLITE OBSERVATIONS AND IMF *Bz* COMPONENT CHANGES

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Abstract. The substorm-associated changes of the particles and fields at the Earthward part of the plasma sheet are examined using data from four THEMIS satellites during the substorm intensification on January 6, 2008, when the satellites were located in the different MLT sectors of the magnetosphere. The enhanced convection field during the *Bz* southward turning of the interplanetary magnetic field leads to the earthward approach of the inner edge of the plasma sheet. The Alfven convective sheets of the 0.8-10 keV electrons are observed in the evening sector. The satellite in the morning sector saw the nose-like structure of the ions 8-10 keV. The outer boundaries of energetic particles became steeper during the substorm growth phase. Before the substorm onset, the isotropic boundary of 29 keV ions was located at radial distance 6.3 Re in the evening sector and in the morning sector at distance 8 Re. After northward turning of IMF, the quick magnetic field line stretching and Energy-Dispersed Ion Structures (EDIS) were observed at the morning sector. Then, ten minutes after the EDIS onset, the pseudo-breakup and injection of higher-energy ions (81-157 keV) occur at the evening sector. We discuss a possible association of the substorm magnetotail dynamics with IMF *Bz* changes.

1. Introduction

Kozelova and Kozelov [2013] reported a detailed analysis of explosive local magnetic field line stretching just before dipolarization observed by THEMIS-C satellite in the pre-midnight sector during the breakup at 18:34 UT followed by local substorm of January 6, 2008. Basing on the simple line-current model, *Kozelova and Kozelov* [2013] proposed that observed magnetic field and particle variations could be manifestations of the magnetospheric generator of the 3-D meridional current system with the driving electric field in the meridional direction during nonlinear growth of ballooning instability when non-MHD processes are also turning on.

Table 1. THEMIS spacecraft location in 18:30 UT.

	THE	THD	THC
x (GSM), Re	-3.2	-1.5	-6.6
y (GSM), Re	-7.0	-5.8	2.18
z (GSM), Re	-2.7	-1.6	-1.5
r, Re	8.2	6.2	6.8
MLT, hr	4.0	4.9	22.75
L-value	8.6	6.5	6.8

Here we continue the consideration of this substorm event on January 6, 2008 and focus now on the changes occur both in the evening and postmidnight sector. Also we will discuss a potential role of IMF *Bz* component changes in the substorm dynamics. Data from THEMIS satellites during the substorm event have been used. Table 1 presents the satellite location near the moment 18:30 UT.

2. Substorm evolution

Fig. 1 shows *Bx*, *By* and *Bz* components of the IMF and the solar wind speed observed by ACE satellite in the interval 17:13 -18:13 UT which corresponds to the interval 17:50-18:50 UT which we will discuss in the magnetosphere. The horizontal line at the panel 3 (from top) presents the time interval 18:20-18:34 UT analyzed in details by THEMIS data. Sudden increase *dBz*>0 from -3.5 nT to +3.5 nT (the external trigger) occurs at the moment 3 after which several long-period (with quasi-period of 4 min) oscillations of the *Bz* were observed. After the moment 4, the *Bz* turned to *Bz*=-1 nT implying a continuation of the loading process in the magnetotail.

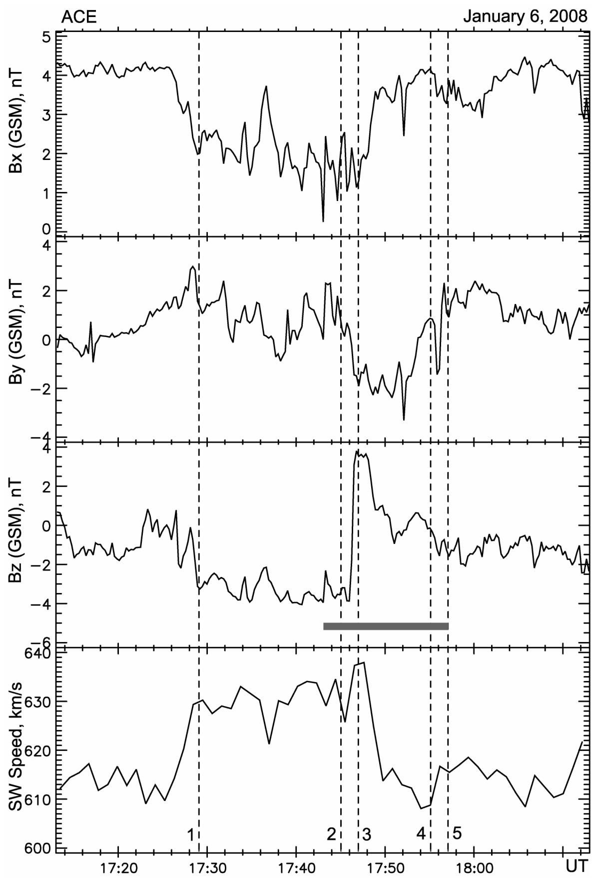

Figure 1. IMF and solar wind conditions. Labeled moments 1-5 are discussed in text.

As it was shown in [*Kozelova and Kozelov,* 2013], during this event in the evening sector the first auroral arc appears near northward horizon of Loparskay (64.9^O N; 113.6^O E) at 17:58 UT. Several weak diffuse azimuthal arcs were observed equatorward of the first arc. These diffuse auroral arcs were slowly moving equatorward. A few small intensifications were observed on these arcs at ~18:06 UT (the moment 1 at Fig. 1) and after the moment 18:22 UT (the moment 2). The auroral perturbation moves from the East to the West. At ~18:31:50 UT (the moment 4), the brightening began at Loparskay equatorward of Harang discontinuity, and the auroral breakup occurs at 18:34 UT (the moment 5) that is 22.75 MLT.

Panels 6 and 7 at Fig. 2 (from top to down) show the H and D components of the magnetic field at ground-based station BRW in the postmidnight sector. One can see first significant auroral electrojet (AEJ) enhancement at ~ 4 MLT at the moment 1. This was a small intensification during the large substorm growth phase. In the interval between the moment 3 and moment 4, the magnetic pulsations with quasi-period of 4 min are observed at BRW, that corresponds to the *Bz* IMF oscillations (Fig.1).

After the moment 5 the AEJ at the postmidnight sector decays (Fig. 2), and at evening sector the AEJ reached the highest value [*Kozelova and Kozelov,* 2013].

3. Observations in the post-midnight sector of the magnetosphere

Fig. 2 also presents observations of the THEMIS-E satellite *r* ~8.2 (4 MLT) during this substorm, panels from top to bottom are: 1 - the low energy (from 6 eV to 30 keV) ESA electron spectrum; 2-4 - the magnetic field components; 5 - the high energy (> 32 keV) SST electron spectrum.

One can see: a) after the moment 1, simultaneously with the small intensification during large-scale substorm growth phase, small impulses of dipolarization and an increase of the high energy SST electron were observed at *r* ~8.2; b) after the moment 2, a sudden drop of *Bz* component (‘*explosive stretching*’) associated with an increase of the high energy electron and a sharp drop of the low energy electron flux (a plasma sheet thinning); c) 2 min after the moment 3, a large dipolarization of the magnetic field occurs and then ends at the moment 5. This dipolarization was associated with increase of the particle fluxes.

Fig. 3 presents the next portion of the THEMIS-E data in the same interval as at Fig. 2. In Fig. 3 from top to bottom: 1 - the total magnetic field; 2-4 - three components of the electric field; 5-10 - six components of the ESA (< 32 keV) ion energy density tensor. From Fig. 3 one can see: a) before the moment 2, the ion energy density was nearly isotropic, a sharp drop of the energy density after the moment 2 was associated with the explosive stretching of the magnetic field observed at the THE; b) in the interval between the moment 2 and the moment 4, the electric field intensively fluctuated and the radial component *Ex* reached the largest values near the moment 3.

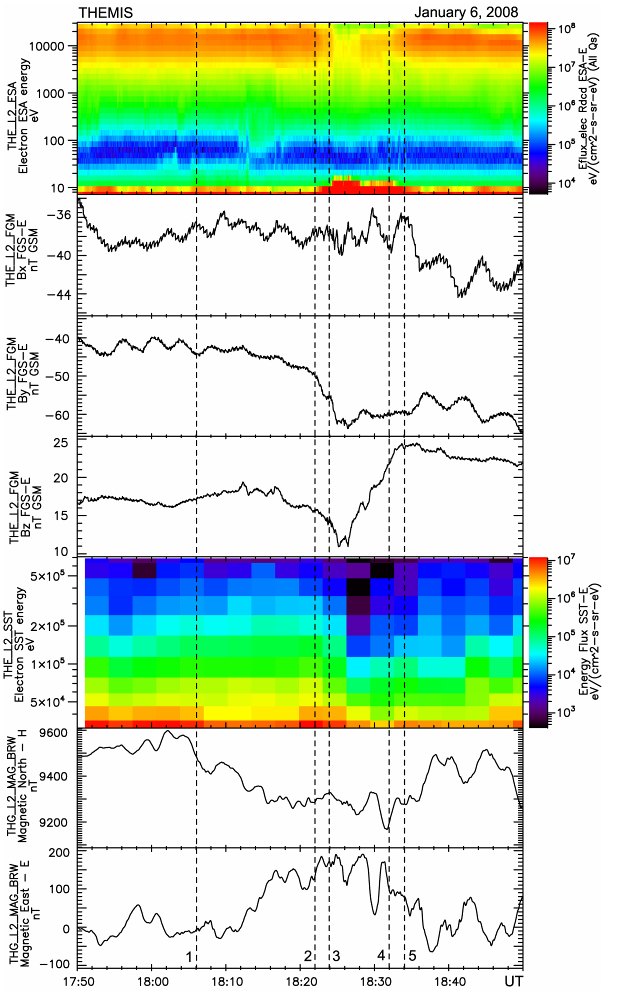

Figure 2. Observations of THEMIS-E satellite (electrons and magetic field) and ground-based magnetic station BRW.

4. EDIS at the post-midnight magnetosphere

In this event after northward turning of IMF, the quick magnetic field line stretching (a plasma sheet thinning**)** and Energy-Dispersed Ion Structures (EDIS) were observed at the morning sector. EDIS are well known ion signatures in the magnetosphere. These ion structures demonstrate monotonic decrease in energy as a function of either time or decreasing latitude depending on their type. In recent observational studies, EDIS observed in the magnetotail have been directly associated with ionospheric and plasma sheet activities [*Elphinstone et al*., 1995; *Sergeev et al*., 2000] and are observed during different substorm phases. They are recognized as the signatures of the *impulsive acceleration processes* at 11–27 Re radial distance.

Similar ion structures were recorded at the interval (18:24-18:32) UT of 6 January 2008 by the THEMIS-E satellite during the substorm intensification in the post-midnight magnetosphere. Fig. 4 shows the observed data in this interval, the panels from top to bottom are: 1 - the high energy SST (> 32 keV) ion spectrum; 2 - the low energy ESA ion spectrum; 3 - the electric field components; and 4 - the *Bz* component.

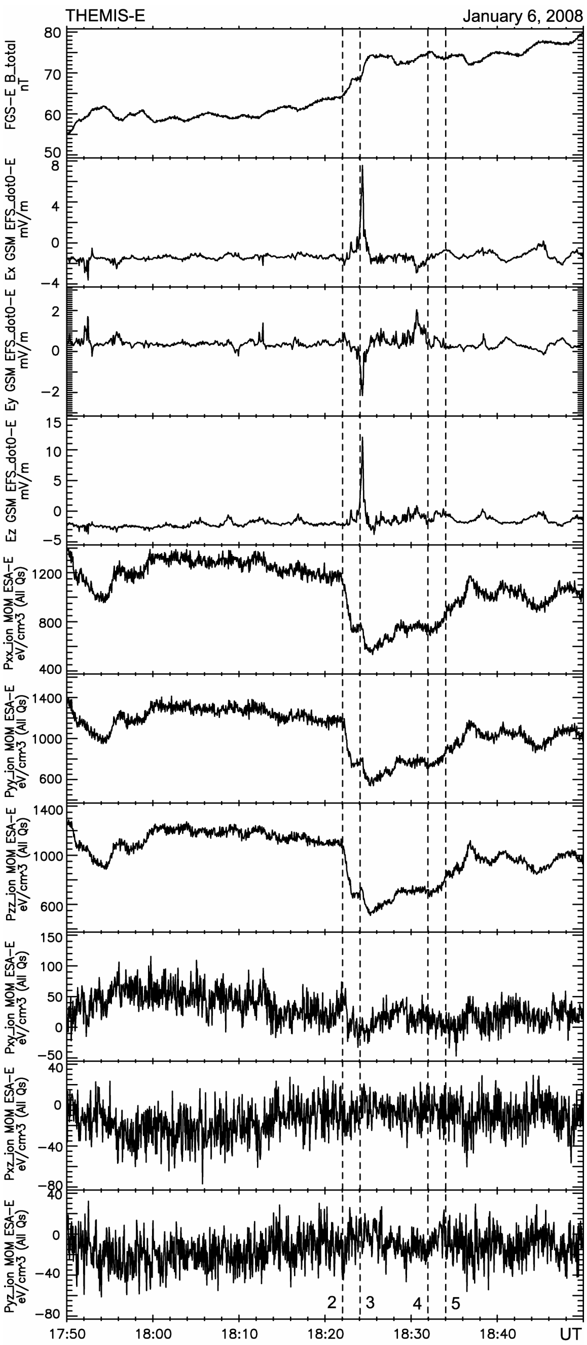

Figure 3. THEMIS-E data: total magnetic field, electric field components, components of the ESA (< 32 keV) ion energy density tensor.

From this figure one can see that the transient, narrow undispersed 2-10 keV ion structure was observed during the large impulse of the radial component *Ex* at the moment labeled ‘‘*A*’’ in Fig. 4 (this is the moment 3 in other figures of this report). This occurs during a sharp drop of the ion flux associated with the explosive stretching of the magnetic field observed by the THEMIS-E. One suppose that behind the outer boundary of the energetic ions in this time the satellite observed a local impulsive acceleration region.

Then, outside the acceleration region, the more large-scale dispersed ion structures *B* and *C* were recorded at 18:26:30 UT and 18:29:30 UT simultaneously with increase of the local dipolarization observed at the THEMIS-E.

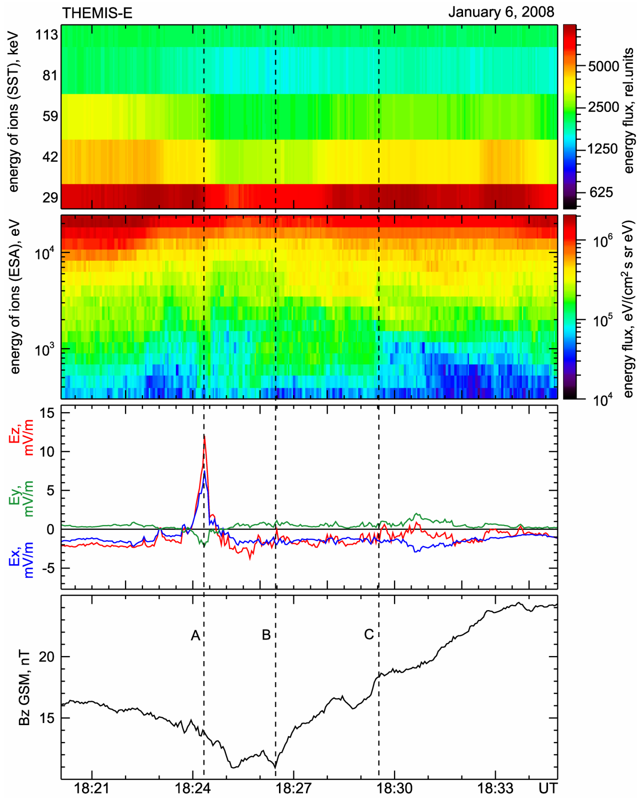

Figure 4. EDIS event observed by THEMIS-E.

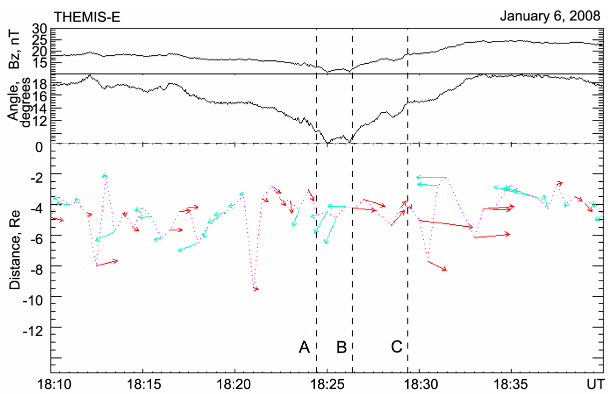

Figure 5. Bottom panel: perturbation currents *dJ* at scale *dt*=10 s deduced by THEMIS-E magnetic data. Top panel: total magnetic field.

Fig. 5 presents the perturbation currents *dJ* at scale *dt*=10 s calculated by THEMIS-E magnetic data under consideration. The procedure of the perturbation currents calculation was discussed in [*Kozelova and Kozelov,* 2013]. Current vector *dJ* (in arbitrary units) is presented on equatorial GSM plane. Current vectors directed to the left (right) corresponds to westward (eastward) current dj_W (dj_E). One can see that during the structure *A* the increased westward current dj_W was located at $r \sim$ 4-5 Re. During structures *B* and *C* the increased eastward current dj_E was located firstly at $r \sim$ 4 Re and then - at $r \sim$ 5-7 Re.

The main peculiarity of this interval was occurrence of prevail radial component of the perturbation current directed from the Earth. For the meridional components Jx <0 and Ex>0, therefore ($Jx \bullet Ex$)<0. So, during the explosive stretching these components were directed as in a generator of three-dimensional meridional current system (MCS) of type ***B*** in the post-midnight sector of the magnetosphere [*Boström*, 1964]. This is a new experimental result.

5. Conclusions

After sharp northward turning of IMF, the quick magnetic field line stretching and narrow non-dispersed 2-10 keV ion structure were observed at the morning sector of the magnetosphere implying a local impulsive acceleration appearance. Then, after ~2 min, the large-scale dipolarization and the EDIS at $L \sim 8.6$ were observed simultaneously with long-period magnetic pulsations at ground-based stations. No significant expansion phase activity occurred during this period probably because of short growth phase duration < 30 min. Note that usually the northward change of IMF triggers the expansion phase onset after ≥ 30 min of southward IMF [*Samson and Yeung*, 1986].

Further, ten minutes after northward IMF turning, the pseudo-breakup and injection of higher-energy ions occur at restricted (localized) part of the evening sector (22.7 MLT). Note, that the IMF changes from Bz = -3 nT to Bz = -1 nT (from the moment 1 to the moment 5) reduces the dawn-to-dusk component of the electric field across the tail. This IMF change might be considered as a possible substorm trigger [*Lyons et al*., 1995].

Mishin et al. [1992], and *Lazutin et al.* [1998] reported that the substorm active phase often consists of two separate phases, active-convective and expansion. During the active-convective phase the loading process is still strong and comparable with the unloading of energy, while during the expansion phase the unloading becomes the main process. The event on January 6, 2008, seem to present active-convective phase [*Mishin et al*., 1992, and *Lazutin et al*., 1998,] or by other words a spontaneous-stimulated substorm [*Kozelova et al*., 1989].

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