Velocity and E-field Variations of Geomagnetic Field During the Passage of Interplanetary Shocks

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Andrey Samsonov, Space Res. Inst.
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- Previous works on velocity and electric field measurements
  - 1980s
    - s/c ISEE 1 and 2
  - No complete simultaneous measurements of different parameters like B, V
  - No high resolution measurements
  - No direct electric field measurements
    - E field is inferred from ExB

Event Characterization

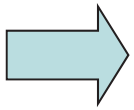
- IP identification
  - Box type variation with a sharp rise in
    - Density
    - Velocity
    - Thermal Speed
    - Temperature
    - Dynamic pressure

  - Box type variation
  - Increase of about twice the background

- Themis A/D/E spacecraft
  - Located within 45^{o} of sun-earth line.
  - Magnetic field
  - Velocity and
  - Electric field measurements
- GOES magnetic field
- Other spacecraft
  - Cluster (?)
  - Geotail
- Ground magnetometers

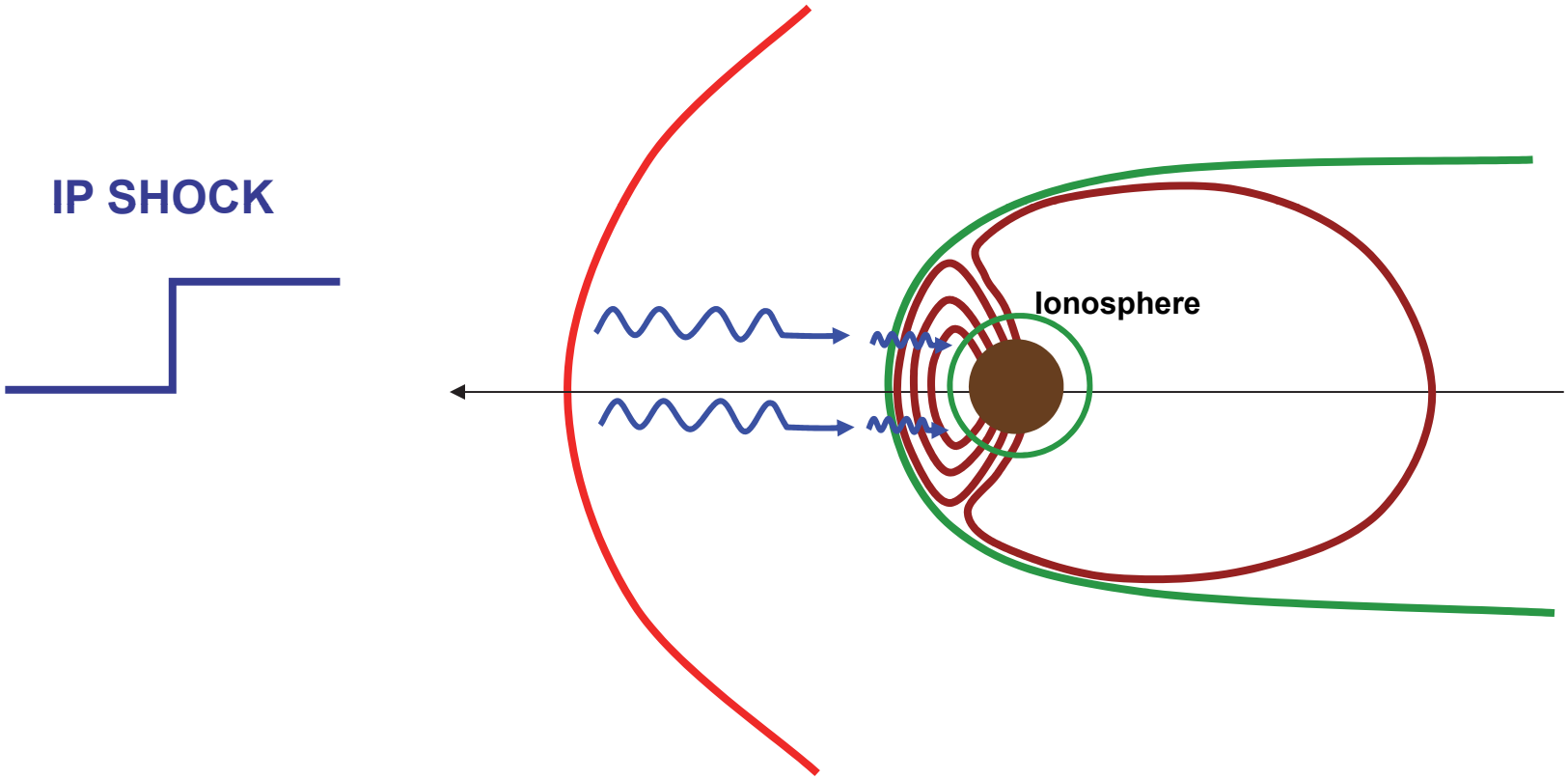
IP shock interaction with magnetosphere

- Interaction with bow shock
- Transmission in the magnetosheath
- Interaction with magnetopause
- Transmission of IP shock into the magnetosphere
  - Mpause inward motion in response to IP shock in the sheath drives a fast wave into the magnetosphere
- **Reflected wave concept ??**
  - **MHD models**
  - **LANL observations**



- Modifications of field aligned and ionospheric current systems
- Magnetic disturbances on the ground

IP shock and magnetosphere



Procedure

- Find IP shock

  → study what Themis sees

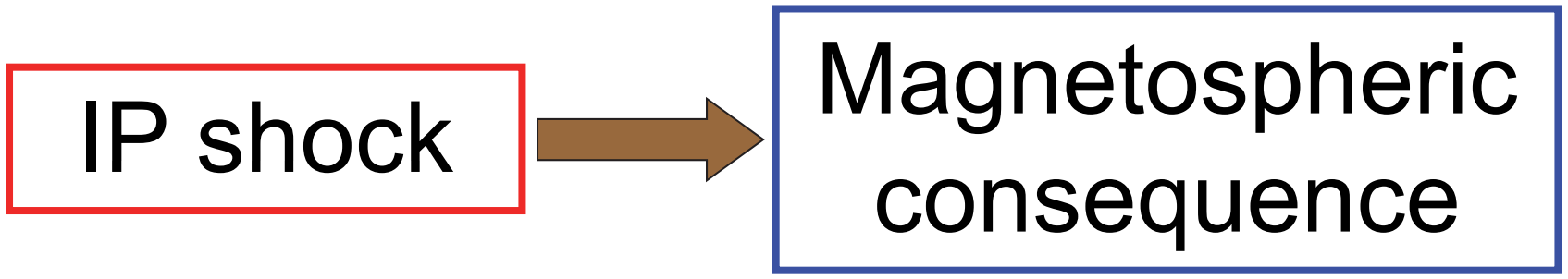
  magnetopause motion

  magnetic field perturbations

  velocity and E-field variations

  ground signatures

  etc.



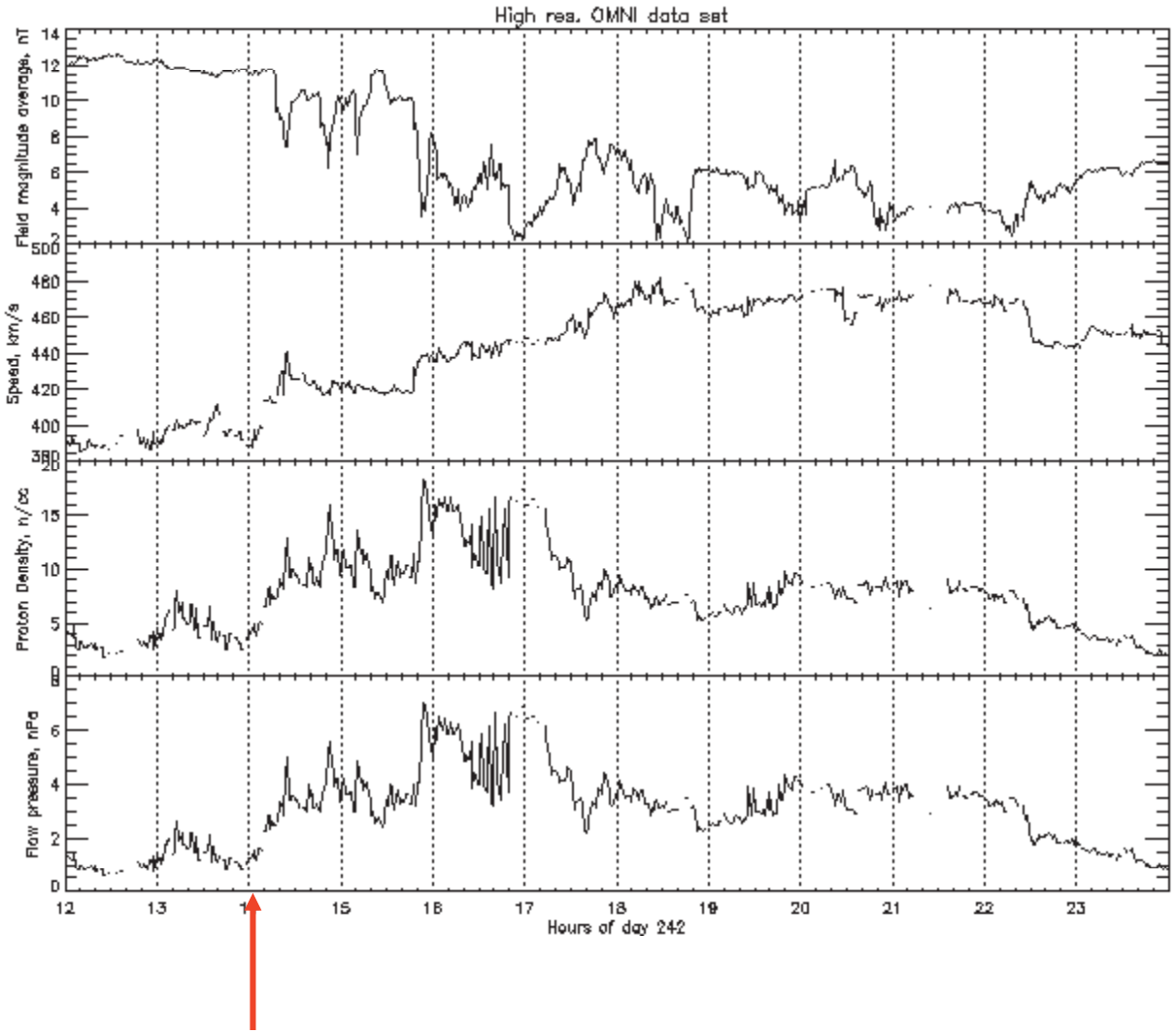
Case-1: August 30, 2009

Btot

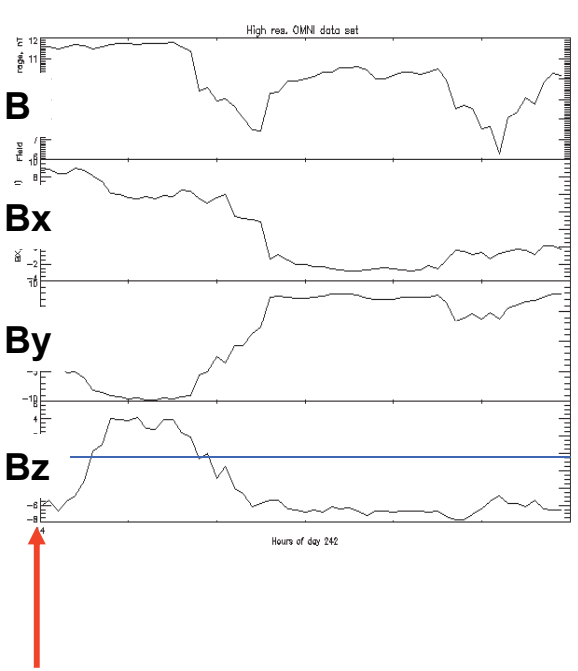
Vsw

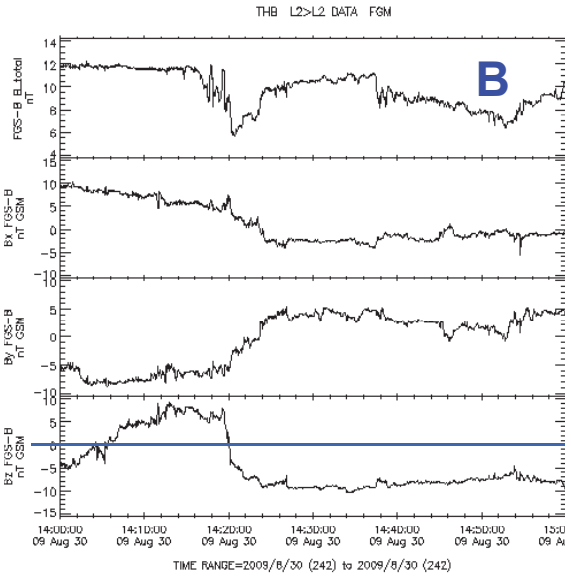
Nsw

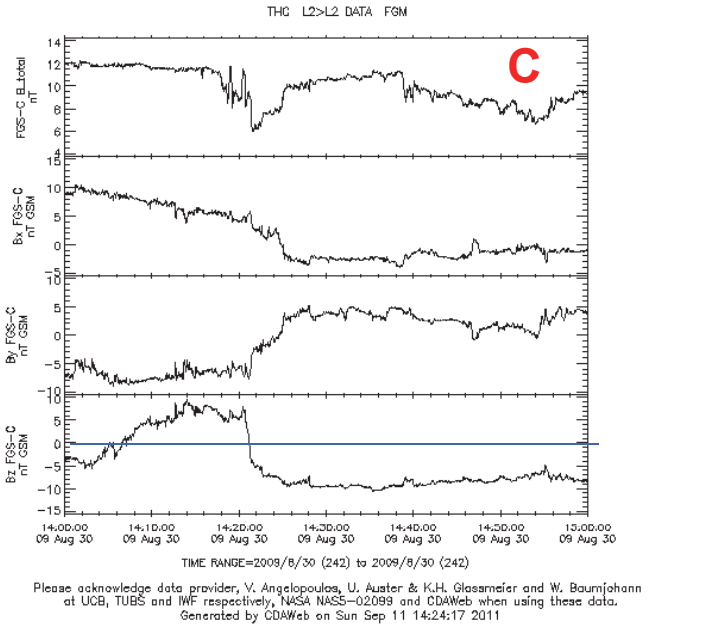
Pdyn

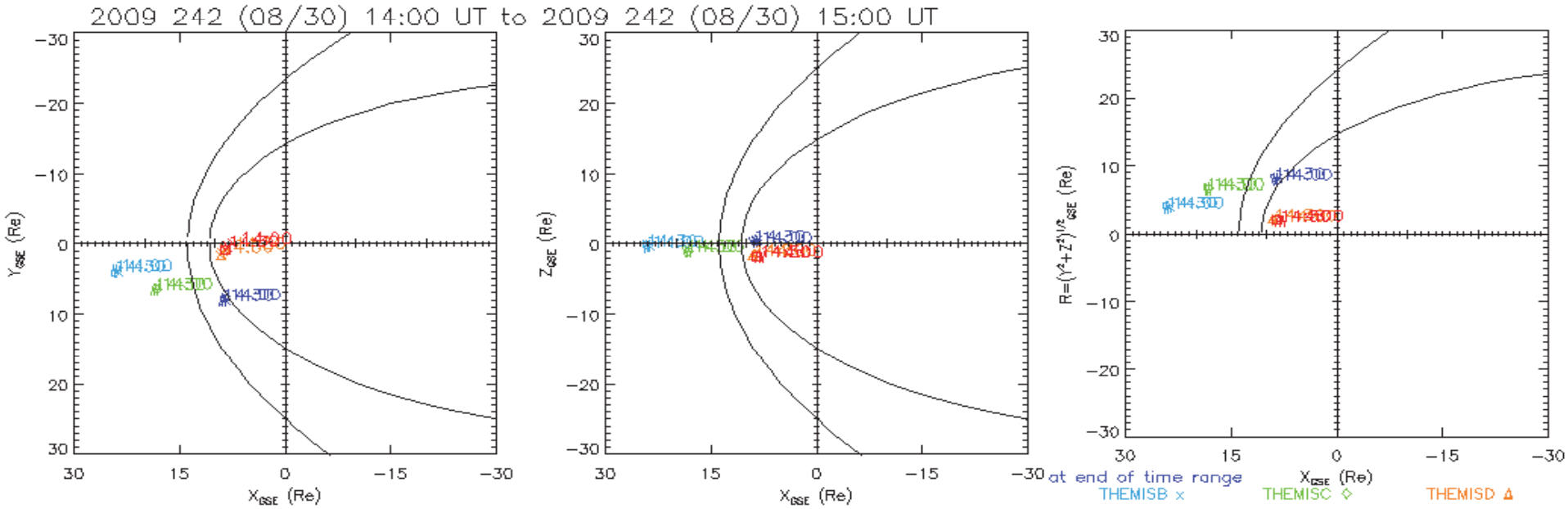


Interplanetary Magnetic Field









TA

Bx

By

Bz

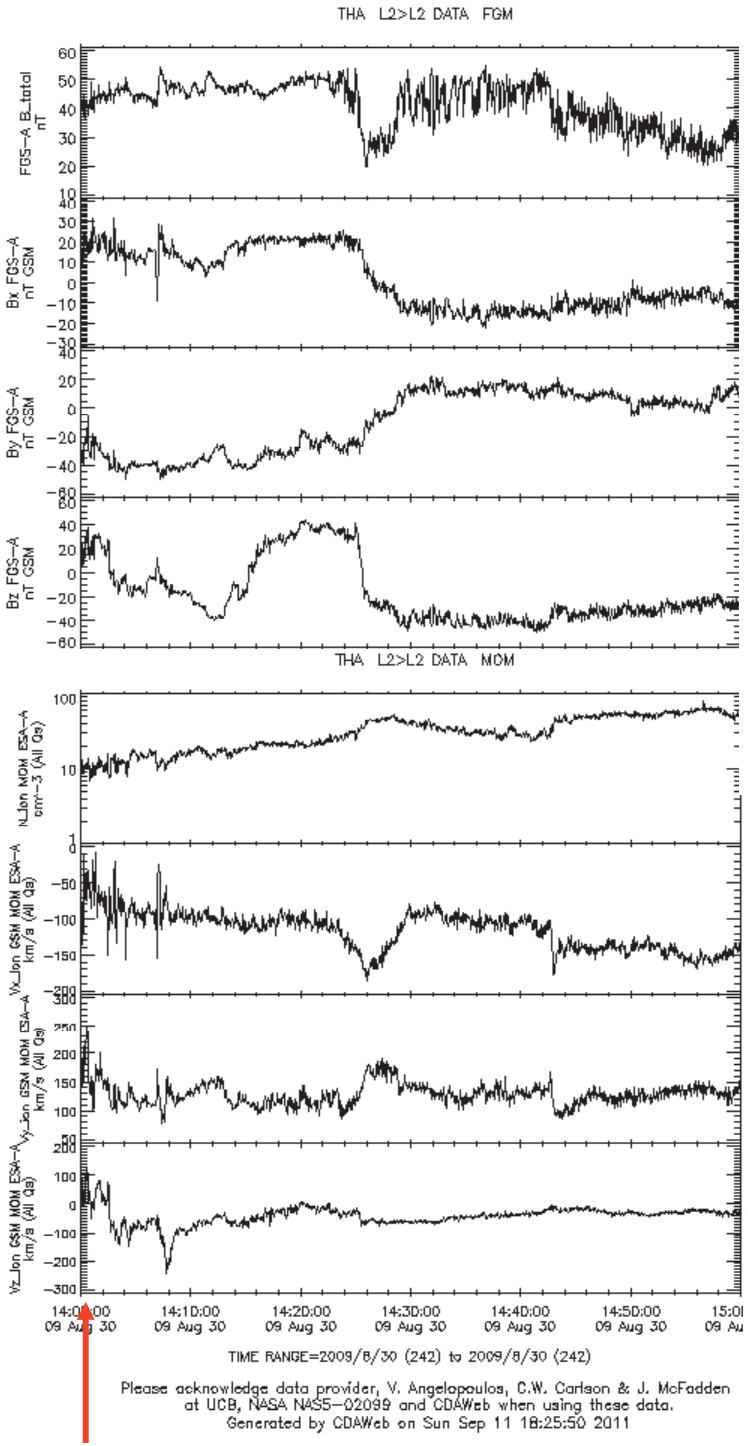
n

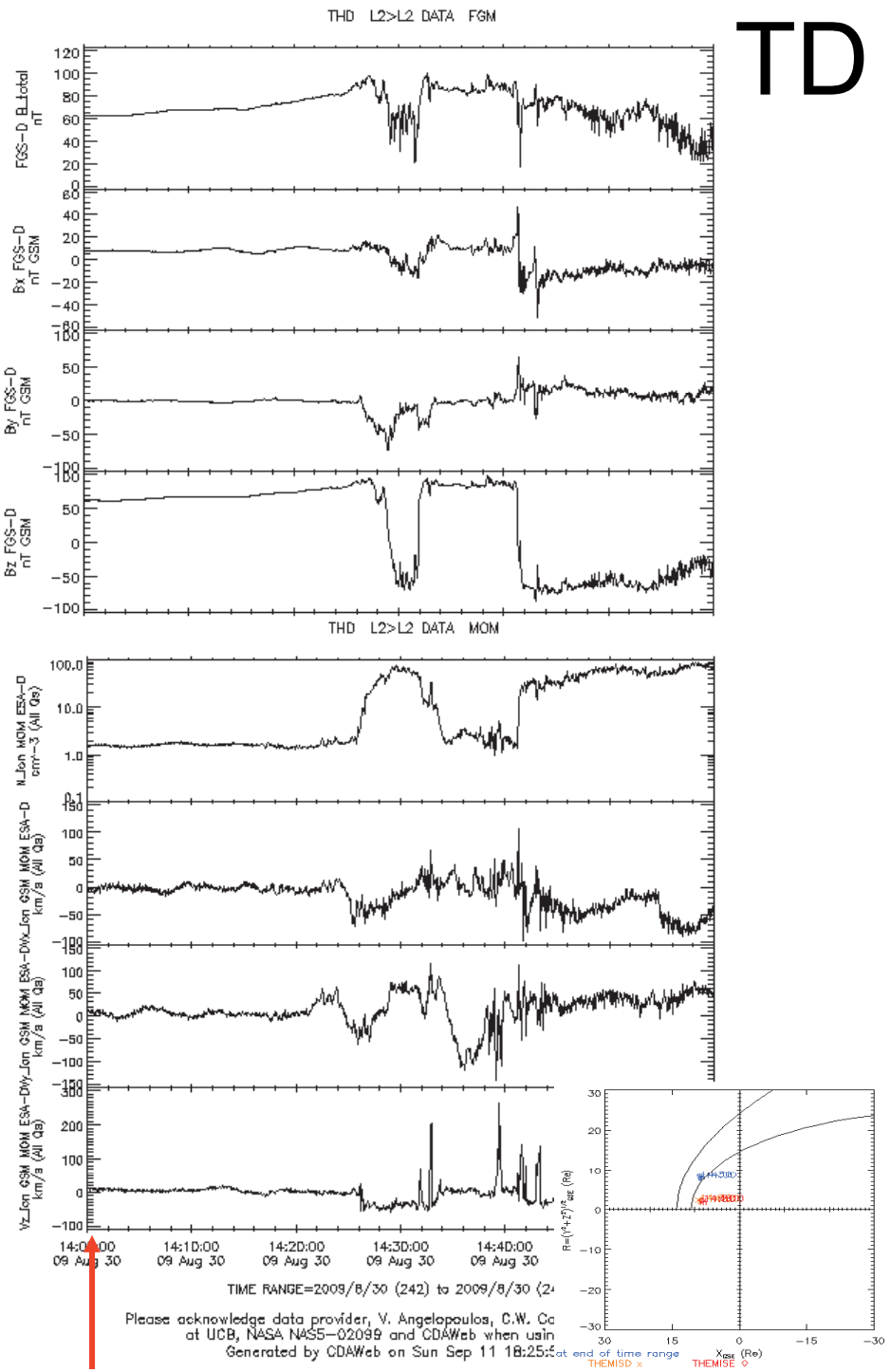
Vx

Vy

Vz

TD





TD

TE

Bx

By

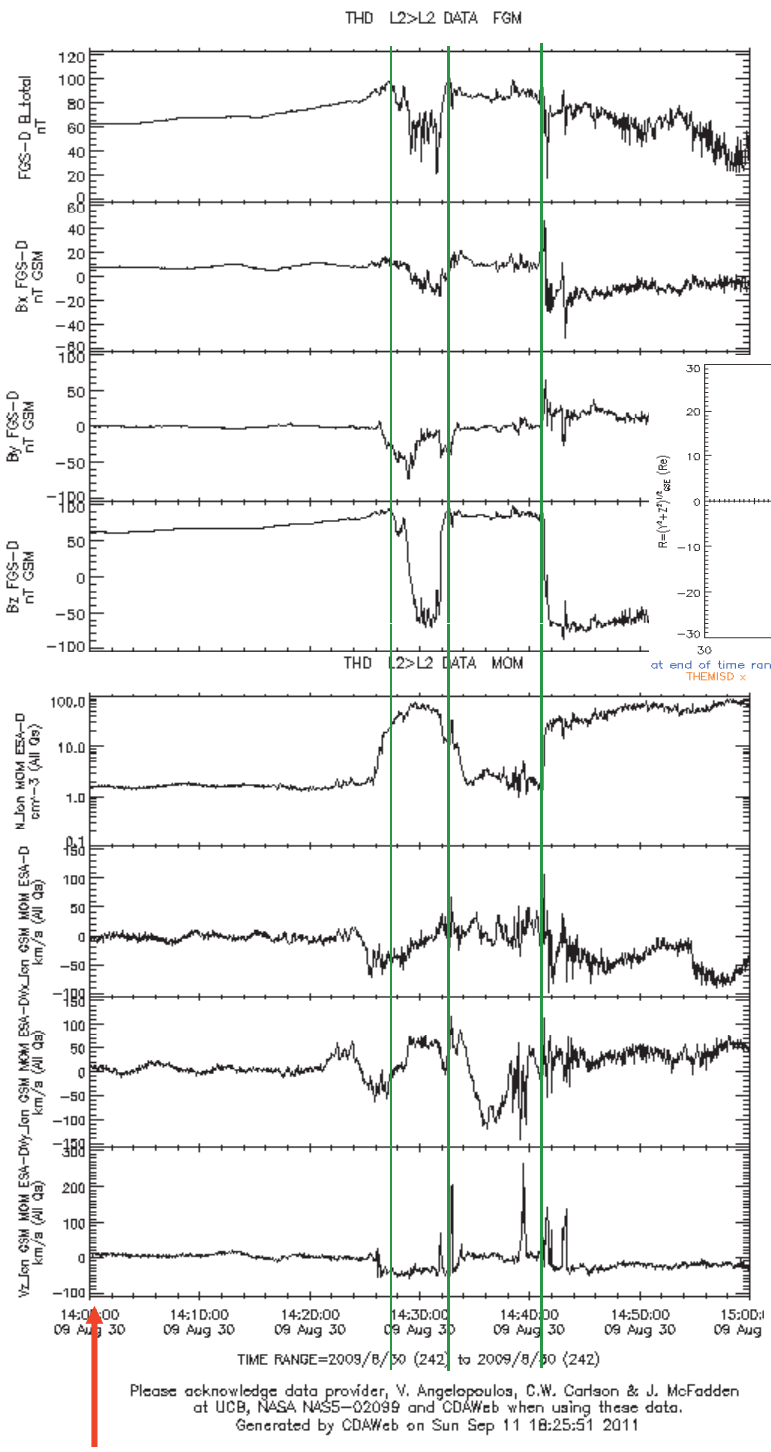
Bz

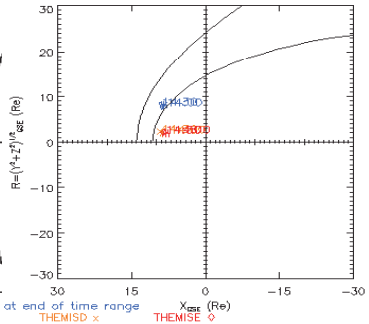
n

Vx

Vy

Vz

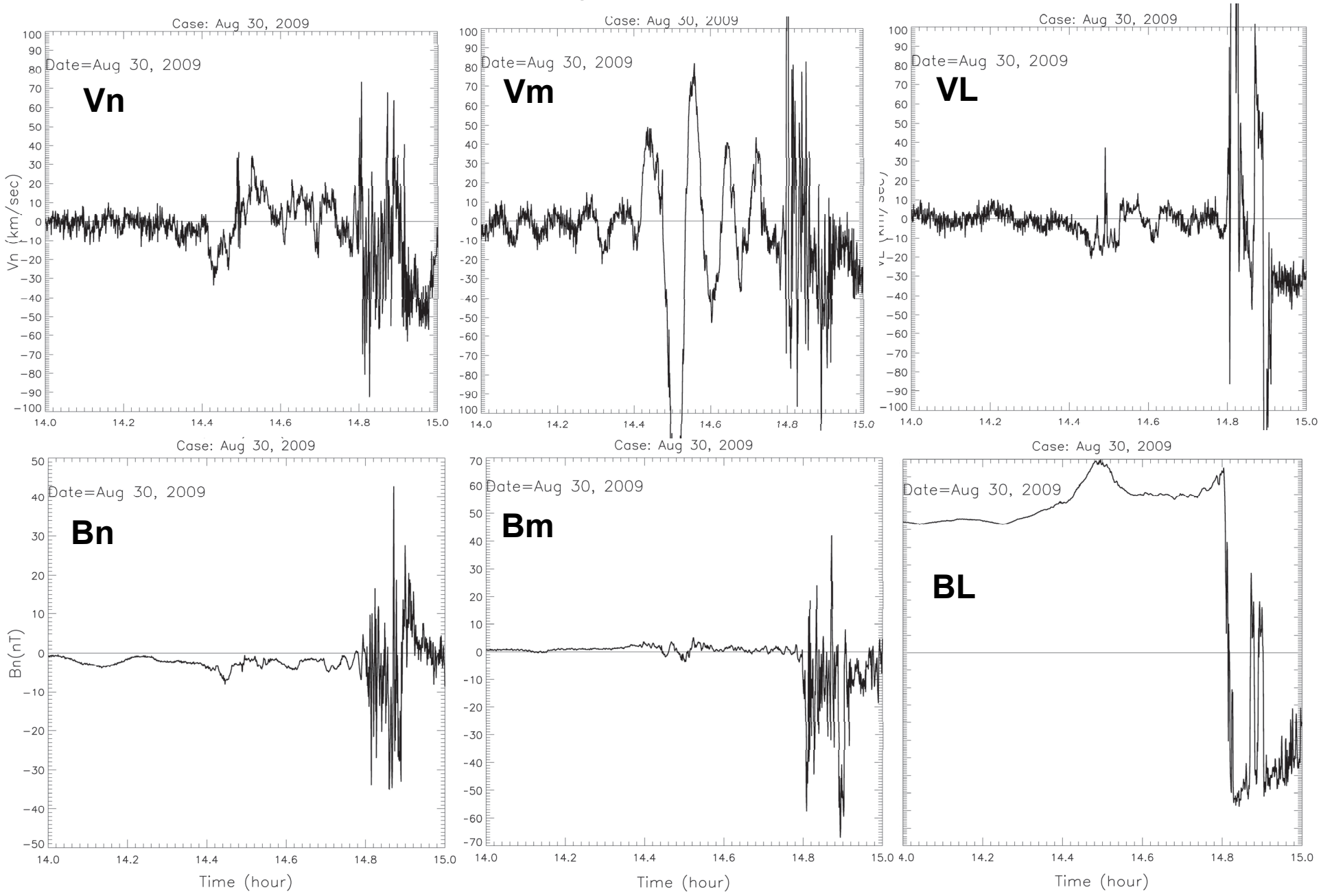




Vy

16min

LMN-boundary coordinates: THE



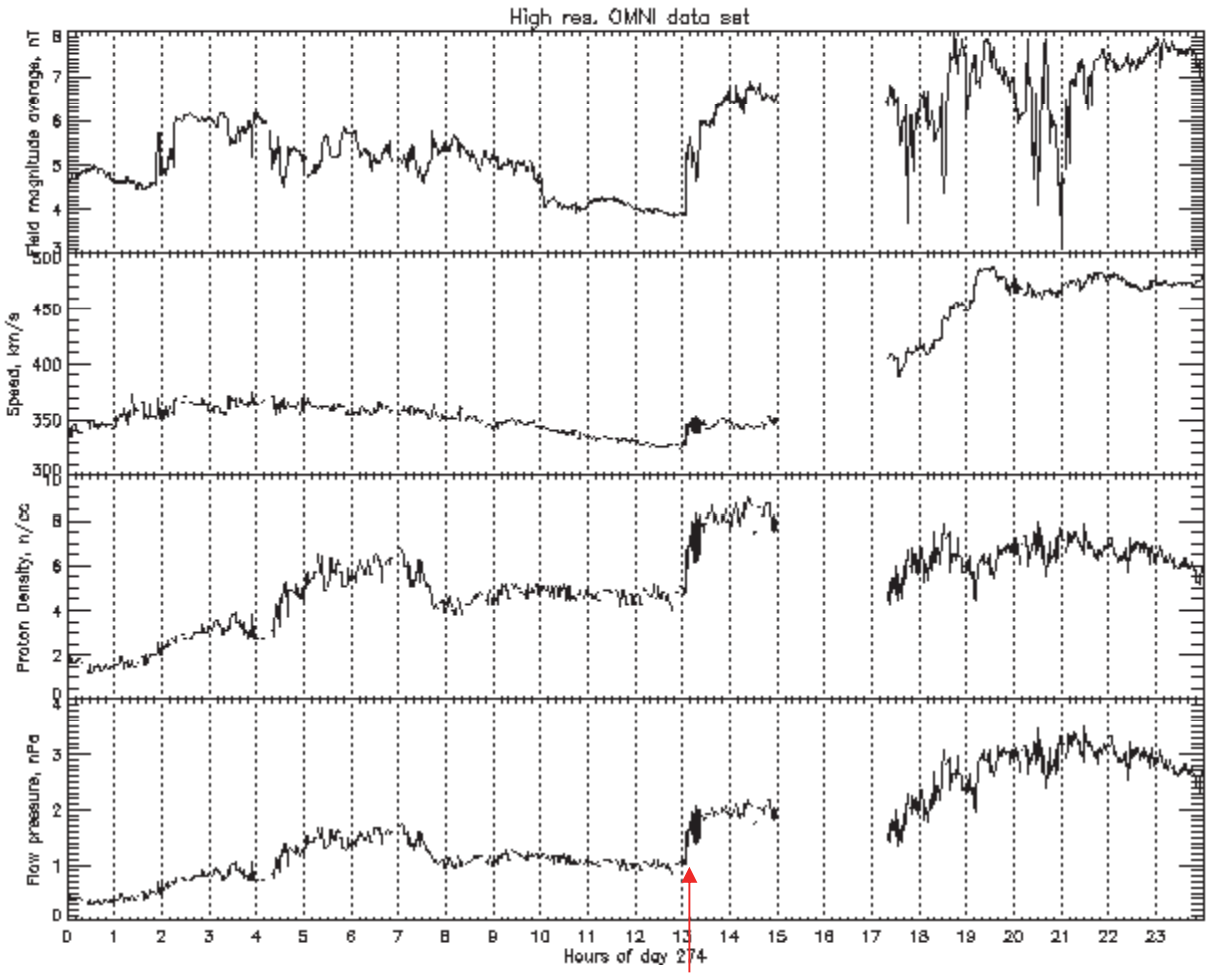
Case 2: Sep 30, 2008

Btot

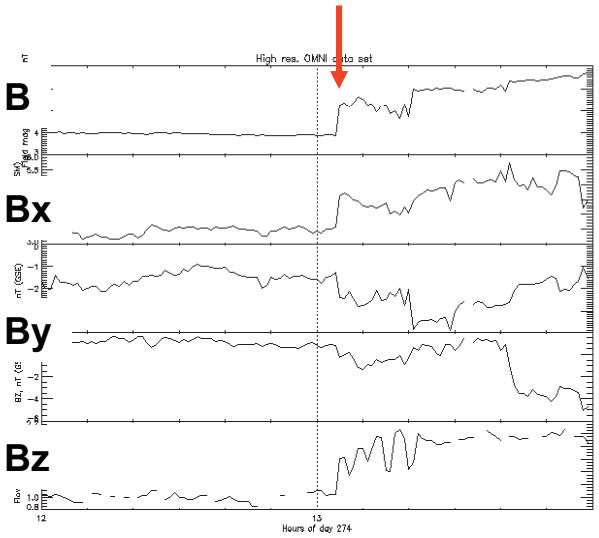
Vsw

Nsw

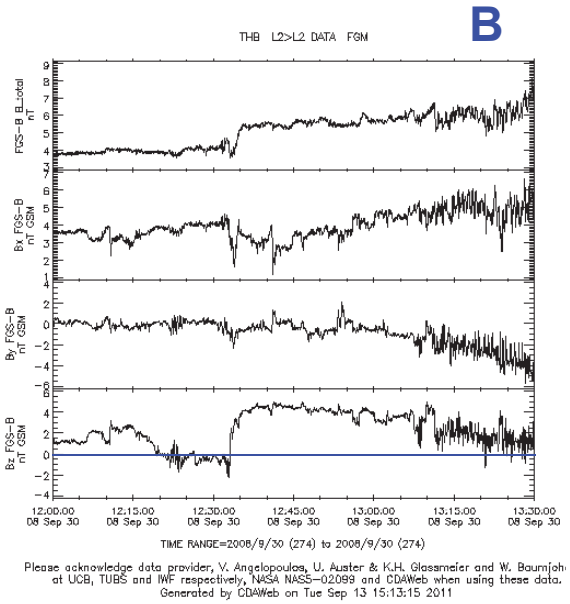
Pdyn

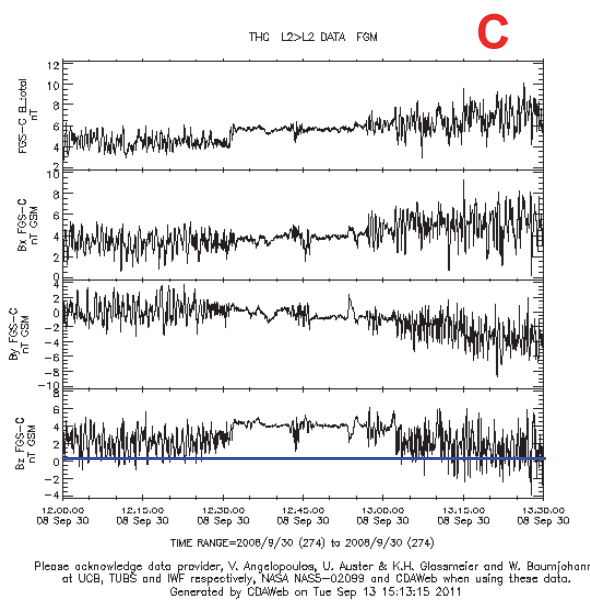


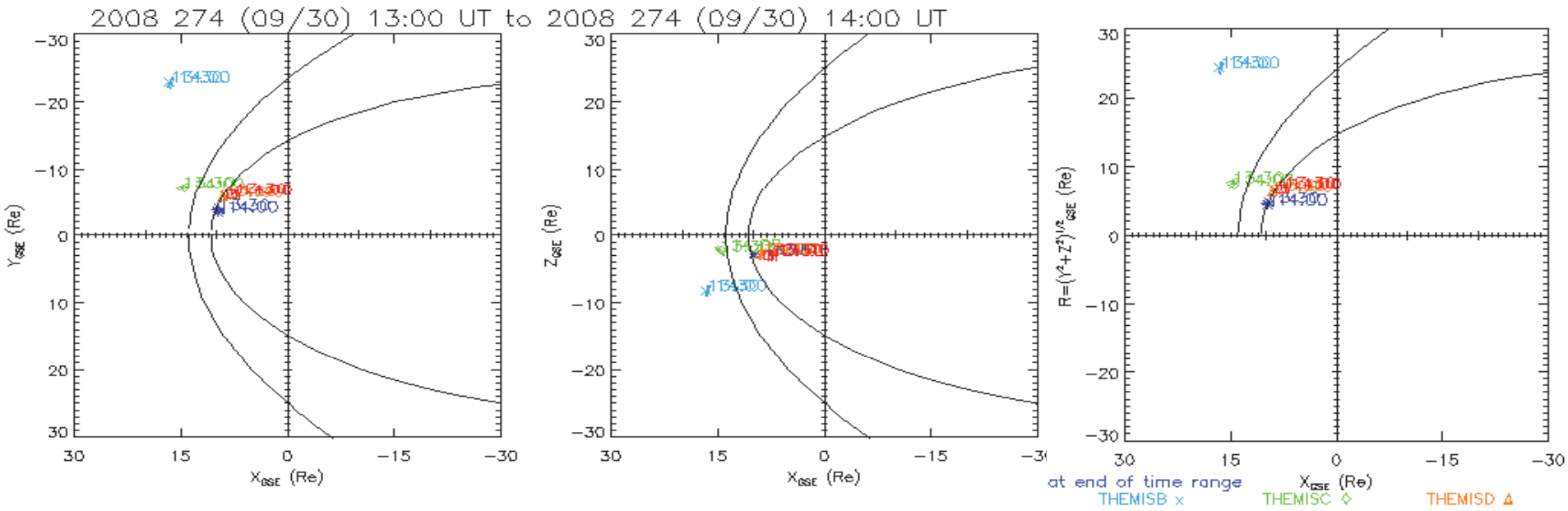
Interplanetary Magnetic Field

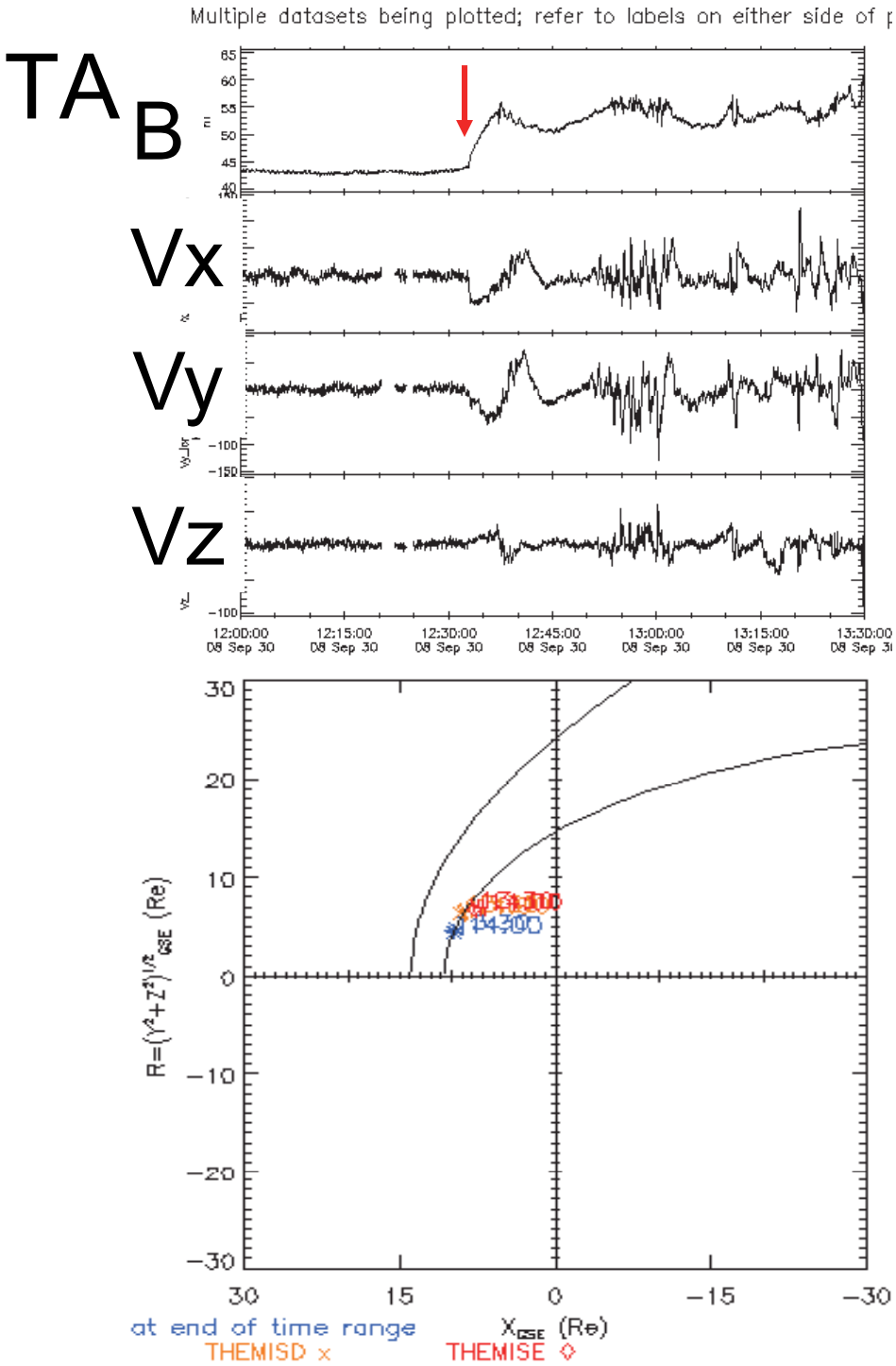


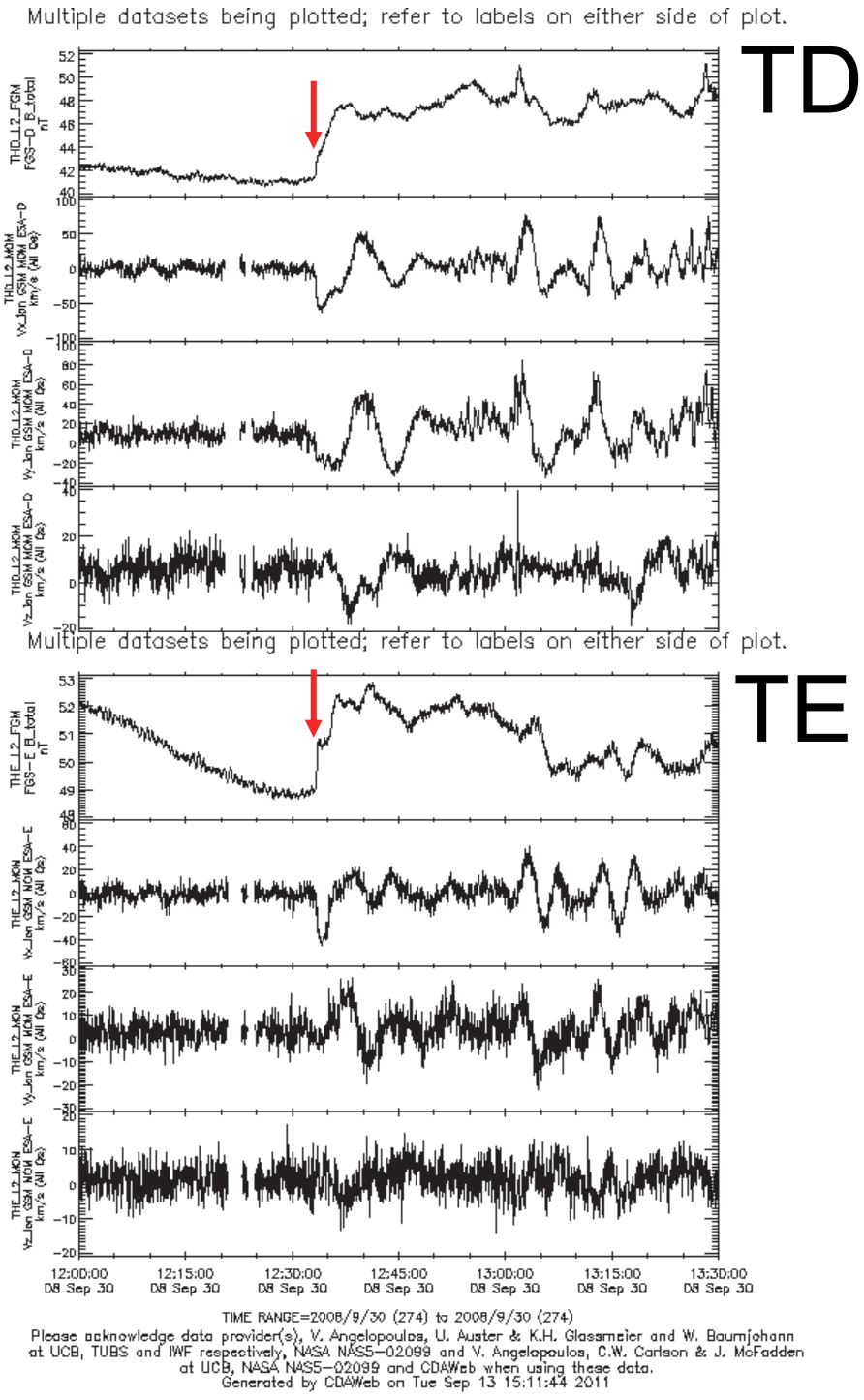
Northward IMF BZ








Multiple datasets being plotted; refer to labels on either side of p
TA
B
Vx
Vy
Vz
12:00:00 08 Sep 30
12:15:00 08 Sep 30
12:30:00 08 Sep 30
12:45:00 08 Sep 30
13:00:00 08 Sep 30
13:15:00 08 Sep 30
13:30:00 08 Sep 30
R=(Y²+Z²)^1/2 GSE (Re)
X GSE (Re)
at end of time range
THEMISD x
THEMISE ◇


Multiple datasets being plotted; refer to labels on either side of plot.
TD
Multiple datasets being plotted; refer to labels on either side of plot.
TE
12:00:00 08 Sep 30
12:15:00 08 Sep 30
12:30:00 08 Sep 30
12:45:00 08 Sep 30
13:00:00 08 Sep 30
13:15:00 08 Sep 30
13:30:00 08 Sep 30
TIME RANGE=2008/9/30 (274) to 2008/9/30 (274)
Please acknowledge data provider(s), V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baumjohann at UCB, TUBS and IWF respectively, NASA NAS5-02099 and V. Angelopoulos, C.W. Carlson & J. McFadden at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Tue Sep 13 15:11:44 2011

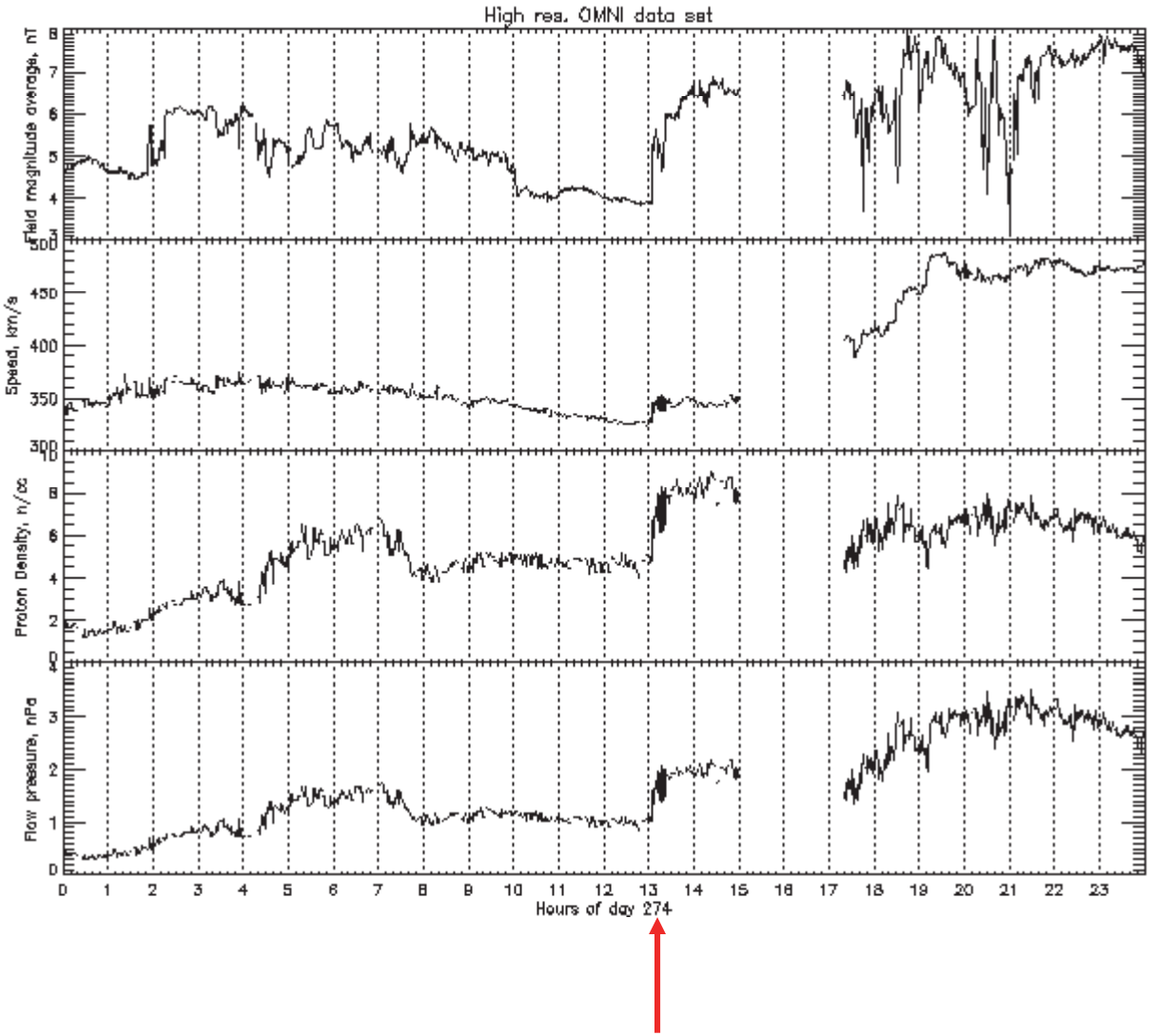
Case 3: July 22, 2008

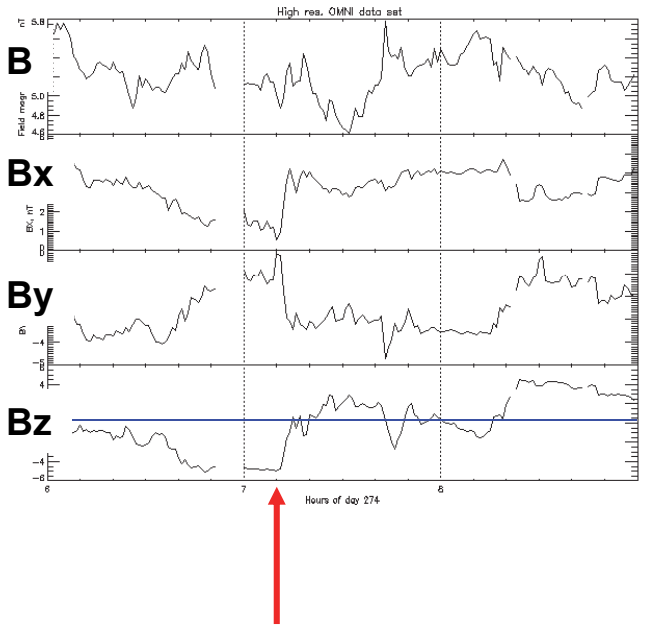
Btot

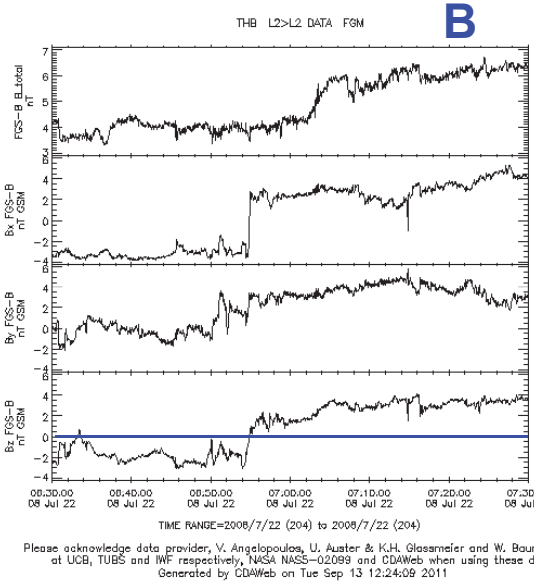
Vsw

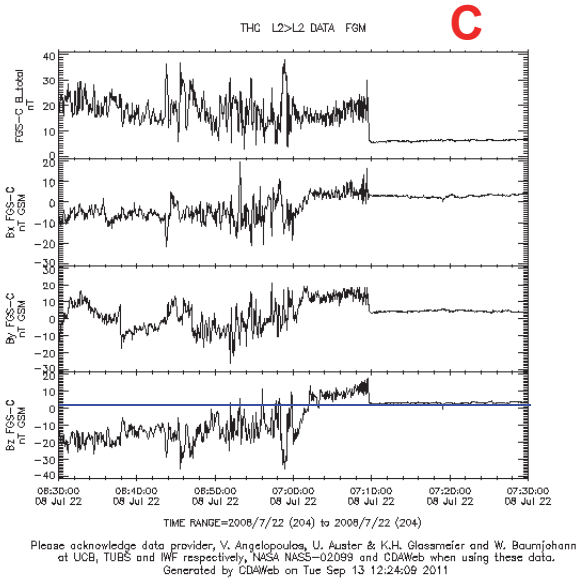
Nsw

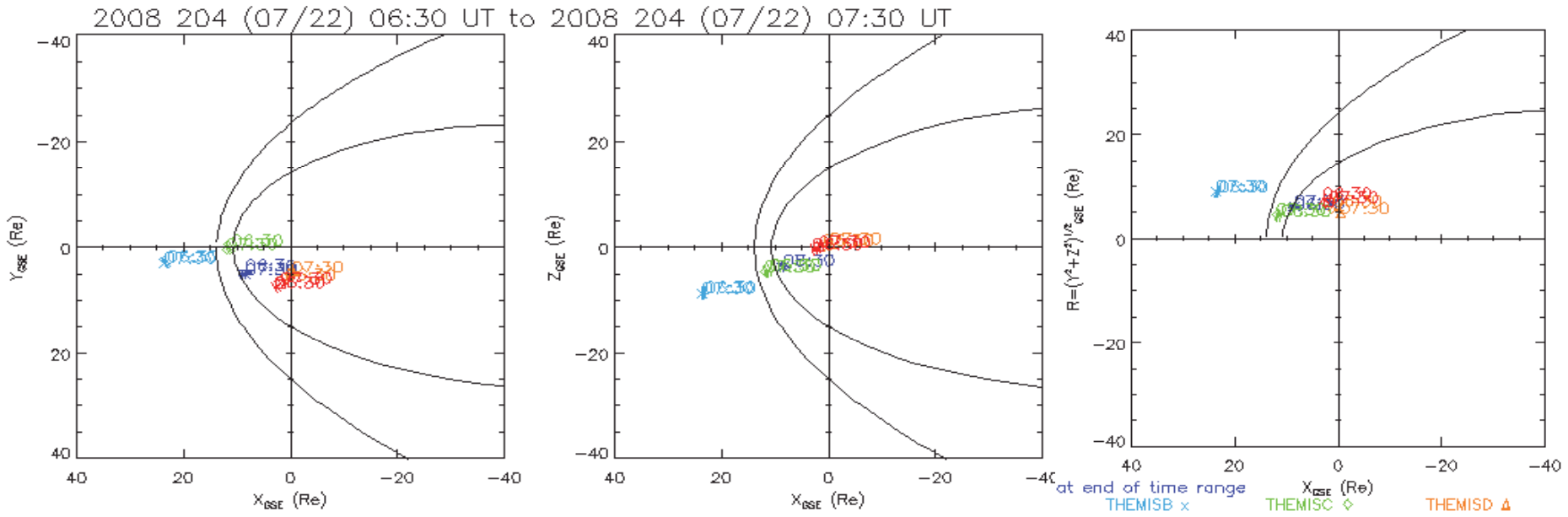
Pdyn




High res. OMNI data set
B
Bx
By
Bz
Hours of day 274


THB L2>L2 DATA FGM
B
TIME RANGE=2008/7/22 (204) to 2008/7/22 (204)
Please acknowledge data provider, V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Bau
at UCB, TUBS and IWF respectively, NASA NAS5-02099 and CDAWeb when using these d
Generated by CDAWeb on Tue Sep 13 12:24:09 2011


THC L2>L2 DATA FGM
C
TIME RANGE=2008/7/22 (204) to 2008/7/22 (204)
Please acknowledge data provider, V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baumjohann
at UCB, TUBS and IWF respectively, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Tue Sep 13 12:24:09 2011


2008 204 (07/22) 06:30 UT to 2008 204 (07/22) 07:30 UT
Y_GSE (Re)
X_GSE (Re)
Z_GSE (Re)
R=(Y²+Z²)^½ GSE (Re)
at end of time range
THEMISB x
THEMISC ◇
THEMISD △

TA

TE

Bx

By

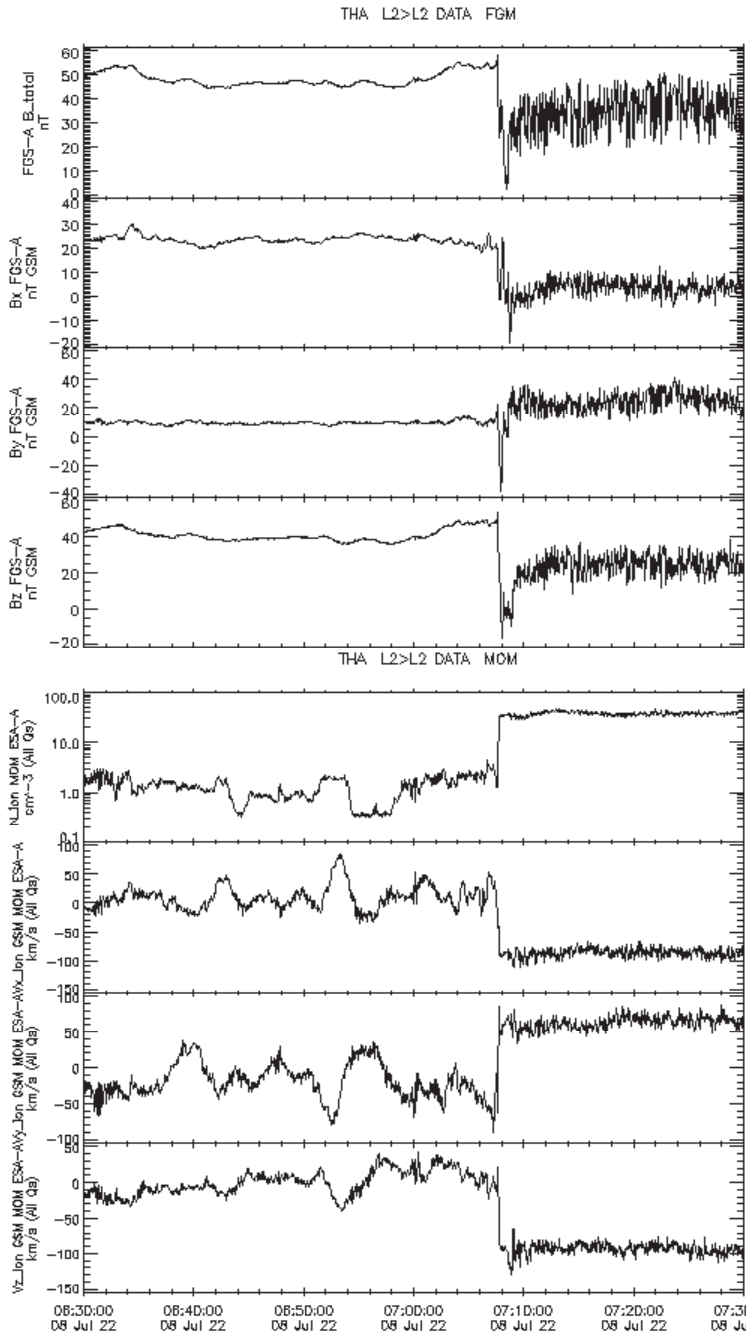
Bz

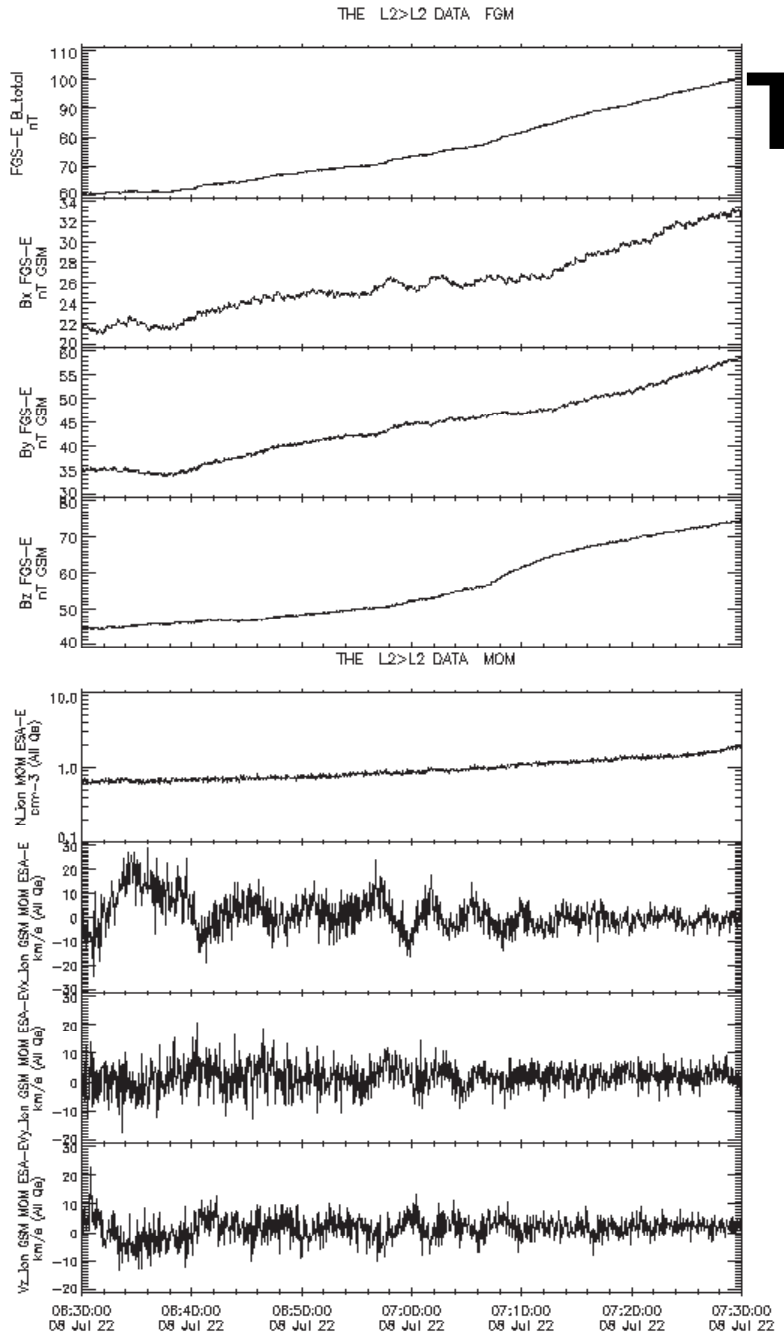
n

Vx

Vy

Vz





- Case 4: multiple shocks
- Case 5: s/c goes into sheath
- Case 6: A does not see anything but D and E sees periodic variations

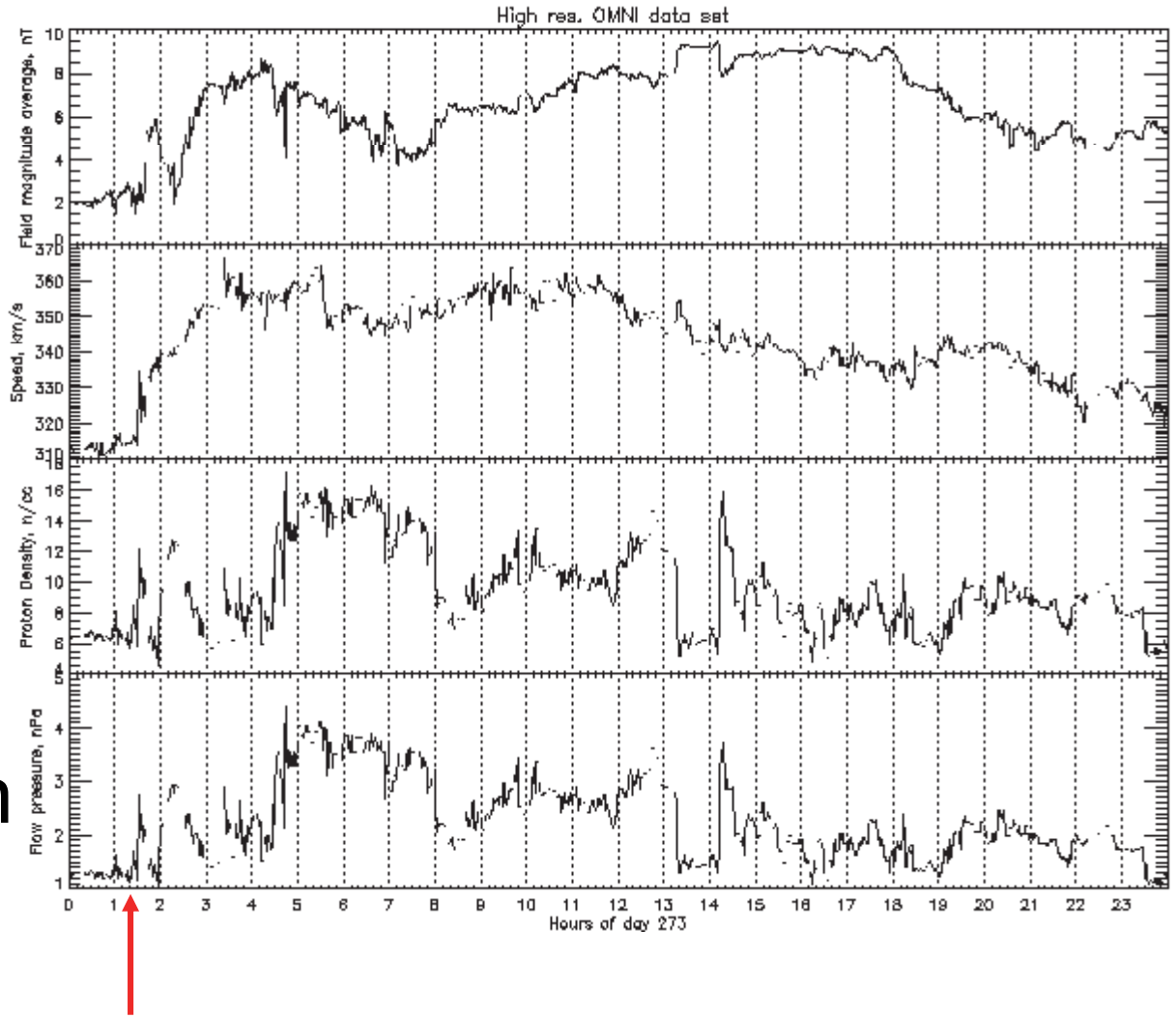
Case 4: Sep 30, 2009

Btot

Vsw

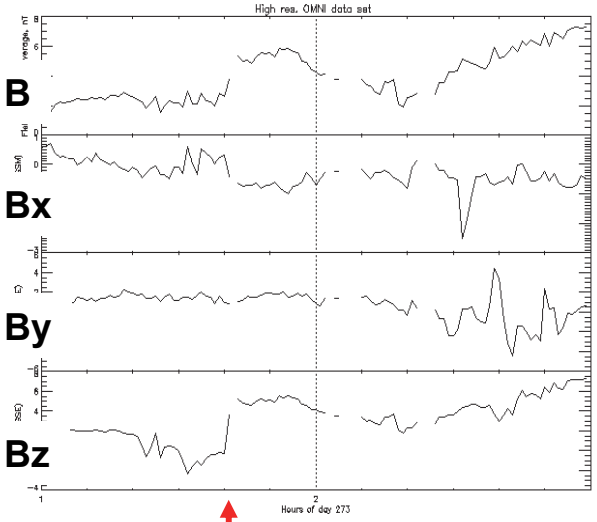
Nsw

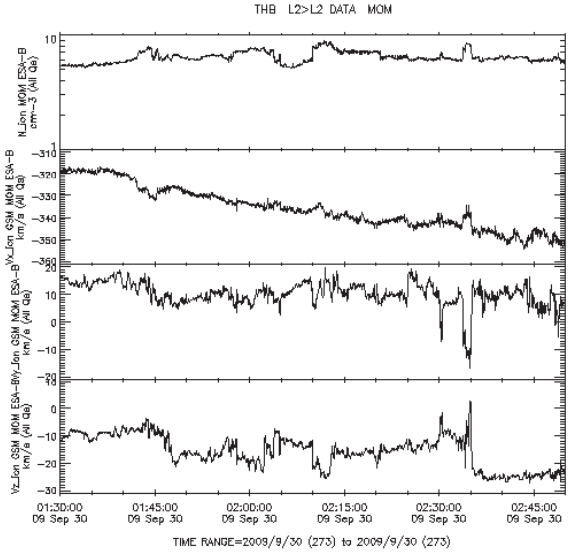
Pdyn

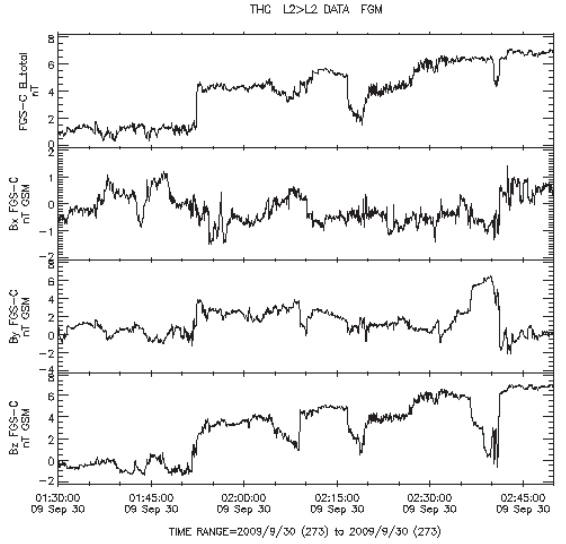


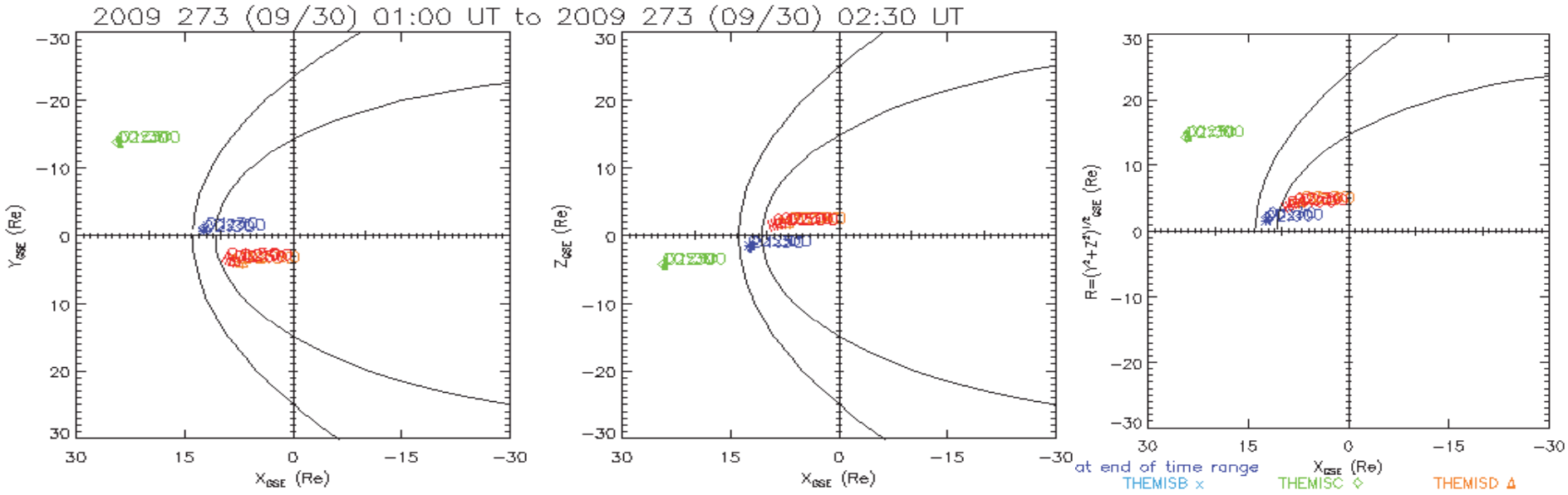
B, mom

C fgm


High res. OMNI data set
B
Bx
By
Bz
Hours of day 273


THB L2>L2 DATA MOM
01:30:00 09 Sep 30
01:45:00 09 Sep 30
02:00:00 09 Sep 30
02:15:00 09 Sep 30
02:30:00 09 Sep 30
02:45:00 09 Sep 30
TIME RANGE=2009/9/30 (273) to 2009/9/30 (273)
Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Mon Sep 12 10:15:45 2011


THC L2>L2 DATA FGM
01:30:00 09 Sep 30
01:45:00 09 Sep 30
02:00:00 09 Sep 30
02:15:00 09 Sep 30
02:30:00 09 Sep 30
02:45:00 09 Sep 30
TIME RANGE=2009/9/30 (273) to 2009/9/30 (273)
Please acknowledge data provider, V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baumjohann at UCB, TUBS and IWF respectively, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Mon Sep 12 10:15:44 2011


2009 273 (09/30) 01:00 UT to 2009 273 (09/30) 02:30 UT
Y_{GSE} (Re)
X_{GSE} (Re)
Z_{GSE} (Re)
$R=(Y^2+Z^2)^{1/2}_{GSE}$ (Re)
at end of time range
THEMISB ×
THEMISC ◇
THEMISD △

TD

Bx

By

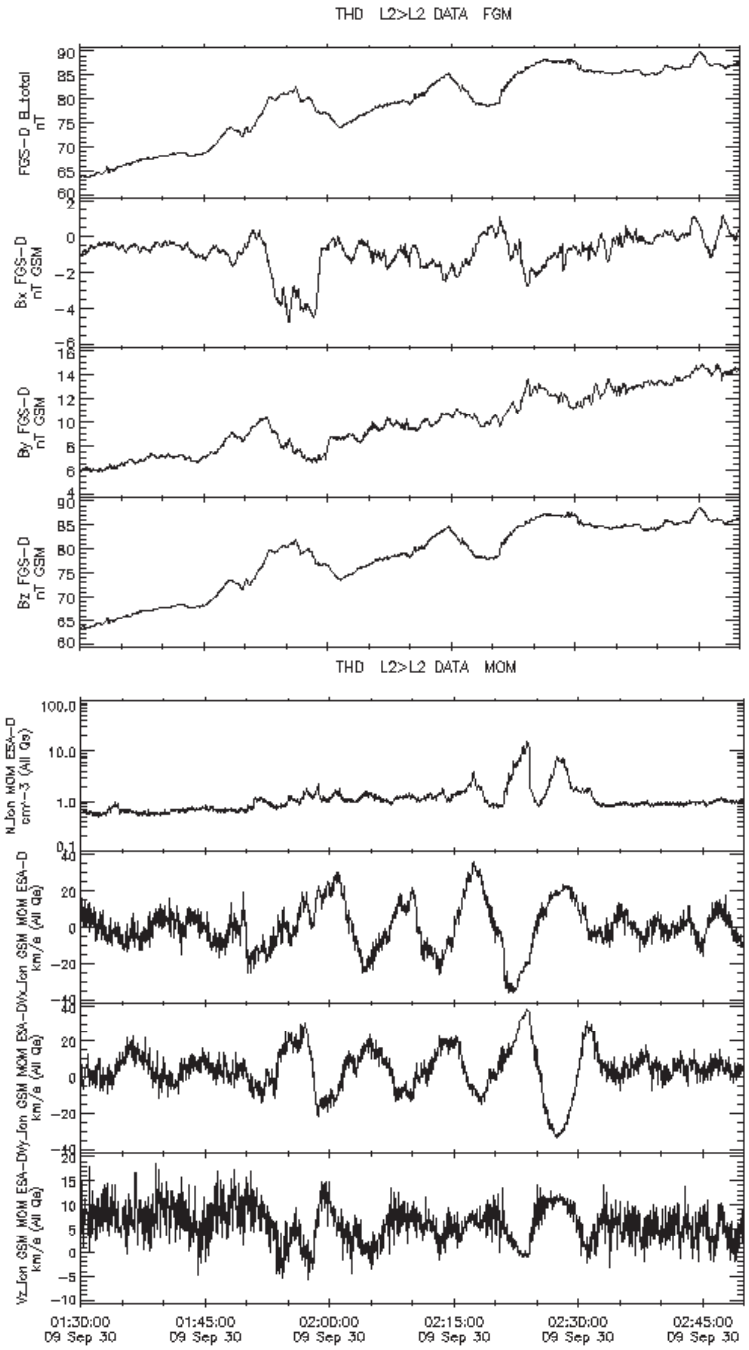
Bz

n

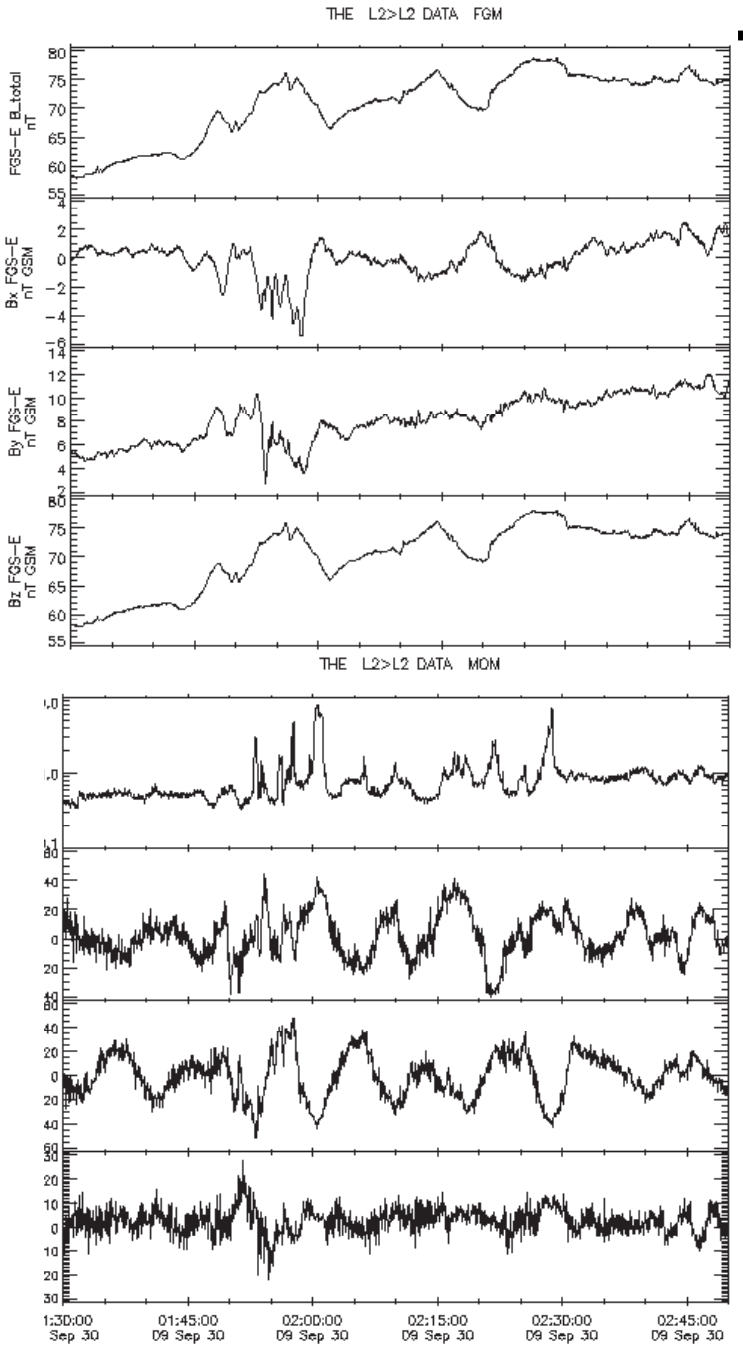
Vx

Vy

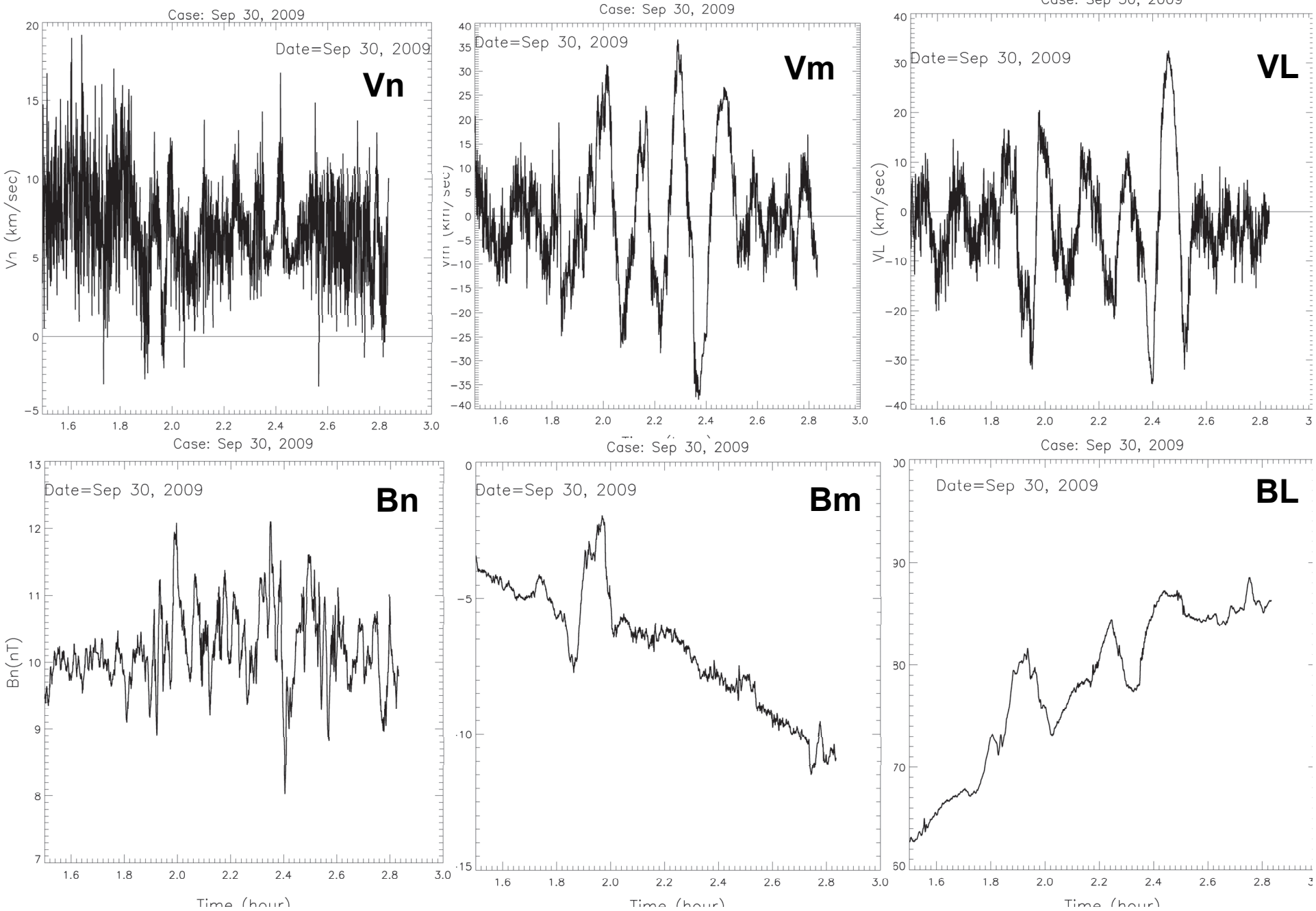
Vz



TE



LMN Boundary Coordinates: THD



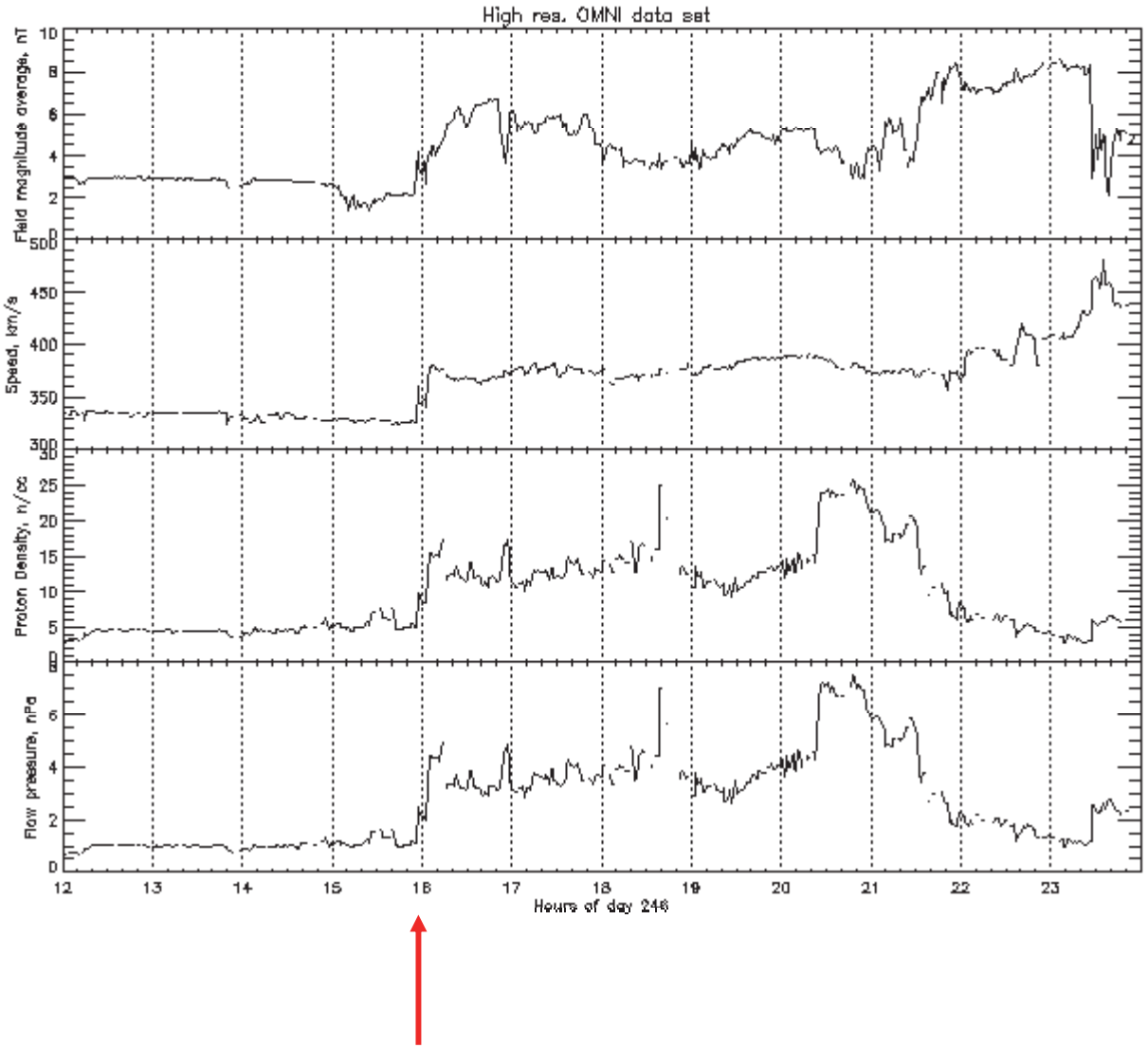
Case-5 Sep 3, 2009

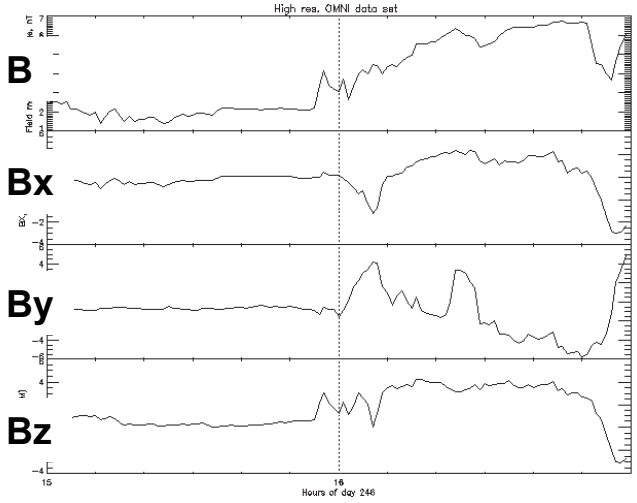
Btot

Vsw

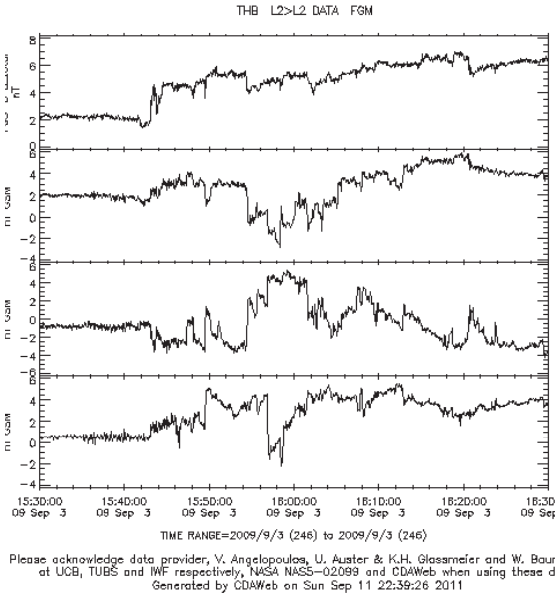
Nsw

Pdyn

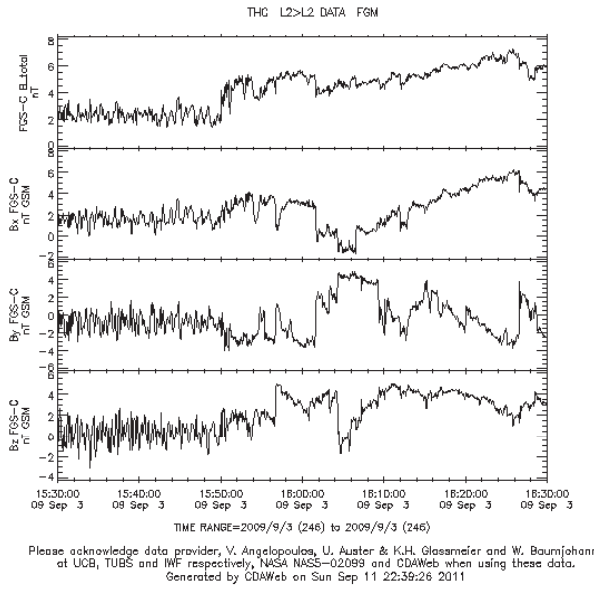


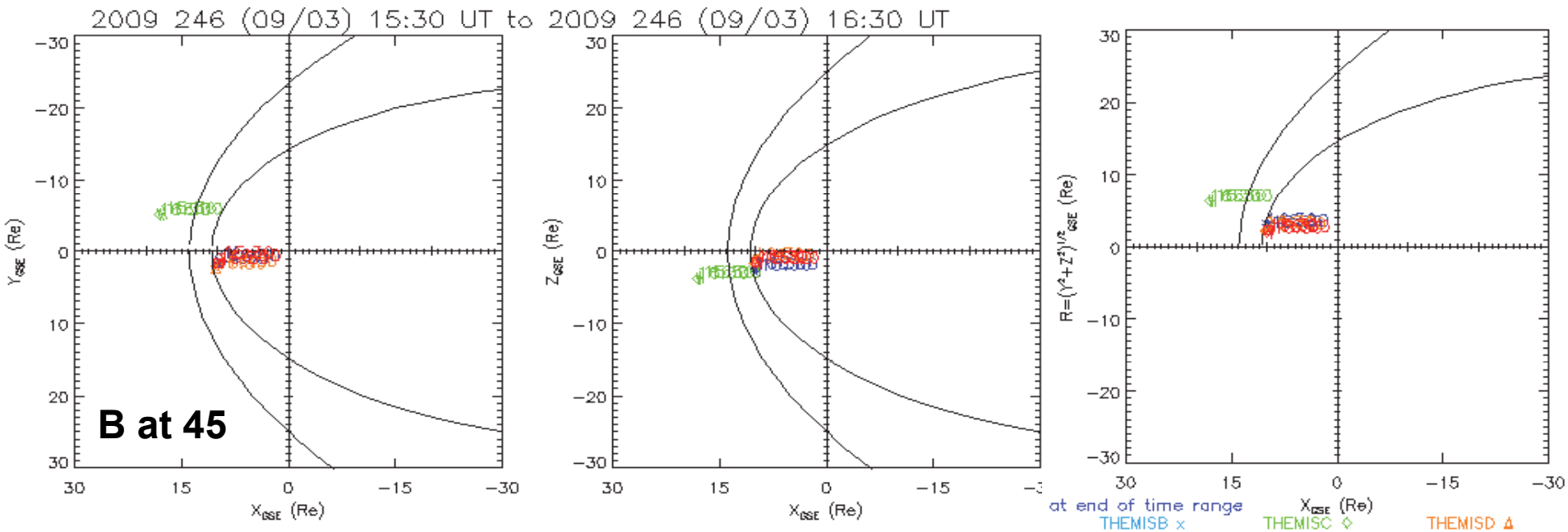

High res. OMNI data set
B
Bx
By
Bz
Hours of day 246

B


THB L2>L2 DATA FGM
15:30:00 09 Sep 3
15:40:00 09 Sep 3
15:50:00 09 Sep 3
16:00:00 09 Sep 3
16:10:00 09 Sep 3
16:20:00 09 Sep 3
16:30 09 Sep 3
TIME RANGE=2009/9/3 (246) to 2009/9/3 (246)
Please acknowledge data provider, V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baur at UCB, TUBS and IWF respectively, NASA NAS5-02099 and CDAWeb when using these d
Generated by CDAWeb on Sun Sep 11 22:39:26 2011

C


THC L2>L2 DATA FGM
FGS-C B total nT
Bx FGS-C nT GSM
By FGS-C nT GSM
Bz FGS-C nT GSM
15:30:00 09 Sep 3
15:40:00 09 Sep 3
15:50:00 09 Sep 3
16:00:00 09 Sep 3
16:10:00 09 Sep 3
16:20:00 09 Sep 3
16:30:00 09 Sep 3
TIME RANGE=2009/9/3 (246) to 2009/9/3 (246)
Please acknowledge data provider, V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baumjohann at UCB, TUBS and IWF respectively, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Sun Sep 11 22:39:26 2011


2009 246 (09/03) 15:30 UT to 2009 246 (09/03) 16:30 UT
B at 45
Y_GSE (Re)
X_GSE (Re)
Z_GSE (Re)
R=(Y²+Z²)^1/2 GSE (Re)
at end of time range
THEMISB x
THEMISC ◇
THEMISD Δ

TA

TD

Bx

By

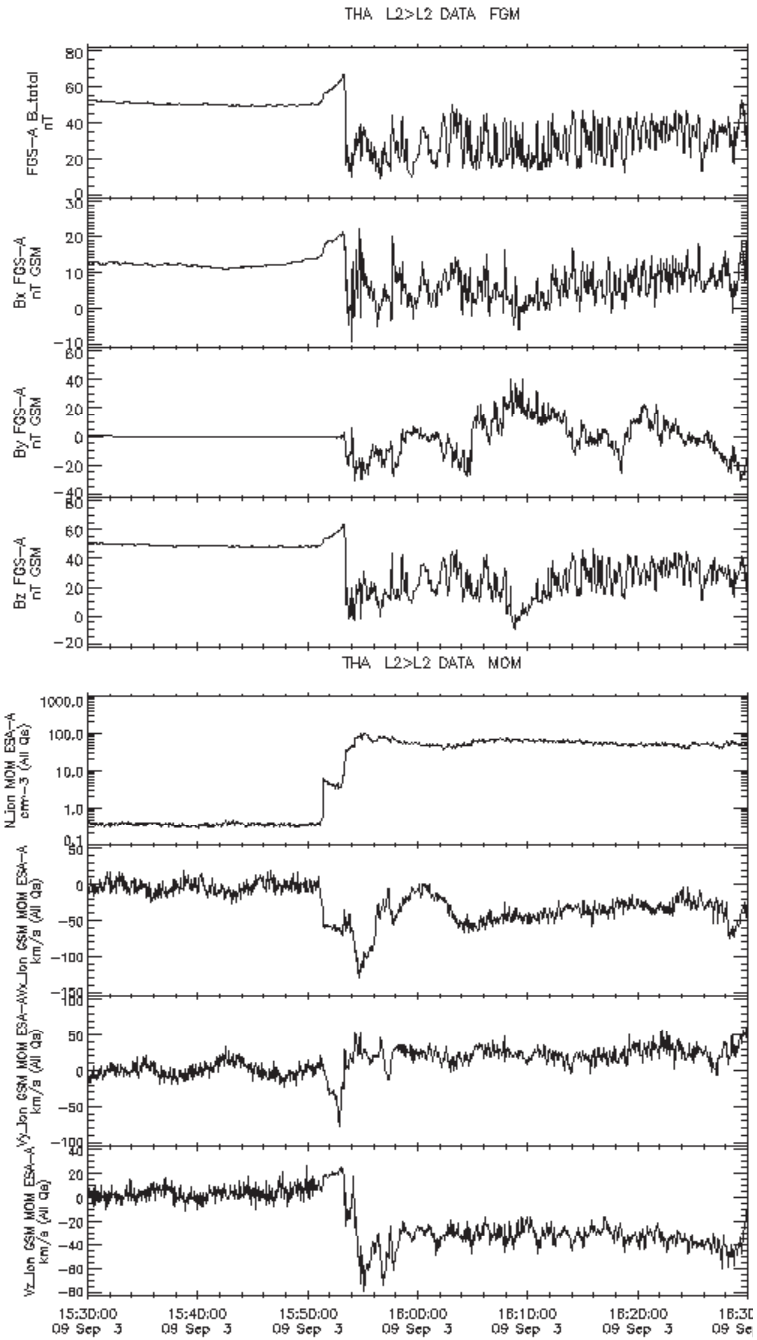
Bz

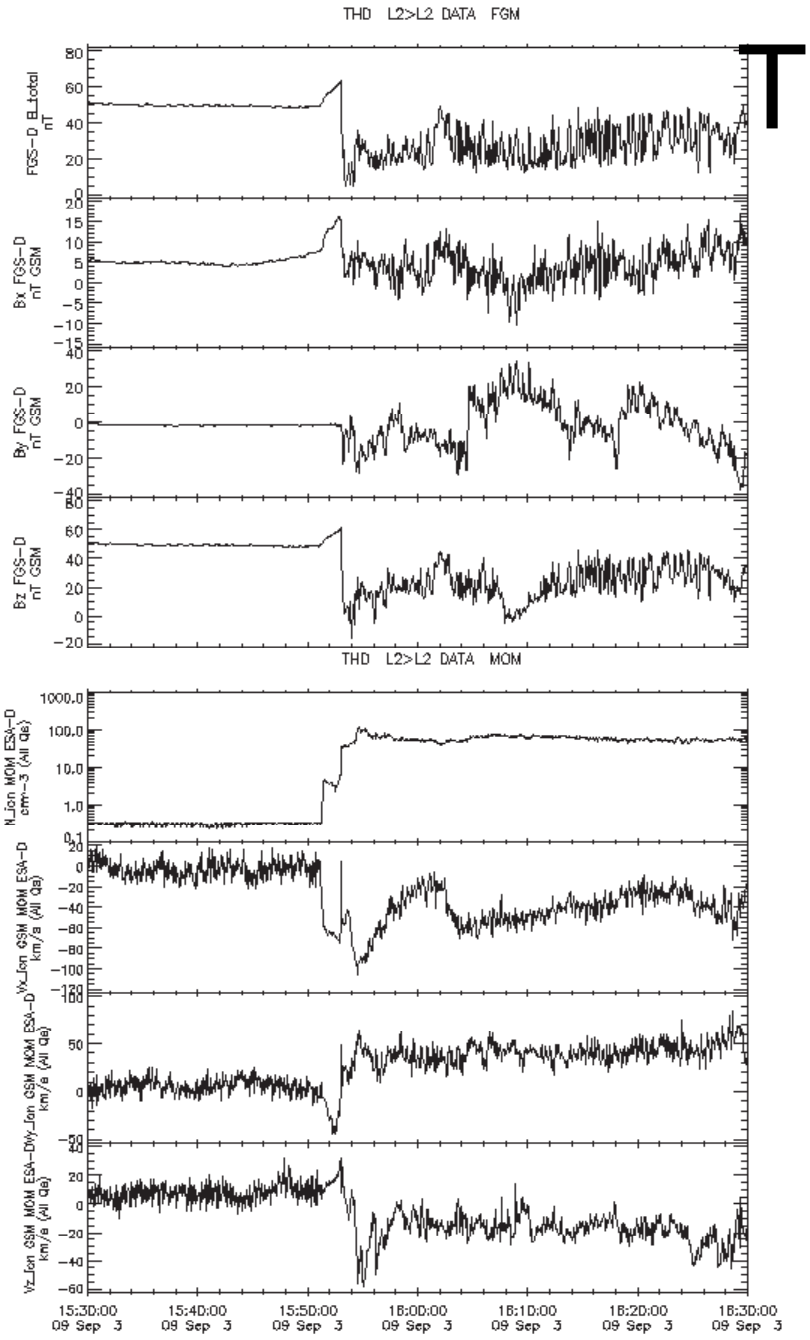
n

Vx

Vy

Vz





TD

TE

Bx

By

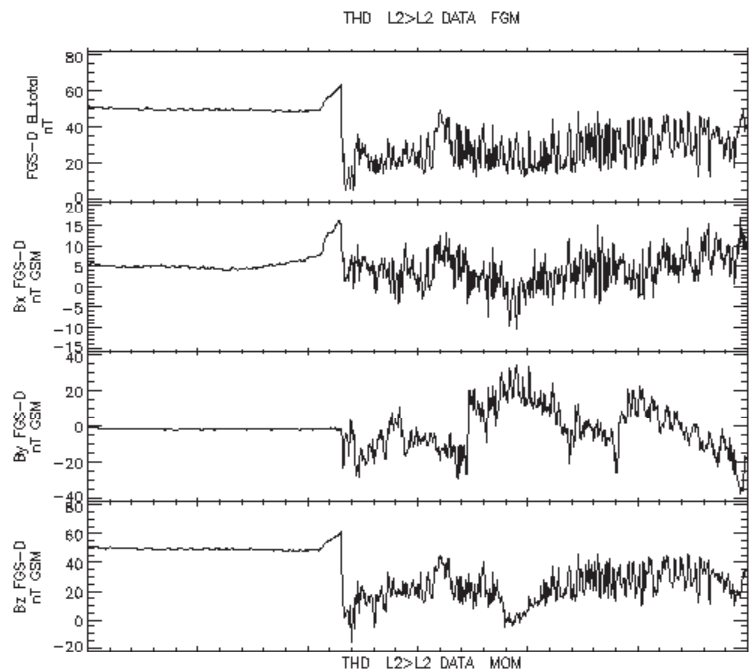
Bz

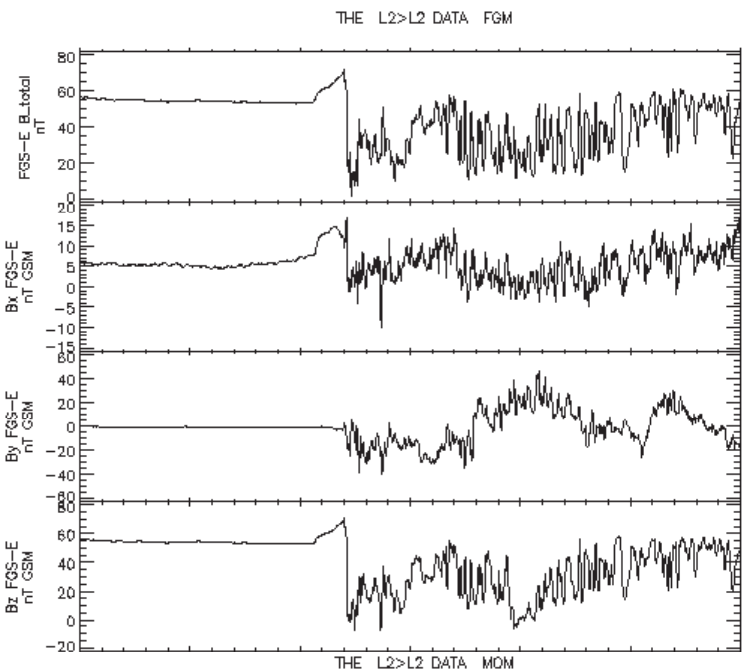
n

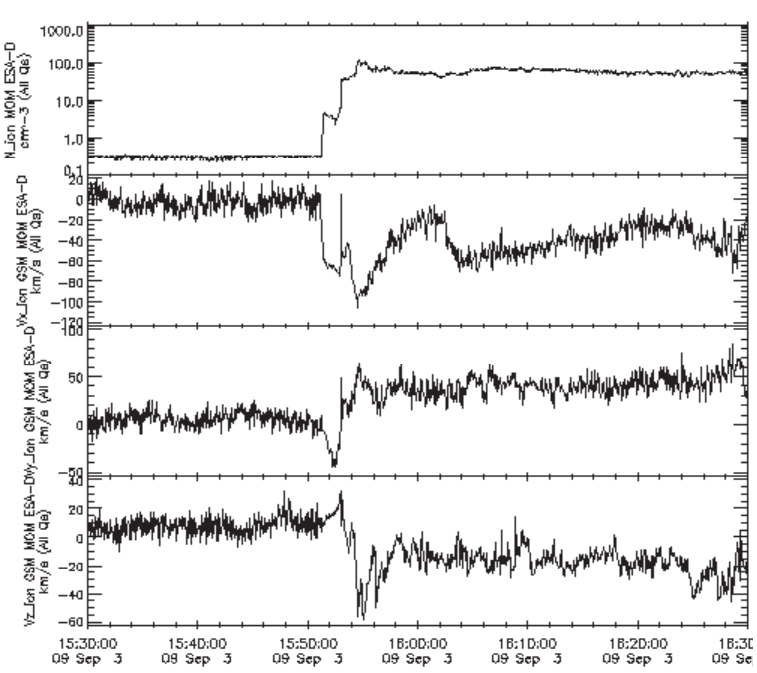
Vx

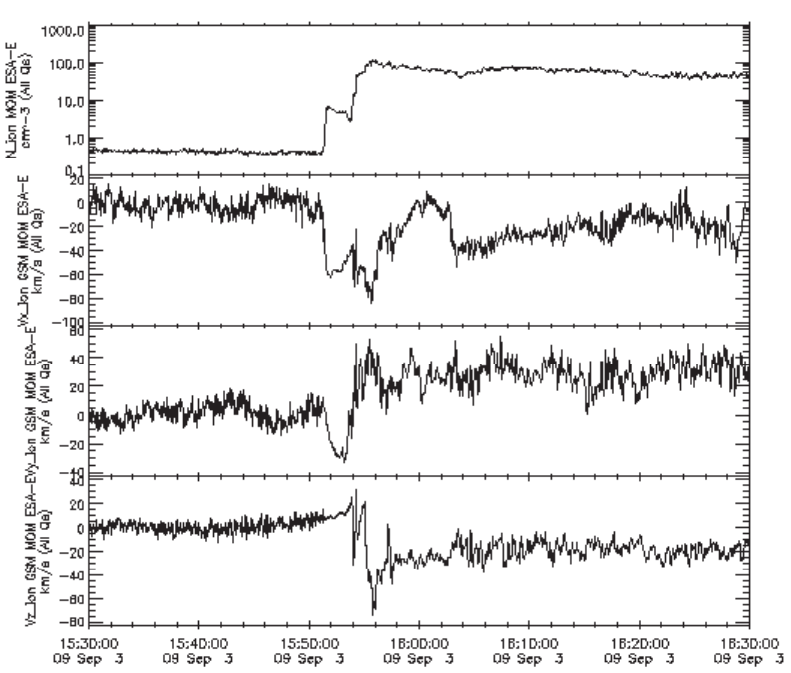
Vy

Vz









TIME RANGE=2009/9/3 (246) to 2009/9/3 (246)

Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Sun Sep 11 22:39:26 2011

TIME RANGE=2009/9/3 (246) to 2009/9/3 (246)

Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Sun Sep 11 22:39:26 2011

TD

Bx

By

Bz

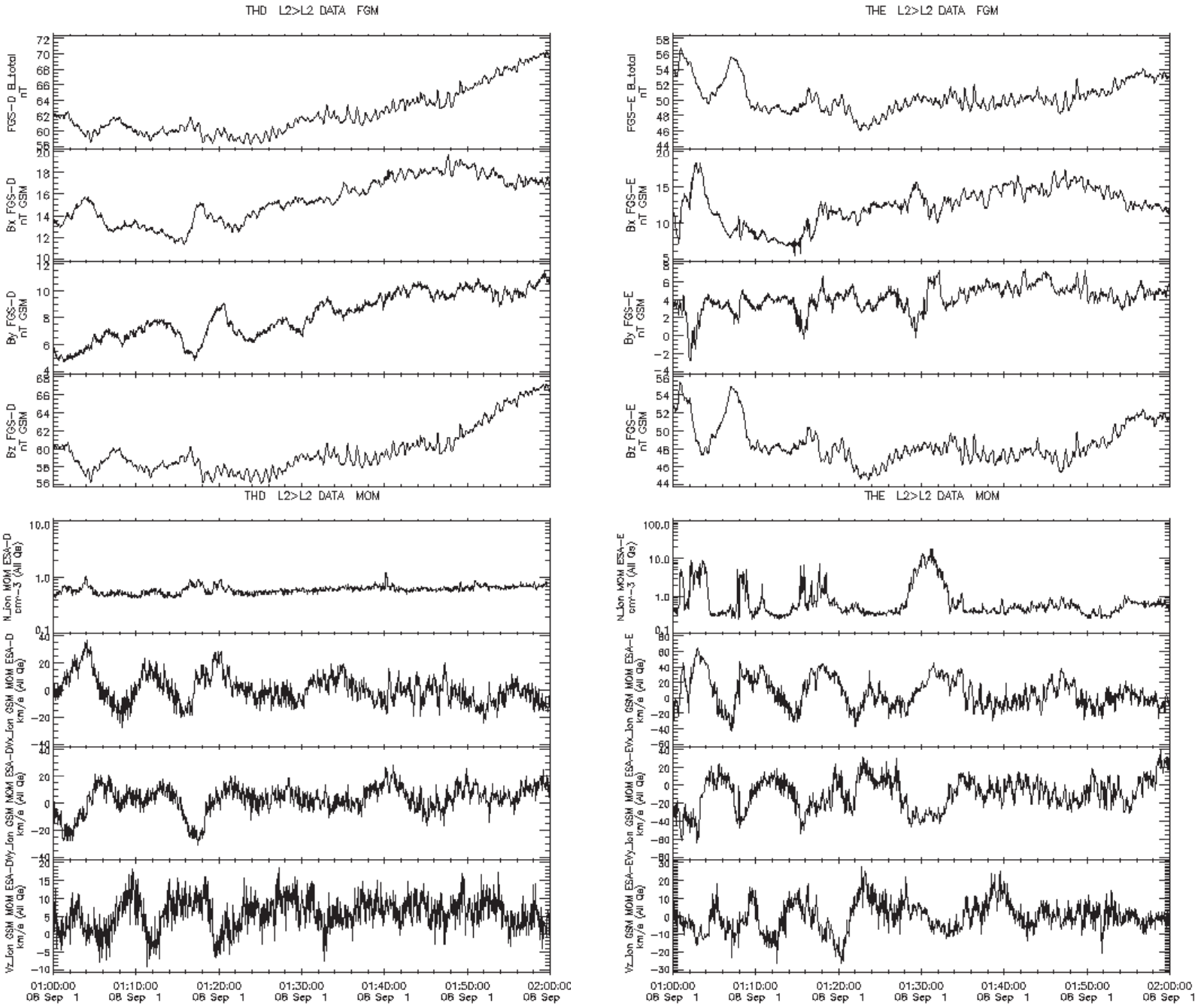
n

Vx

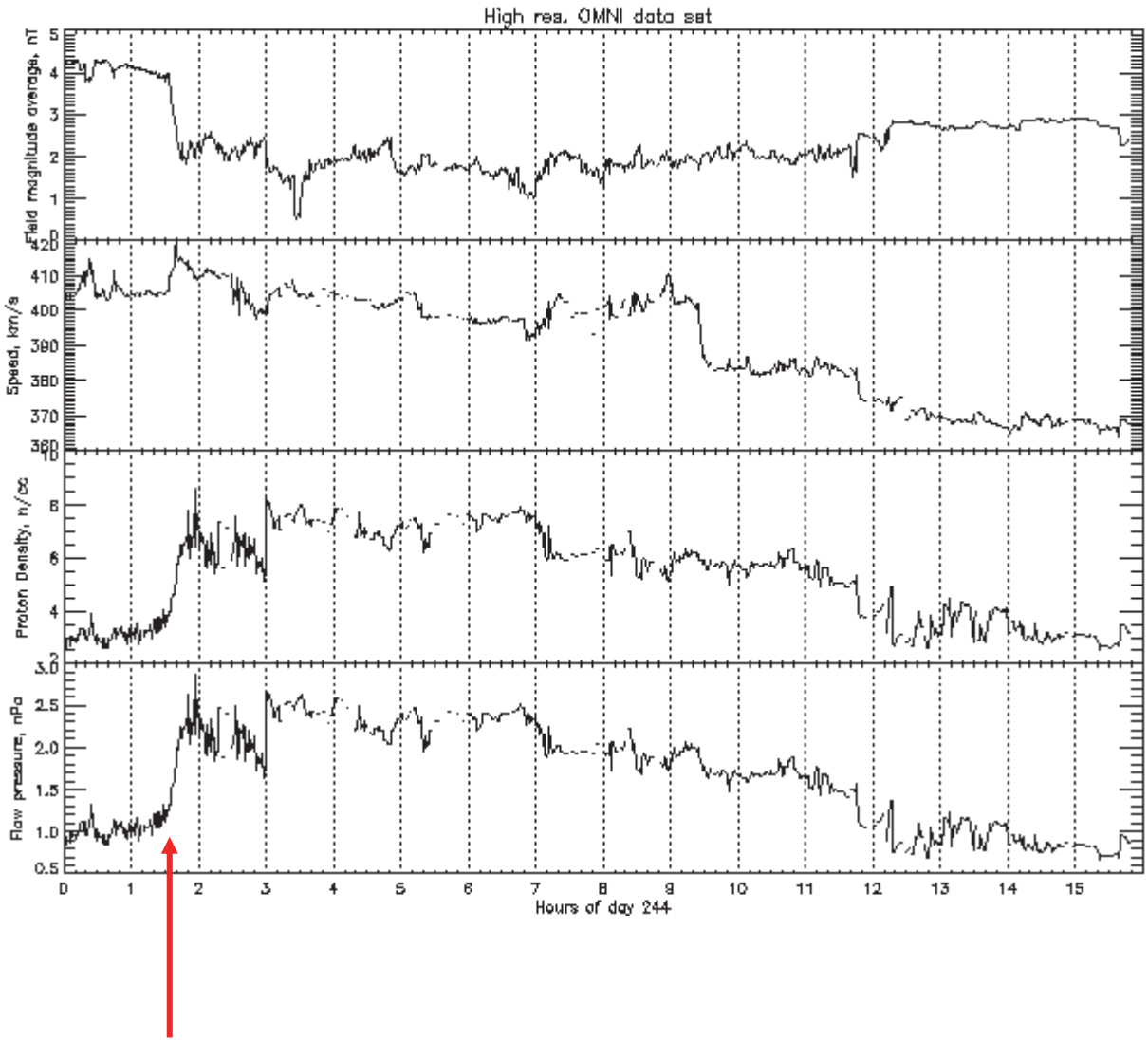
Vy

Vz

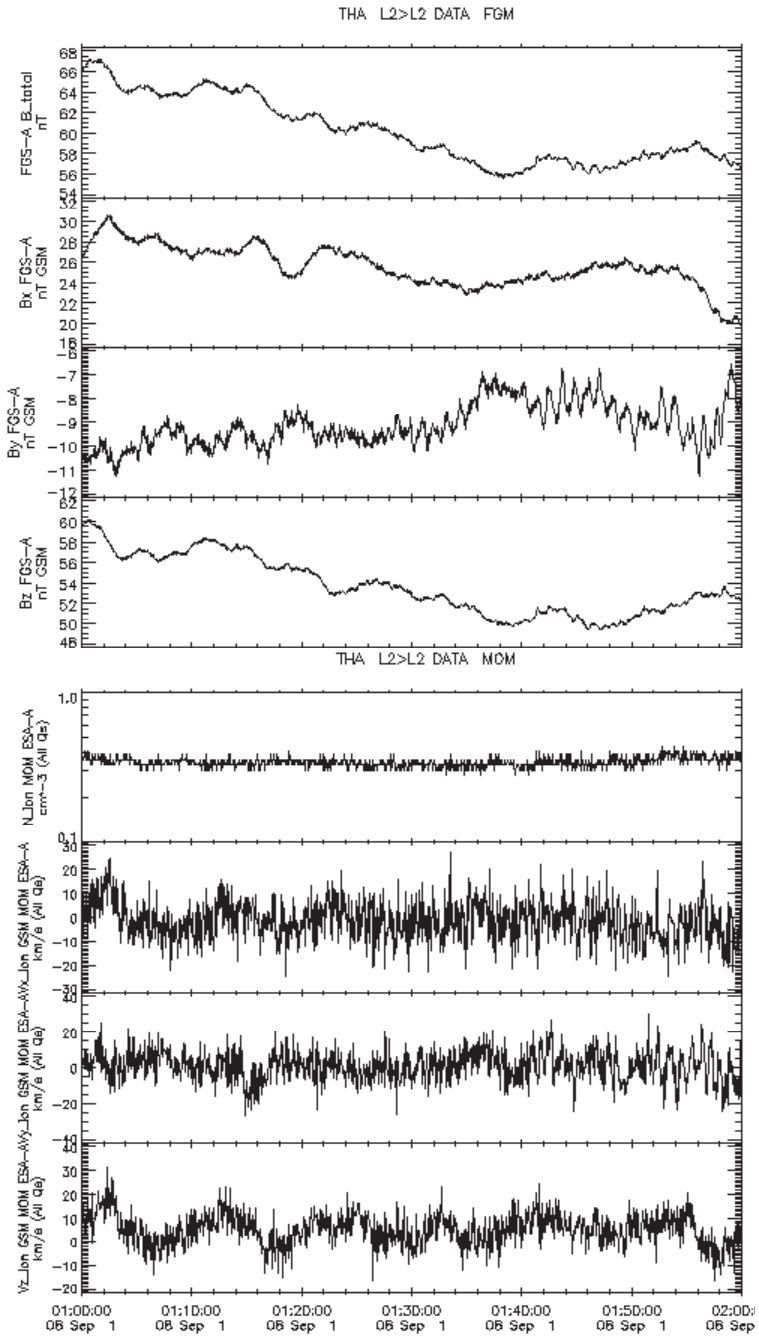
TE



Case-6: Sep 1, 2009



TA


THA L2>L2 DATA FGM
FGS-A B_total nT
Bx FGS-A nT GSM
By FGS-A nT GSM
Bz FGS-A nT GSM
THA L2>L2 DATA MOM
N_Ion MOM ESA-A cm^-3 (All Qs)
Vx_Ion GSM MOM ESA-AVx_Ion GSM MOM ESA-A km/s (All Qs)
Vy_Ion GSM MOM ESA-AVy_Ion GSM MOM ESA-A km/s (All Qs)
Vz_Ion GSM MOM ESA-AVz_Ion GSM MOM ESA-A km/s (All Qs)
01:00:00 08 Sep 1
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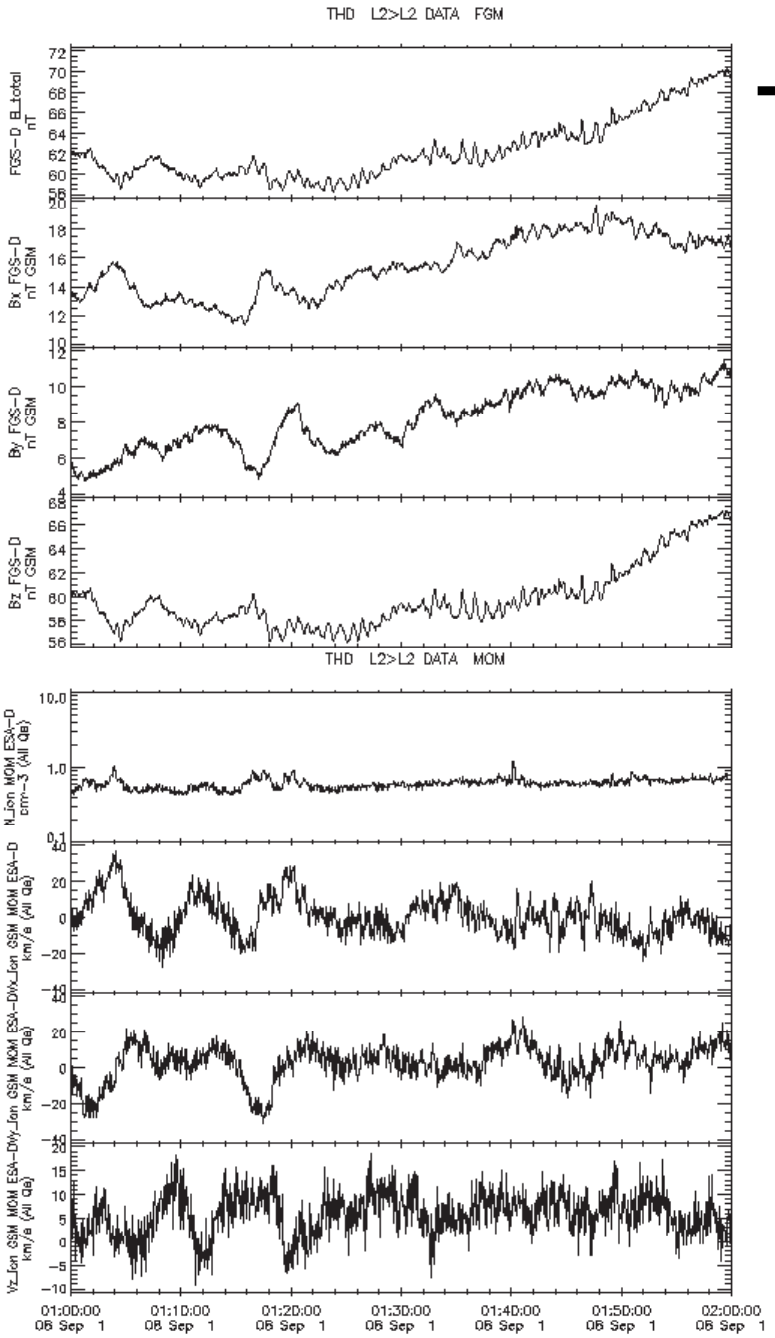
TIME RANGE=2008/9/1 (245) to 2008/9/1 (245)
Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden
at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Tue Sep 13 10:19:38 2011

TD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Bx FGS-D nT GSM
By FGS-D nT GSM
Bz FGS-D nT GSM
THD L2>L2 DATA MOM
N_Ion MOM ESA-D cm^-3 (All Qs)
Vx_Ion GSM MOM ESA-DVx_Ion GSM MOM ESA-D km/s (All Qs)
Vy_Ion GSM MOM ESA-DVy_Ion GSM MOM ESA-D km/s (All Qs)
Vz_Ion GSM MOM ESA-DVz_Ion GSM MOM ESA-D km/s (All Qs)
01:00:00 08 Sep 1
01:10:00 08 Sep 1
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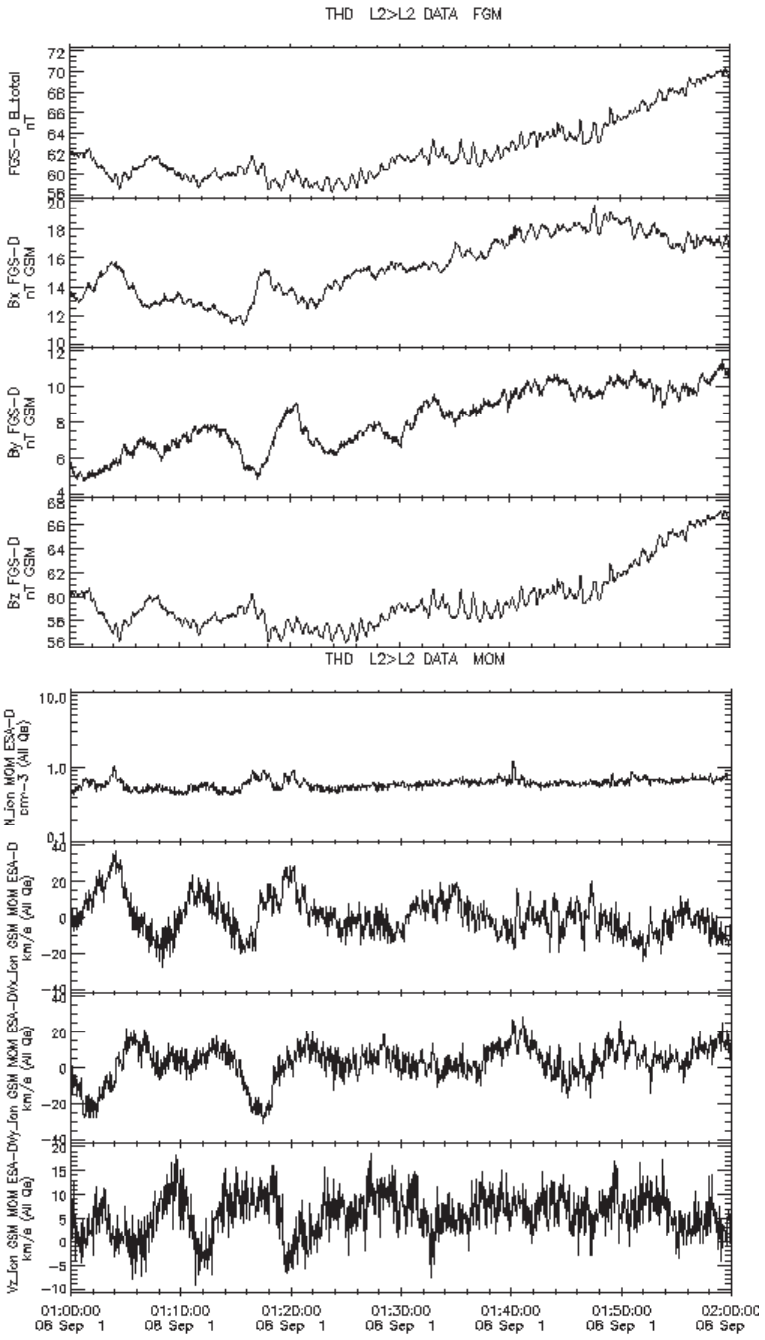
TD



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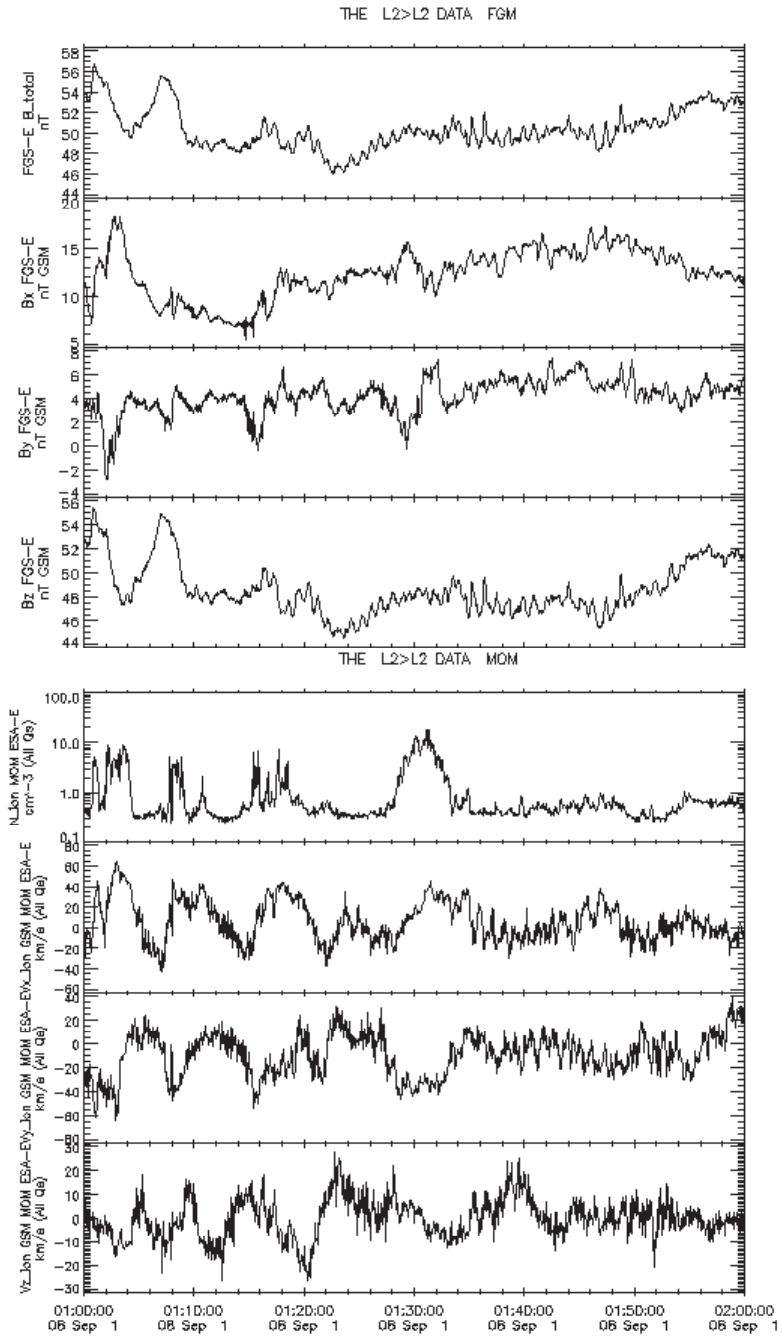
Generated by CDAWeb on Tue Sep 13 10:19:39 2011

TE



Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden
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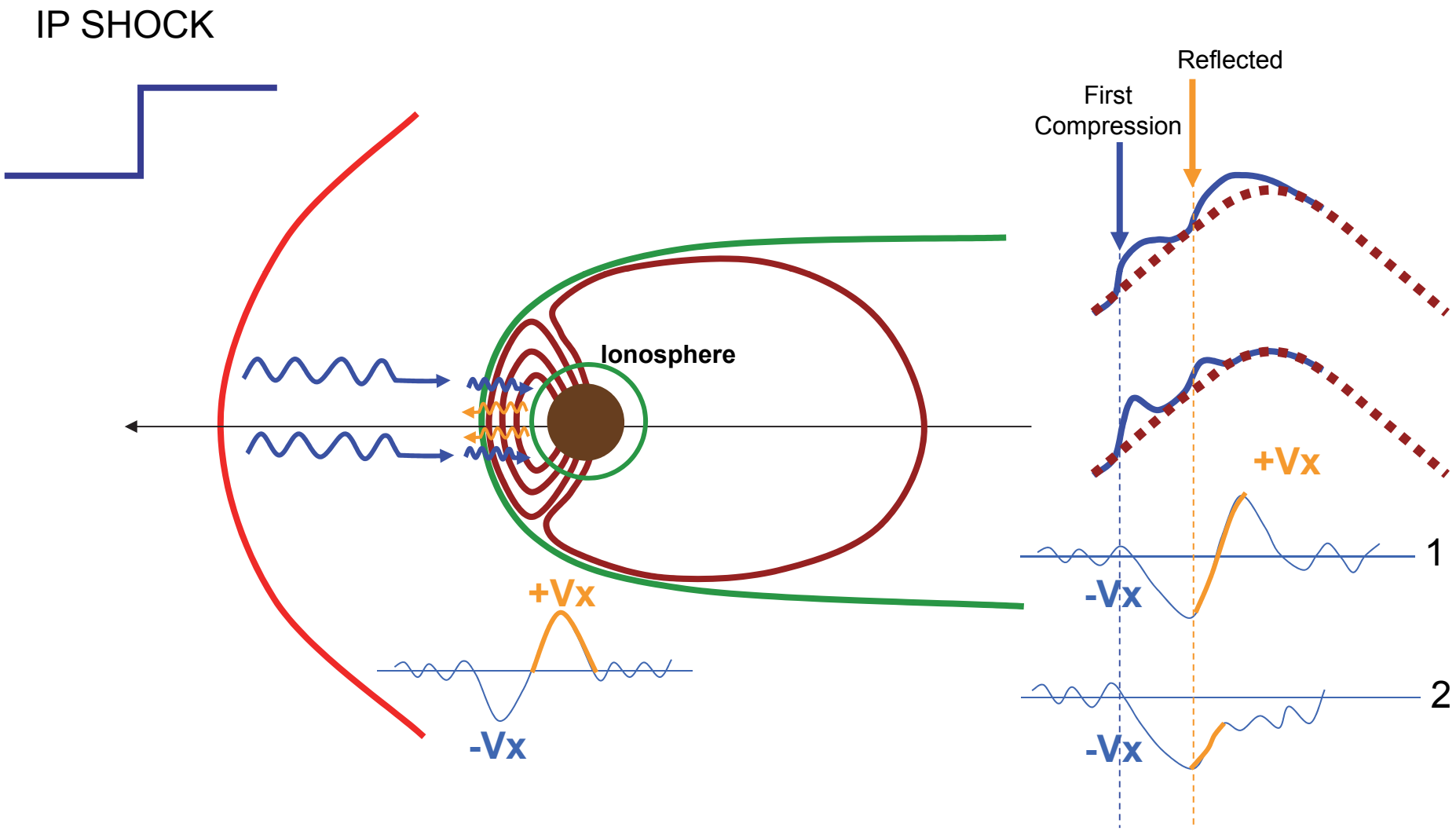
Generated by CDAWeb on Tue Sep 13 10:19:39 2011

Concept of Reflected Wave



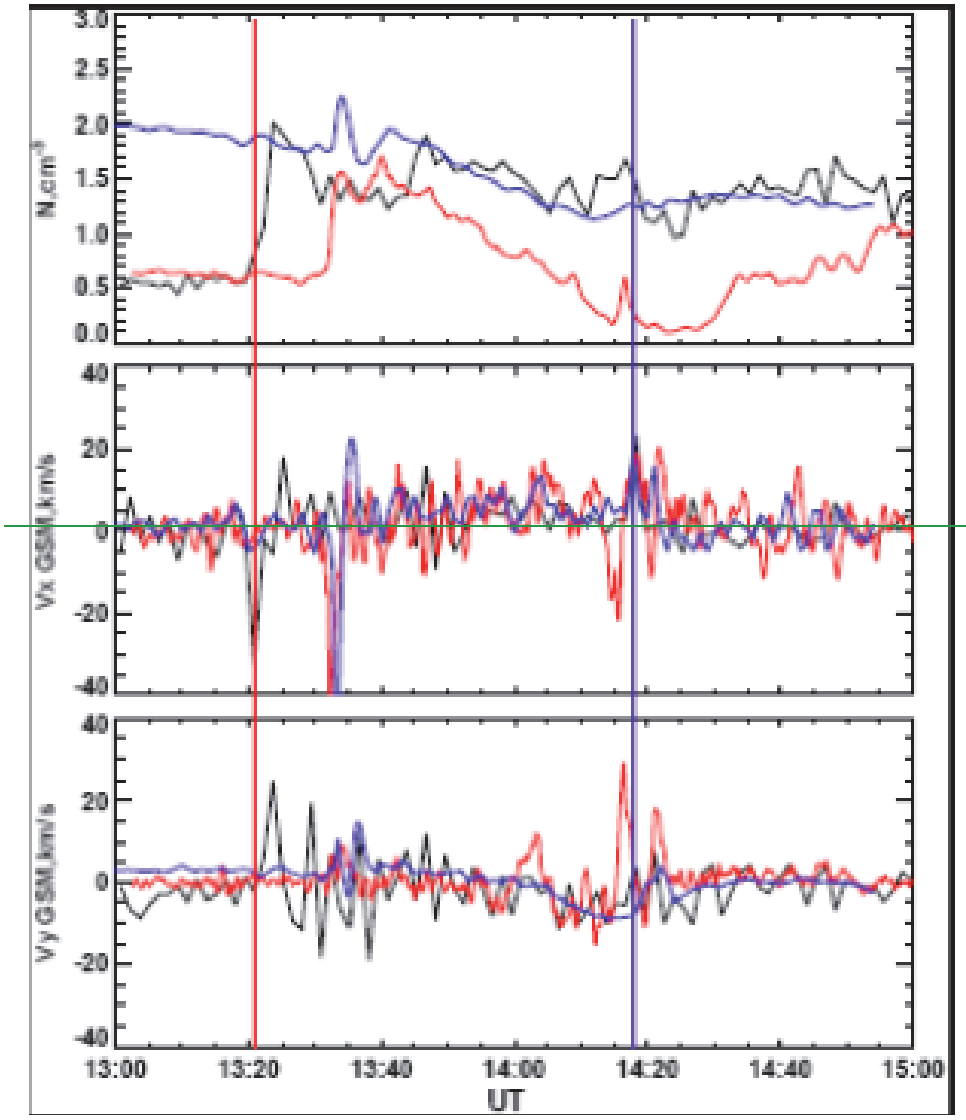
Concept of reflected wave

- Ridley 2006
  - Results from global MHD model, BATSRUS
  - Simulating interaction between strong IP shock and the magnetosphere
    - Transmitted through msheath and msphere
    - Reflected from inner numerical boundary
    - Continue moving outward towards mpause
  - Assumed reflection boundary is plasmapause
  - Transmitted IP shock propagated around the flanks of the mpshere toward mtail
  - Dayside bow shock moved inward until it interacted with the reflected shock

Concept of reflected wave

- Lee and hudson (2001)
- 3-D dipole model for magnetosphere
- To study Similar problem
- Propagation of a sudden impulse associated with IP shock inside the msphere
- To simulate th eresponse they invoked an abrupt electric field variation at the outer boundary of their model
  - Their results indicate that:
    - Most of impulse energy penetrates the plasmapause to excite strong low frequency pulsations in th eplasmasphere
    - Small portion of th einitial impulse however is reflected from the plasmapause and returns to the outer boundary

Concept of reflected wave



LANL ion moment Measurements (black lines)
Red: batsrus
Blue: LFM

Samsonov et al, 2007

Summary

- We found 40 clear box type IP shock events during 2008-2010.
  - In response to the IP shock magnetosphere oscillates
  - The motion is easier in the y-direction, least in the z-direction
  - Variations last 10-40 min (recovery)
  - Speeds both in x and y vary between 20-100 km/sec
  - Clear Reflected wave among the events we found is not seen→ needs more work
  - Boundary Normal coordinate analysis is under way to understand the motion of the magnetosphere better

Welcome

- Suggestions and comments

Thank you and

- THEMIS mission
- Nasa’s guest program

Summary

- Dayside response of the magnetosphere
- We found 40 clear box type IP shock events during 2008-2010.
- We excluded
  - multiple shocks and
  - weak shocks where jump in pressure less than 2 factor of background
- Depends on the location of s/c
  - 45^{o} of Sun-Earth line

- In response to the IP shock magnetosphere oscillates
- The motion is easier in the y-direction, least in the z- direction
- Variations last 10-40 min (recovery)
- Speeds both in x and y vary between 20-100 km/sec
- Clear Reflected wave among the events we found is not seen→ needs more work
- Boundary Normal coordinate analysis is under way to understand the motion of the magnetosphere better
- ----------

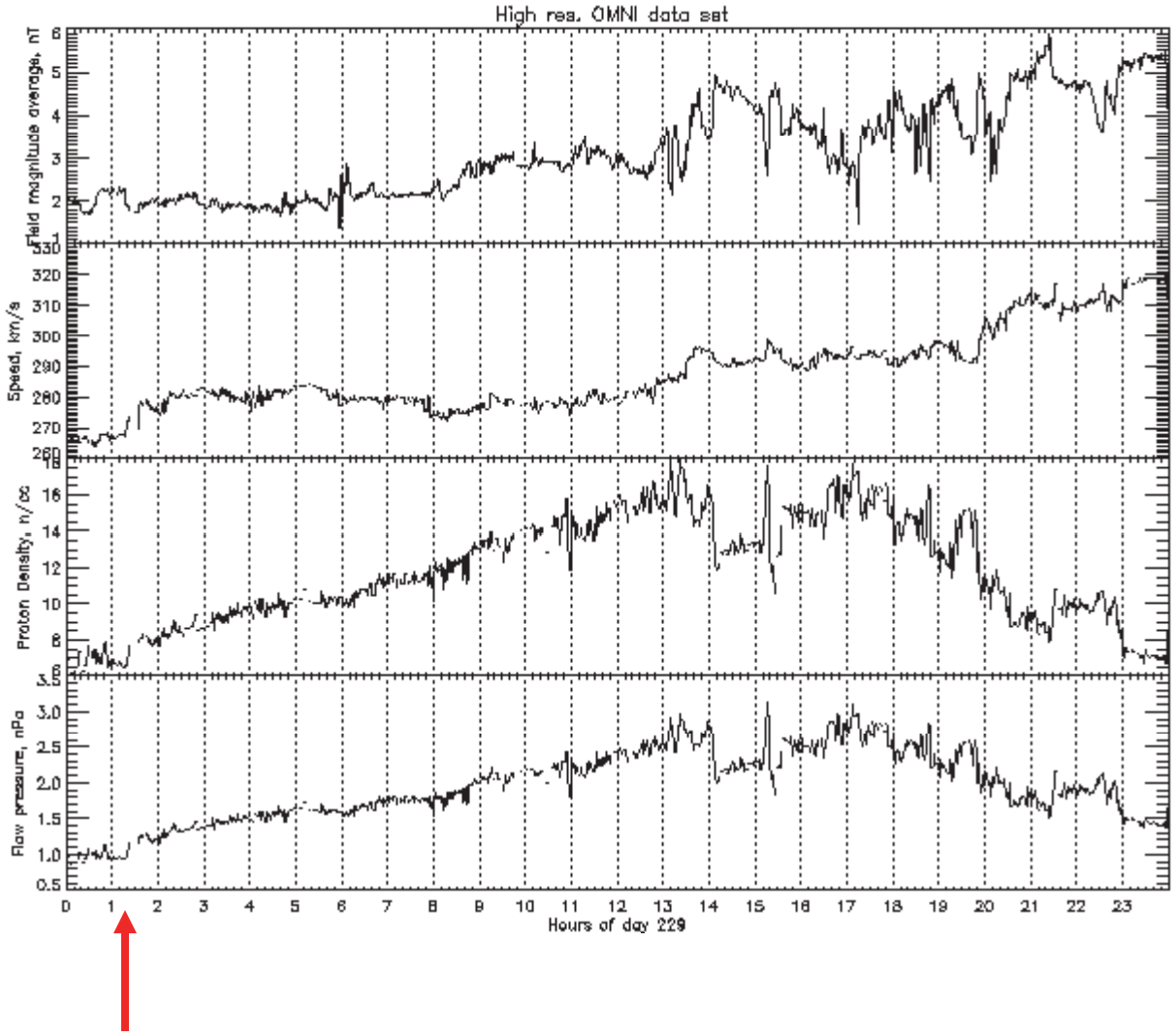
- In some cases, the IP signal is weak but stil drives magnetosphere at the same rates
- In some cases, IP is strong but the response is weak.
  - Response in term of magnitude of the periodic oscillations

- Study is underway with
  - Electric field measurements
  - GOES measurements
  - Ground magnetometer
- Any of my events (50), no Cluster and Geotail measurements on the dayside are available

Thank you and

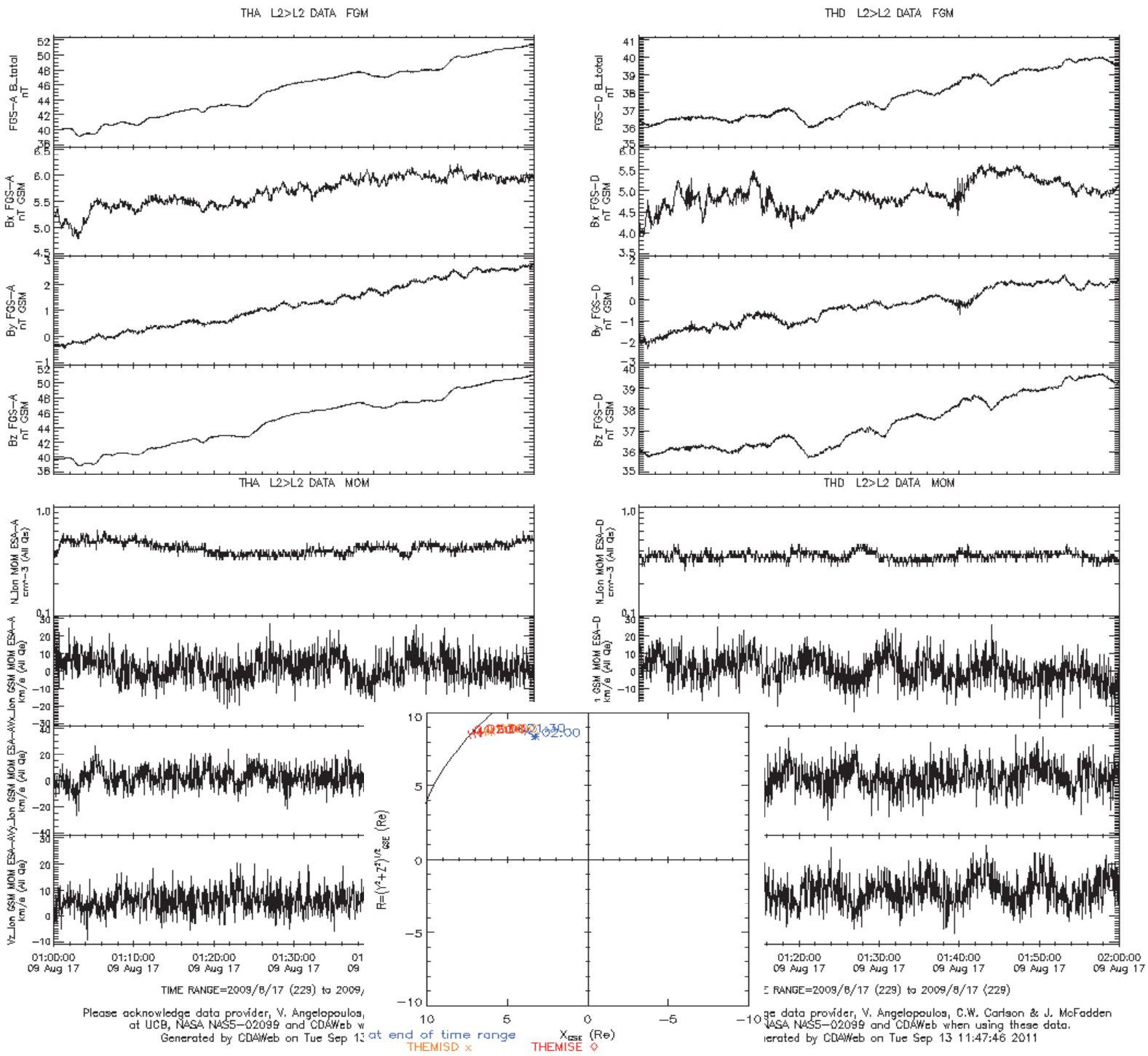
- THEMIS mission
- Nasa’s guest program

Case 7: Aug 17, 2009



Weak Shock

TA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THD L2>L2 DATA FGM
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Bx FGS-A nT GSM
By FGS-A nT GSM
Bz FGS-A nT GSM
FGS-D B_total nT
Bx FGS-D nT GSM
By FGS-D nT GSM
Bz FGS-D nT GSM
THA L2>L2 DATA MOM
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N_Ion MOM ESA-A cm^-3 (All Qs)
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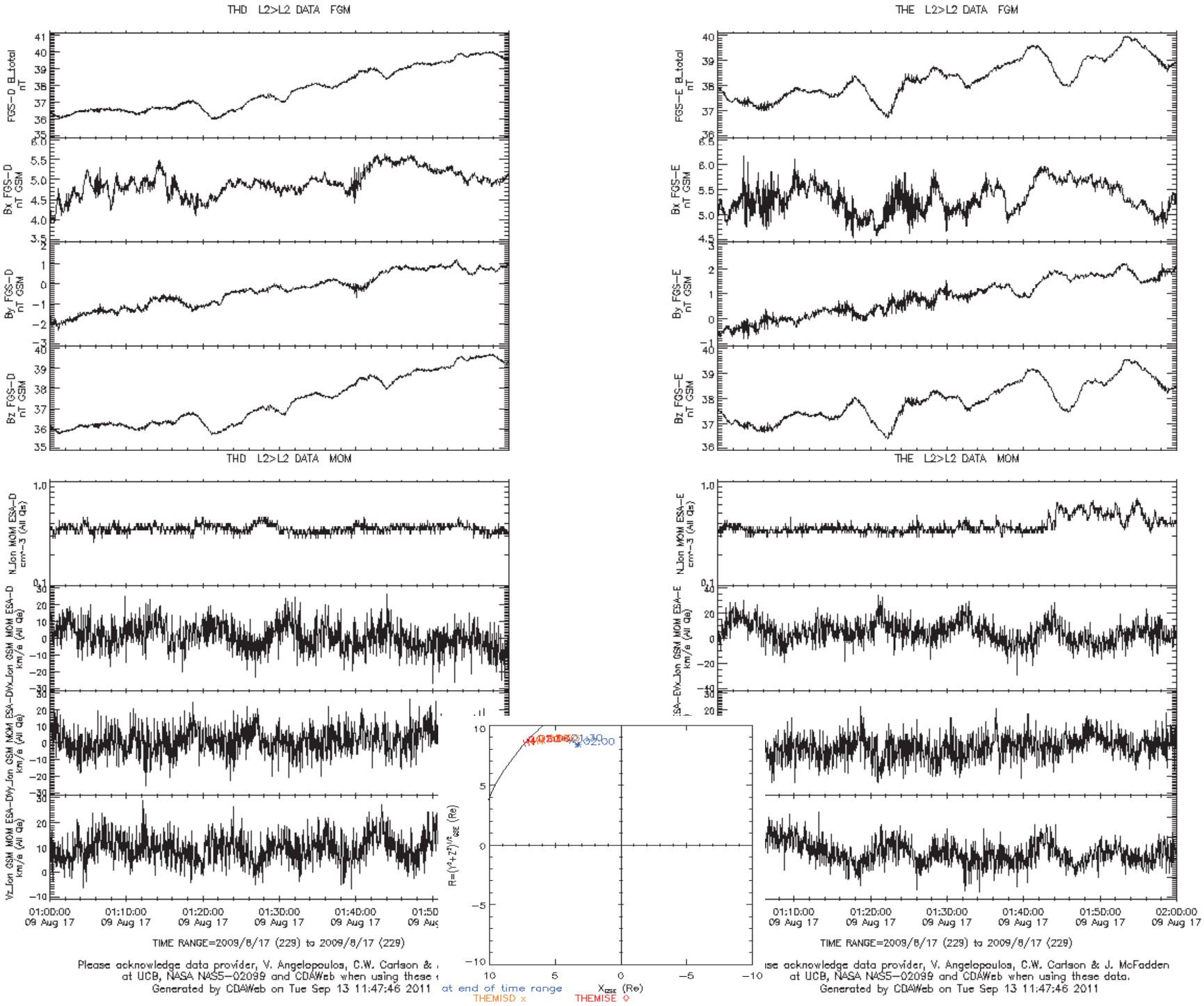
Vy_Ion GSM MOM ESA-A km/s (All Qs)
Vz_Ion GSM MOM ESA-A km/s (All Qs)
V_Ion GSM MOM ESA-D km/s (All Qs)
01:00:00 09 Aug 17
01:10:00 09 Aug 17
01:20:00 09 Aug 17
01:30:00 09 Aug 17
01:40:00 09 Aug 17
01:50:00 09 Aug 17
02:00:00 09 Aug 17
TIME RANGE=2009/8/17 (229) to 2009/8/17 (229)
R=(Y²+Z²)^1/2 GSE (Re)
X GSE (Re)
at end of time range
THEMISD x
THEMISE ◇
Please acknowledge data provider, V. Angelopoulos, C.W. Carlson & J. McFadden
at UCB, NASA NAS5-02099 and CDAWeb when using these data.
Generated by CDAWeb on Tue Sep 13 11:47:46 2011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FGS-D B_total nT
Bx FGS-D nT GSM
By FGS-D nT GSM
Bz FGS-D nT GSM
THD L2>L2 DATA MOM
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Vz_Ion GSM MOM ESA-D km/s (All Qs)
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R=(Y²+Z²)^1/2 GSE (Re)
X GSE (Re)
at end of time range
THEMISD x
THEMISE ◇
THE L2>L2 DATA FGM
FGS-E B_total nT
Bx FGS-E nT GSM
By FGS-E nT GSM
Bz FGS-E nT GSM
THE L2>L2 DATA MOM
N_Ion MOM ESA-E cm^-3 (All Qs)
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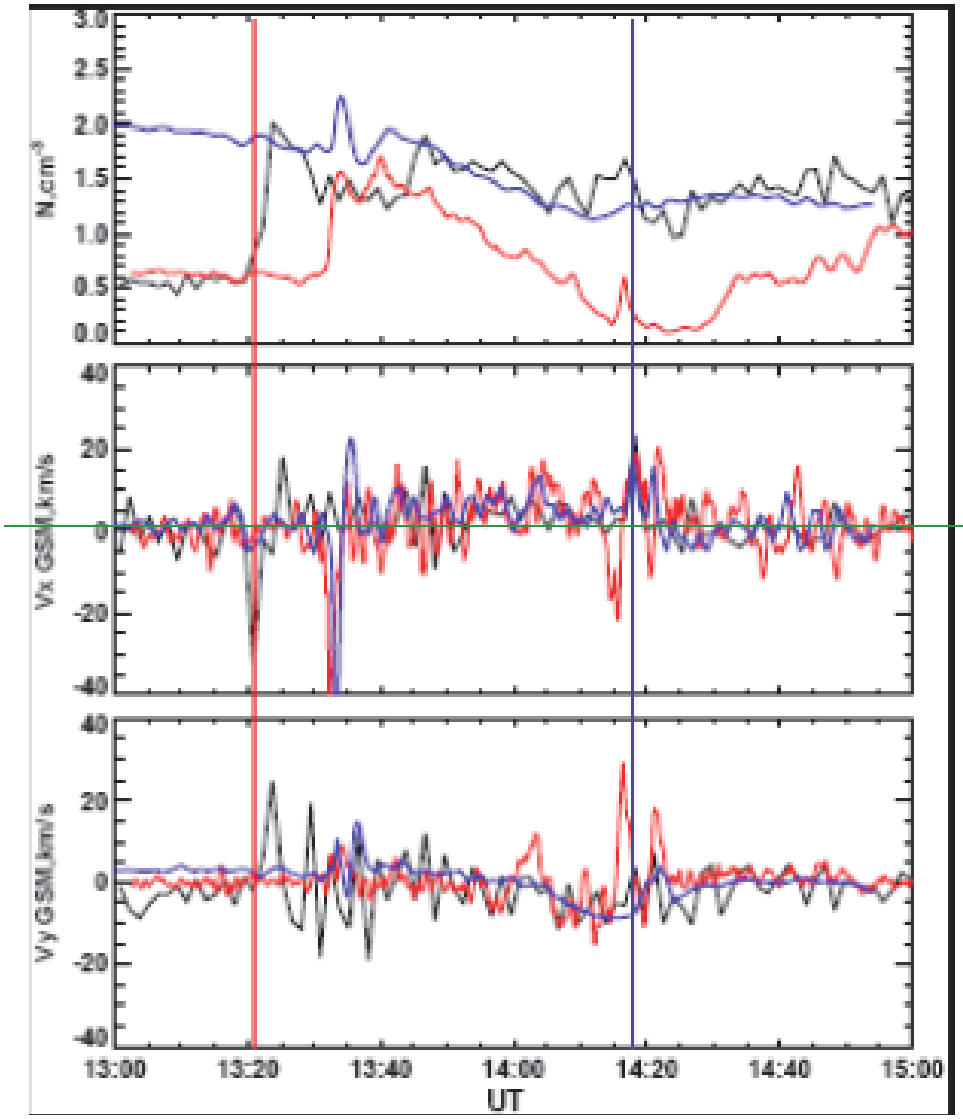
Concept of reflected wave



LANL ion moment Measurements (black lines)
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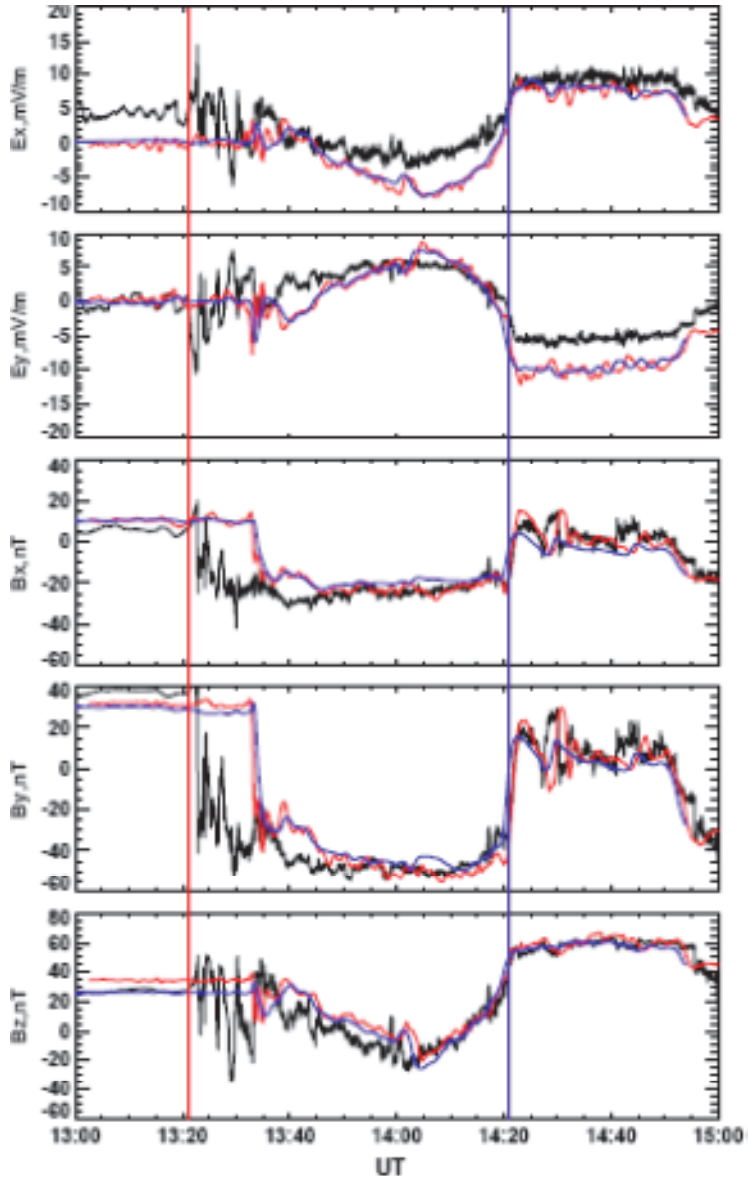

Geotail measurements of E field and B field

Samsonov et al, 2007