FTE Dynamics and Effects on Local and Remote Regions near the Dayside Magnetopause Reconnection Layer: Using the Space Weather Explorer at CCMC

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Outline

• CCMC: Space Weather Explorer and Magnetic Topology Maps for an FTE

• THEMIS example: 8 June 2007 FTE

• High-resolution (0.0626) $R_E$ CCMC MHD simulation of FTE: Comparison with THEMIS

• Summary
Magnetic Topology Map

06/08/2007 Time = 22:05:00 UT \( y = 4.80R_E \)

Model at CCMC: BATS-R-US
Introduction

Main characteristics of FTEs [e.g. Paschmann et al., 1982; Sibeck et al., 2008]:

1. Bipolar variation of normal magnetic field.
2. Enhanced magnetic field strength at FTE core (guide-field situation).
3. Imbalance of total pressure (\(P_{\text{tot}}=P_B+P_i+P_e\)) measured inside and outside.
4. Mixed particle (magnetosphere & magnetosheath) populations inside the FTE.
5. Dayside FTEs occur most frequently for southward IMF.
Spacecraft locations on 20070608 2200-2400 UT

2130-2330 UT

\[ \begin{align*}
\gamma_{GSM} (R_E) & \quad 6.5 \\
\chi_{GSM} (R_E) & \quad 9.0, 9.5, 10.0, 10.5 \\
Z_{GSM} (R_E) & \quad -2.0 \\
\end{align*} \]

Relative Distance

<table>
<thead>
<tr>
<th>Time</th>
<th>( X_{GSM} )</th>
<th>( Y_{GSM} )</th>
<th>( Z_{GSM} )</th>
<th>HH:MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.2</td>
<td>3.8</td>
<td>-1.3</td>
<td>-1.3</td>
<td>2200</td>
</tr>
<tr>
<td>9.8</td>
<td>4.8</td>
<td>-1.3</td>
<td>-1.3</td>
<td>2300</td>
</tr>
<tr>
<td>10.3</td>
<td>5.6</td>
<td>-1.4</td>
<td>-0.0</td>
<td>0000</td>
</tr>
</tbody>
</table>

Jun 08 Jun 09
Solar wind context:
08 June 2007 2100-0000 UT

ACE solar wind data shifted to match TH-B clock angle. Wind shifted to match ACE (Bx, By, |B|).

Rw=(257.5, 50.6, 22.7) Re (GSE)
Ra=(233.9, -40.4, 10.3) Re (GSE)
dR=95 Re

Steady solar wind speed and IMF conditions.

Gradual dynamic pressure increase (1 to 1.5 nPa) at TH-B magnetopause transition.
Evidence for Reconnection at TH-B and TH-C
Walen relation satisfied at TH-B

\[ V_{H\tau} = [-94,265,80] \text{ km/s} \]
\[ D/D0 = 0.0194 \]
\[ \text{slope} = 0.87 \]
\[ \text{c.c.} = 0.97 \]

\[ V \times B \text{ (mV/m)} \]
\[ V_A \text{ (km/s)} \]

TH-B 2007-06-08
22:27:00-22:32:00 UT
Walen relation satisfied at TH-C
High-resolution (0.0626 RE) CCMC BATSRUS MHD simulation using upstream solar wind conditions on 8 June 2007
CCMC/BATSRUS
High Resolution (0.0626 RE)

Virtual "probes" along the magnetopause normal at GSM (X,Y,Z) RE:
- (8.91, 4.45, -1.25)
- (9.56, 4.71, -1.25)
- (10.30, 5.00, -1.25)
- (11.60, 5.52, -1.25)
CCMC/BATSRUS
High Resolution (0.0626 RE)

06/08/2007 Time = 22:03:50 UT z = -1.25R_E

Virtual “probes” along the magnetopause normal at GSM (X,Y,Z) RE:
- (8.91, 4.45, -1.25)
- (9.56, 4.71, -1.25)
- (10.30, 5.00, -1.25)
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Model at CCMC: BATSRUS
CCMC/BATSRUS
High Resolution (0.0626 RE)

Virtual “probes” along the magneto-pause normal at GSM (X,Y,Z) RE:
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(  9.56, 4.71, -1.25)
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CCMC/BATSRUS
High Resolution (0.0626 RE)

06/08/2007 Time = 22:04:20 UT z = -1.25Re

Virtual “probes” along the magneto-pause normal at
GSM (X,Y,Z) RE:
- (8.91, 4.45, -1.25)
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CCMC/BATSRUS
High Resolution (0.0626 RE)

06/08/2007 Time = 22:04:40 UT z = -1.25R_E

Virtual "probes" along the magnetopause normal at
GSM (X,Y,Z) RE:
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High Resolution (0.0626 RE)

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Virtual “probes” along the magnetopause normal at GSM (X,Y,Z) RE:
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Model at CCMC: BATSRUS
CCMC/BATSRUS
High Resolution (0.0626 RE)

06/08/2007 Time = 22:05:30 UT z= -1.25R_E

Virtual “probes” along the magnetopause normal at GSM (X,Y,Z) RE:
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Model at CCMC: BATSRUS
CCMC time series from a series of 30 “probes” (0.1 RE apart) along the magnetopause normal

\((X,Y,Z)=(8.91, 4.45, -1.25)\) RE

\((X,Y,Z)=(9.56, 4.71, -1.25)\)

\((X,Y,Z)=(10.30, 5.00, -1.25)\)

\((X,Y,Z)=(11.60, 5.52, -1.25)\)
Is there any evidence of the BL signature at the negative BN spikes? Yes.

Note: TH-C BM and BL signatures of the magnetosheath structure very similar also to MHD prediction of this FTE.
Is there any evidence of a magnetospheric VN “wave”?
Is there any evidence of a magnetospheric VN “wave”?

Yes, and it occurs around the time of the dayside cold ion dispersion signature at the time of the “FTEs”.

![Diagram showing THEMIS-C data with various parameters like electric field (E), magnetic field (B), ion velocity (V), and ion density (N). The data spans from 2200 to 2230 hours with specific values for Xgsm, Ygsm, Zgsm, and Xhmm, Yhmm, Zhmm, indicating data from 2007 Jun 08.]
CCMC time series profiles from all 30 “probes”:

Central probe at (X,Y)=(10.3,5.0) indicated by vertical line.

Times when FTE is closest to central probe at this (X,Y) are indicated by “F”.

06/08/2007 Time = 23:06:00 UT z = −1.25R_E
CCMC time series profiles from all 30 "probes":

Central probe at \((X,Y)=(10.3,5.0)\) indicated by vertical line.

Times when FTE is closest to central probe at this \((X,Y)\) are indicated by "F".

Model at CCMC: BATSRUS
CCMC time series profiles from all 30 “probes”:

Central probe at \((X,Y) = (10.3, 5.0)\) indicated by vertical line.

Times when FTE is closest to central probe at this \((X,Y)\) are indicated by “F”.

06/08/2007 Time = 22:06:00 UT \(z = -1.25R_E\)

Model at CCMC: BATSRUS
Unusual bifurcated dayside magnetopause current sheet when no large-scale FTE was observed....
Conclusions

- THEMIS confirms that remote bipolar signatures are that of one (likely) main flux tube in the active magnetopause reconnection layer.

- MHD simulation suggests that the observed bifurcated magnetopause current sheet may have been generated in the wake of a passing FTE.
Conclusions

- MHD simulation also provides good agreement with the *uncharacteristic negative BN* feature of the remotely observed magnetosheath FTE signature.

- The passing FTE generates a *wave signature in the VN component* with a maximum VN signal at some distance Earthward of the magnetopause. $\mathbf{E} \times \mathbf{B}$ consistent with $\mathbf{V}$. Very good candidate to explain the energy-time dispersed cold ion signatures observed by THEMIS.
Bipolar field behavior is thought to result primarily from the draping of the magnetosheath field around a single reconnected flux tube [Paschmann et al., 1982].

Schematic view of pre-noon magnetopause from the Sun. IMF $B_z<0$ and IMF $B_y>0$ (blue). [NOTE: THEMIS event for IMF $B_y<0$ at post-noon side]
Time-dependent ("bursty") reconnection

Reconnection is activated, reaches a certain merging rate and then ceases.

Simulation by Scholer [1988] (right) showing top-half of reconnection plane after reconnection has been forced to cease.

Very top is here unaffected by reconnection exhaust. A bulge similar in shape to observed FTEs is generated.
## Summary FTE Observations

| FTE | Time (UT) | BN sequence                      | |B| |
|-----|-----------|----------------------------------|---|
| #1  | 2210      | “+/-” (all)                      | B | msheath |
| #2  | 2217      | “+/-” (all)                      | B | msphere |
| #3  | 2252      | “+/-” (all)                      | B | |
| #4  | 2325      | “-” (D,C) & “+/-/+” (E)          | B | |
| #5  | 2338      | “-” (D) & “+/-/+” (C,E)          | B | |