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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[4]Technische Universitat, Braunschweig, Germany
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[6]IGPP, University of California, Los Angeles, CA, USA

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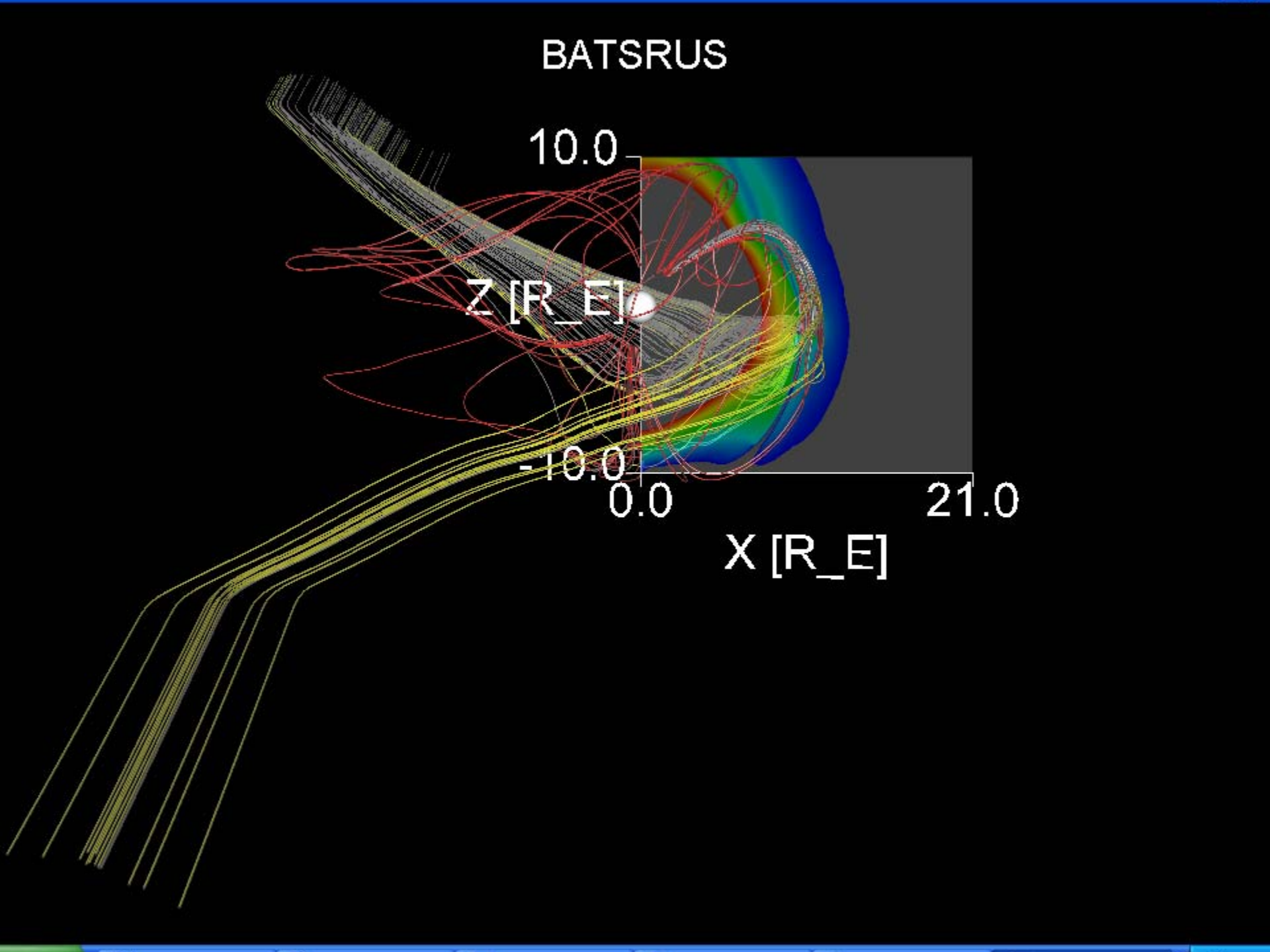
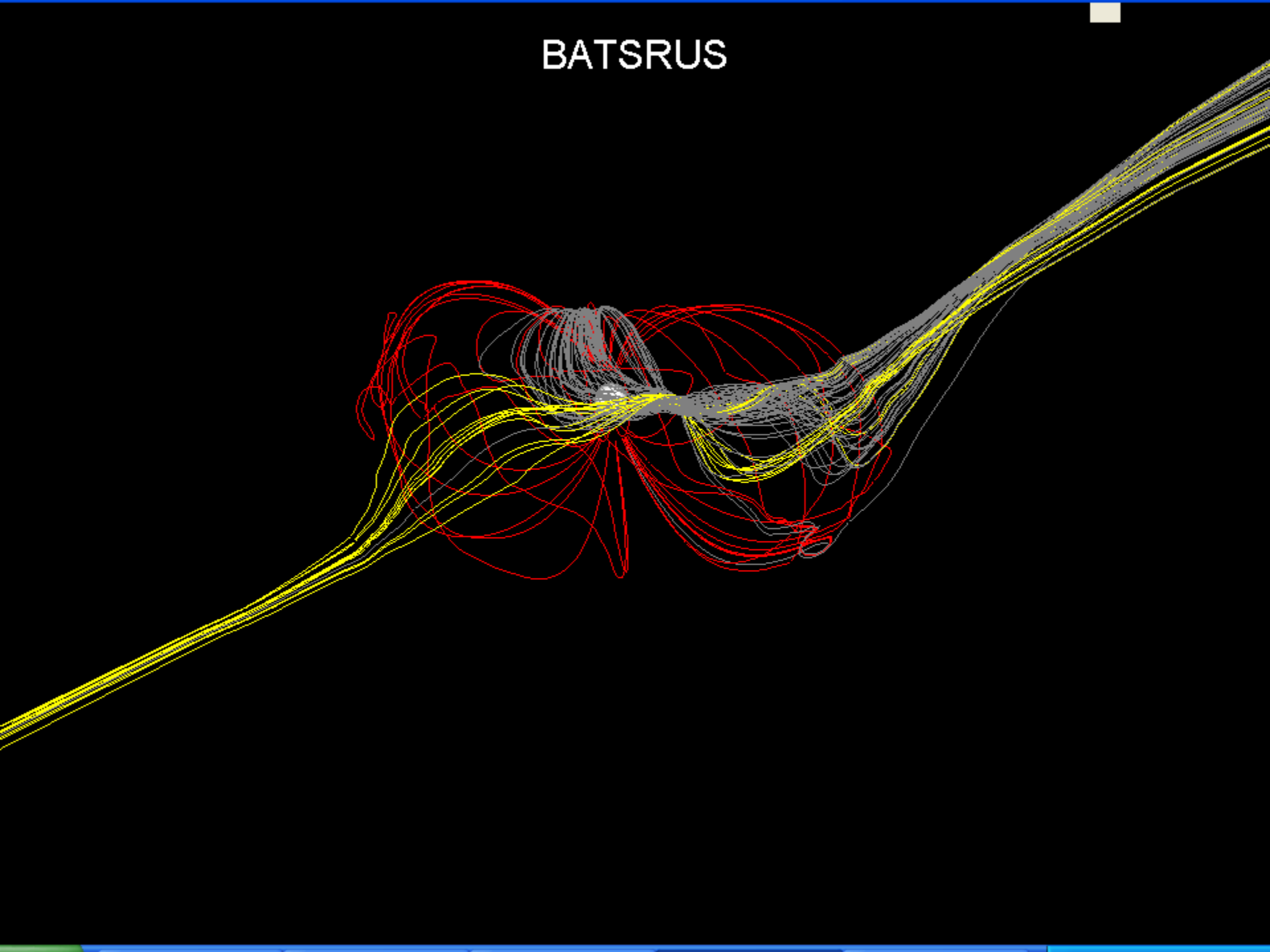
Outline

- 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


BATSRUS
10.0
Z [R_E]
-10.0
0.0
21.0
X [R_E]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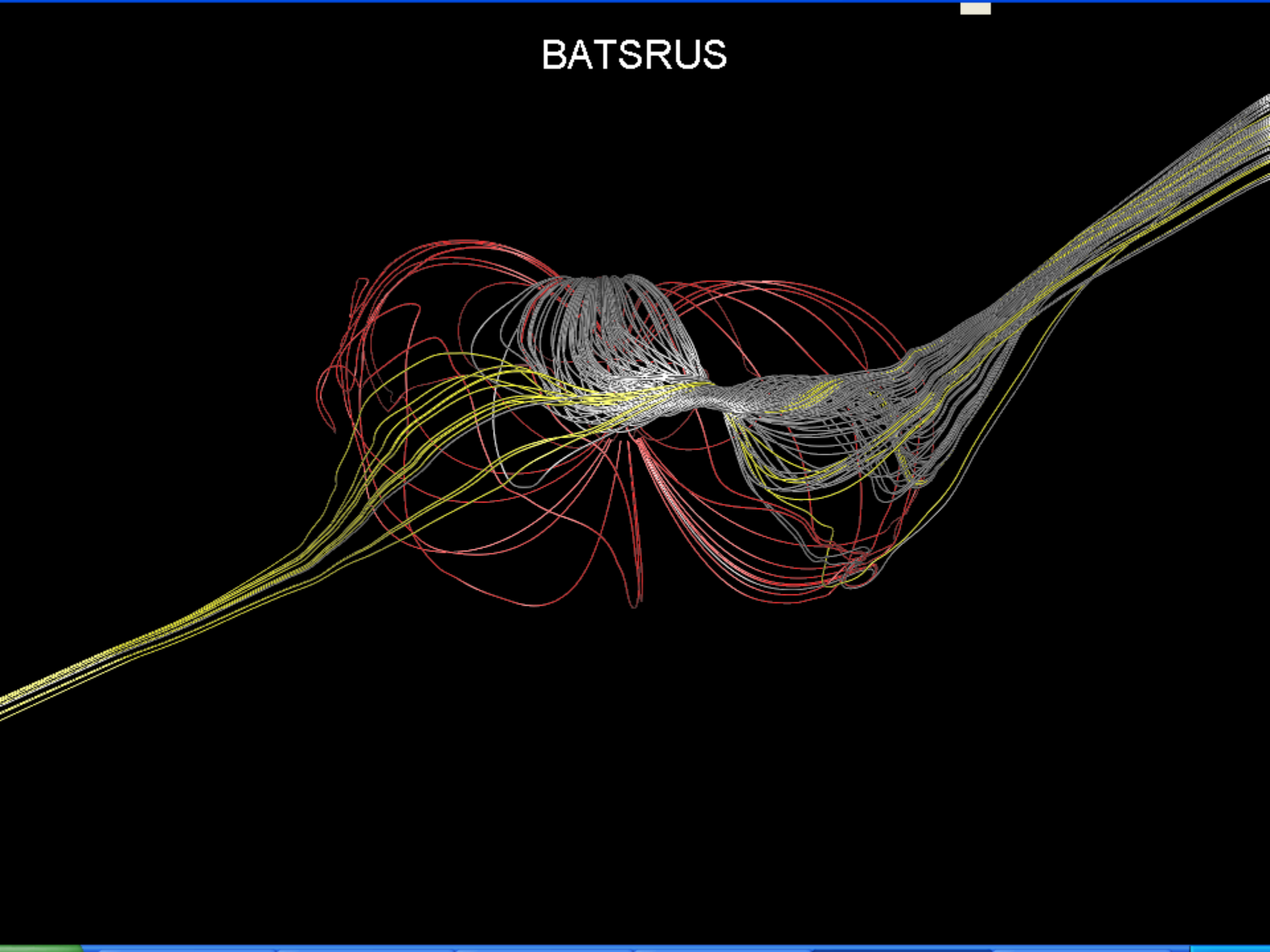
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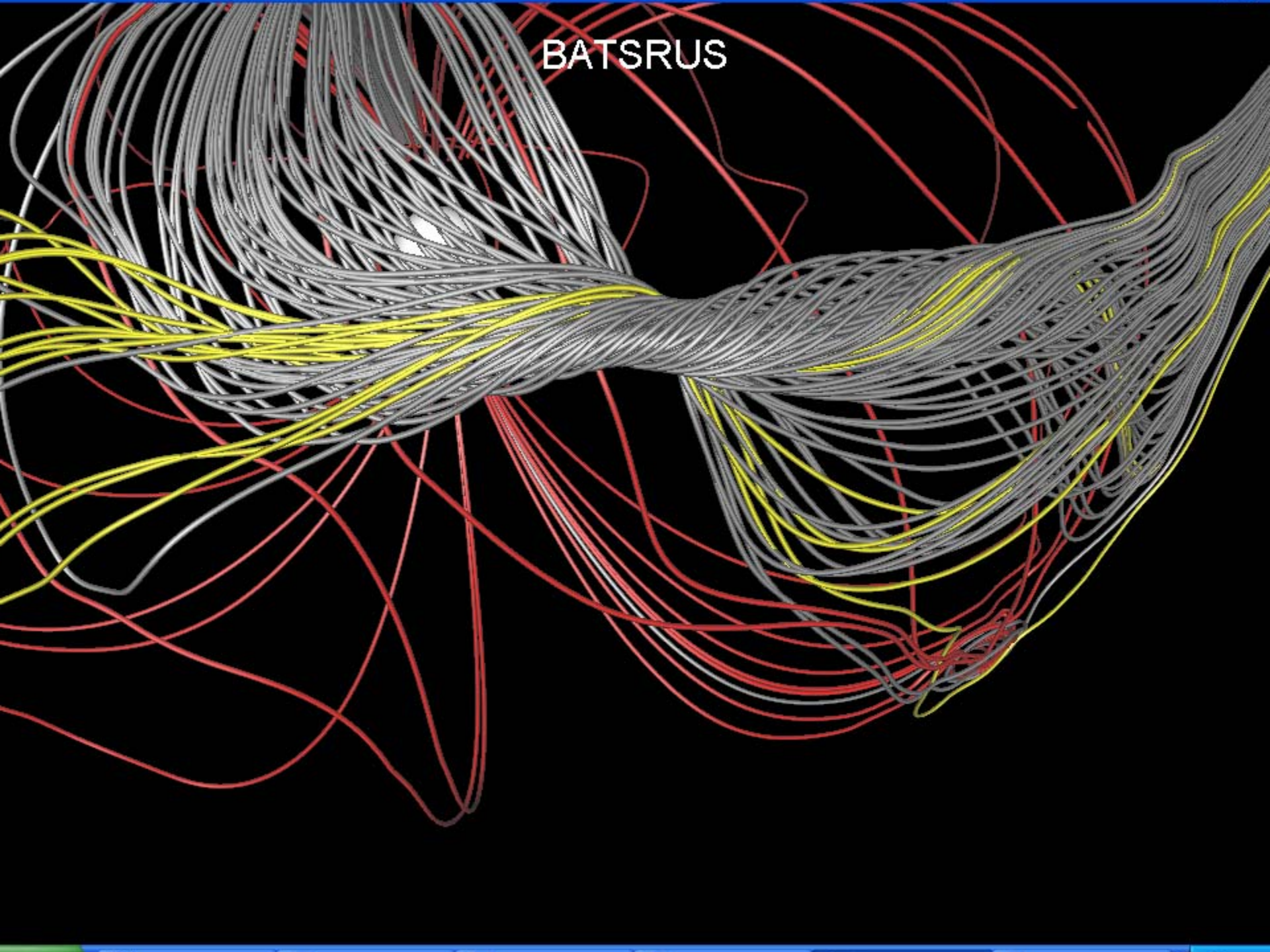
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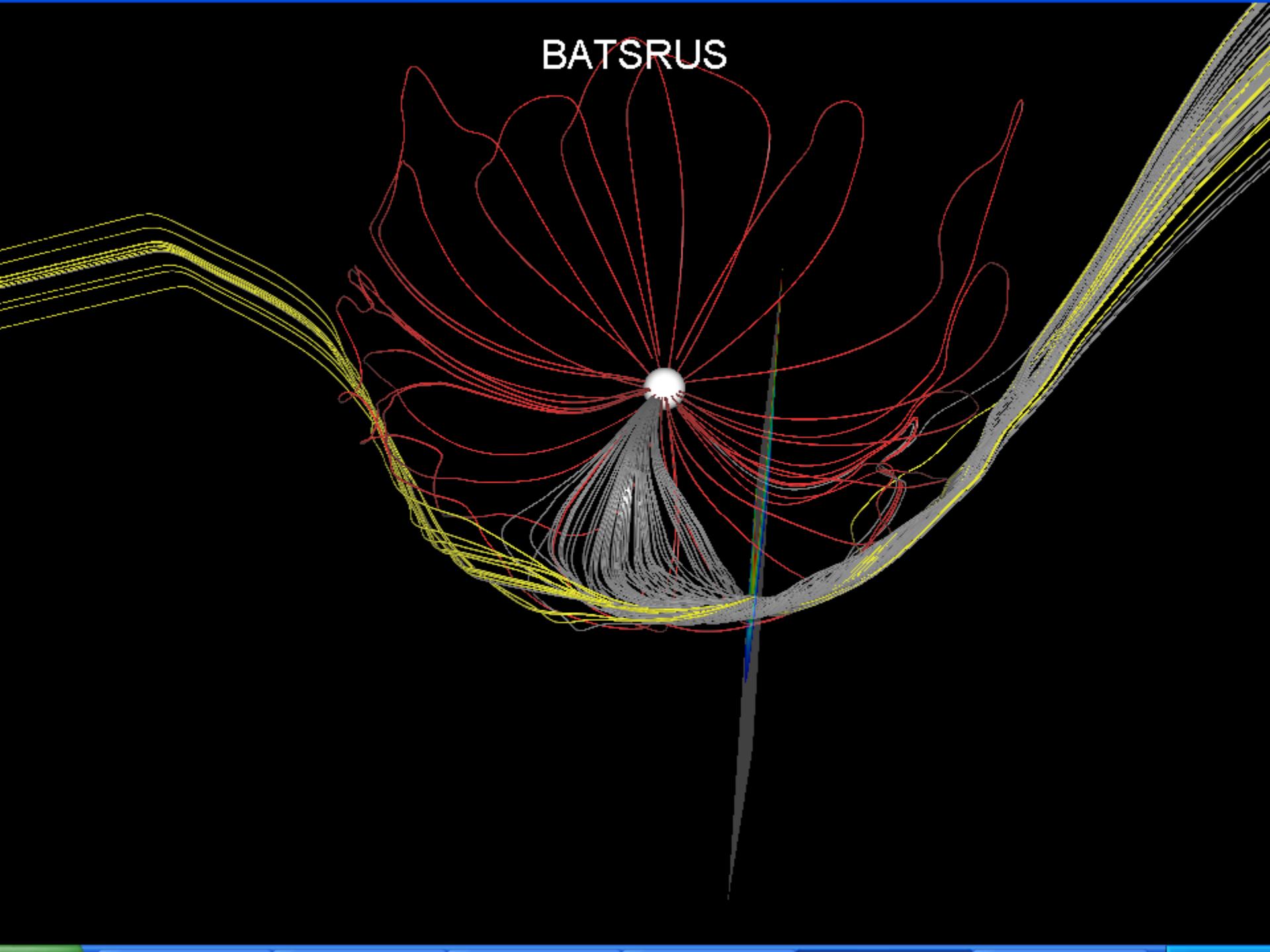
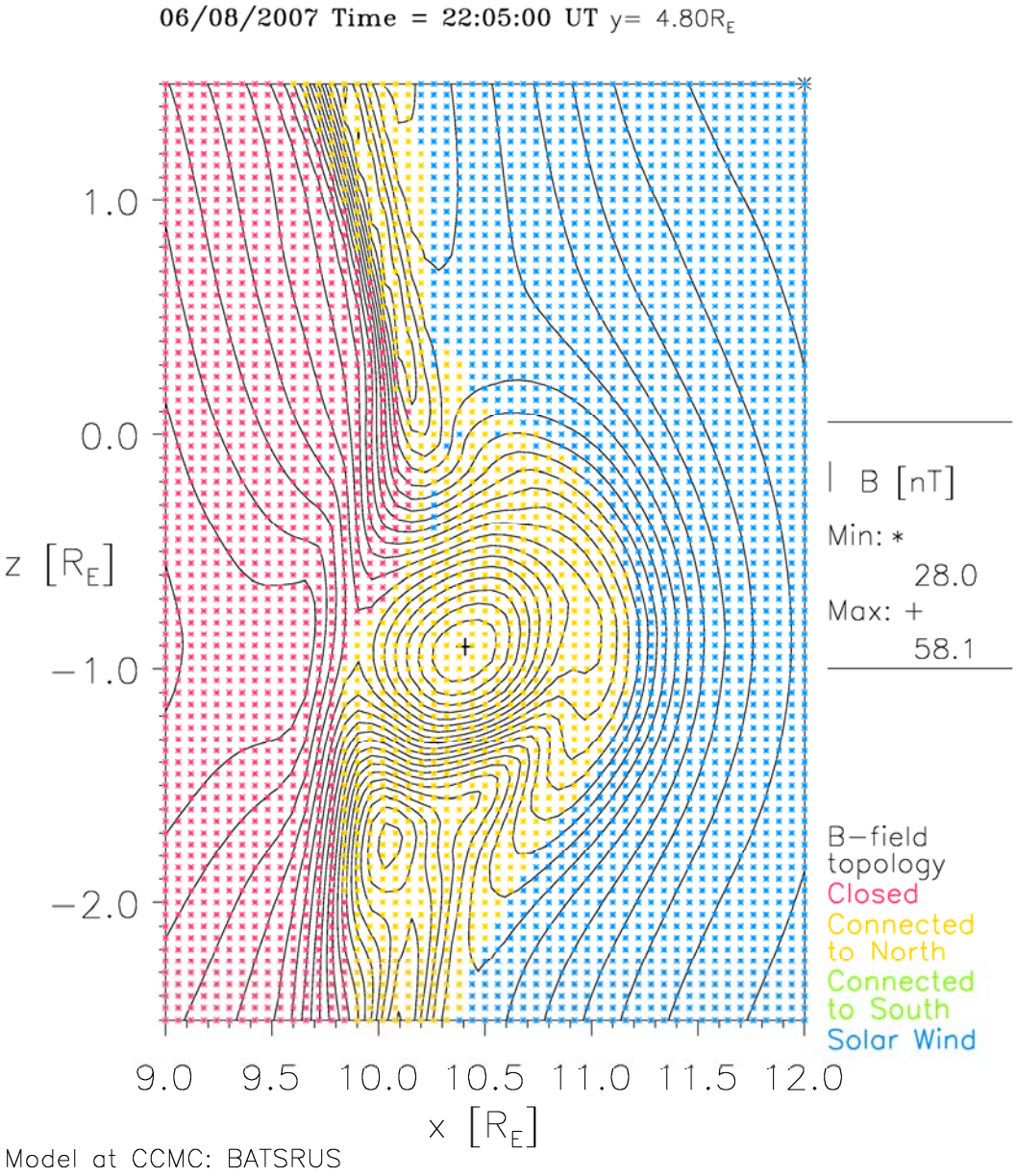
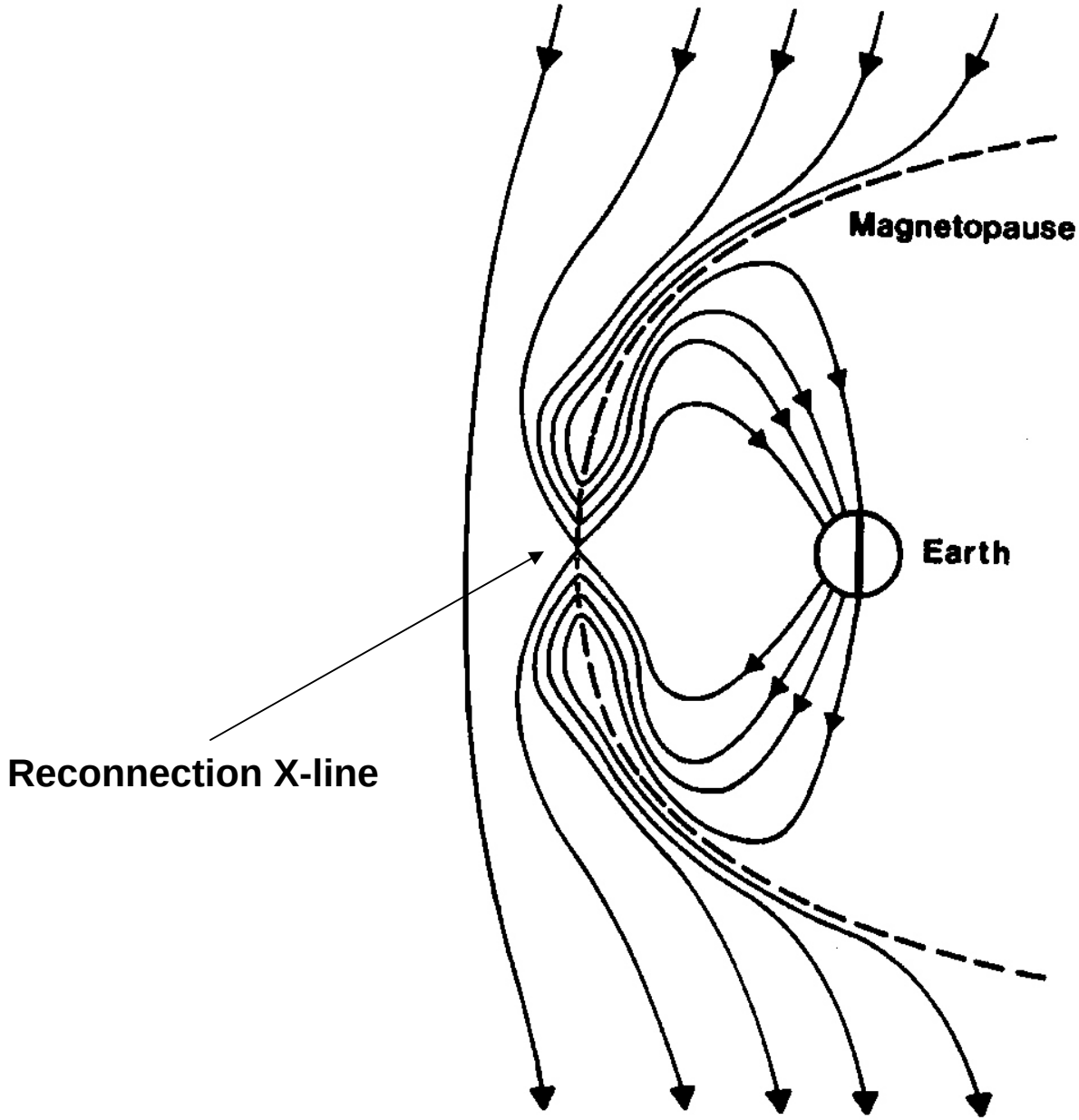

BATSRUS

Magnetic Topology Map



Model at CCMC: BATSRUS



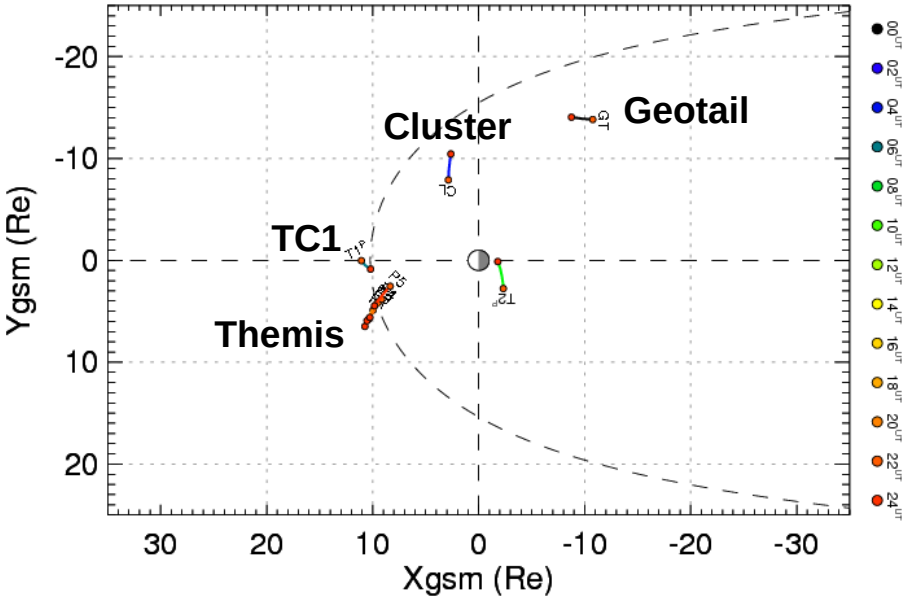
Scholer [1988]

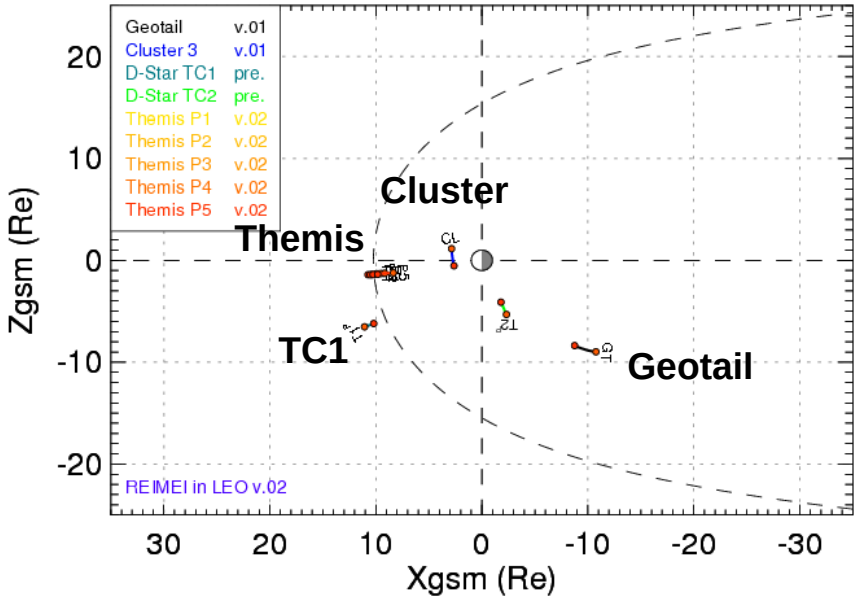
Introduction

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

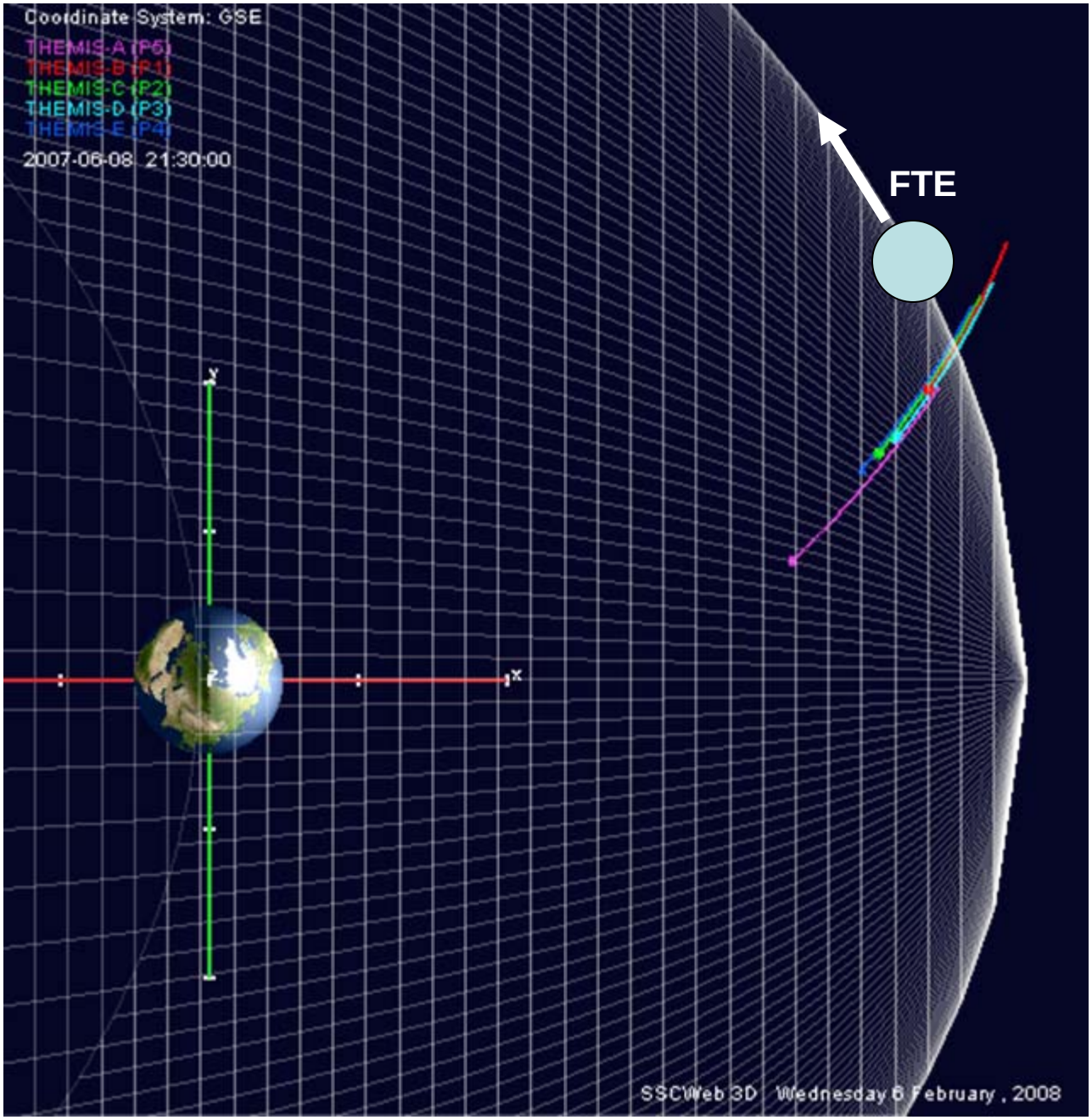
(1) Bipolar variation of normal magnetic field.
(2) Enhanced magnetic field strength at FTE core (guide-field situation).
(3) Imbalance of total pressure (Ptot=PB+Pi+Pe) measured inside and outside.
(4) Mixed particle (magnetosphere & magnetosheath) populations inside the FTE.
(5) Dayside FTEs occur most frequently for southward IMF.

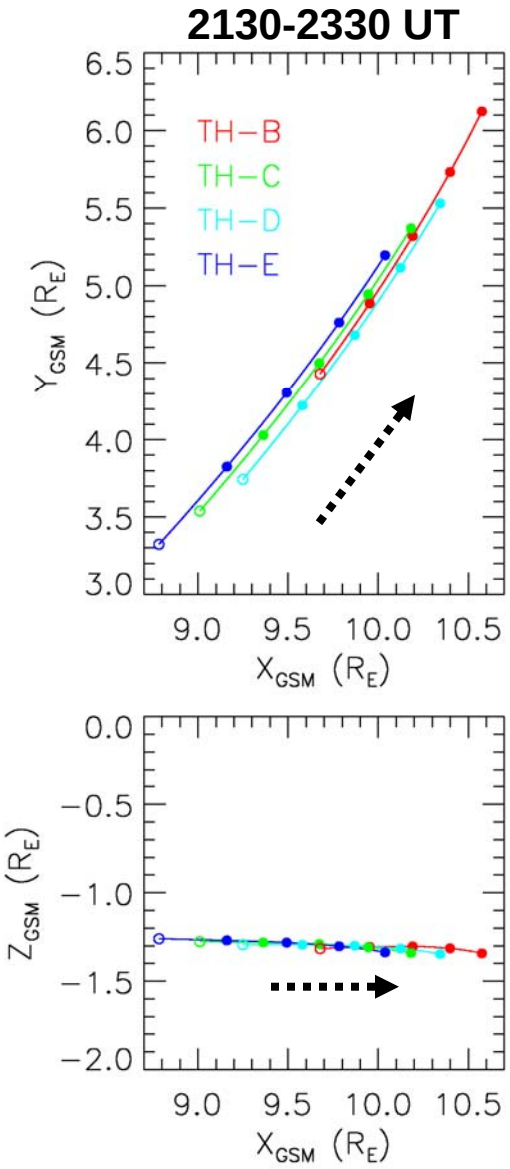
Spacecraft locations on 20070608 2200-2400 UT

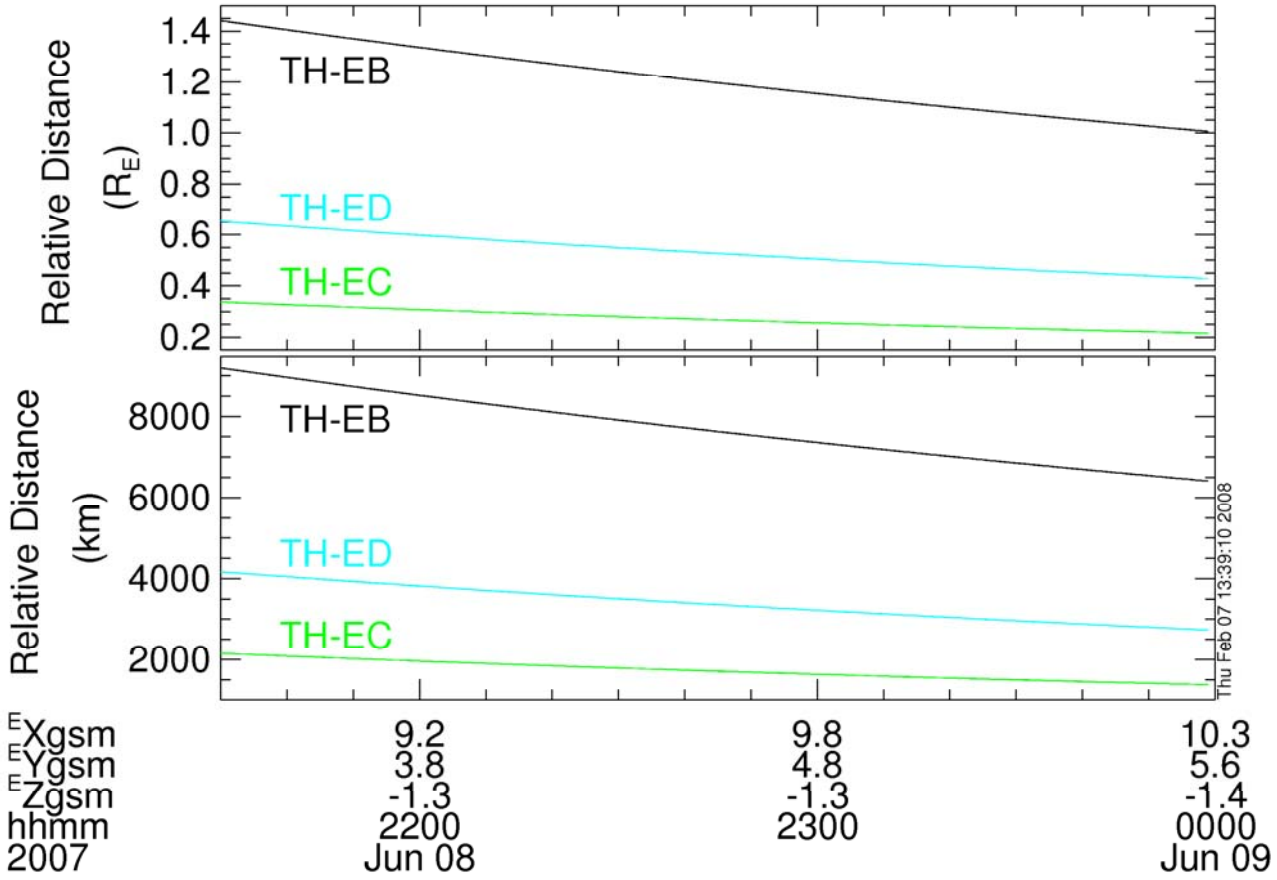




acknowledgment: ISAS/JAXA “Conjunction Event Finder” http://www.darts.isas.jaxa.jp/stp/cef/cef.cgi


Coordinate System: GSE
THEMIS-A (P5)
THEMIS-B (P1)
THEMIS-C (P2)
THEMIS-D (P3)
THEMIS-E (P4)
2007-06-08 21:30:00
FTE
Y
Z
X
SSCWeb 3D Wednesday 6 February , 2008


2130-2330 UT
TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)
Z_{GSM} (R_E)
X_{GSM} (R_E)


Relative Distance (R_E)
TH-EB
TH-ED
TH-EC
Relative Distance (km)
TH-EB
TH-ED
TH-EC
Thu Feb 07 13:39:10 2008
E Xgsm 9.2 9.8 10.3
E Ygsm 3.8 4.8 5.6
E Zgsm -1.3 -1.3 -1.4
hhmm 2200 2300 0000
2007 Jun 08 Jun 09

Solar wind context:

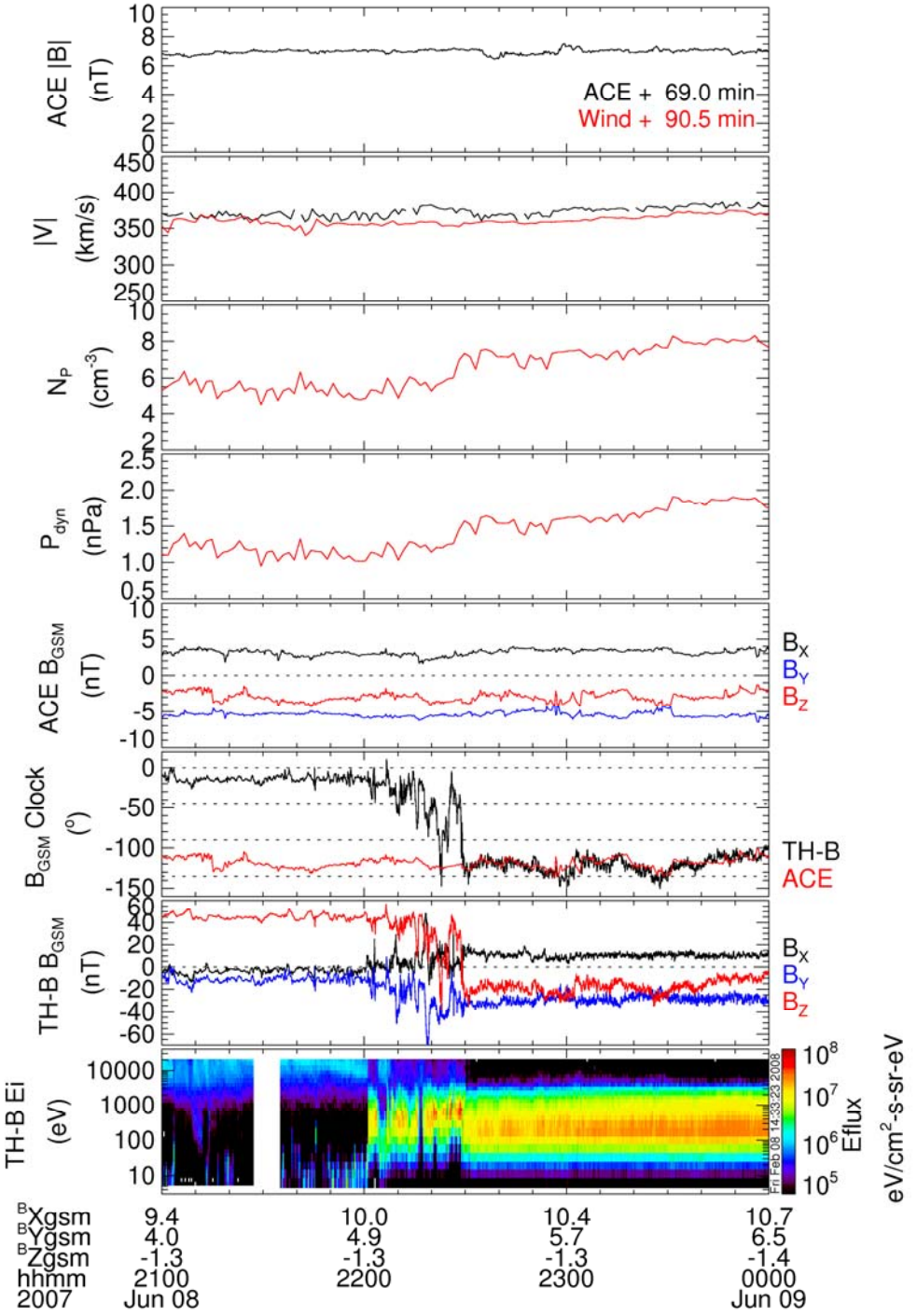
08 June 2007 2100-0000 UT

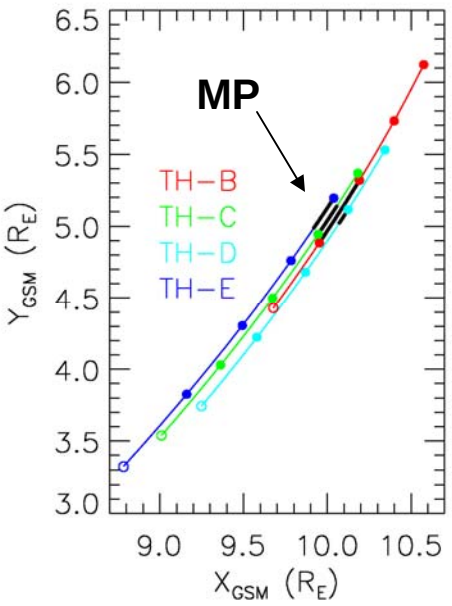
ACE solar wind data shifted to match TH-B clock angle. Wind shifted to match ACE (Bx, By, |B|).

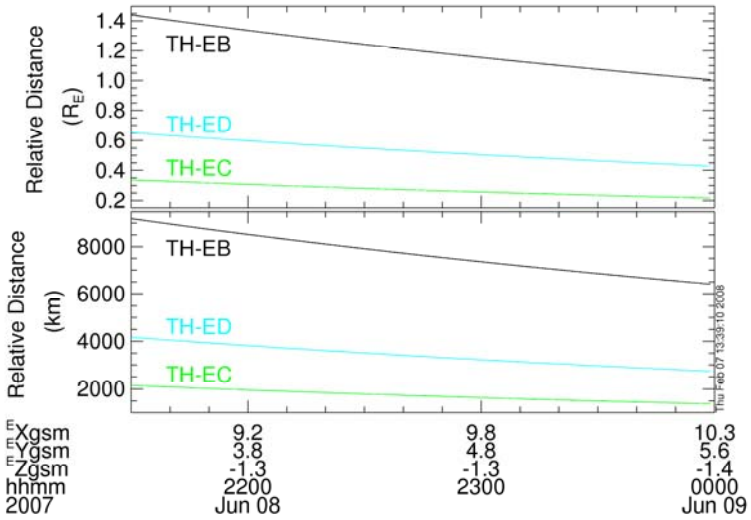
Rw=(257.5, 50.6, 22.7) Re (GSE)
Ra=(233.9, -40.4, 10.3) Re (GSE)
dR=95 Re

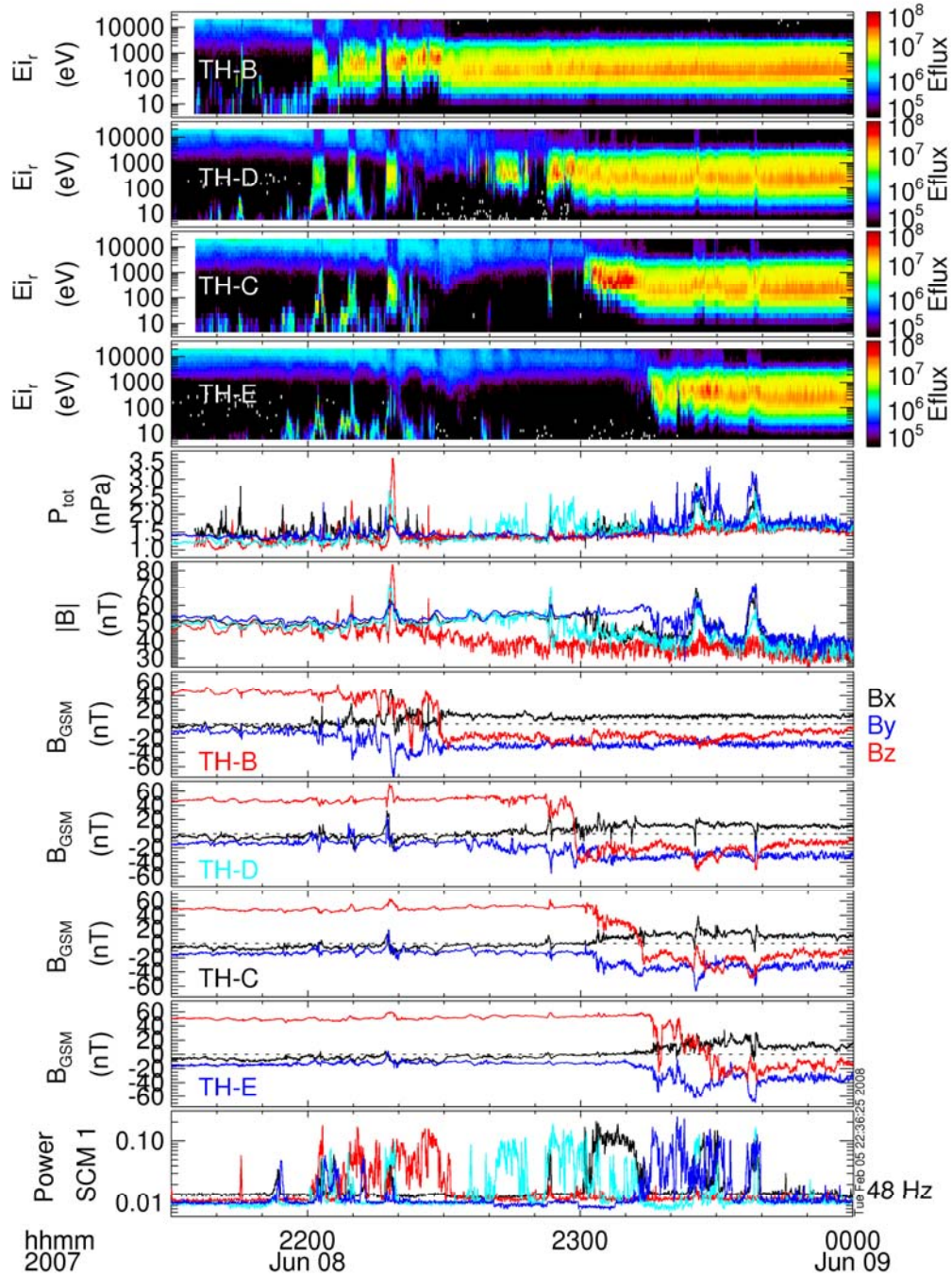
Steady solar wind speed and IMF conditions.

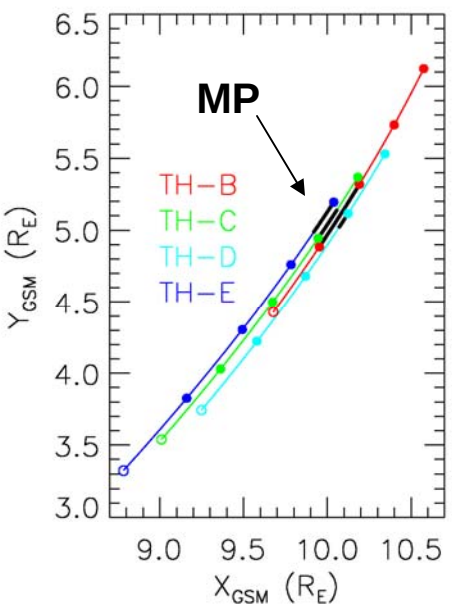
Gradual dynamic pressure increase (1 to 1.5 nPa) at TH-B magnetopause transition.

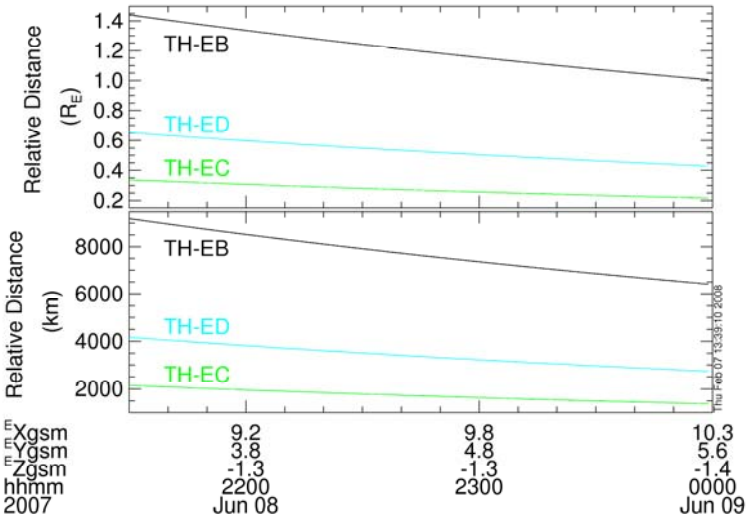


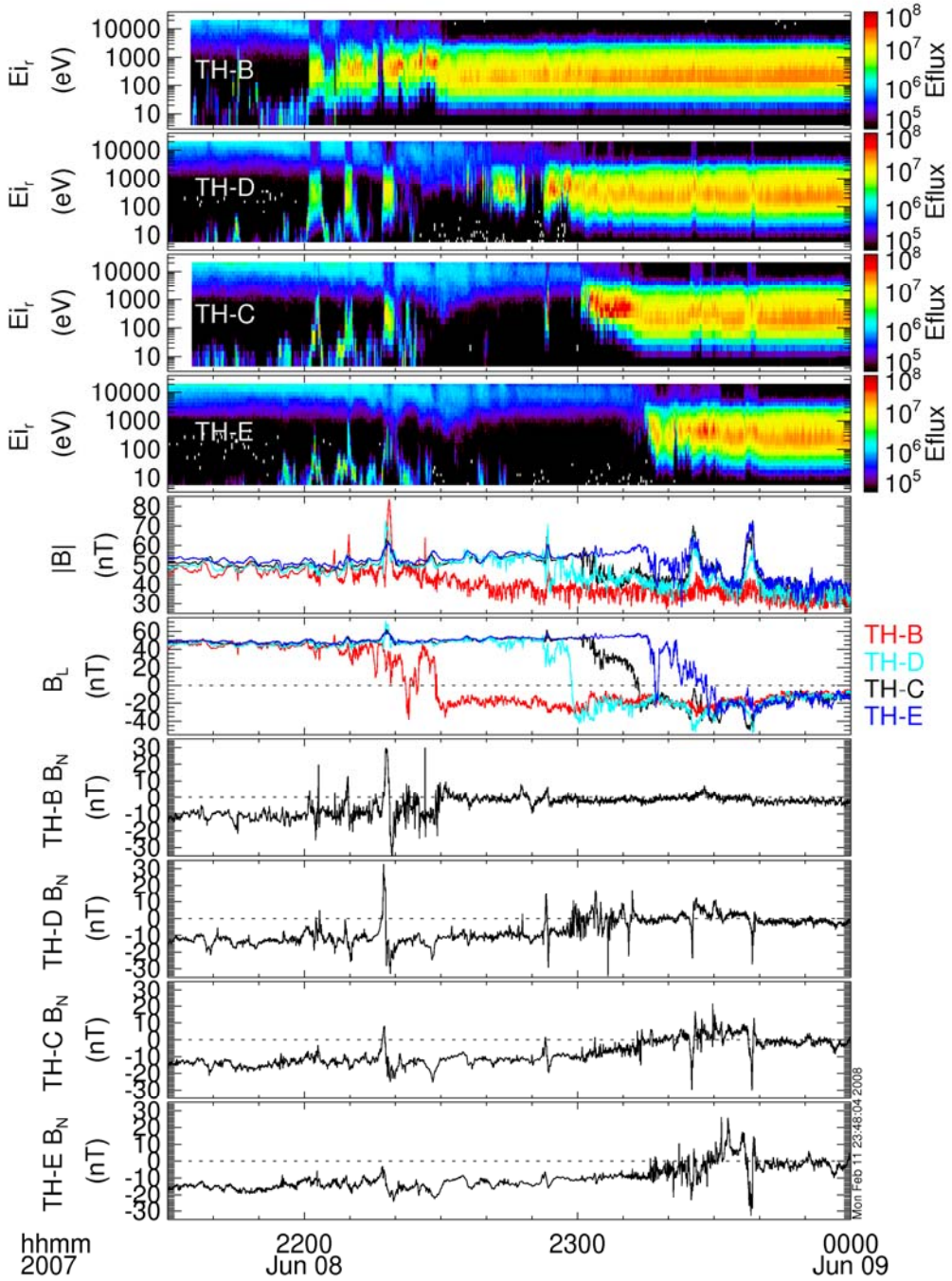

MP
TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)

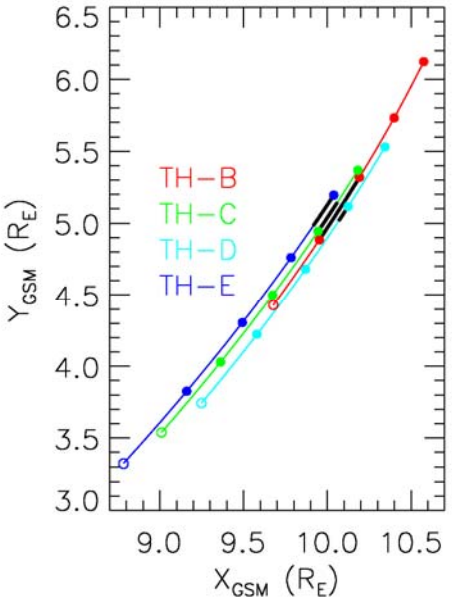

Relative Distance (R_E)
TH-EB
TH-ED
TH-EC
Relative Distance (km)
Xgsm 9.2 9.8 10.3
Ygsm 3.8 4.8 5.6
Zgsm -1.3 -1.3 -1.4
hhmm 2200 2300 0000
2007 Jun 08 Jun 09

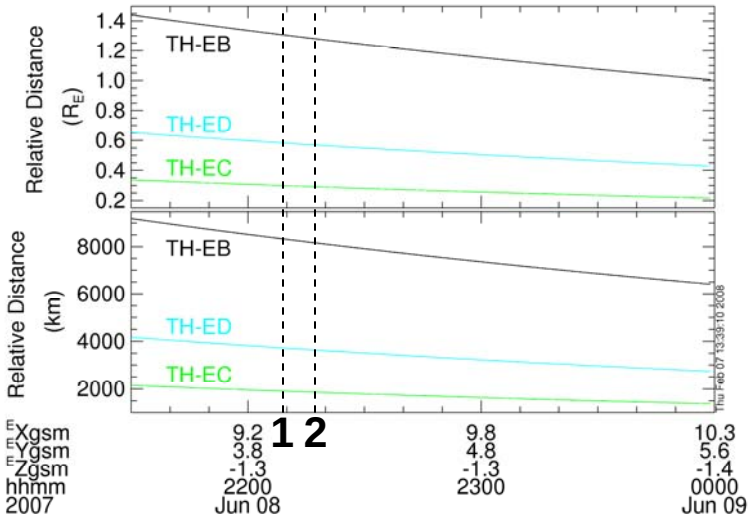

Ei$_r$ (eV)
TH-B
TH-D
TH-C
TH-E
Eflux
P_{tot} (nPa)
|B| (nT)
B_{GSM} (nT)
Bx
By
Bz
Power SCM 1
48 Hz
hhmm
2007
2200
Jun 08
2300
0000
Jun 09

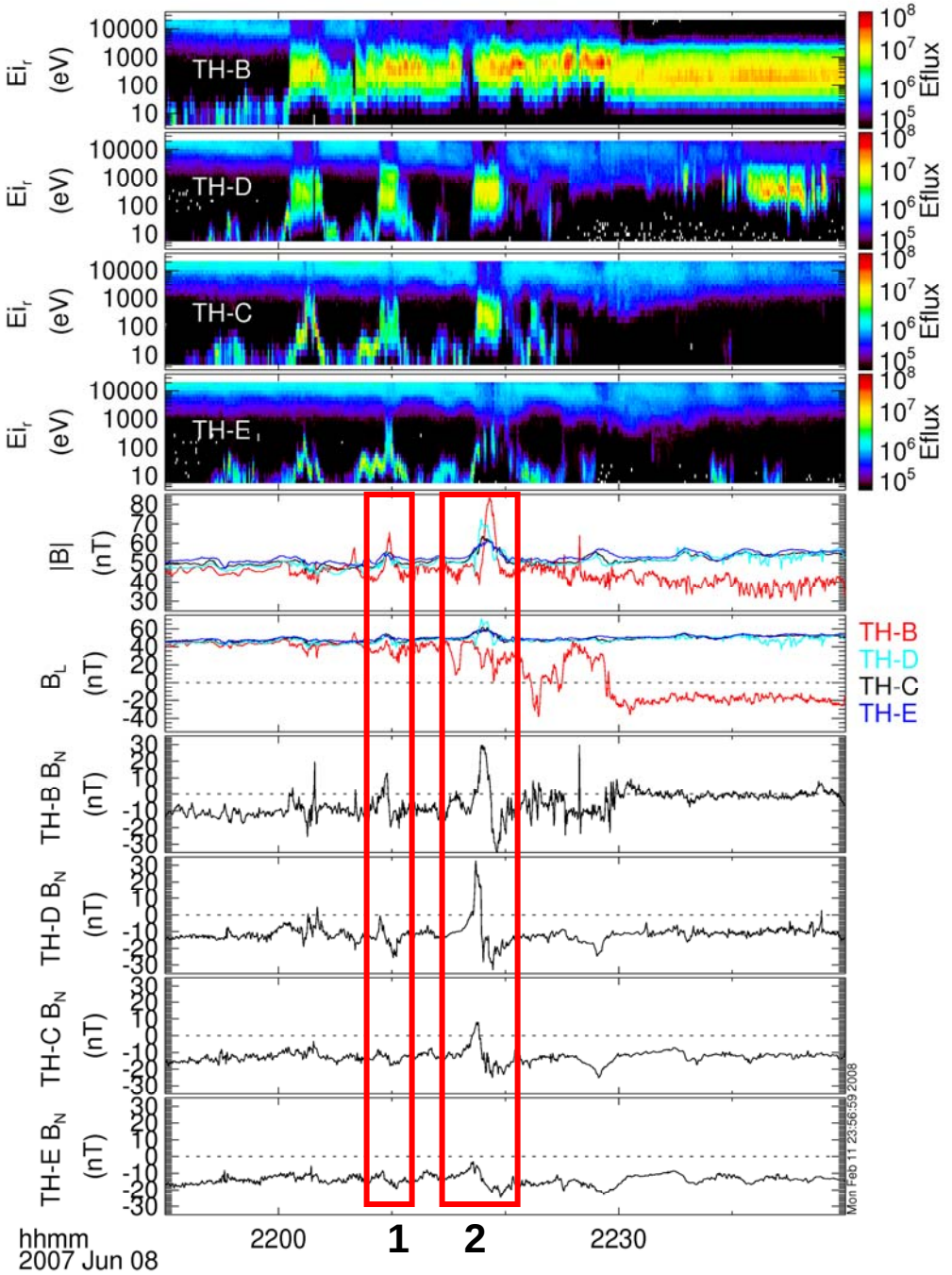

MP
TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)

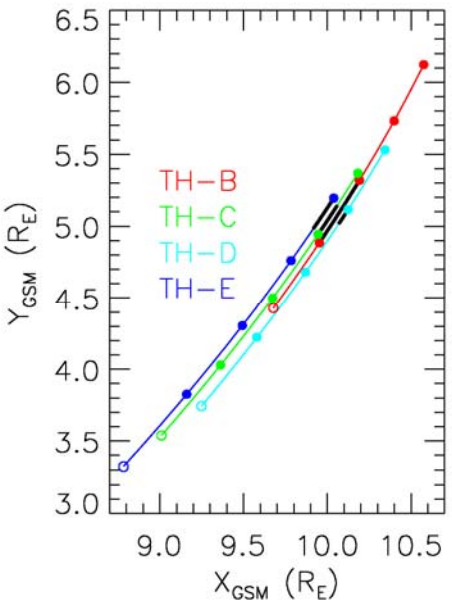

Relative Distance (R_E)
TH-EB
TH-ED
TH-EC
Relative Distance (km)
Xgsm
Ygsm
Zgsm
hhmm
2007
9.2
3.8
-1.3
2200
Jun 08
9.8
4.8
-1.3
2300
10.3
5.6
-1.4
0000
Jun 09

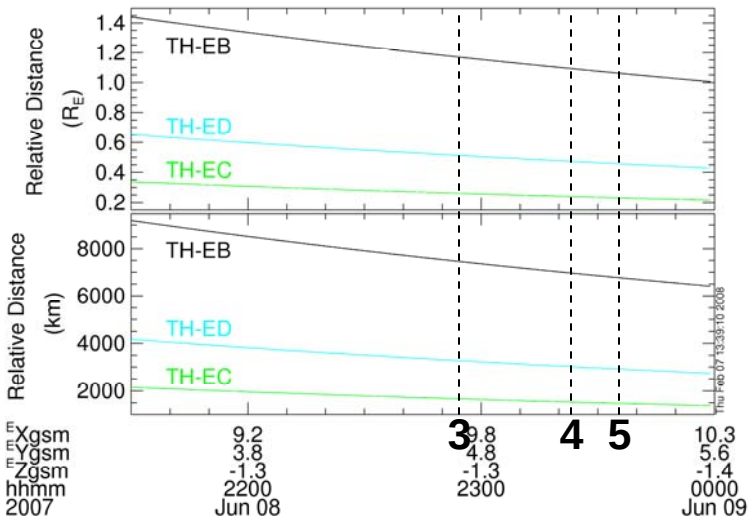

TH-B
TH-D
TH-C
TH-E
Ei (eV)
Eflux
|B| (nT)
B_L (nT)
TH-B B_N (nT)
TH-D B_N (nT)
TH-C B_N (nT)
TH-E B_N (nT)
hhmm
2007
2200
Jun 08
2300
0000
Jun 09

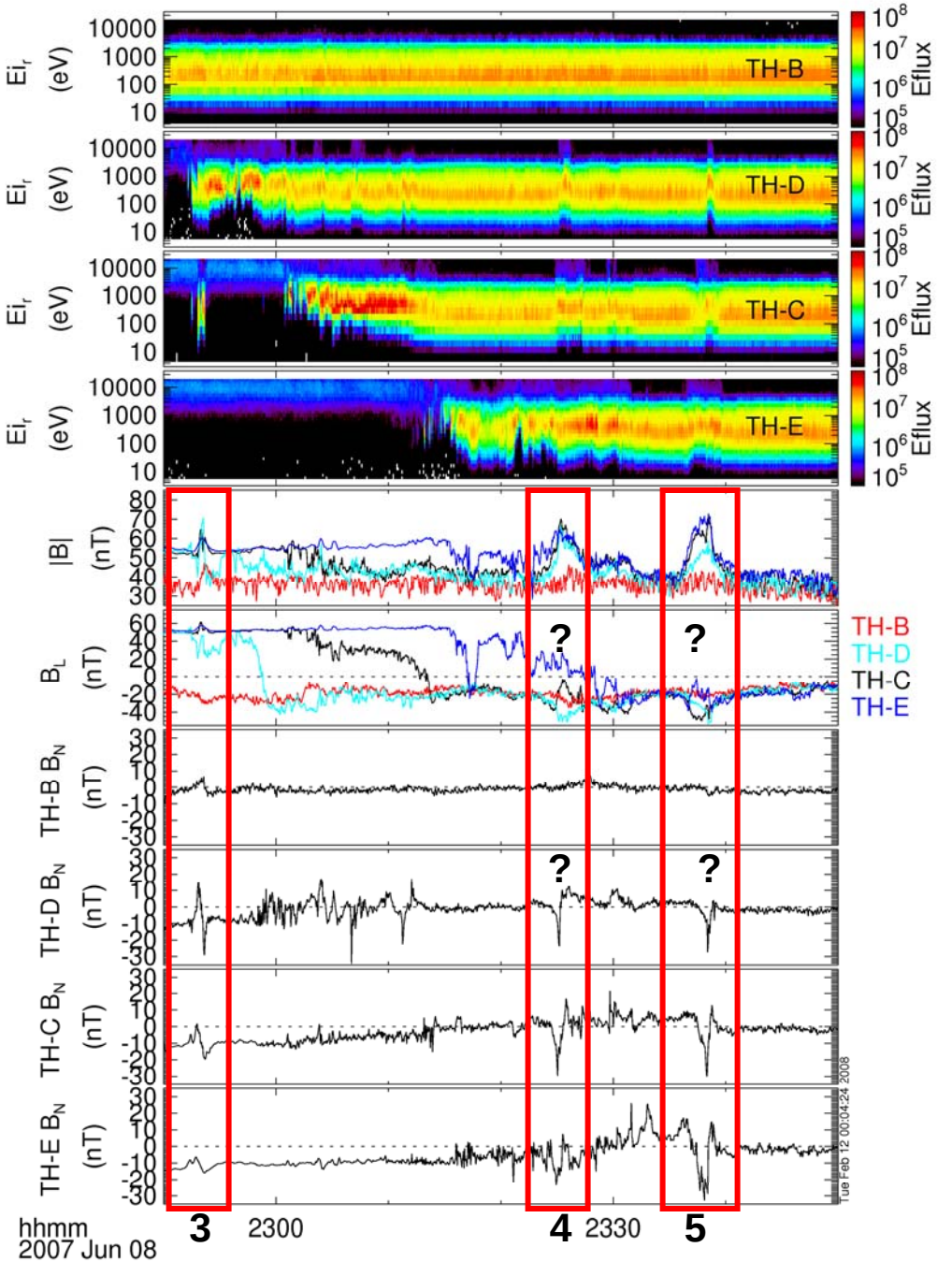

TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)


Relative Distance (R_E)
TH-EB
TH-ED
TH-EC
Relative Distance (km)
Xgsm
Ygsm
Zgsm
hhmm
2007
9.2
3.8
-1.3
2200
Jun 08
9.8
4.8
-1.3
2300
10.3
5.6
-1.4
0000
Jun 09
1 2

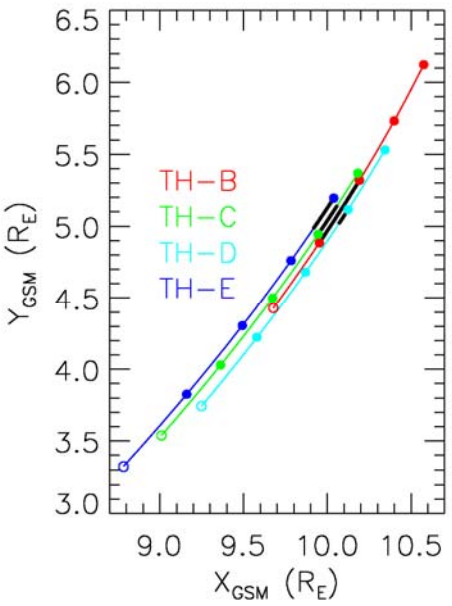

Ei (eV)
TH-B
TH-D
TH-C
TH-E
Eflux
|B| (nT)
B_L (nT)
TH-B B_N (nT)
TH-D B_N (nT)
TH-C B_N (nT)
TH-E B_N (nT)
TH-B
TH-D
TH-C
TH-E
hhmm
2007 Jun 08
2200
2230
1 2

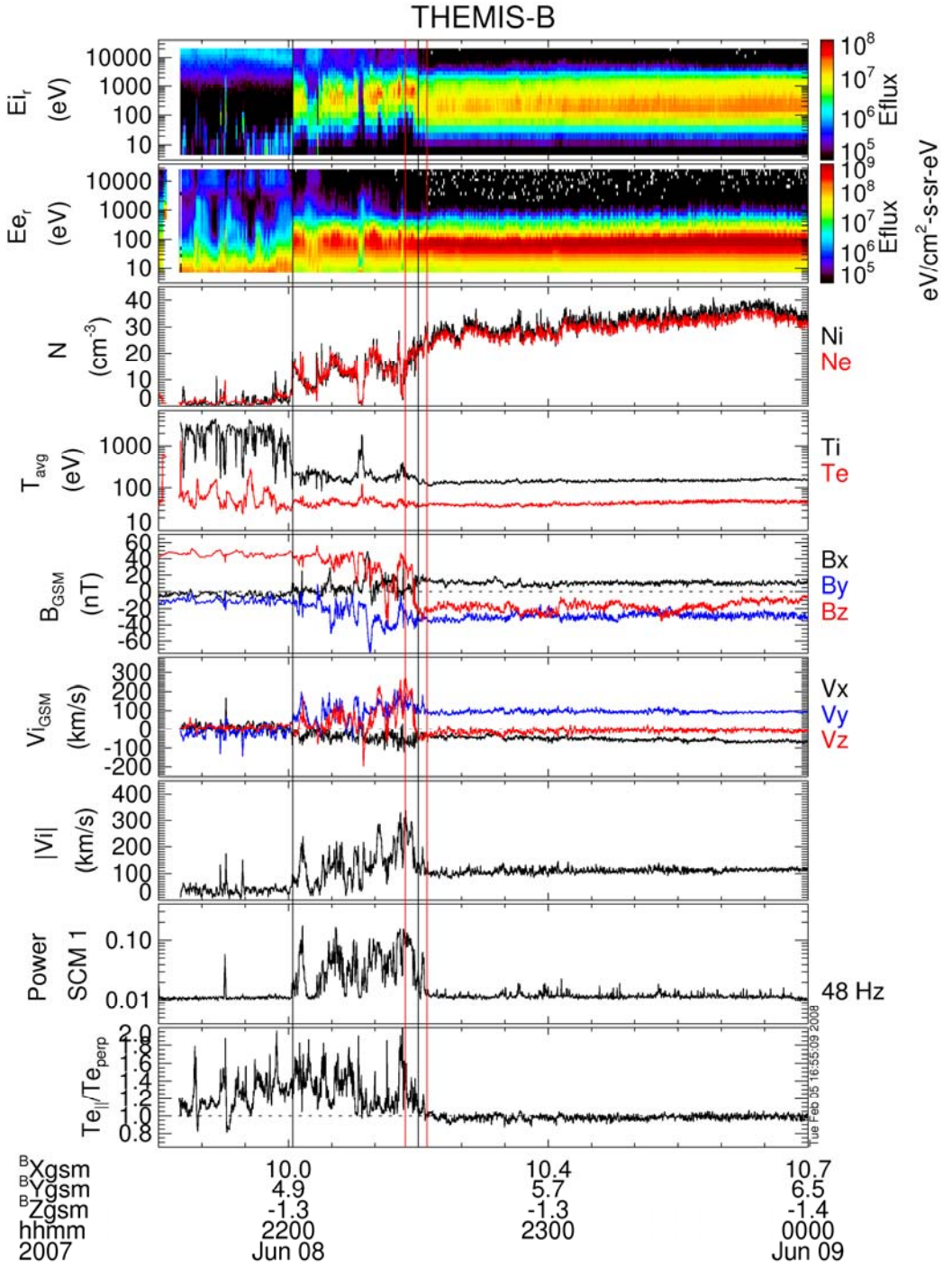

TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)


Relative Distance (R_E)
TH-EB
TH-ED
TH-EC
Relative Distance (km)
Xgsm 9.2 9.8 10.3
Ygsm 3.8 4.8 5.6
Zgsm -1.3 -1.3 -1.4
hhmm 2200 2300 0000
2007 Jun 08 Jun 09
3 4 5

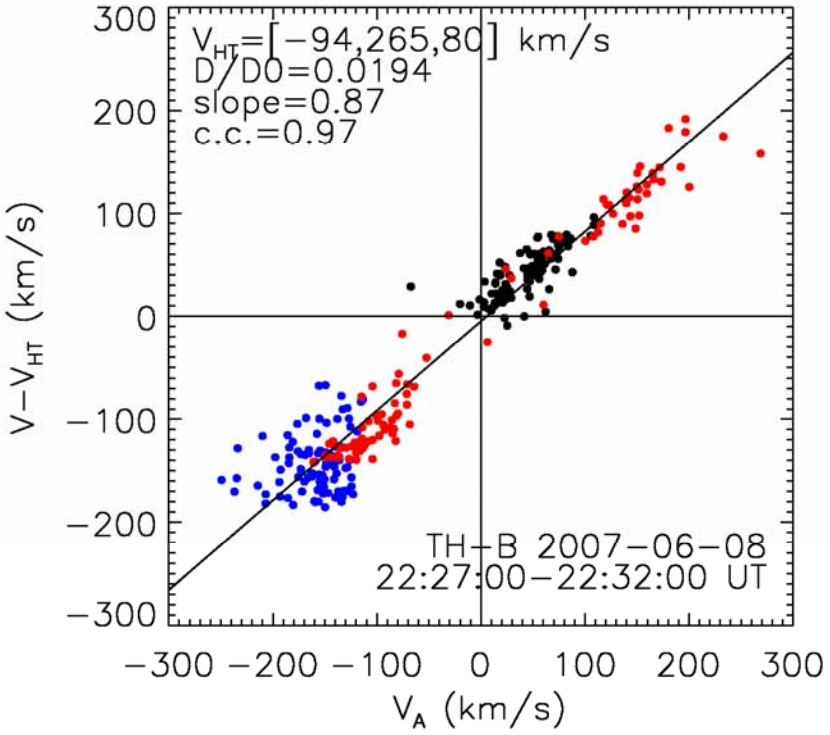

Ei (eV)
TH-B
TH-D
TH-C
TH-E
Eflux
|B| (nT)
B_L (nT)
TH-B B_N (nT)
TH-D B_N (nT)
TH-C B_N (nT)
TH-E B_N (nT)
?
hhmm
2007 Jun 08
3 2300 4 2330 5

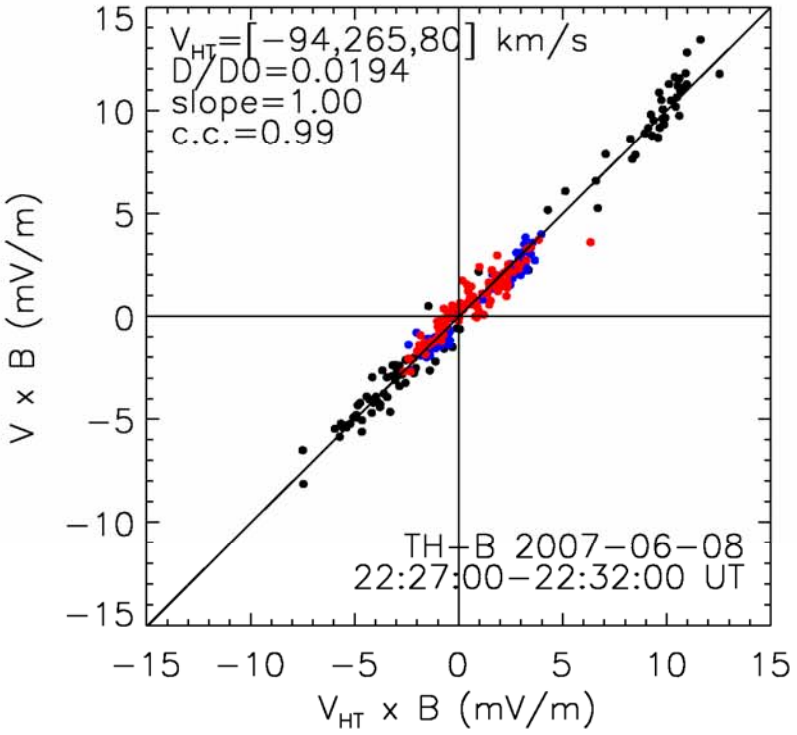
Evidence for Reconnection at TH-B and TH-C

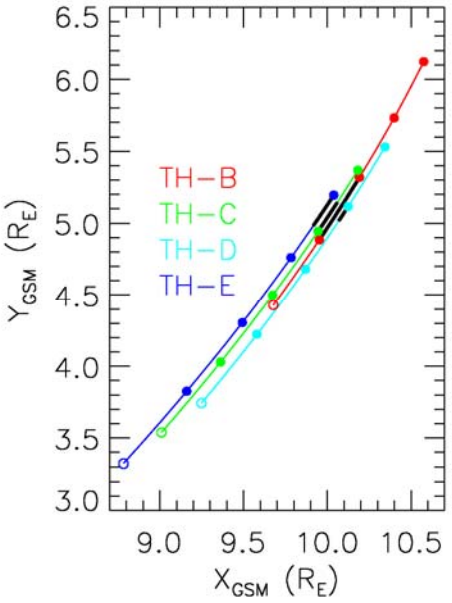

TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)

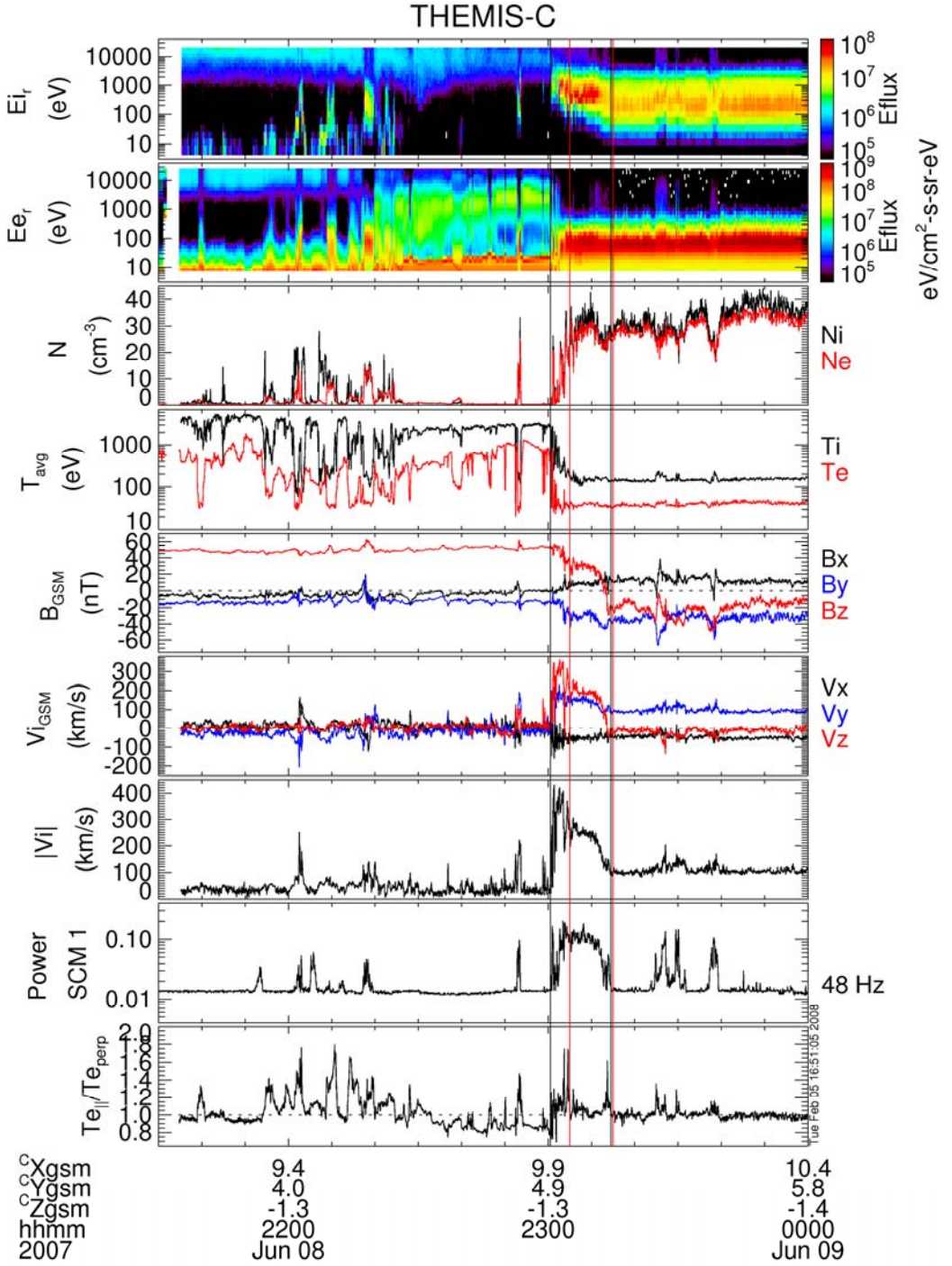

THEMIS-B
Ei$_r$ (eV)
Ee$_r$ (eV)
Eflux
eV/cm^2-s-sr-eV
N (cm^{-3})
Ni
Ne
T_{avg} (eV)
Ti
Te
B_{GSM} (nT)
Bx
By
Bz
Vi_{GSM} (km/s)
Vx
Vy
Vz
|Vi| (km/s)
Power SCM 1
48 Hz
Te$_{||}$/Te$_{perp}$
Tue Feb 05 16:55:09 2008
BXgsm 10.0 10.4 10.7
BYgsm 4.9 5.7 6.5
BZgsm -1.3 -1.3 -1.4
hhmm 2200 2300 0000
2007 Jun 08 Jun 09

Walen relation satisfied at TH-B

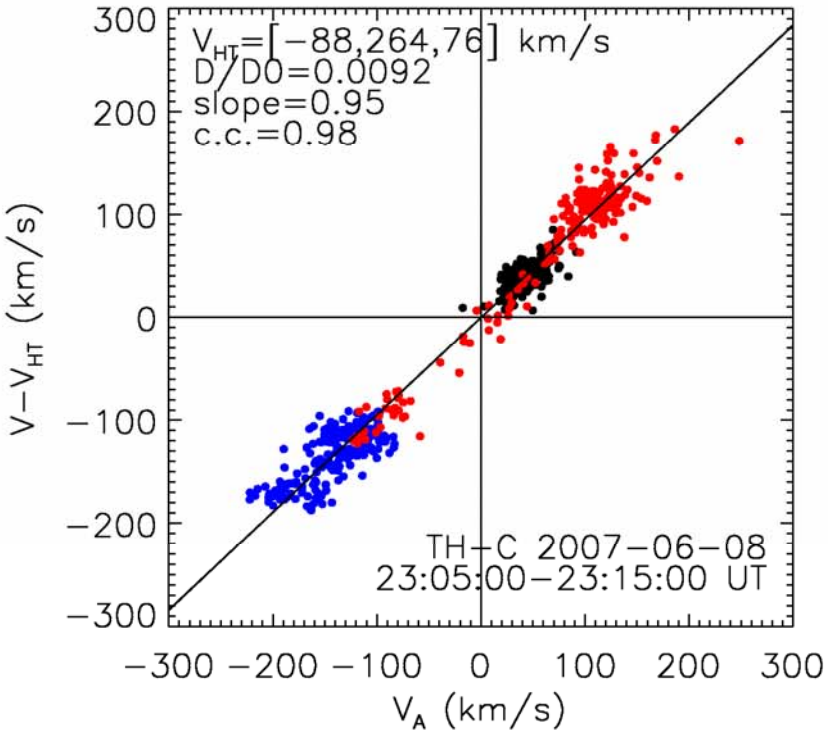


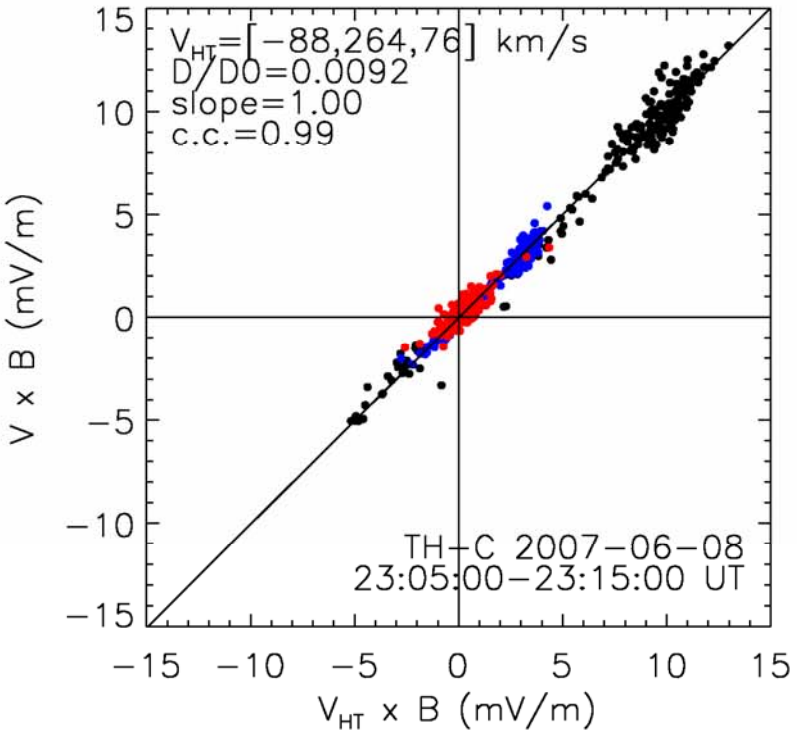



TH−B
TH−C
TH−D
TH−E
Y_{GSM} (R_E)
X_{GSM} (R_E)


THEMIS-C
Ei_r (eV)
Ee_r (eV)
Eflux
eV/cm^2-s-sr-eV
N (cm^{-3})
Ni
Ne
T_{avg} (eV)
Ti
Te
B_{GSM} (nT)
Bx
By
Bz
Vi_{GSM} (km/s)
Vx
Vy
Vz
|Vi| (km/s)
Power SCM 1
48 Hz
$Te_{||}/Te_{perp}$
Tue Feb 05 16:51:05 2008
Xgsm 9.4 9.9 10.4
Ygsm 4.0 4.9 5.8
Zgsm -1.3 -1.3 -1.4
hhmm 2200 2300 0000
2007 Jun 08 Jun 09

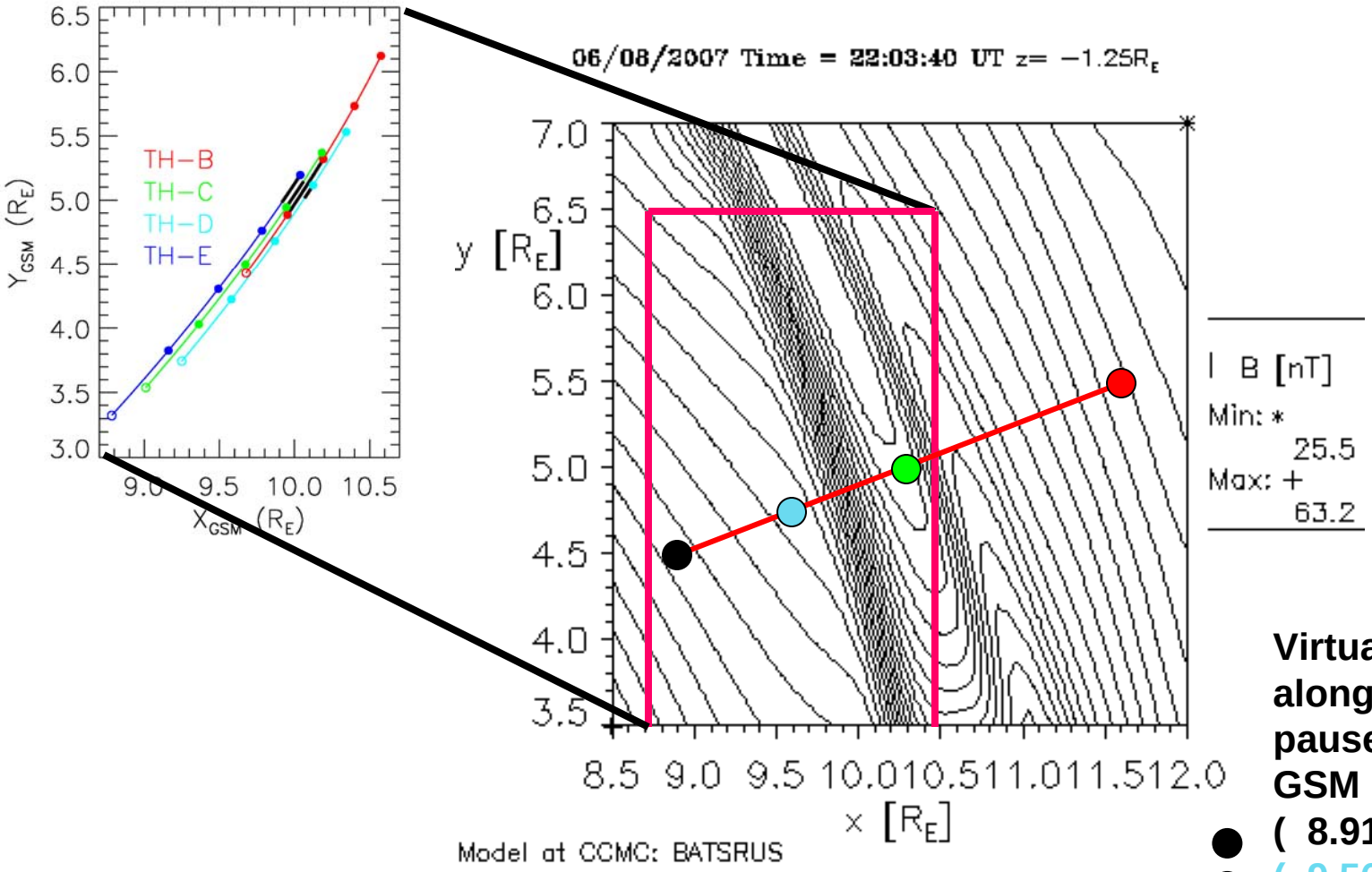
Walen relation satisfied at TH-C





High-resolution (0.0626 RE) CCMC BATSRUS MHD simulation using upstream solar wind conditions on 8 June 2007

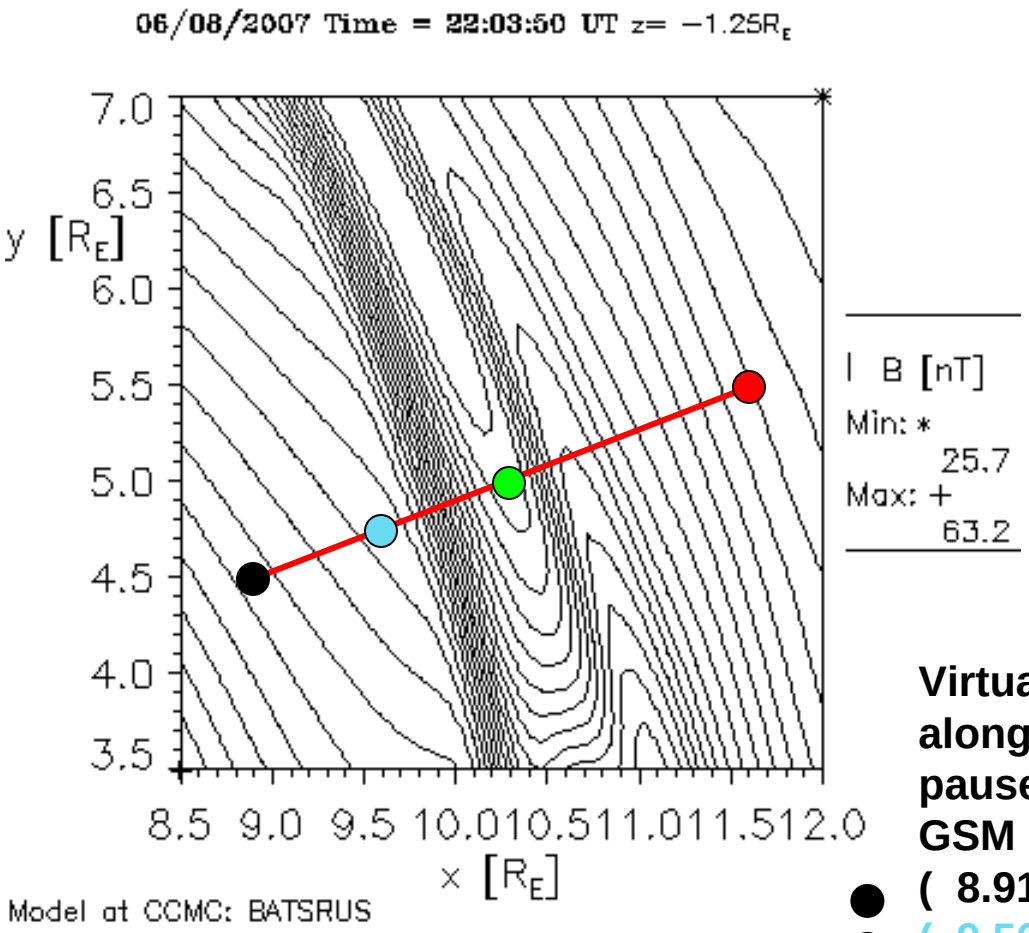
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)**

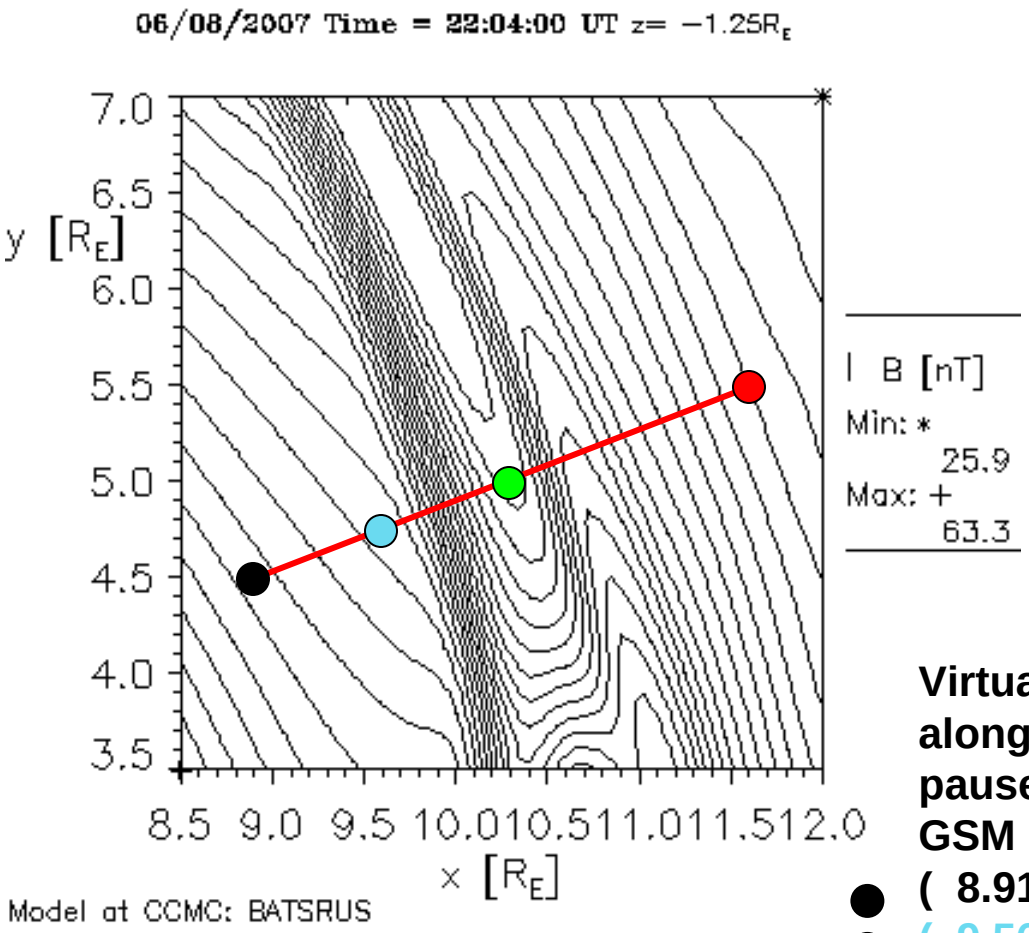
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)**

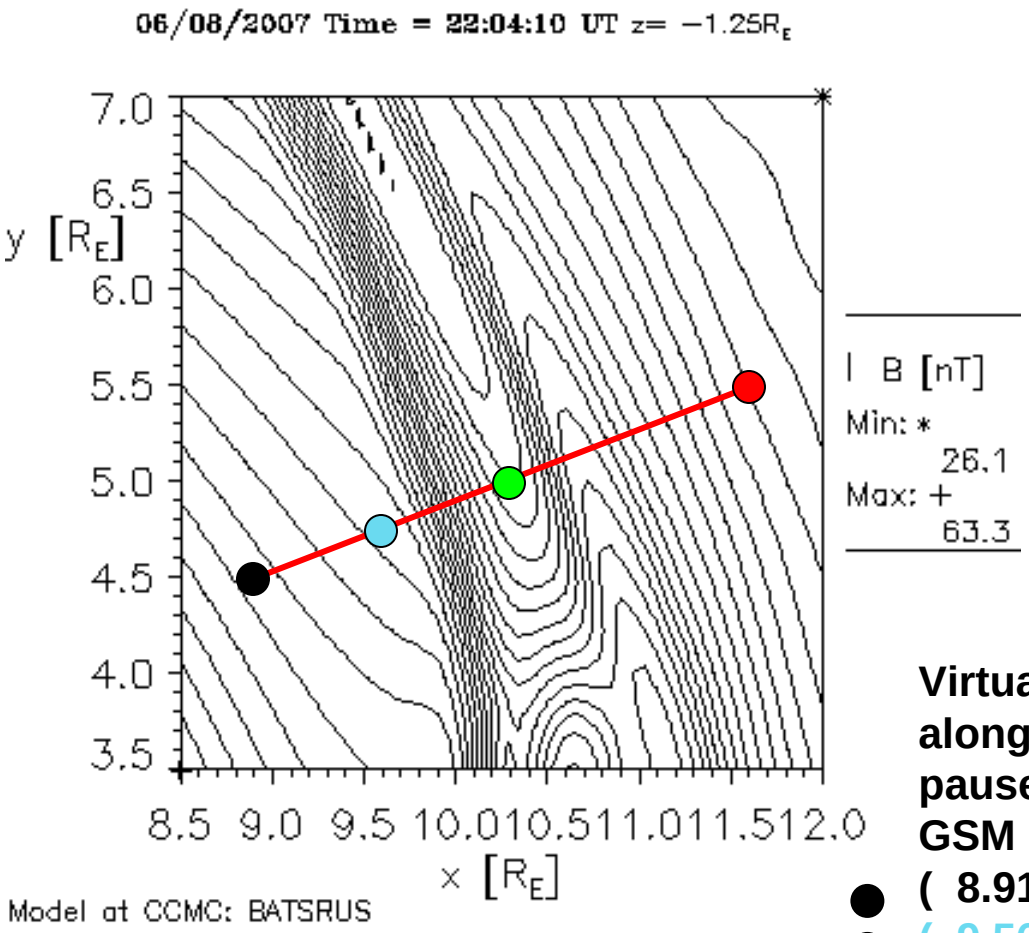
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)**

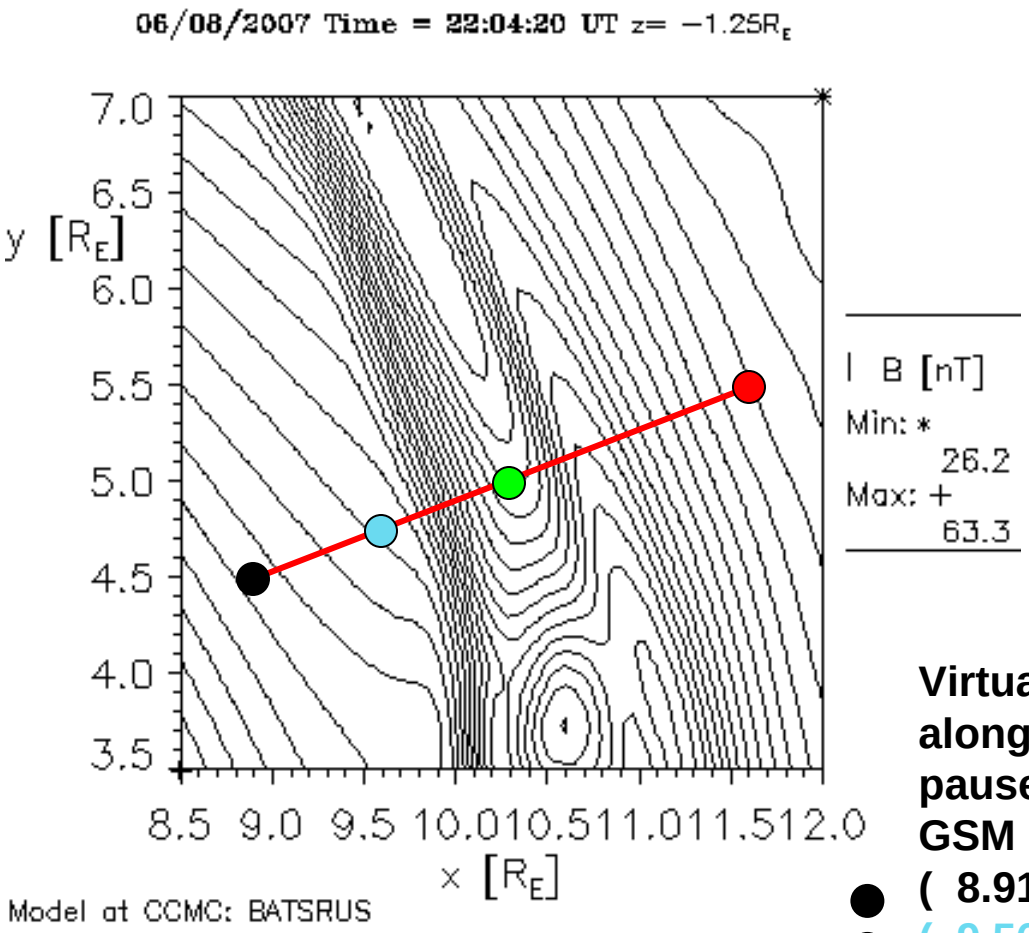
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)**

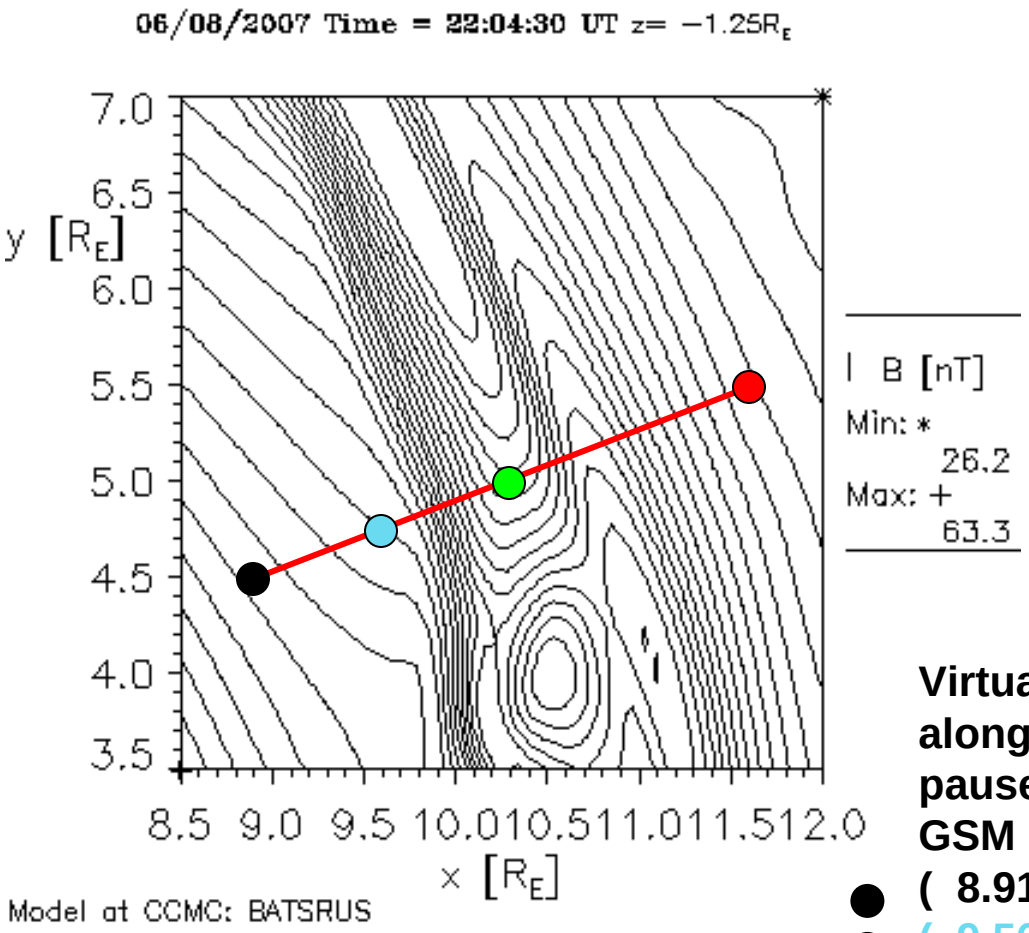
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)**

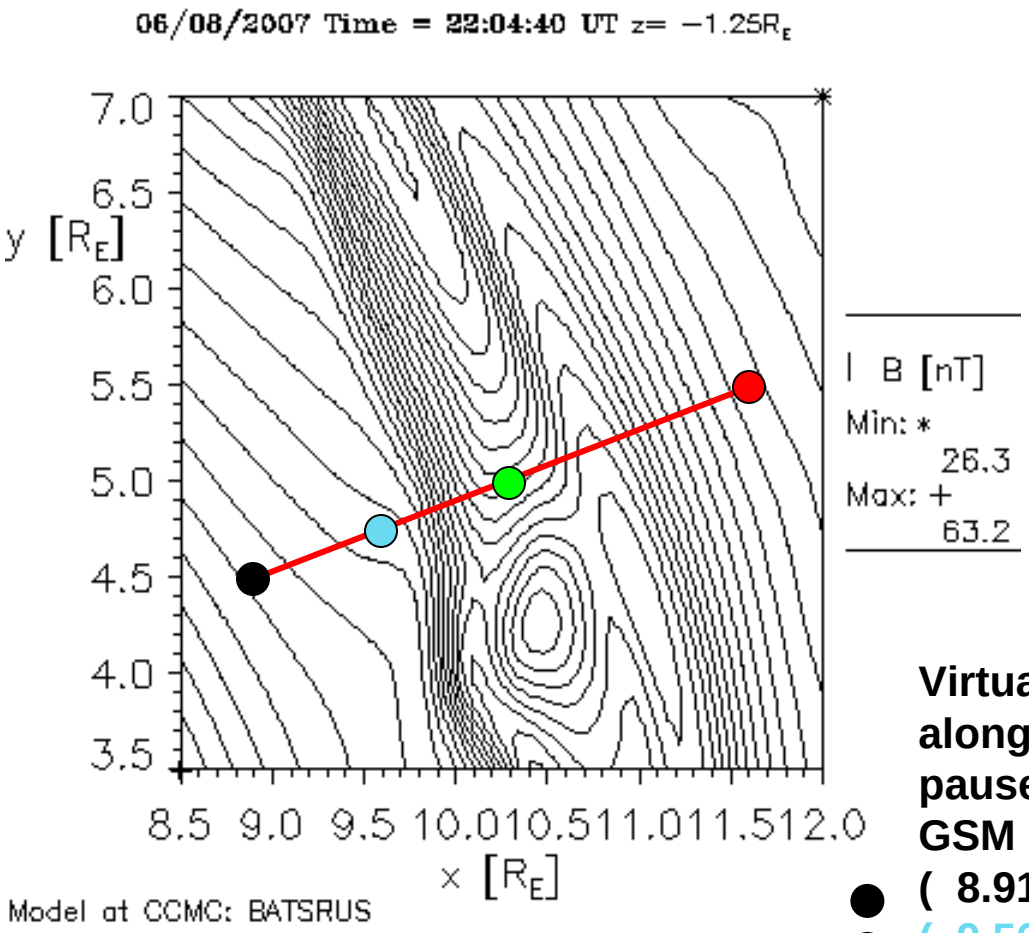
CCMC/BATSRUS
High Resolution (0.0626 RE)



Virtual "probes" along the magneto-pause 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)



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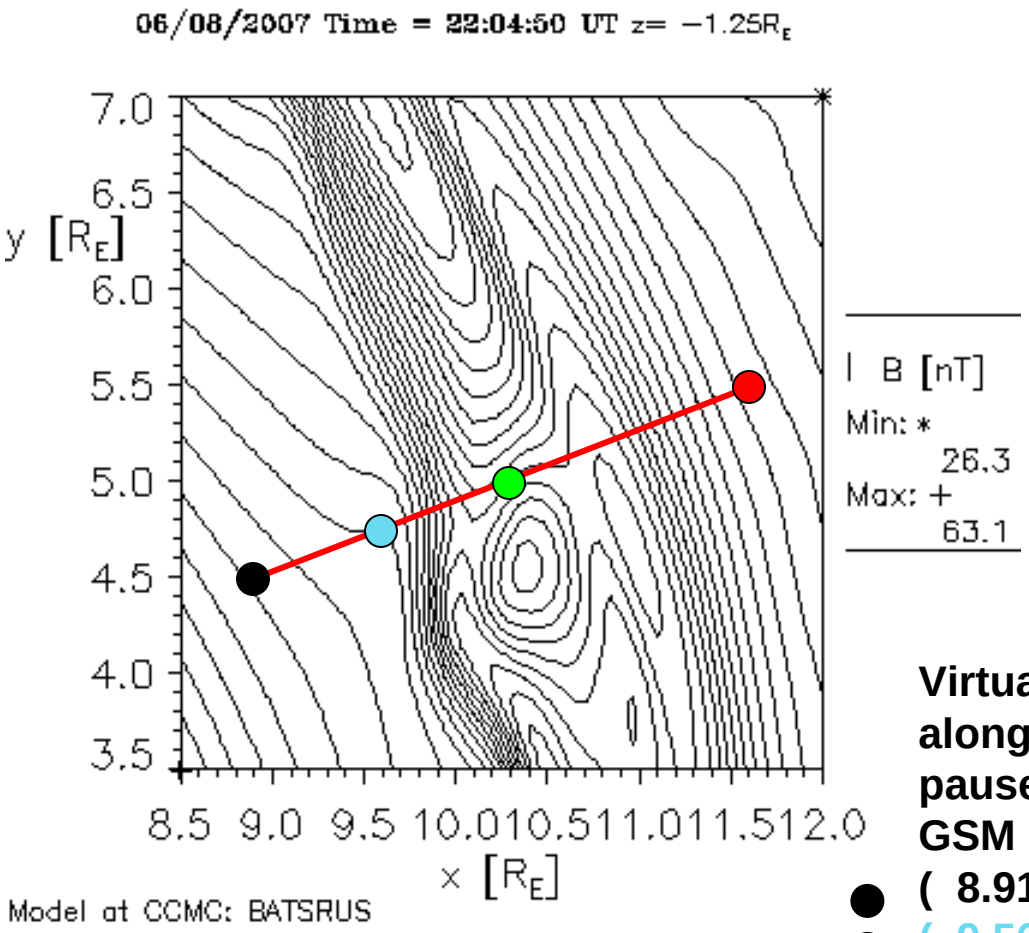

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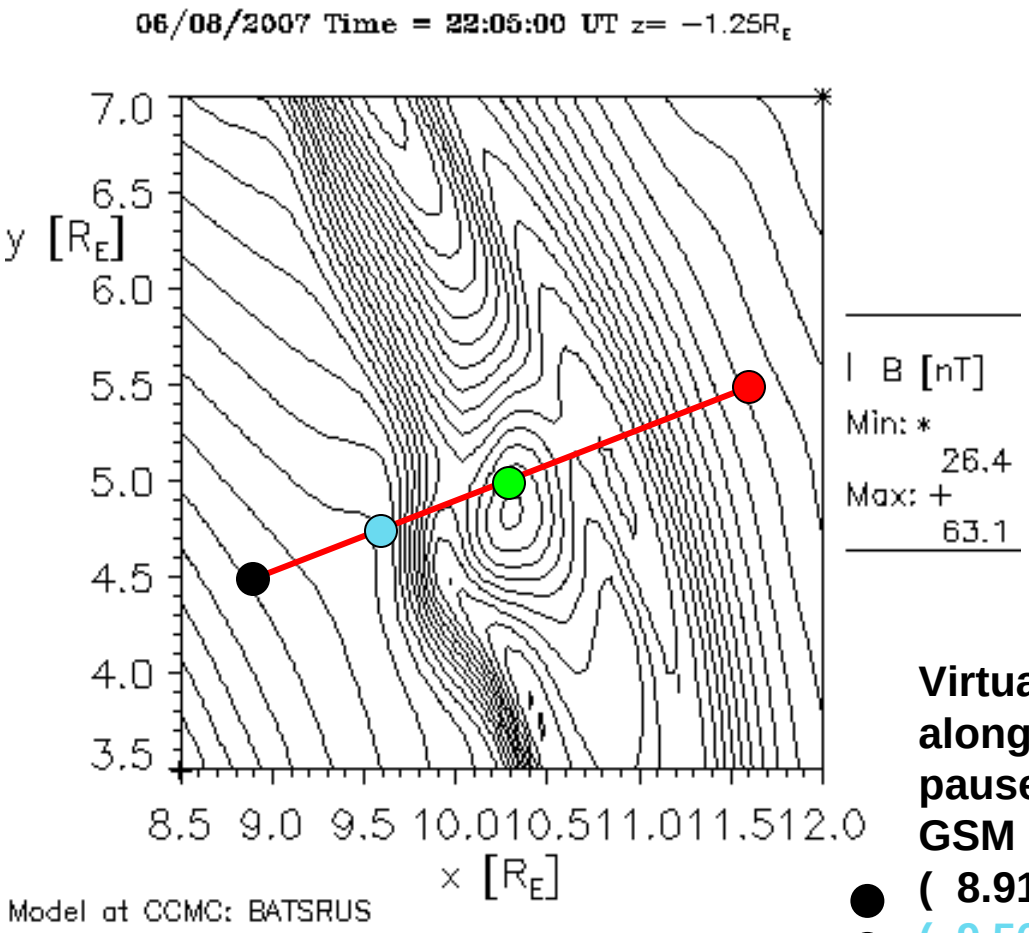

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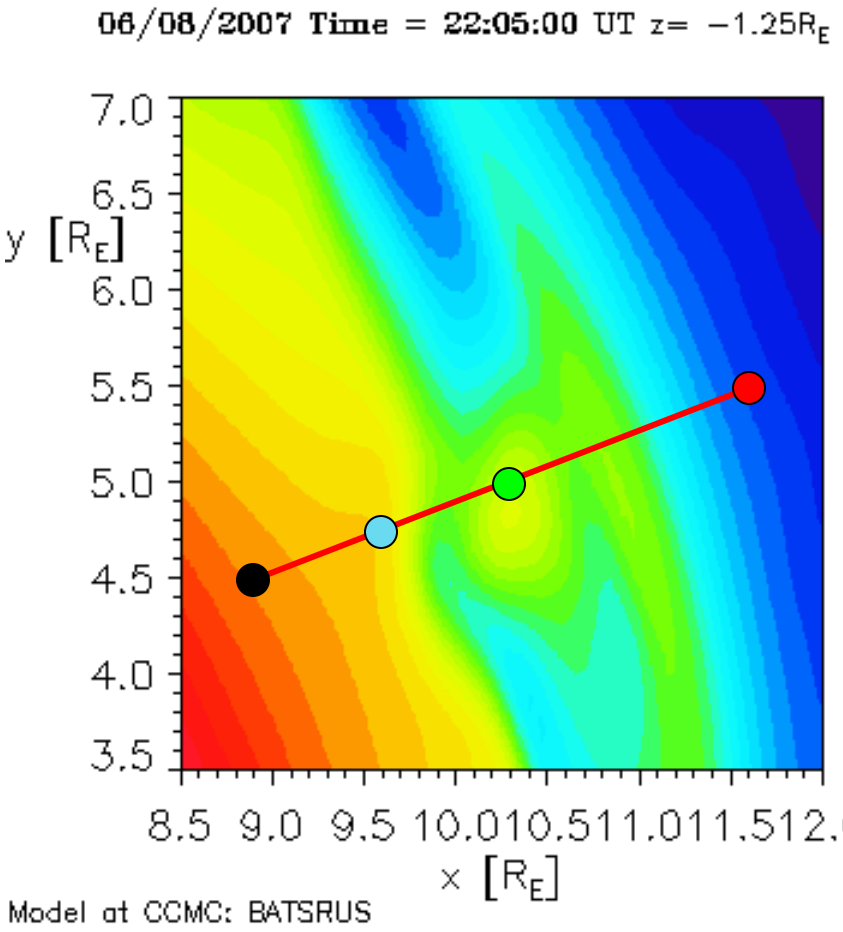

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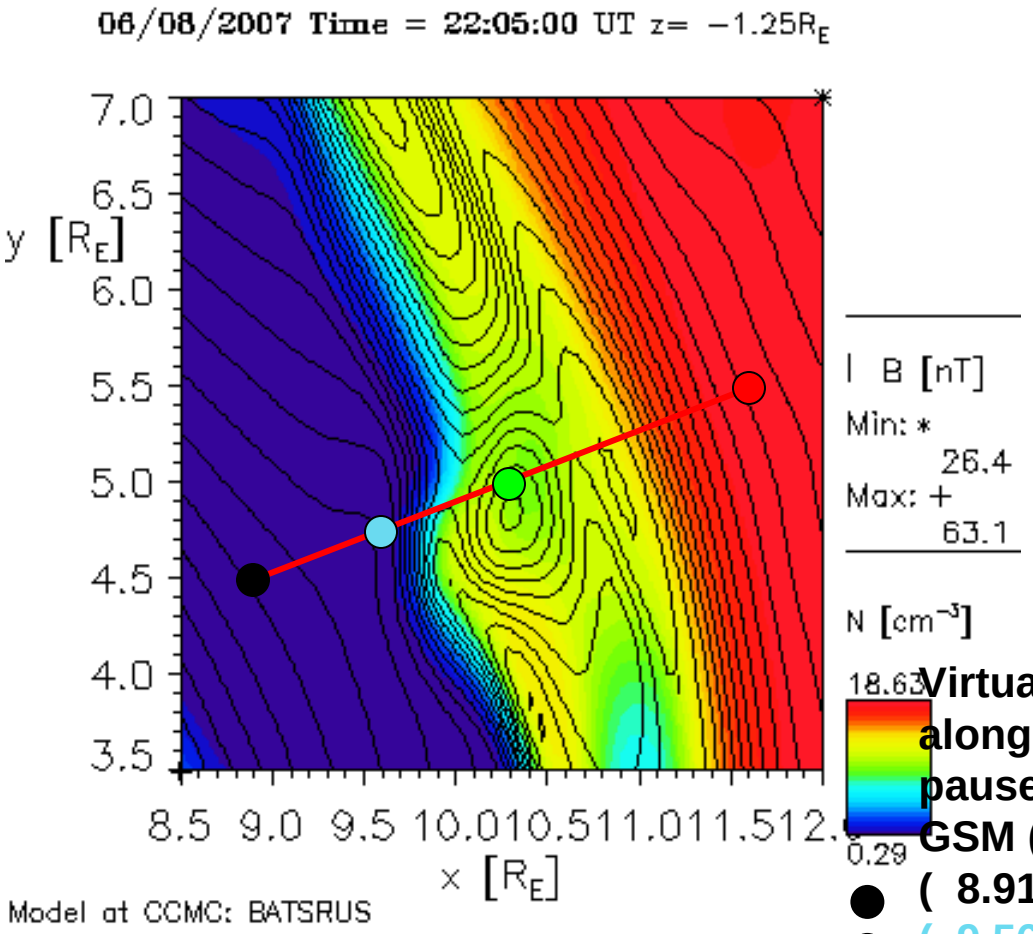
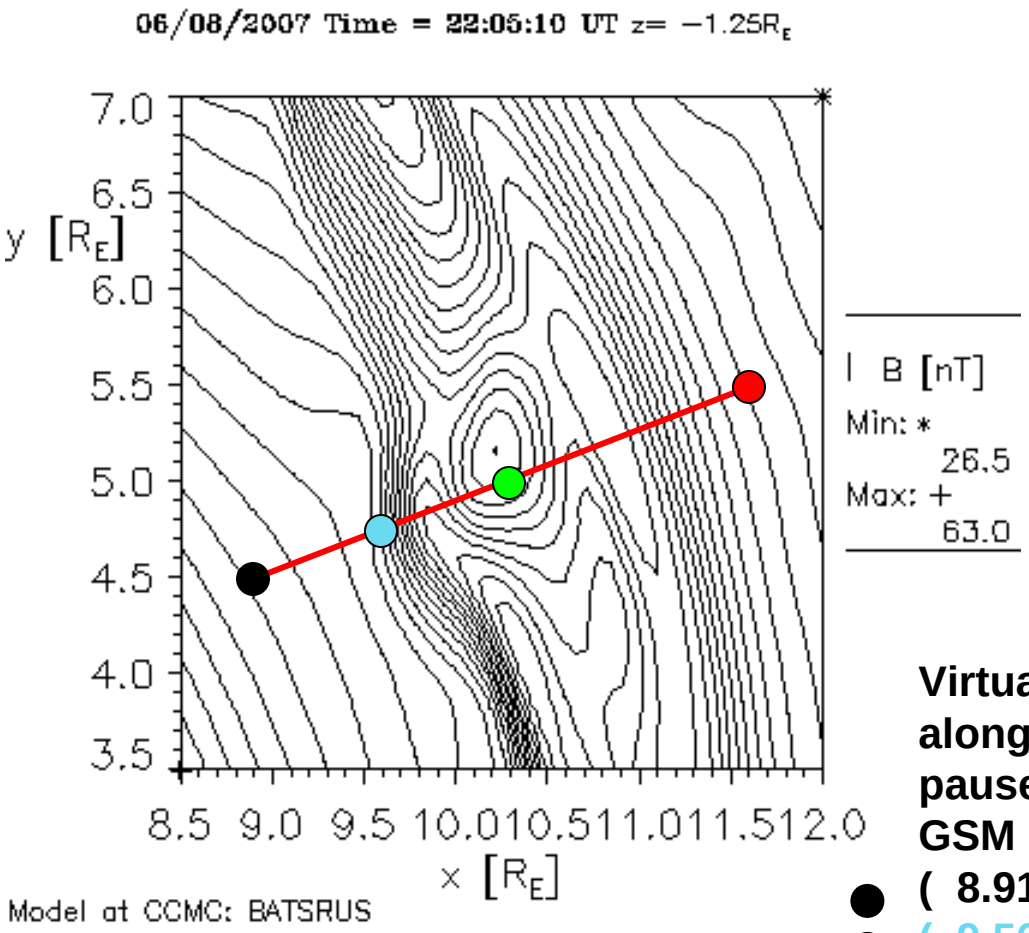


CCMC/BATSRUS
High Resolution (0.0626 RE)



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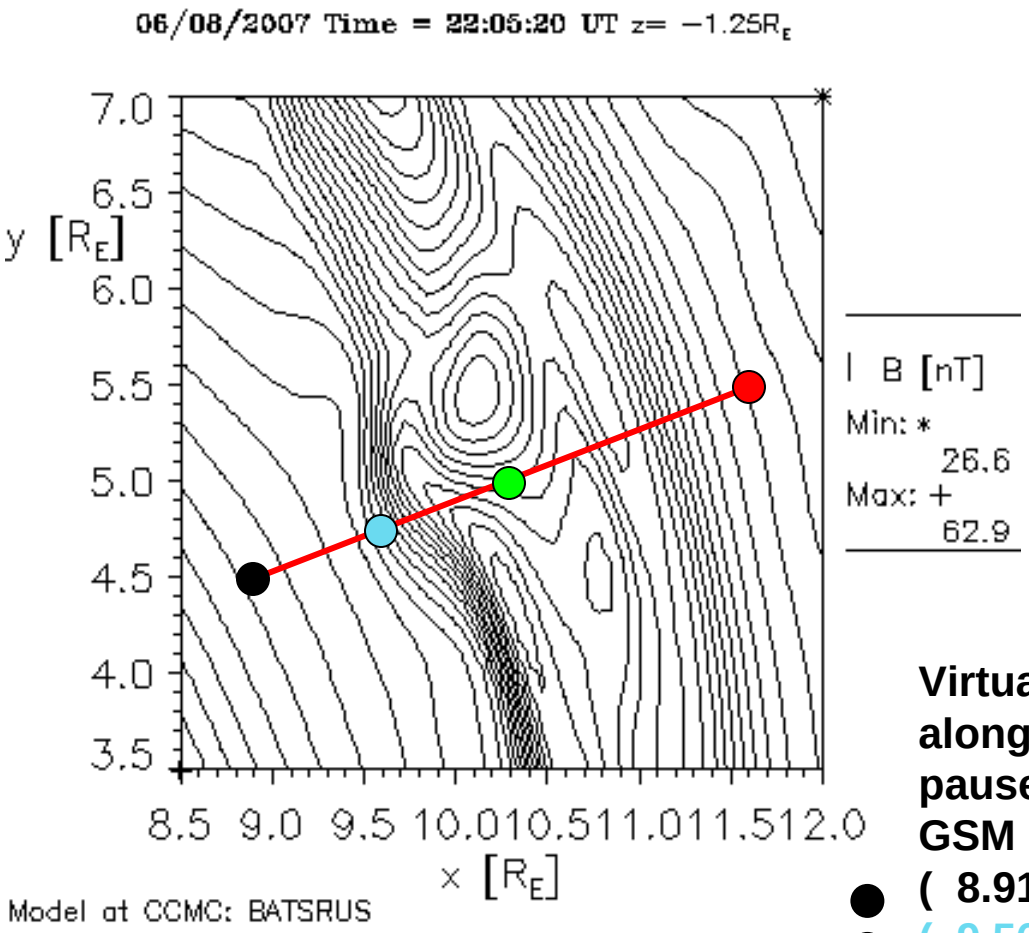

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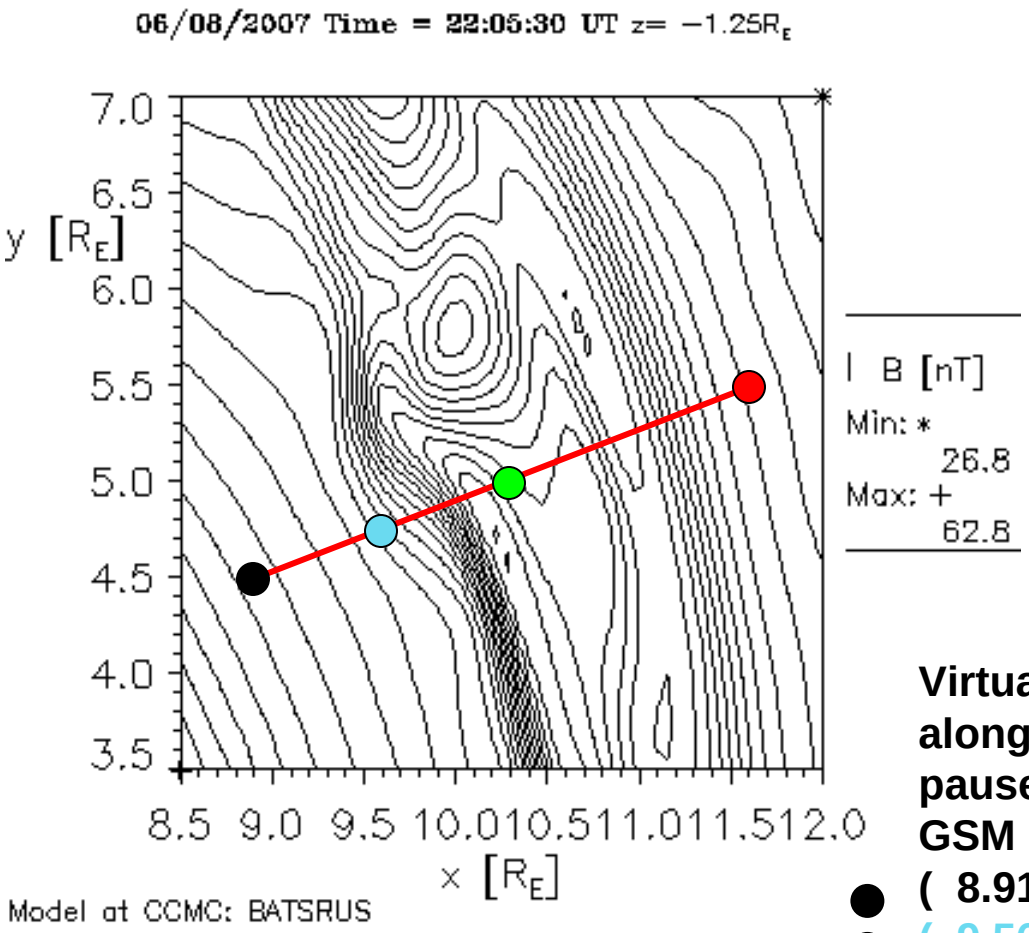

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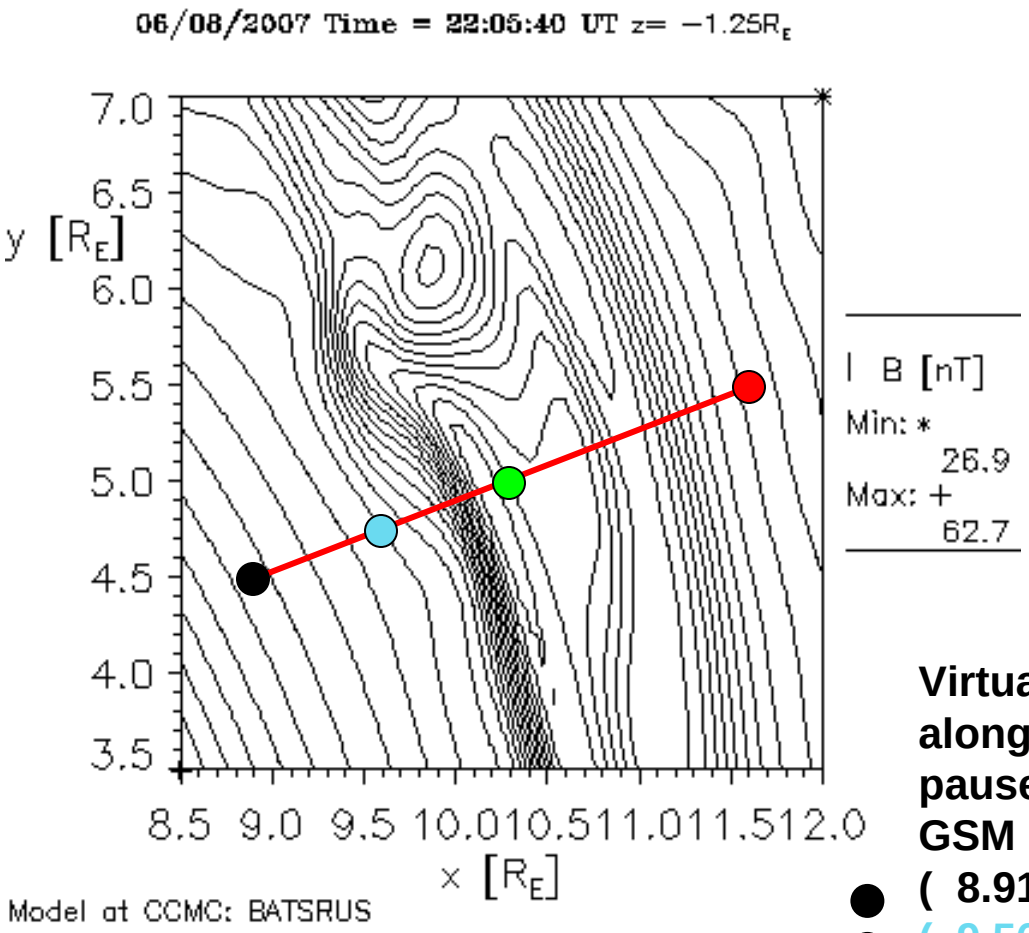

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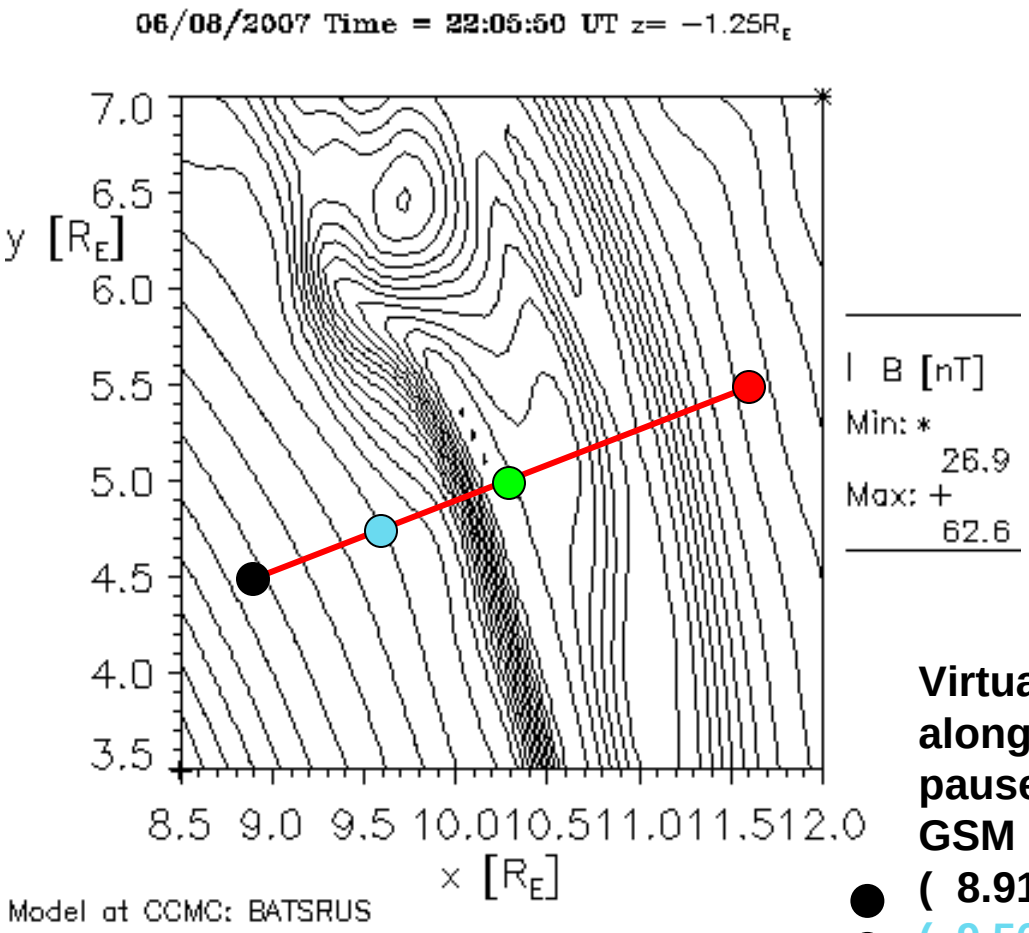

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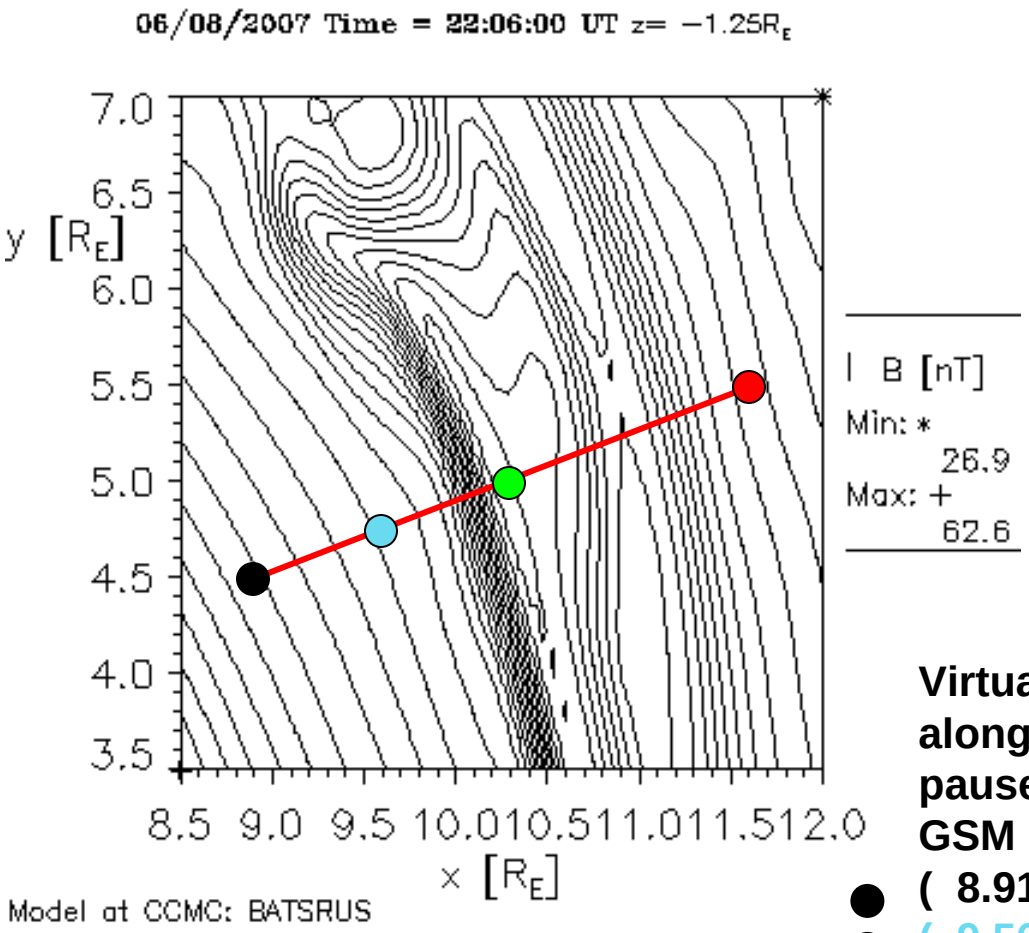

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- **(11.60, 5.52, -1.25)**

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

…….

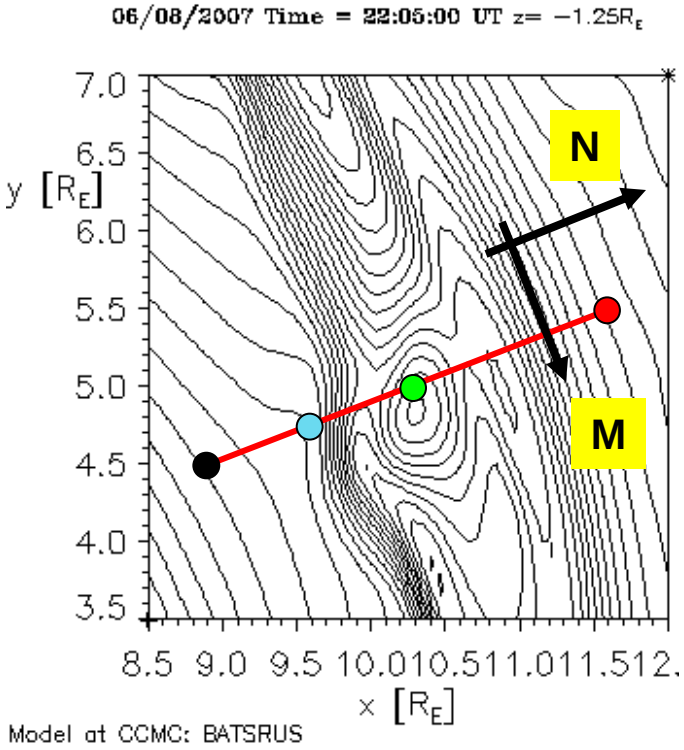
(X,Y,Z)=(9.56, 4.71, -1.25)

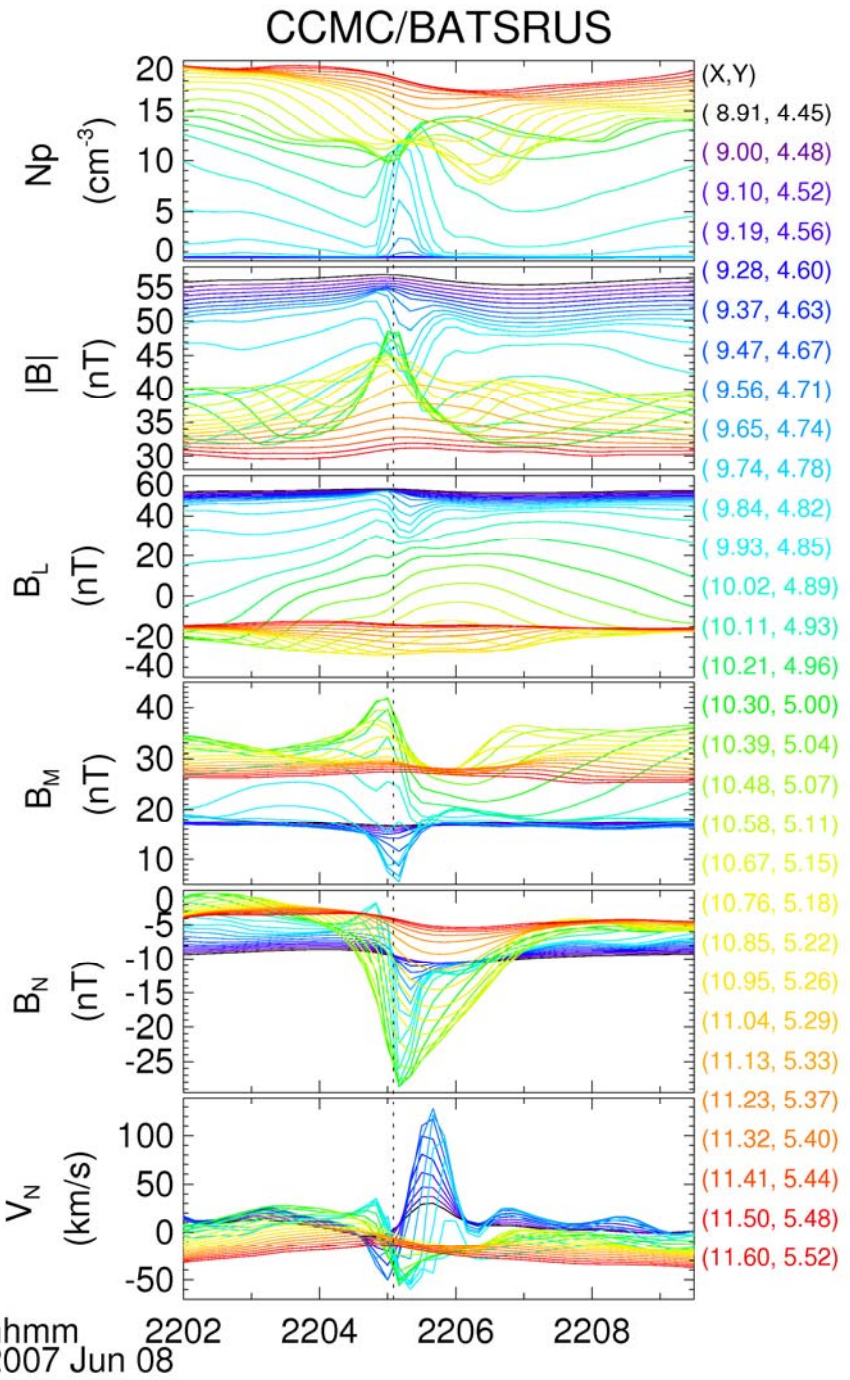
…….

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

…….

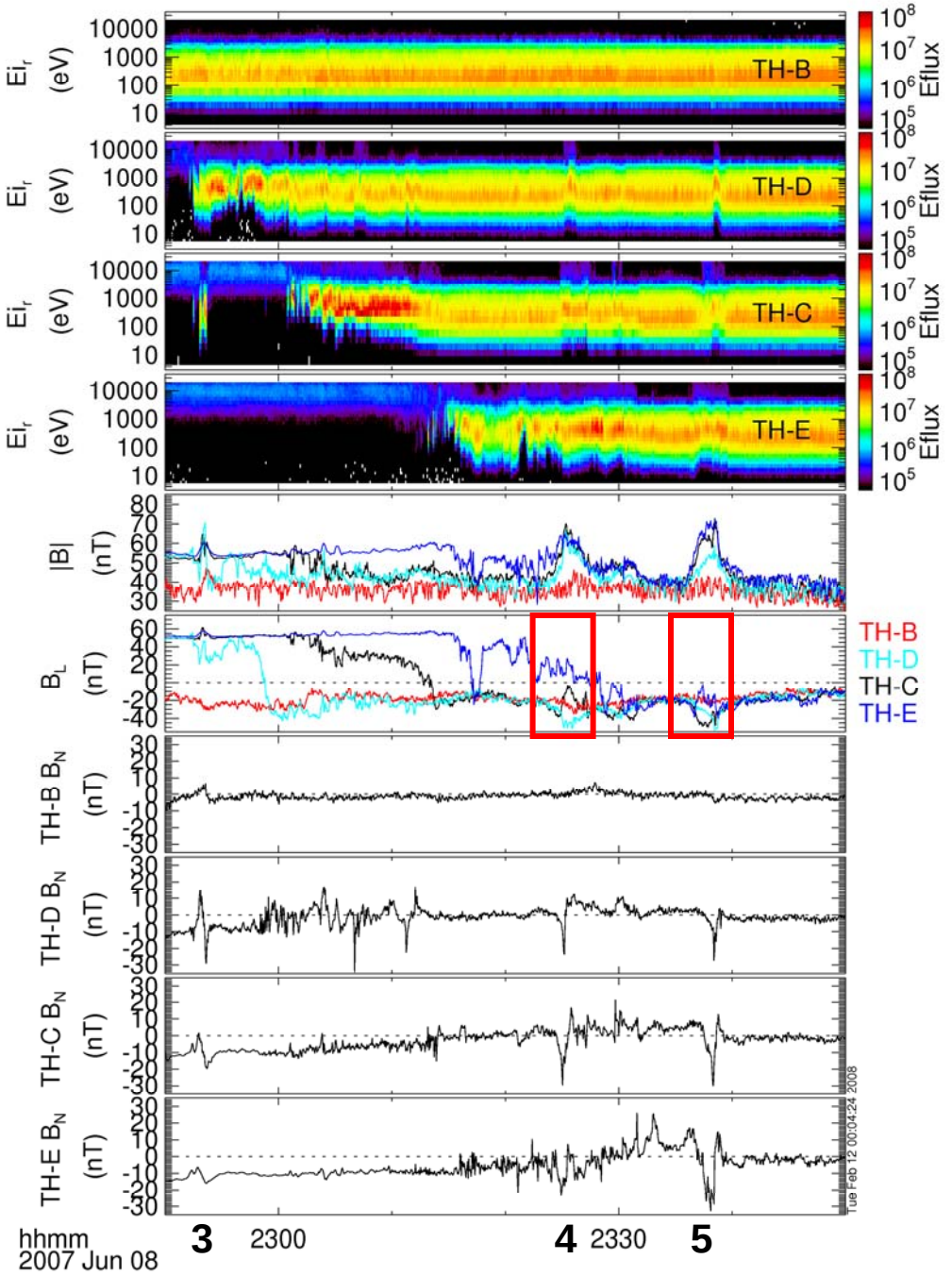
(X,Y,Z)=(11.60, 5.52, -1.25)



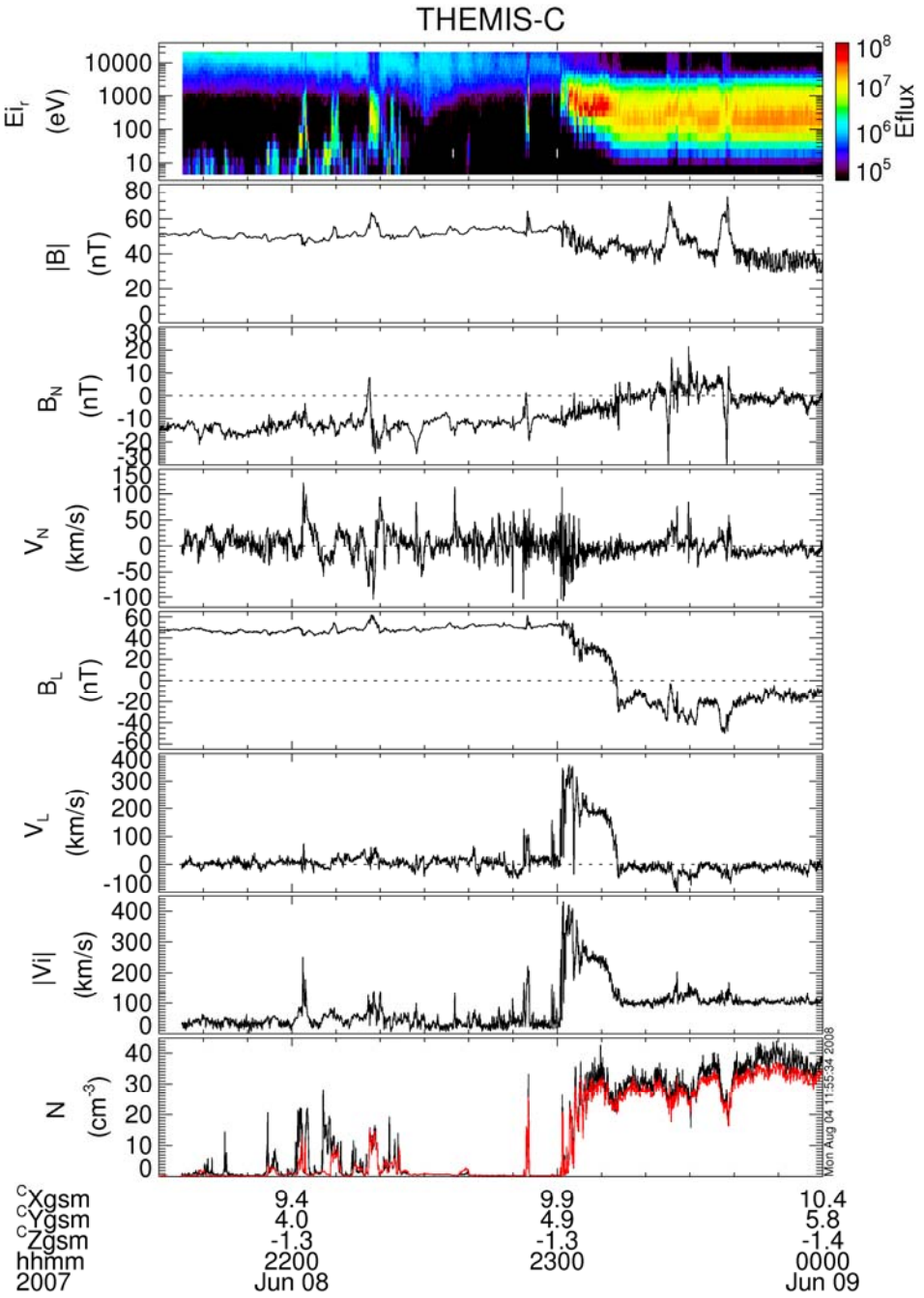


Is there any evidence of the BL signature at the negative BN spikes? Yes.

Note: TH-C BM and BL signatures of the magnetosheath structure *very* similar also to MHD prediction of this FTE.

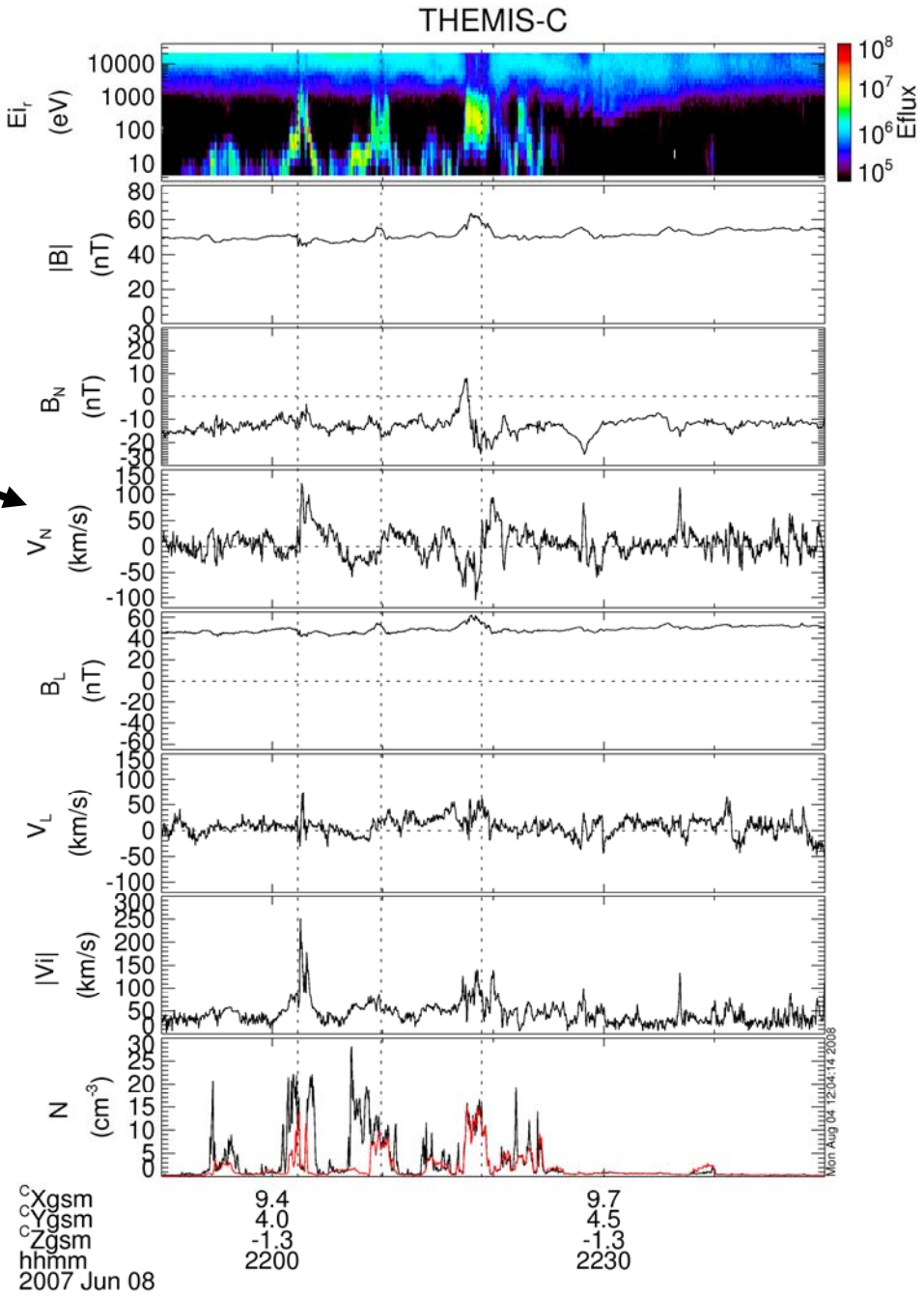


Is there any evidence of a magnetospheric VN “wave”?



Is there any evidence of a magnetospheric VN “wave”?

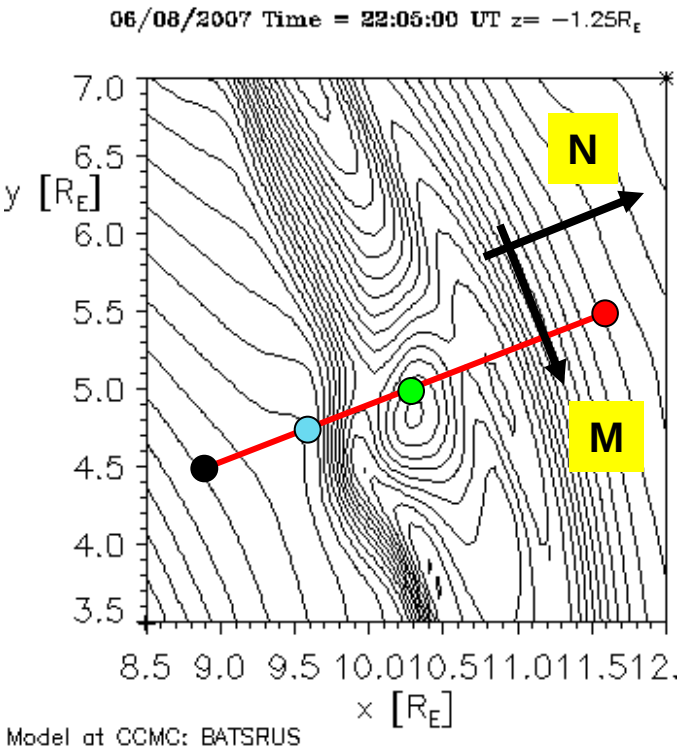
Yes, and it occurs around the time of the dayside cold ion dispersion signature at the time of the “FTEs”.

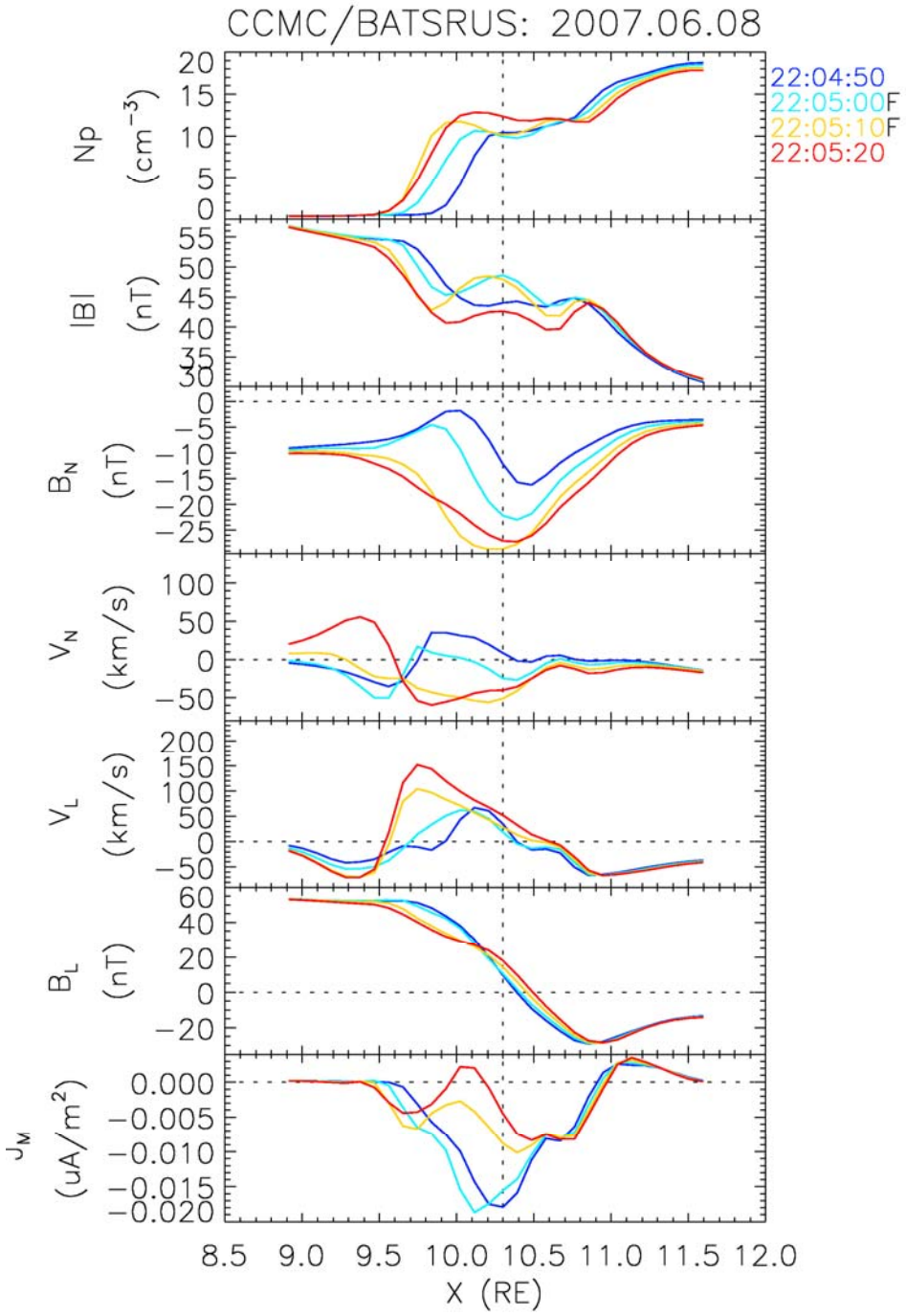


CCMC time series profiles from all 30 “probes”:

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”.





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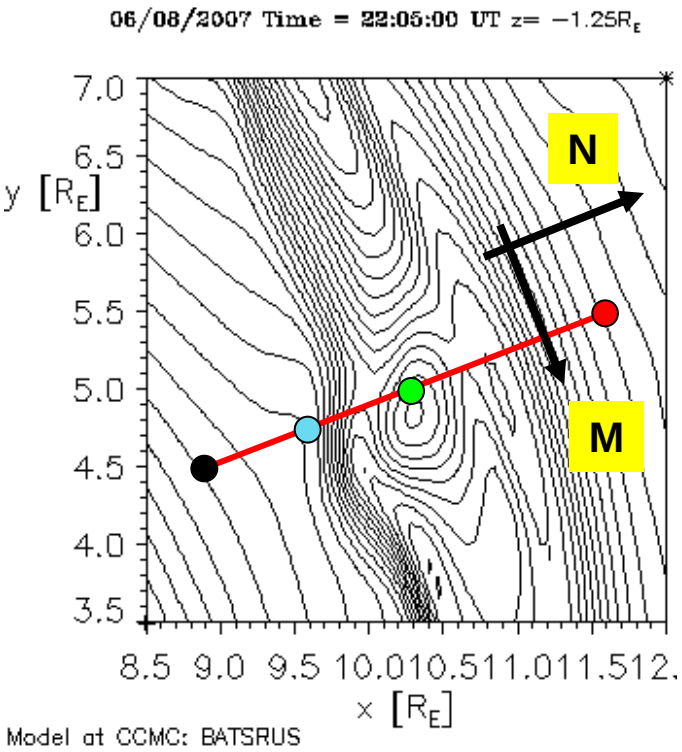

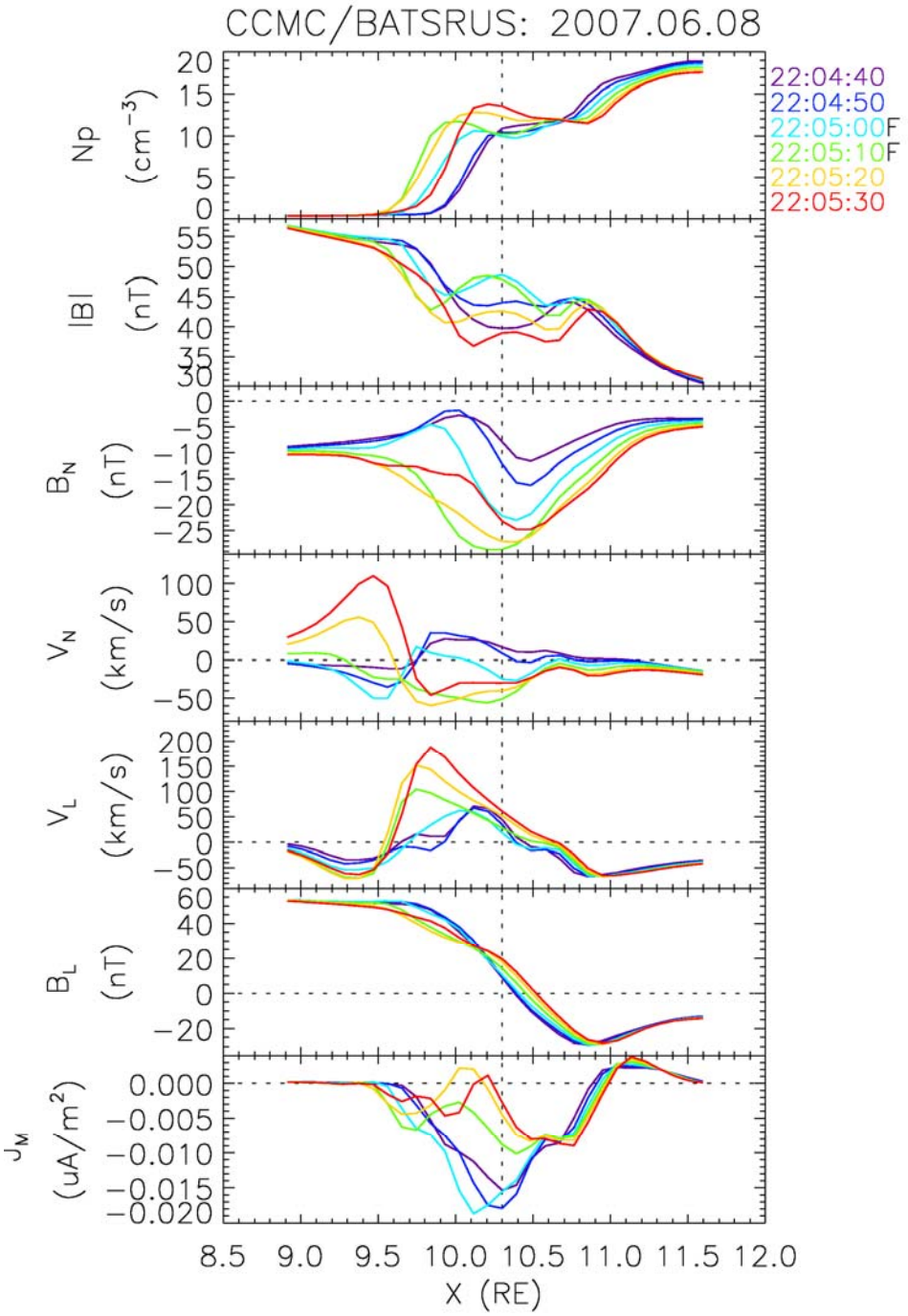

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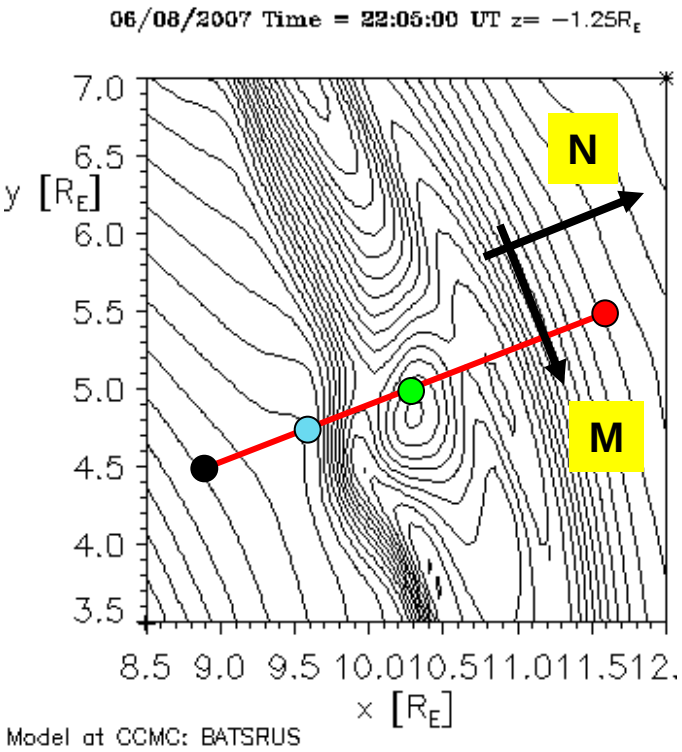
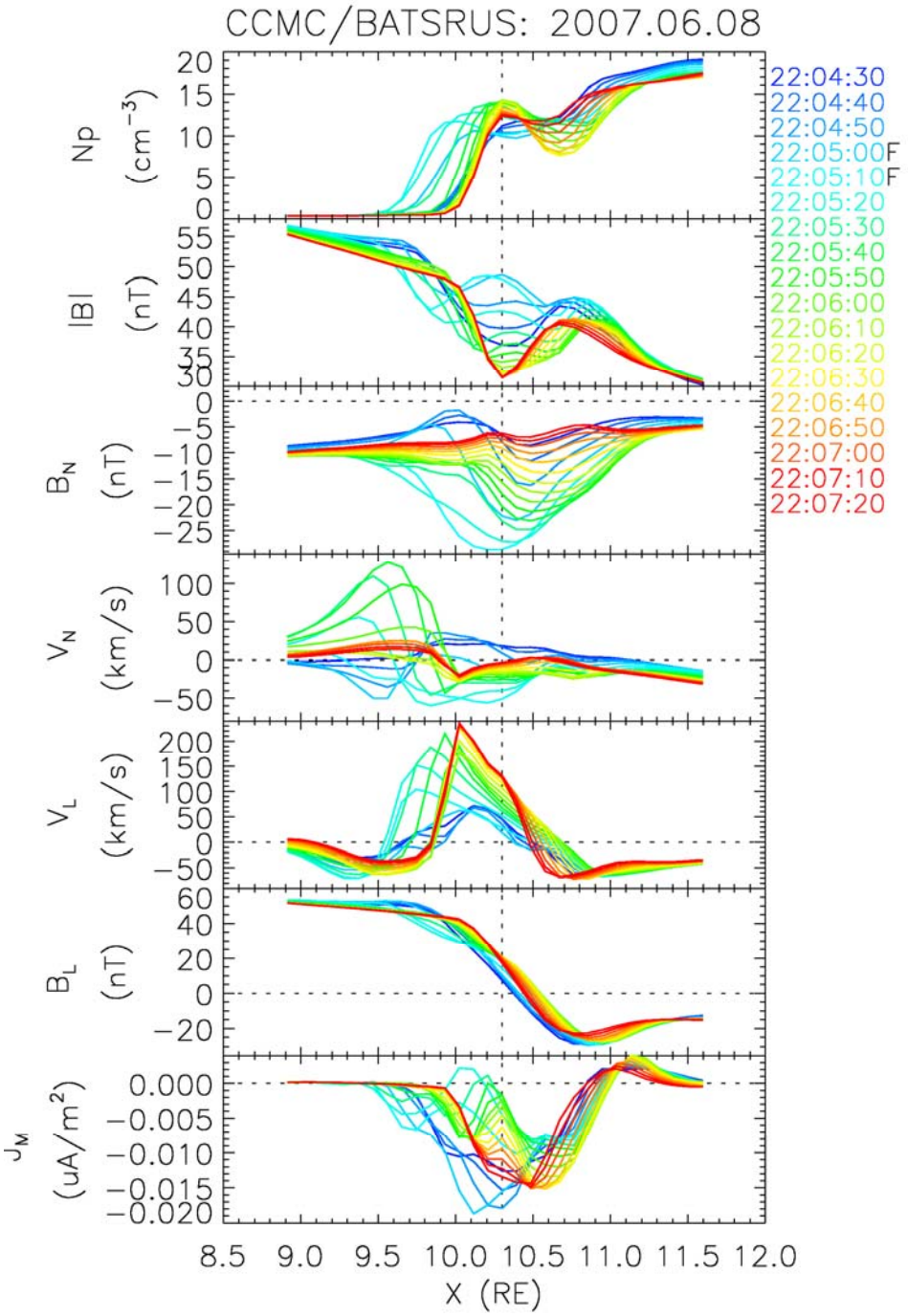
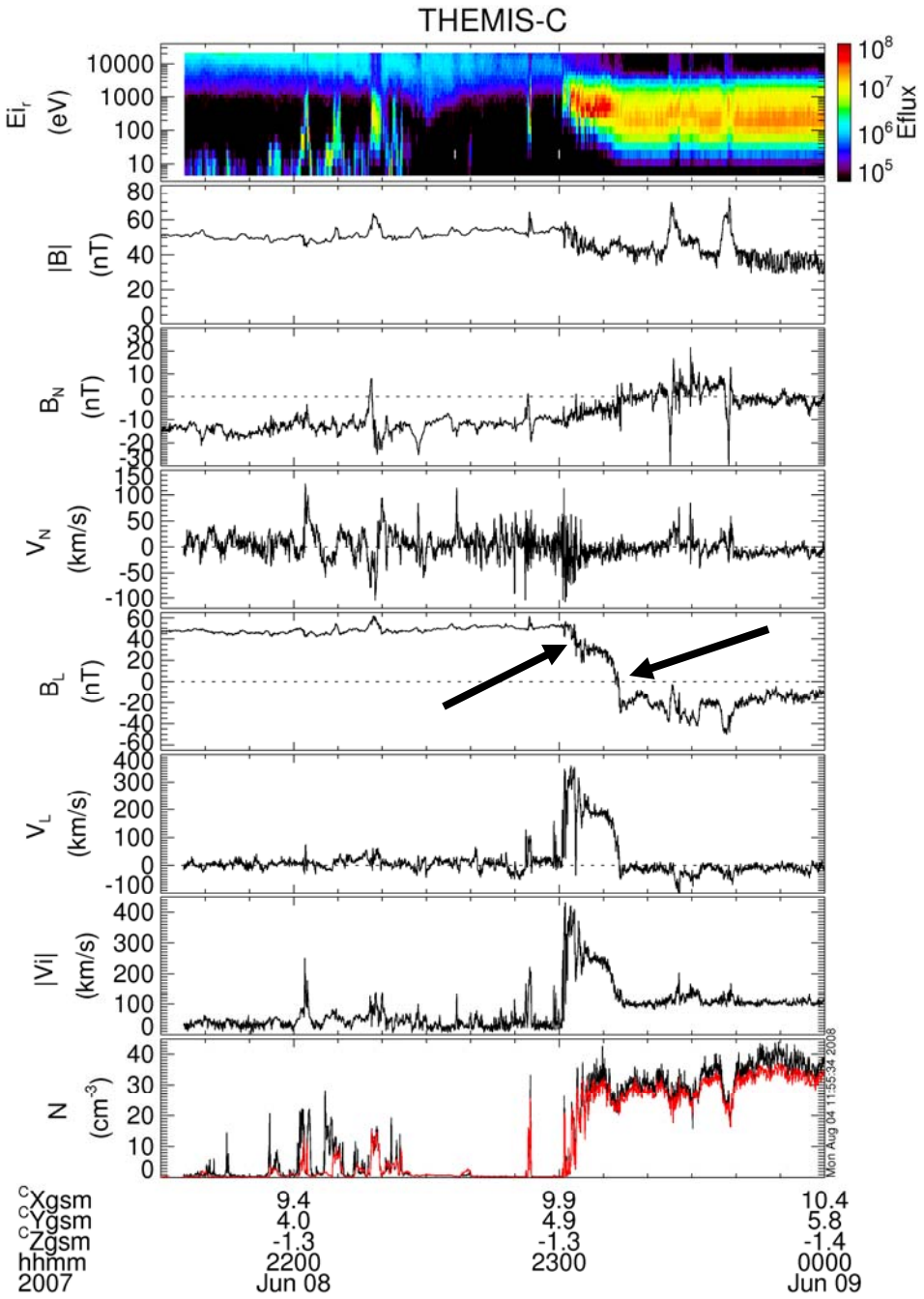




Unusual bifurcated dayside magnetopause current sheet when no large-scale FTE was observed….



Conclusions

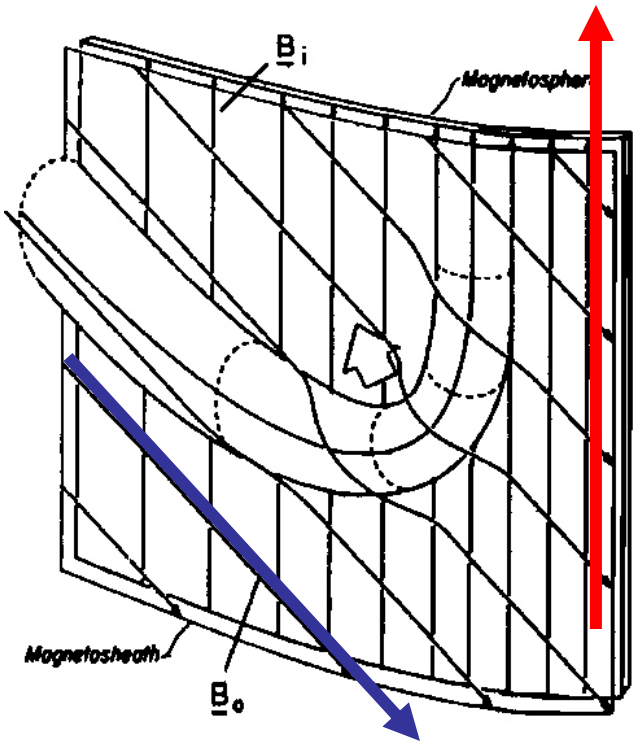
- THEMIS confirms that remote bipolar signatures are that of one (likely) main flux tube in the *active magnetopause reconnection layer*.

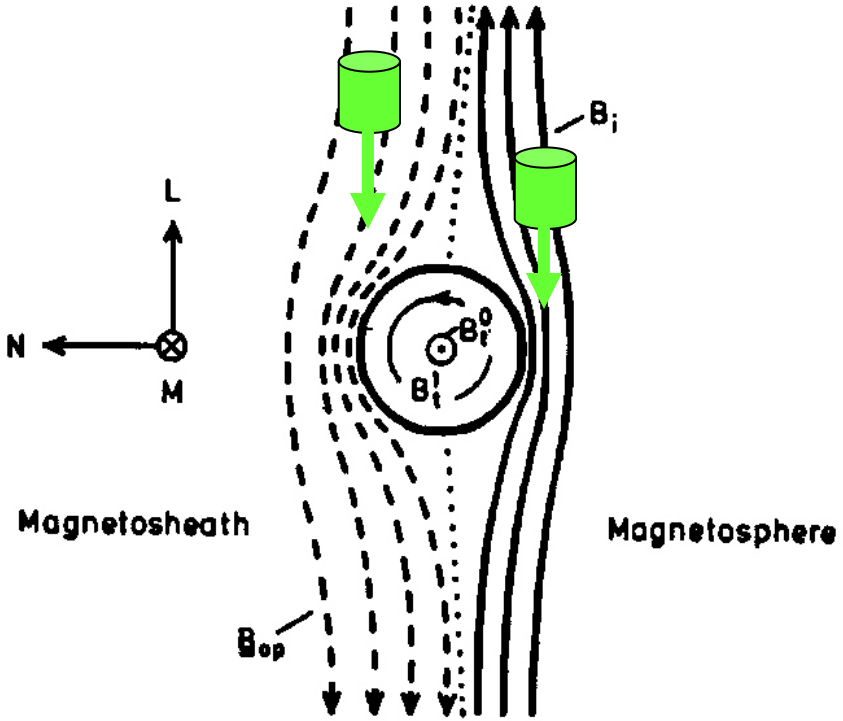
- MHD simulation suggests that the observed *bifurcated magnetopause current sheet* may have been generated in the *wake* of a passing FTE.

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. **E**x**B** consistent with **V**. Very good candidate to explain the energy-time dispersed cold ion signatures observed by THEMIS.





Schematic view of pre-noon magnetopause from the Sun. IMF Bz<0 and IMF By>0 (blue).
[NOTE: THEMIS event for IMF By<0 at post-noon side]

Cross-section of flux tube.

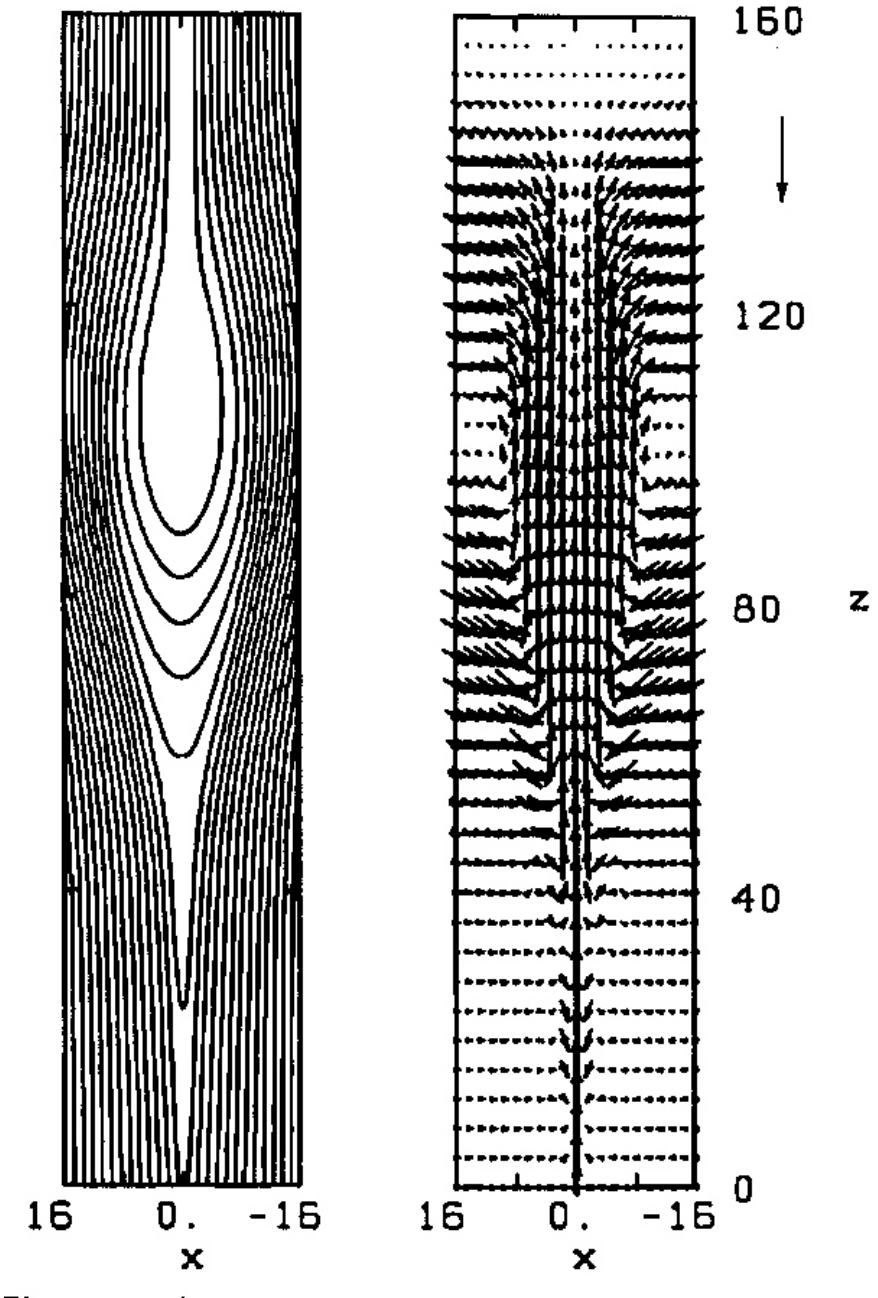
Bipolar field behavior is thought to result primarily from the draping of the magnetosheath field around a single reconnected flux tube [Paschmann et al., 1982].

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
#1	2210	“+/-” (all)
#2	2217	“+/-” (all)
#3	2252	“+/-” (all)
#4	2325	“-” (D,C) & “+/-/+” (E)
#5	2338	“-” (D) & “+/-/+” (C,E)