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# Dipolarization fronts in the magnetotail plasma sheet

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ABSTRACT

We present a THEMIS study of a dipolarization front associated with a bursty bulk flow (BBF) that was observed in the central plasma sheet sequentially at $X=-20.1$, $-16.7$, and $-11.0R_E$. Simultaneously, the THEMIS ground network observed the formation of a north–south auroral form and intensification of westward auroral zone currents. Timing of the signatures in space suggests earthward propagation of the front at a velocity of 300 km/s. Spatial profiles of current and electron density on the front reveal a spatial scale of 500 km, comparable to an ion inertial length and an ion thermal gyroradius. This kinetic-scale structure traveled a macroscale distance of $10R_E$ in about 4 min without loss of coherence. The dipolarization front, therefore, is an example of space plasma cross-scale coupling. THEMIS observations at different geocentric distances are similar to recent particle-in-cell simulations demonstrating the appearance of dipolarization fronts on the leading edge of plasma fast flows in the vicinity of a reconnection site. Dipolarization fronts, therefore, may be interpreted as remote signatures of transient reconnection.



## 1. Introduction

Dynamic events in planetary magnetospheres, such as substorms, bursty bulk flows (BBFs), and high-energy particle injections, involve coupling between macro- (global), meso- (typical time scale 1–10 min), and micro-scale (time scale less than 10 s, spatial scale less than or equal to ion gyroradius) processes. Macro-scale interaction between solar wind carrying the interplanetary magnetic field (IMF) and a planetary magnetosphere defines the boundary conditions for meso- and micro-scale processes. Bursty bulk flows (Angelopoulos et al., 1992), a meso-scale phenomenon, may result from a plasma sheet instability (tearing/reconnection, interchange) developed in response to changes in global-scale boundary conditions converting magnetic energy to plasma kinetic energy. Earthward BBFs observed in the plasma sheet within a wide range of geocentric distances from 5 to $30R_E$ are characterized by an increase in the magnetic field $Z$-component (normal to the undisturbed cross-tail current sheet) and a decrease in plasma density and plasma pressure (Ohtani et al., 2004). Thus, the BBFs display a reduction in plasma tube entropy ($pV^{\gamma}$), as described by the bubble model (see Wolf et al., 2009, for review). It is worth noting that entropy-depleted flux tubes (bubbles) are a natural consequence of magnetic reconnection in the magnetotail current sheet (e.g., Wolf et al., 2009). The earthward reconnection outflow carrying an enhanced northward magnetic field ($B_z>0$ in the GSM coordinate system) may reach velocities comparable with the asymptotic Alfvén speed, calculated using the lobe magnetic field (800–1000 km/s) in the reconnection inflow region.

BBFs carrying an enhanced magnetic flux interact with the ambient plasma sheet, which leads to formation of thin boundary layers and a system of field-aligned currents (FACs) that link the BBFs to the ionosphere (e.g., Sergeev et al., 1996; Birn et al., 2004; Nakamura et al., 2004). FAC closure through the ionosphere by the electrojet current results in perturbations in the geomagnetic field observed by ground-based magnetometers (e.g., McPherron et al., 1973). Auroral signatures related to BBFs include polar boundary intensifications (PBI, Zesta et al., 2000) and streamers, often with

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north–south orientation (Sergeev et al., 2000a, b; Nakamura et al., 2001).

The thin boundary layer separating BBF plasma from the ambient plasma sheet, often observed as a step-like increase in the $B_z$ component, is referred to as a dipolarization front (e.g., Nakamura et al., 2002; Sitnov et al., 2009; Runov et al., 2009). Dipolarization front is comparable to an ion thermal gyroradius (Runov et al., 2009; Sergeev et al., 2009). A dipolarization front is a kinetic-scale plasma structure, a vertical localized current sheet (Sergeev et al., 2009).

In this paper we discuss detailed observations of a dipolarization front associated with a bursty bulk flow detected successively by four THEMIS probes close to the midnight meridian in the plasma sheet. Multi-spacecraft measurements allow us to follow the front's motion from mid-tail to the near-Earth plasma sheet and observe the evolution of its meso- and micro-scale properties. Simultaneous ground-based all-sky camera and magnetometer observations make it possible to identify the front's optical and magnetic signatures in the auroral zone. This combination, along with solar wind/IMF monitoring provided by Cluster, gives a comprehensive picture illustrating multi-scale magnetotail dynamics.

## 2. Data analysis

### 2.1. Overview of global (macro) scale observations

We start with a brief overview of space- and ground-based observation between 0700 and 0900 UT on February 27, 2009. The Cluster spacecraft, located in the solar wind upstream of the bow shock, provided monitoring of solar wind and IMF conditions. According to Ion Spectrometer (CIS, Rème et al., 2001) data, the solar wind velocity absolute value at the Cluster spacecraft varied between 450 and 490 km/s. No significant variations in solar wind density were observed. The Cluster Fluxgate Magnetometer (FGM, Balogh et al., 2001) shows that IMF $B_z$ was predominantly northward between 0130 and 0400 UT and between 0440 and 0700 UT. The IMF at Cluster-3 (C3), located at [17.8, 2.2, −11.0] $R_E$ (GSM coordinate system is used throughout this paper), from 0700 to 0900 UT is shown in Fig. 1, panels a–c.

The THEMIS pseudo-AL index, calculated from the THEMIS magnetometer array in Northern America (Russell et al., 2008; Mann et al., 2008), began to increase gradually, while the $\delta B_x$ (daily median value subtracted) at the CANMOS Yellowknife station (YKC, 69.11°N, 297.9°E, geomagnetic) showed a sharp

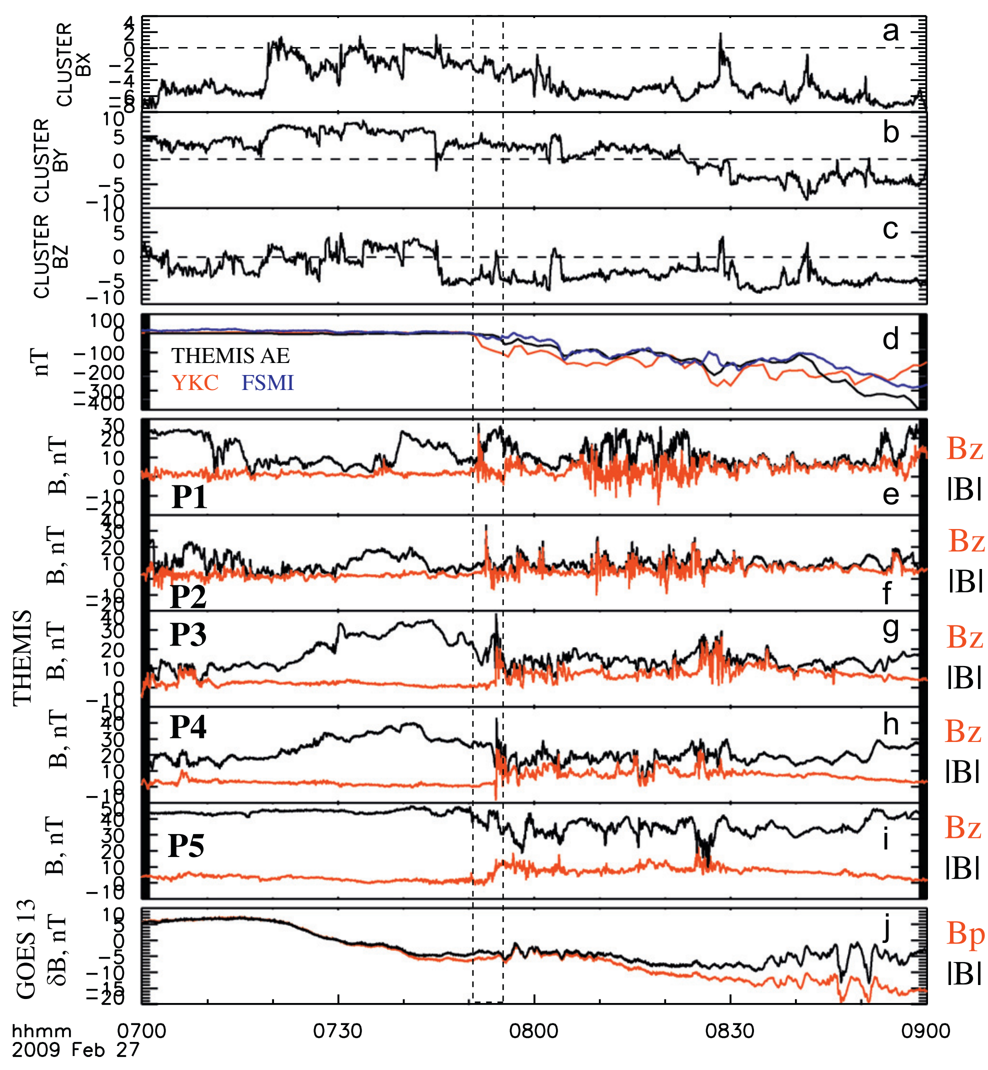


**Fig. 1.** Overview of space and ground-based magnetic field observations between 0700 and 0900 UT on February 27, 2009: GSM components of the IMF from Cluster 3 (a–c), THEMIS pseudo-AL, $\delta B_x$ at FSMI (blue) and YKC (red) (d), absolute value and *Z*-component of the magnetic field from THEMIS spacecraft (e–i), absolute value and *p*-component at the geosynchronous GOES-13 satellite (j). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)