User Feedback: Geospace

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(One) User(s) Feedback: Geospace

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Outline

- Geospace Services
- Geospace Experiences
- Summary

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  - Instant model runs
  - Runs on request
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- Geospace Services
  - Instant model runs
  - Runs on request
- Geospace Experiences
  - Students taking space weather courses
  - Students working on Doctoral projects
  - Visiting Researchers
  - My own activities
- Summary

Geospace Services

- Instant Model Runs
  - Magnetosphere
    - LANL*: L* calculation (important for Van Allen Probes)
    - AE-8/AP-8 Radbelt flux maps (also important for them)
    - IGRF magnetic field
    - WINDMI Dst and AL
  - Ionosphere
    - ABBYnormal electron density profiles
    - IRI ionospheric density, temp, comp, ion drift, TEC
    - Weimer electric potentials
    - MSISE neutral temps and densities

Geospace Services

- Runs on Request
  - Ionosphere
    - 5 models
  - Inner Magnetosphere
    - 6 models of which one is Tsyganenko magnetic field
  - Magnetosphere
    - BATS-R-US, SWMF with RCM or CRCM, GUMICS, CMIT/ LFM-MIX

Geospace Services
That My Visitors and I Use

- Runs on Request
  - Ionosphere
    - 5 models
  - Inner Magnetosphere
    - 6 models of which one is Tsyganenko magnetic field
  - Magnetosphere
    - BATS-R-US, SWMF with RCM or CRCM, GUMICS, CMIT/LFM-MIX

Geospace Experiences

- Brazilian students (3 graduate students, 2 post-docs)
  - Space weather forecasting
  - Location and extent of reconnection line
  - Nature of transient reconnection
- Russian visitor
  - Response to abrupt changes in SW P
- My own activities
  - Magnetospheric magnetic field configurations
  - FTE structure
  - Magnetotail cross section
  - Subsolar pressures
  - Analysis for mission proposals

Space Weather Forecasting

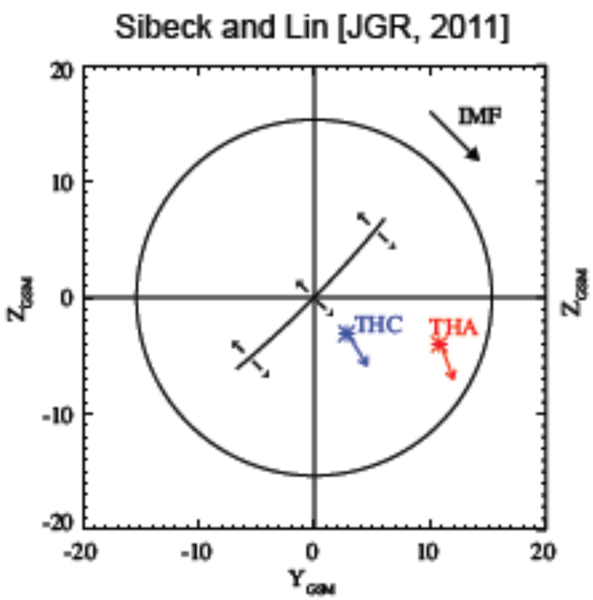
- Brazil has set up a space weather forecasting center:
  - http://www2.inpe.br/climaespacial/en/introducao
  - Our visiting Brazilian students enrolled in the CCMC/SWRC Space Weather REDI Boot Camp

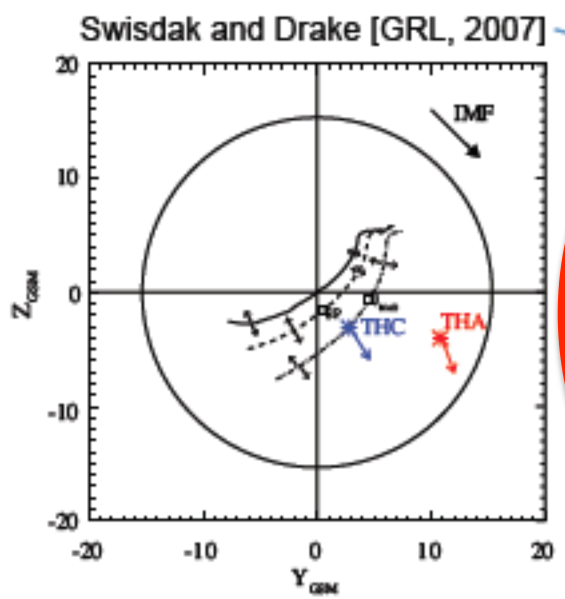
Brazilian Student #1: Vitor Moura Cardoso e Silva Souza

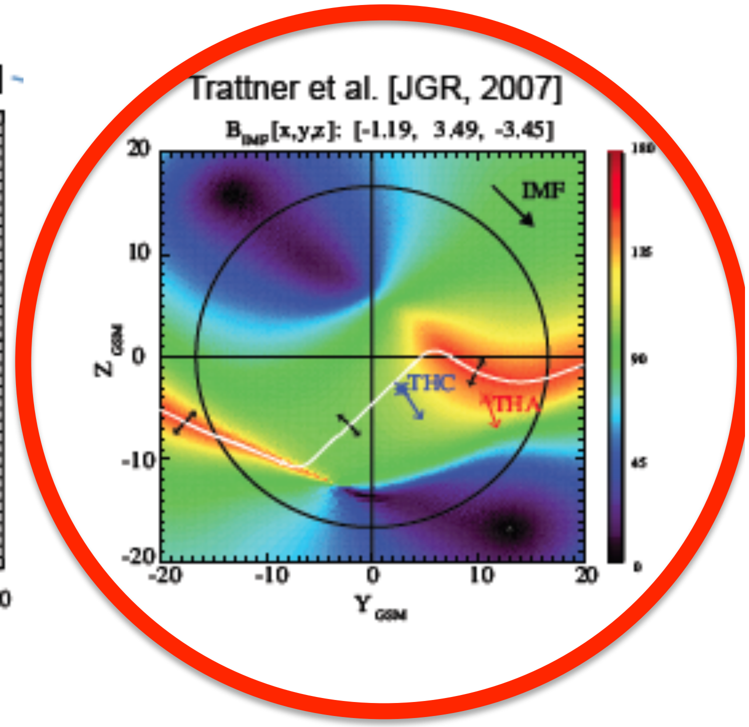
- Working on Doctoral Thesis
- Seeks to compare predicted location and extent of reconnection on the dayside magnetopause with multipoint observations
- Needs to use output from global MHD simulations because analytical models for fields and plasmas are not self-consistent
- CCMC action- higher spatial resolution runs to capture conditions at magnetopause

Brazilian Student #1: Vitor Moura Cardoso e Silva Souza

Three Models for Reconnection Line Location







Fall AGU 2013 Presentation

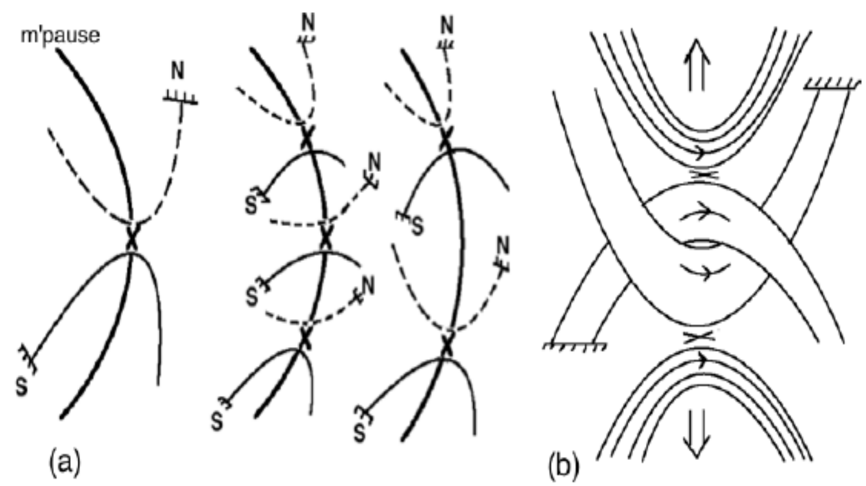
He picked this one as giving the best fit to observed flow directions and topology

Brazilian Student #2: Flavia Reis Cardoso

- Was Post-doc, now professor in Brazil
- Sought to understand the complicated topology of FTEs formed by multiple bursty reconnection sites at the magnetopause
- Needed output from global MHD simulations to determine connectivity of events
- CCMC action: prepared higher time and spatial (1/16 RE) resolution runs to study event evolution

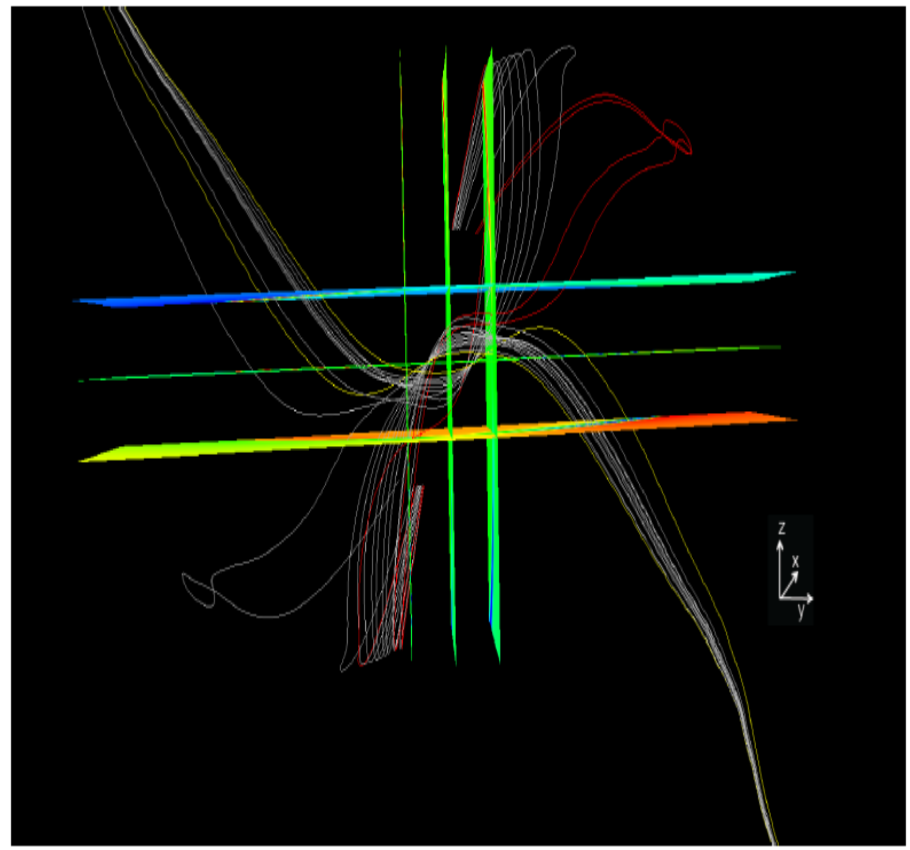
Brazilian Student #2:
Flavia Reis Cardoso

➢ ***Theory predicts elbow-shaped interlinked flux tubes [Hesse et al., 1990]***



Sketch of three steps in the evolution of the X line configurations.

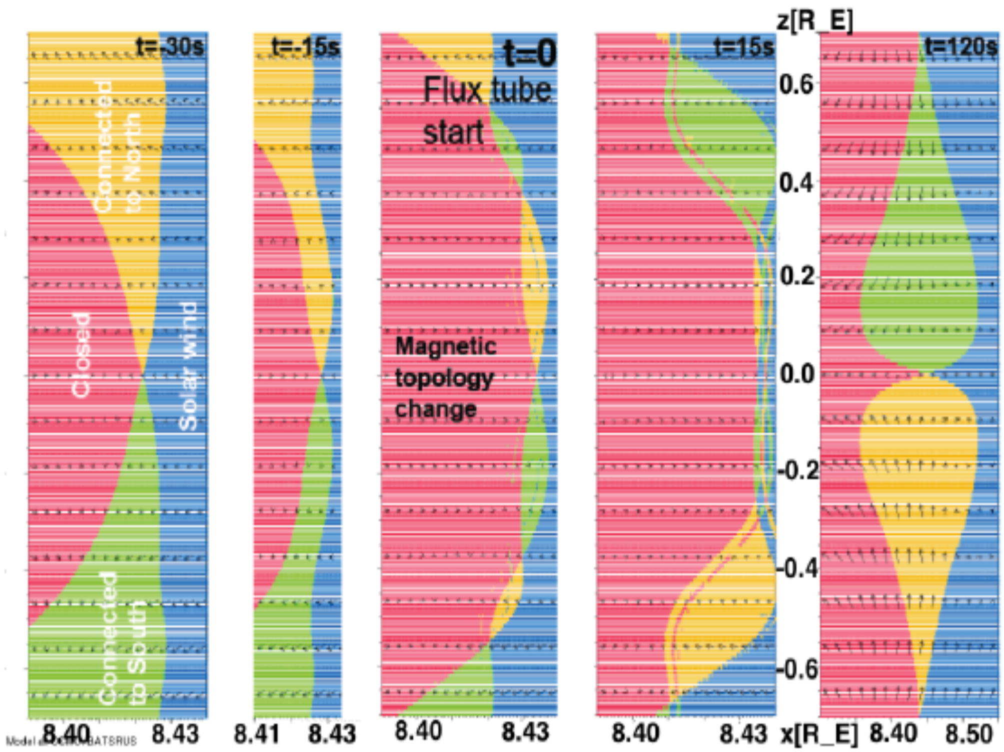
Use CCMC Visualization Tool



Reconnected magnetic field lines drawn at t = 30s. The lines exhibit the interlinked flux tube configuration.

Brazilian Student #2:
Cardoso et al. [Ann. Geophys, 2013

X-Z Plane



Magnetic topology for the noon-midnight plane (x-z plane) for different time instants: t = −30, −15, 0, +15, 120 s, considering t = 0 as the time when the magnetic topology changes (interlinked flux tubes onset). Colors are related to the magnetic topology: red = closed; yellow = connected to north; green = connected to south; and blue = IMF. Arrows indicate flow velocity.

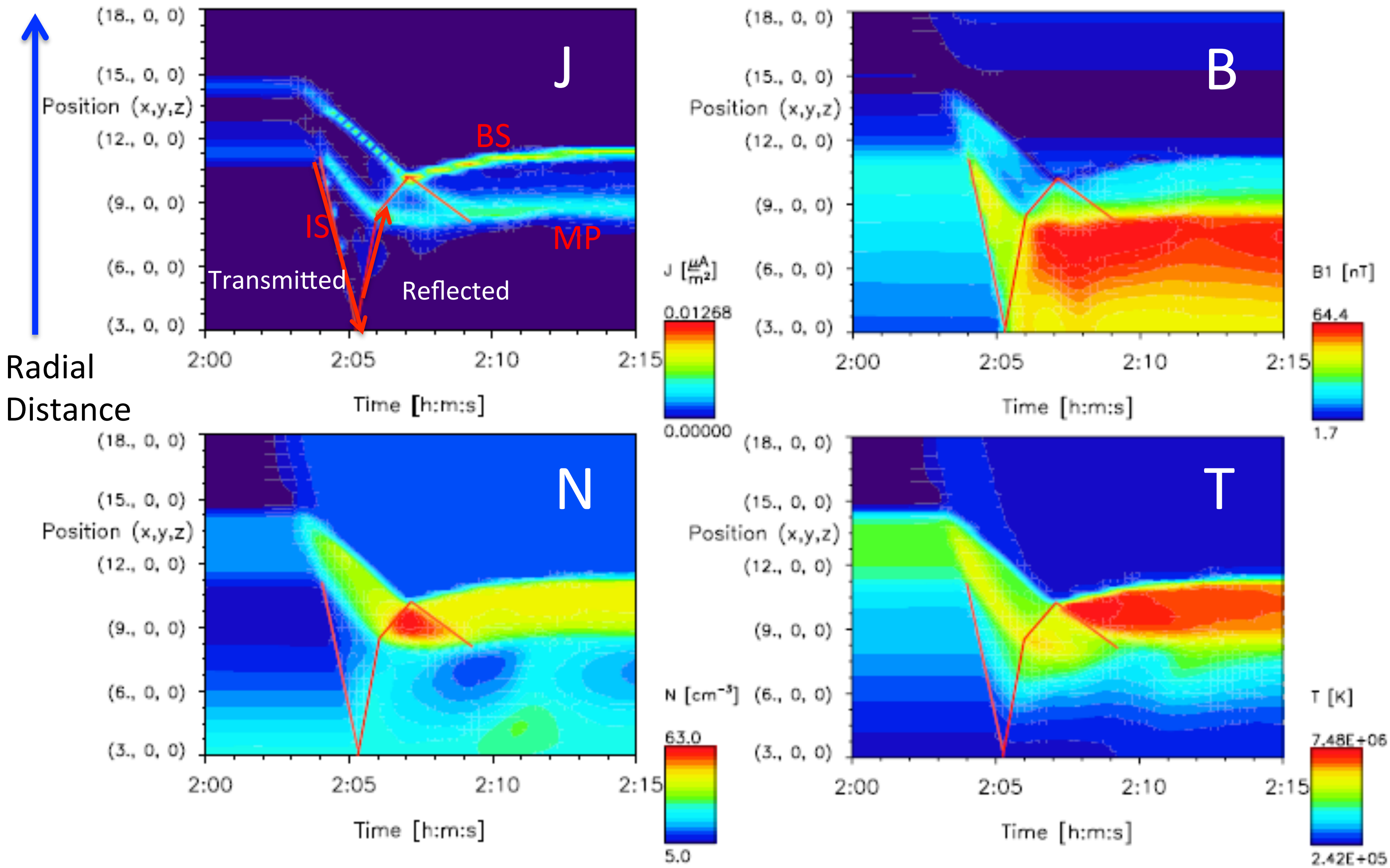
TIME

Russian Visitor:
Andrey Samsonov

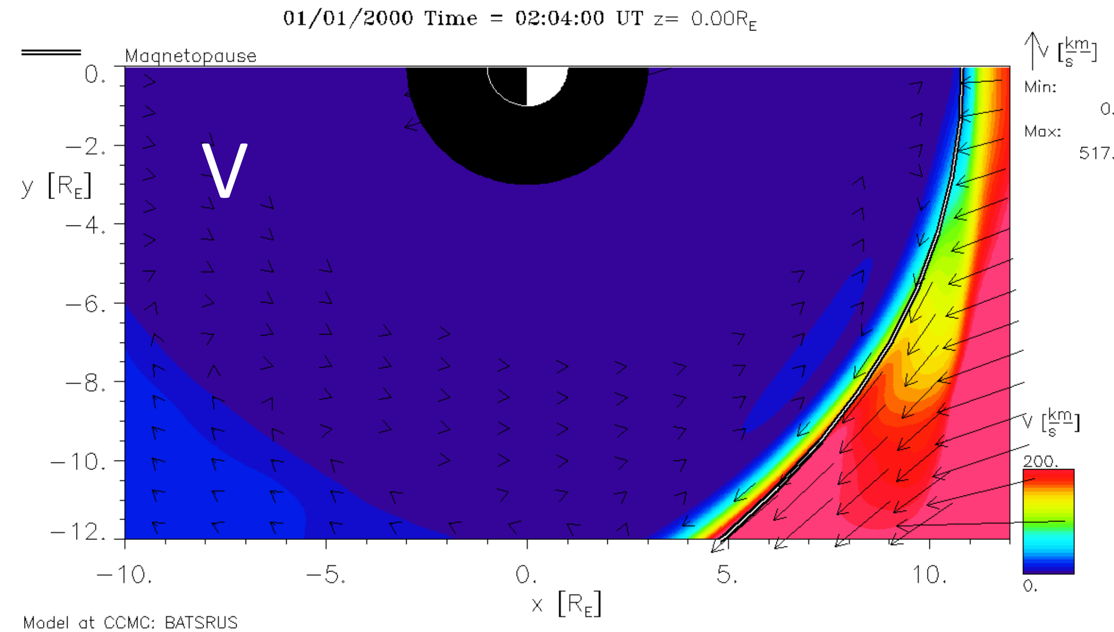
- Visits each year from U. St. Petersburg.

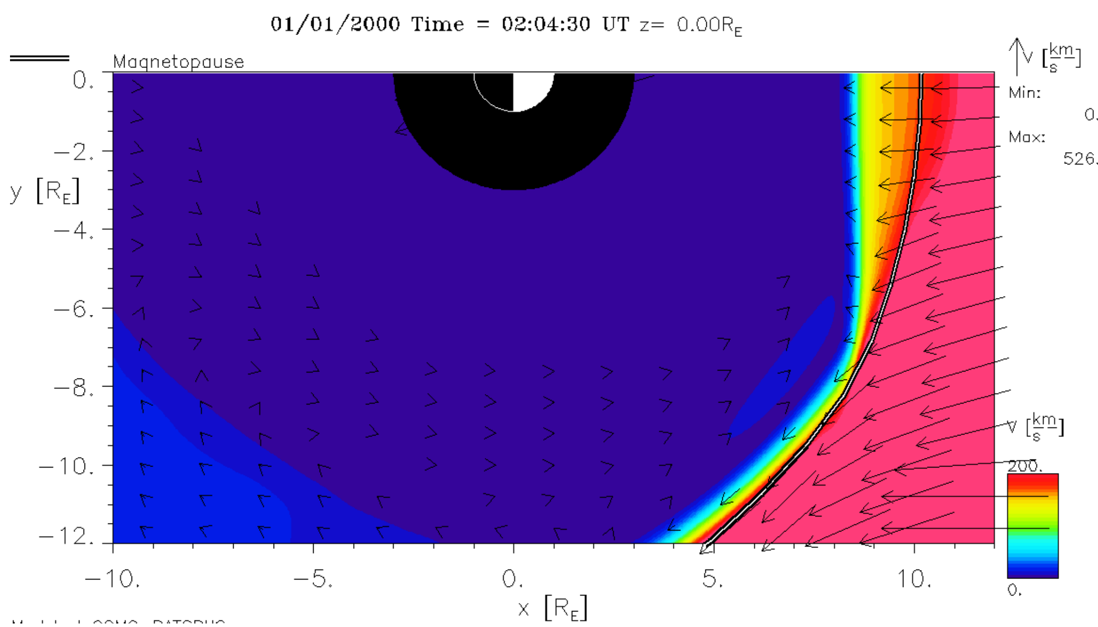
- Wants to understand the relationship of magnetospheric flow vortices to interplanetary shocks

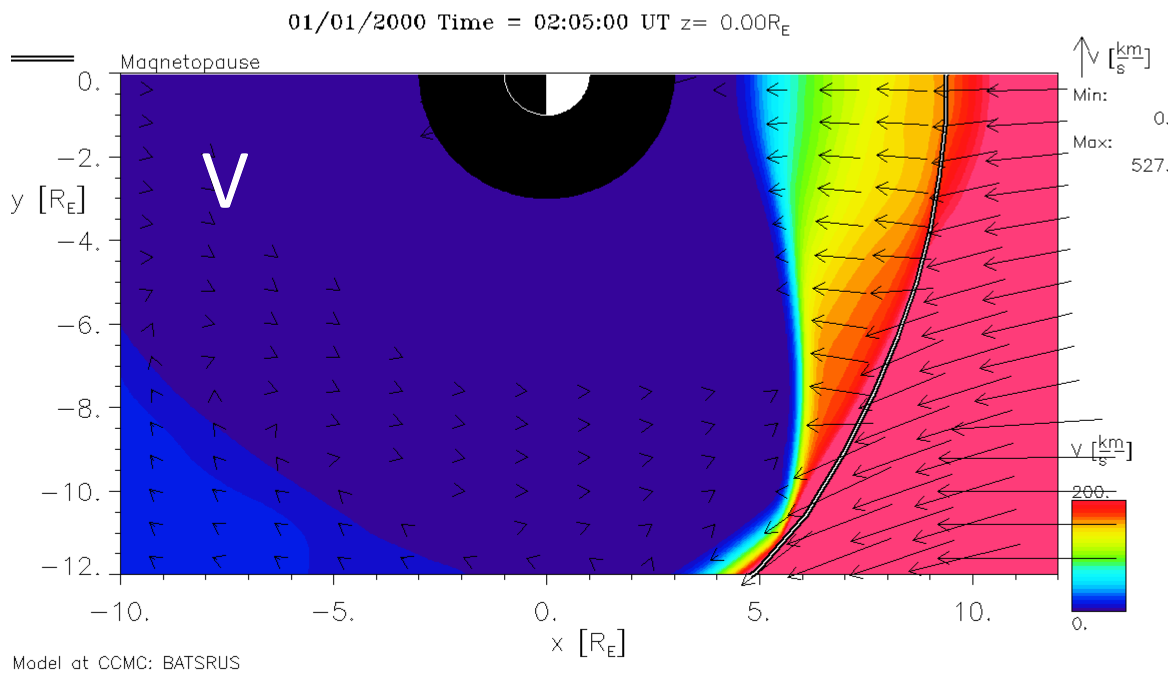
Tracks the Transmitted and Reflected Shock Through the MHD Simulation

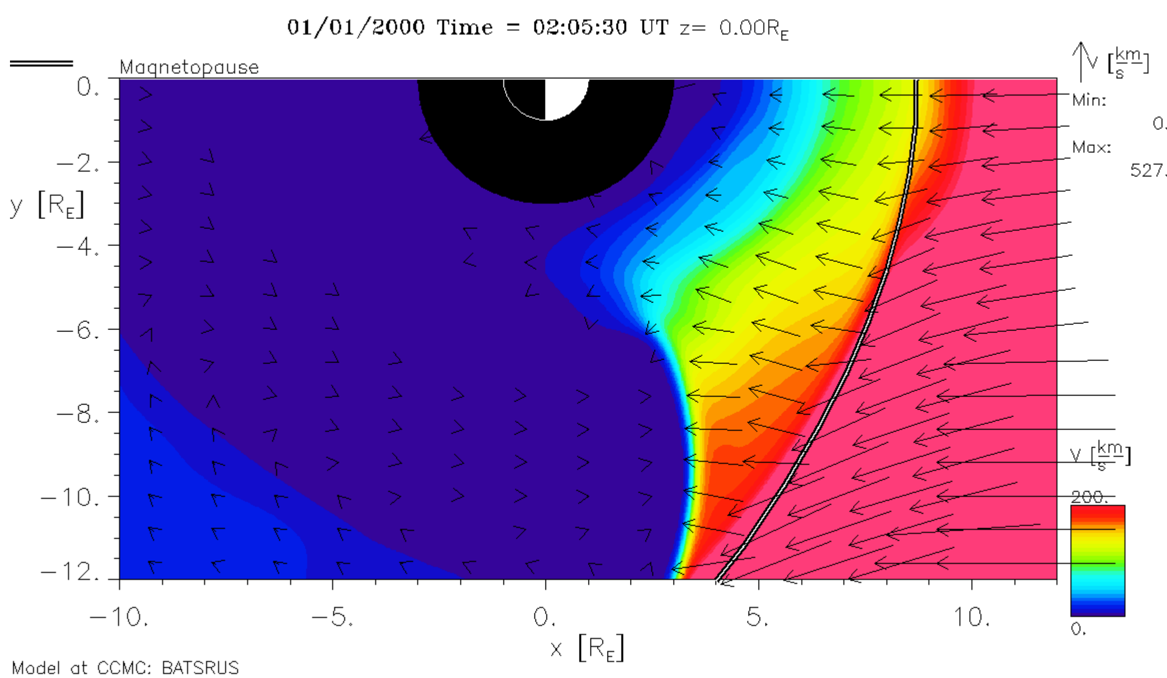


STUDIES THE VORTICES THAT IT GENERATES IN MAGNETOSPHERE






01/01/2000 Time = 02:05:00 UT z= 0.00R_E
Magnetopause
V
y [R_E]
x [R_E]
V [km/s]
Min: 0.
Max: 527.
200.
0.
Model at CCMC: BATSRUS


01/01/2000 Time = 02:05:30 UT z= 0.00R_E
Magnetopause
y [R_E]
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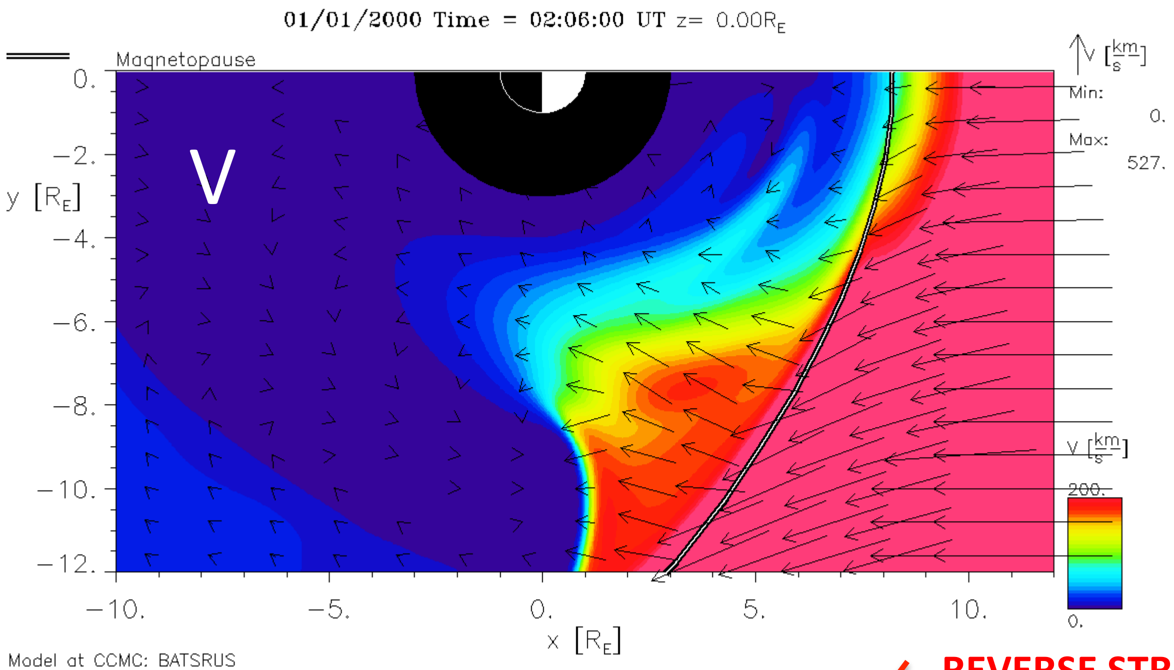
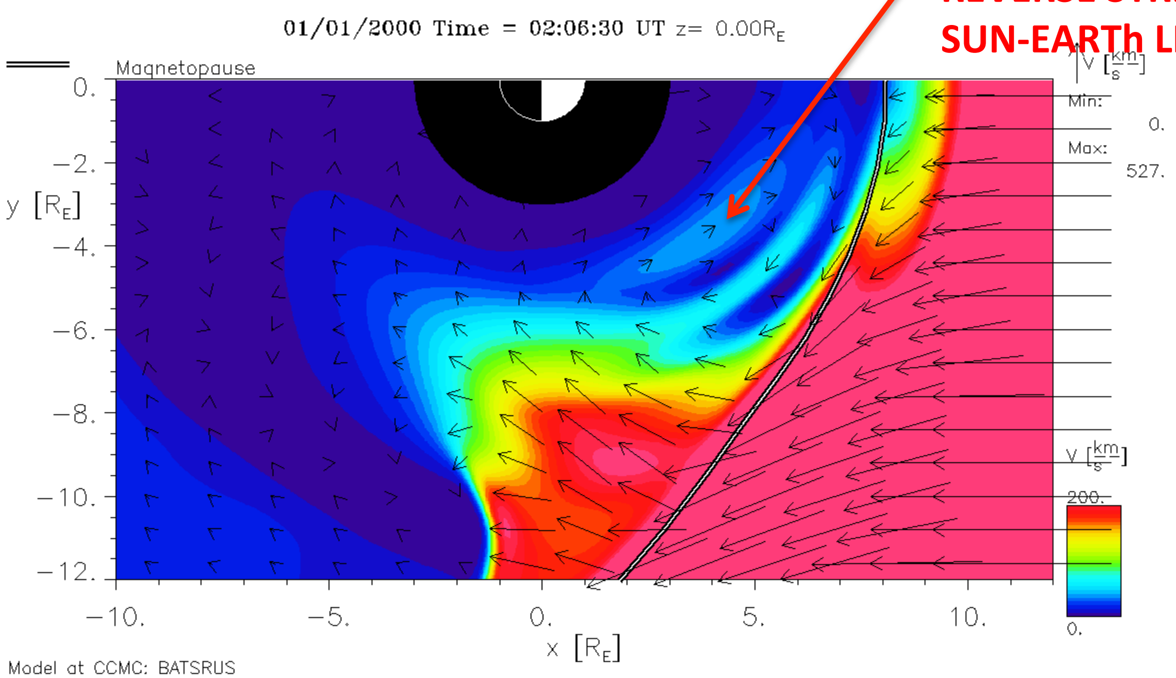
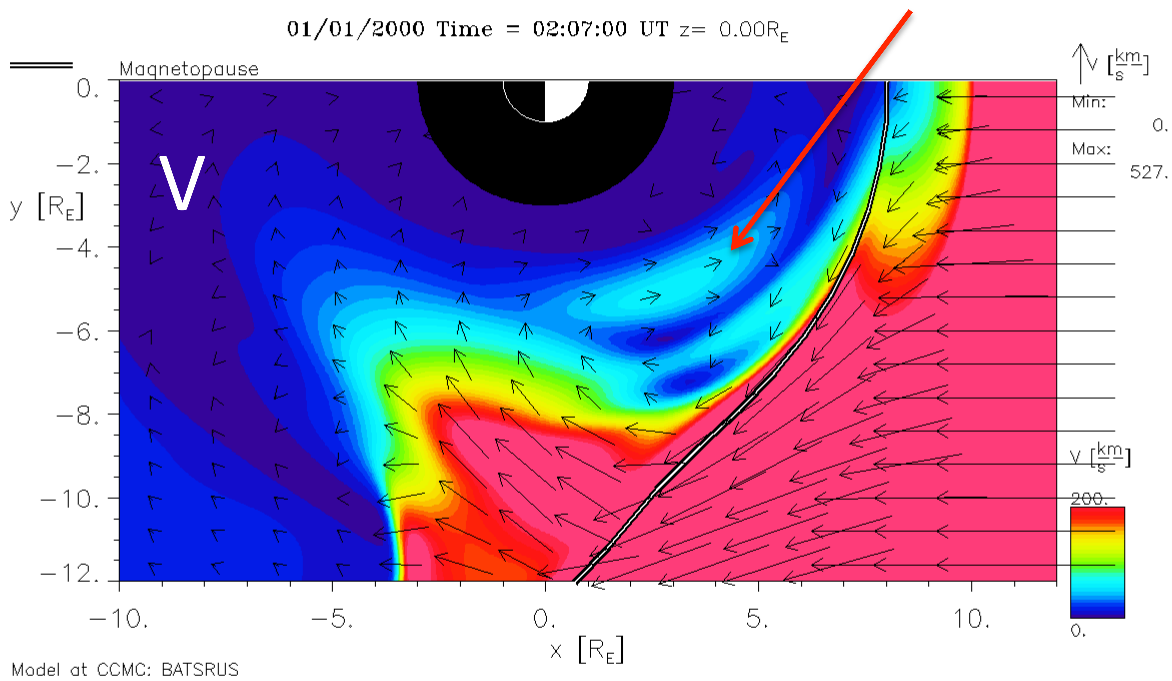
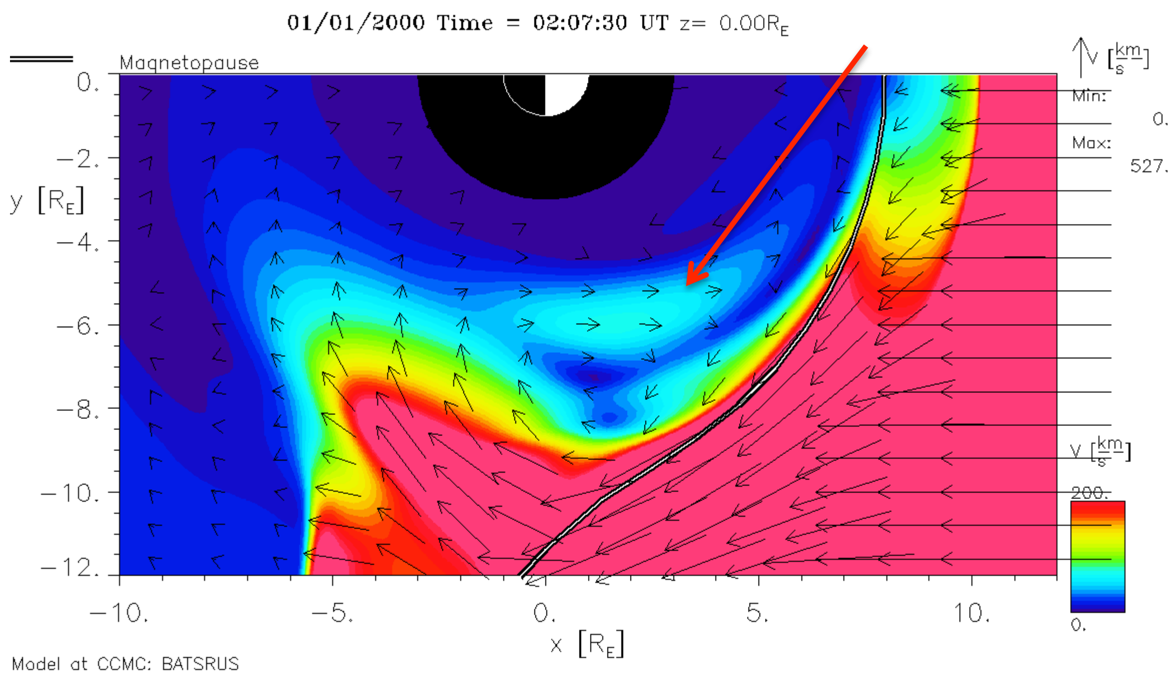
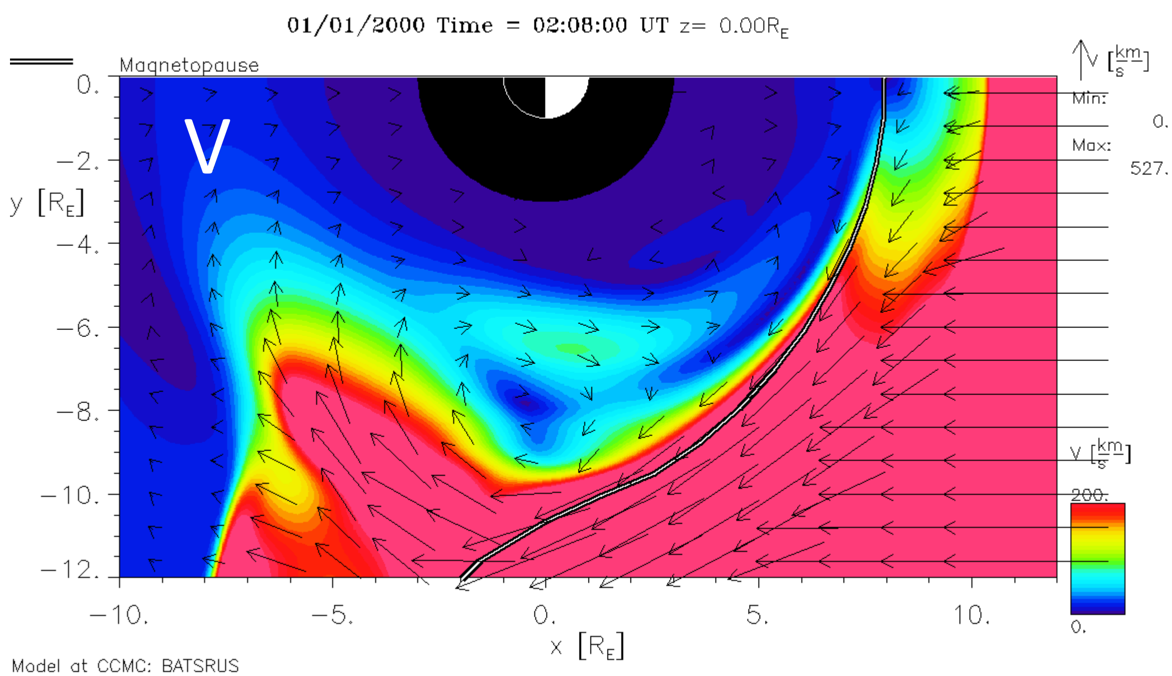


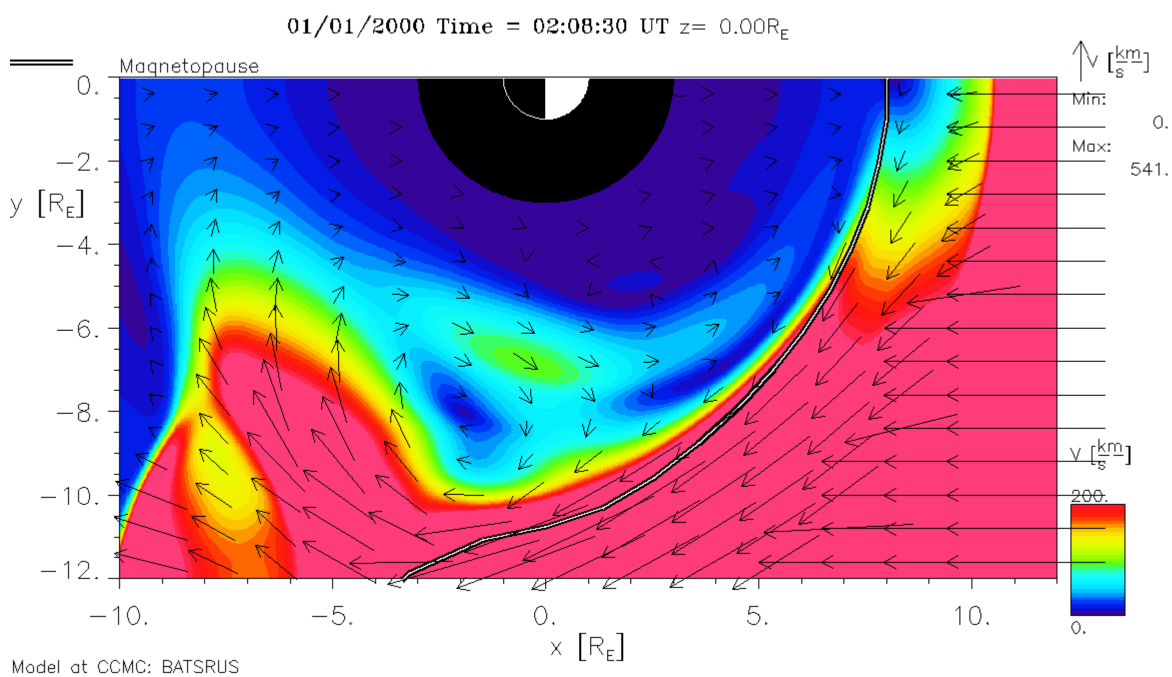
REVERSE STREAM TOWARD SUN-EARTh LINE



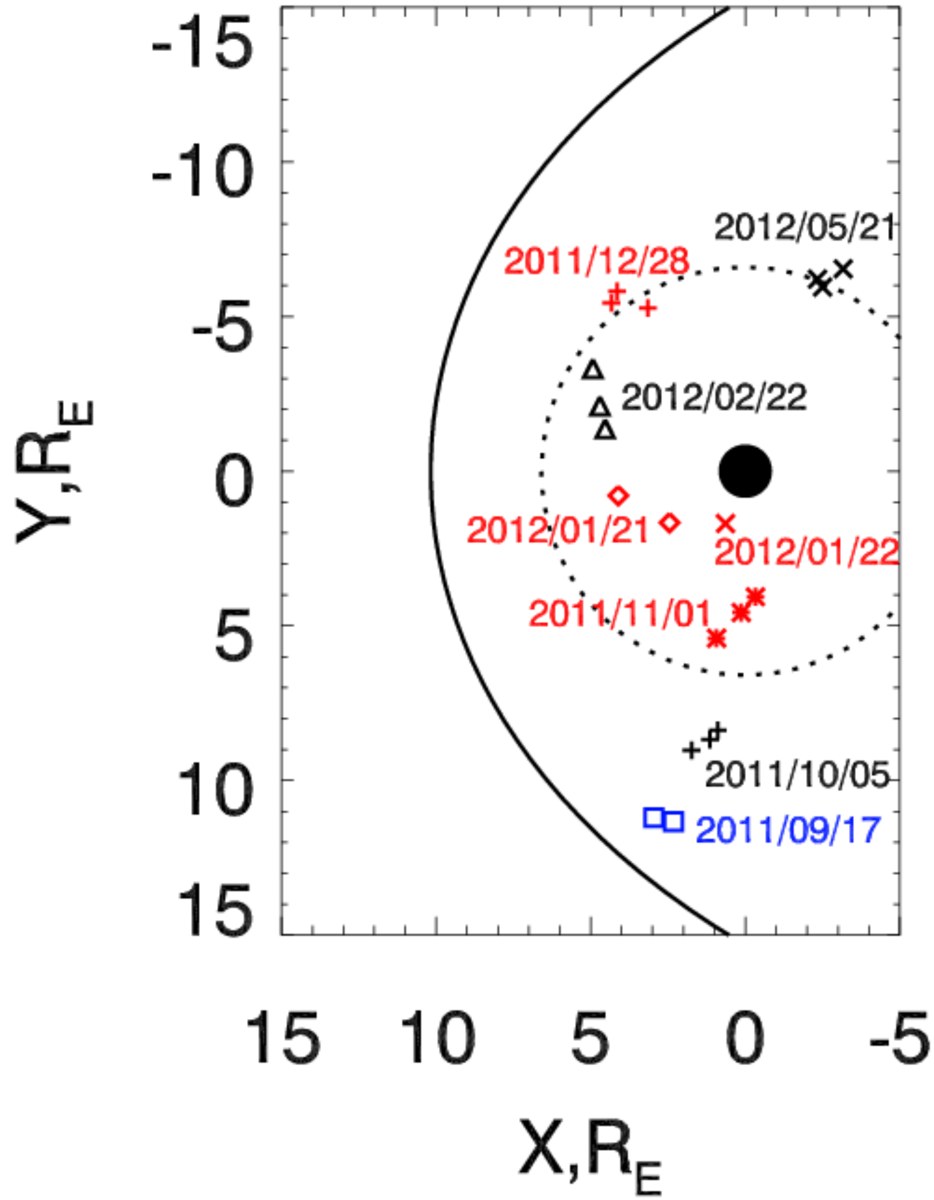

01/01/2000 Time = 02:07:00 UT z= 0.00R_E
Magnetopause
V
y [R_E]
x [R_E]
Min: 0.
Max: 527.
Model at CCMC: BATSRUS


01/01/2000 Time = 02:07:30 UT z= 0.00R_E
Magnetopause
y [R_E]
x [R_E]
Min: 0.
Max: 527.
Model at CCMC: BATSRUS


01/01/2000 Time = 02:08:00 UT z= 0.00R_E
Magnetopause
V
y [R_E]
x [R_E]
V [km/s]
Min: 0.
Max: 527.
v [km/s]
200.
0.
Model at CCMC: BATSRUS

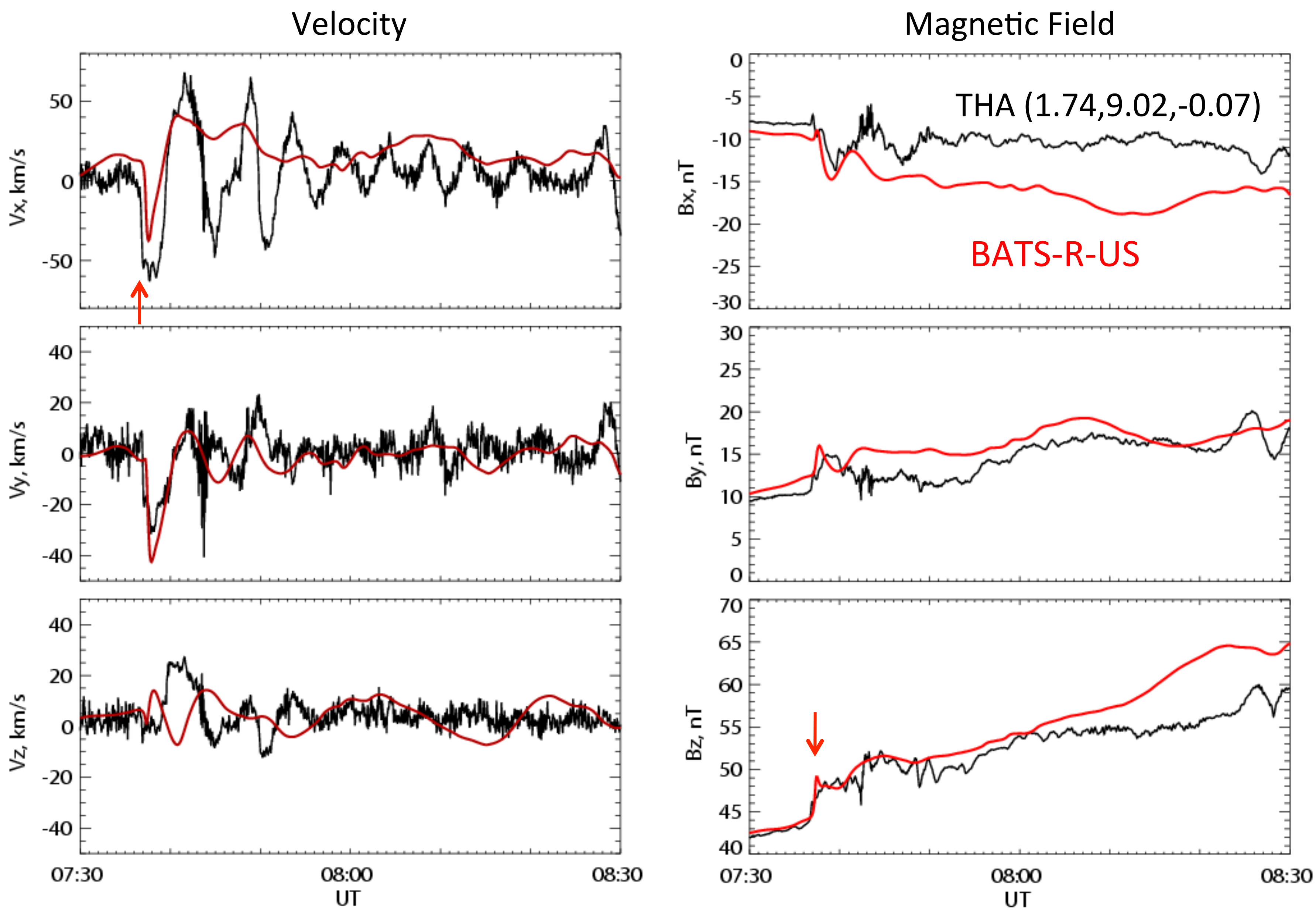

01/01/2000 Time = 02:08:30 UT z= 0.00R_E
Magnetopause
y [R_E]
x [R_E]
V [km/s]
Min: 0.
Max: 541.
v [km/s]
200.
0.
Model at CCMC: BATSRUS

Looks for Vortices in Observations: THEMIS positions



N>50 cm^{-3}

Compare event on 10/05/2011 with simulations



Samsonov
MAIN CONCLUSIONS

- MHD models show that interplanetary shocks drive magnetosheath flow vortices
- THEMIS observes the vortices as velocity oscillations.
- ΔV and ΔB increase with geocentric distance.
- MHD models damp faster than the real magnetosphere.
- Submitted to JGR last week.

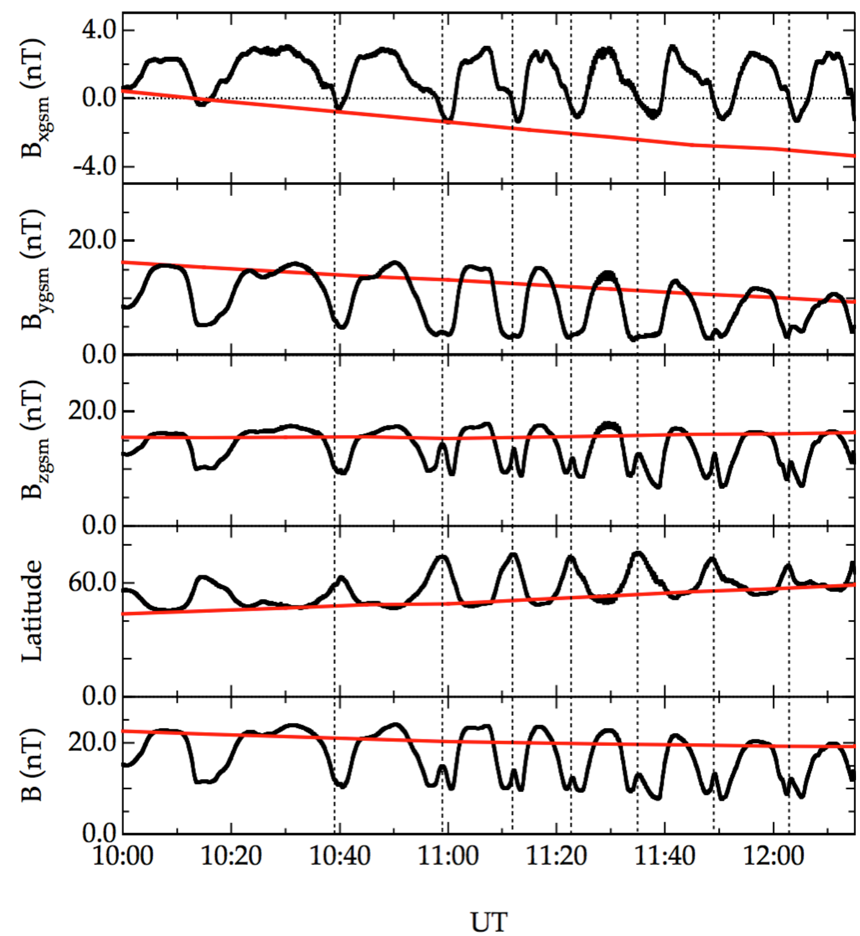
D. G. Sibeck Research: Geomagnetic Pulsations

Need a baseline for magnetospherc Pulsations.

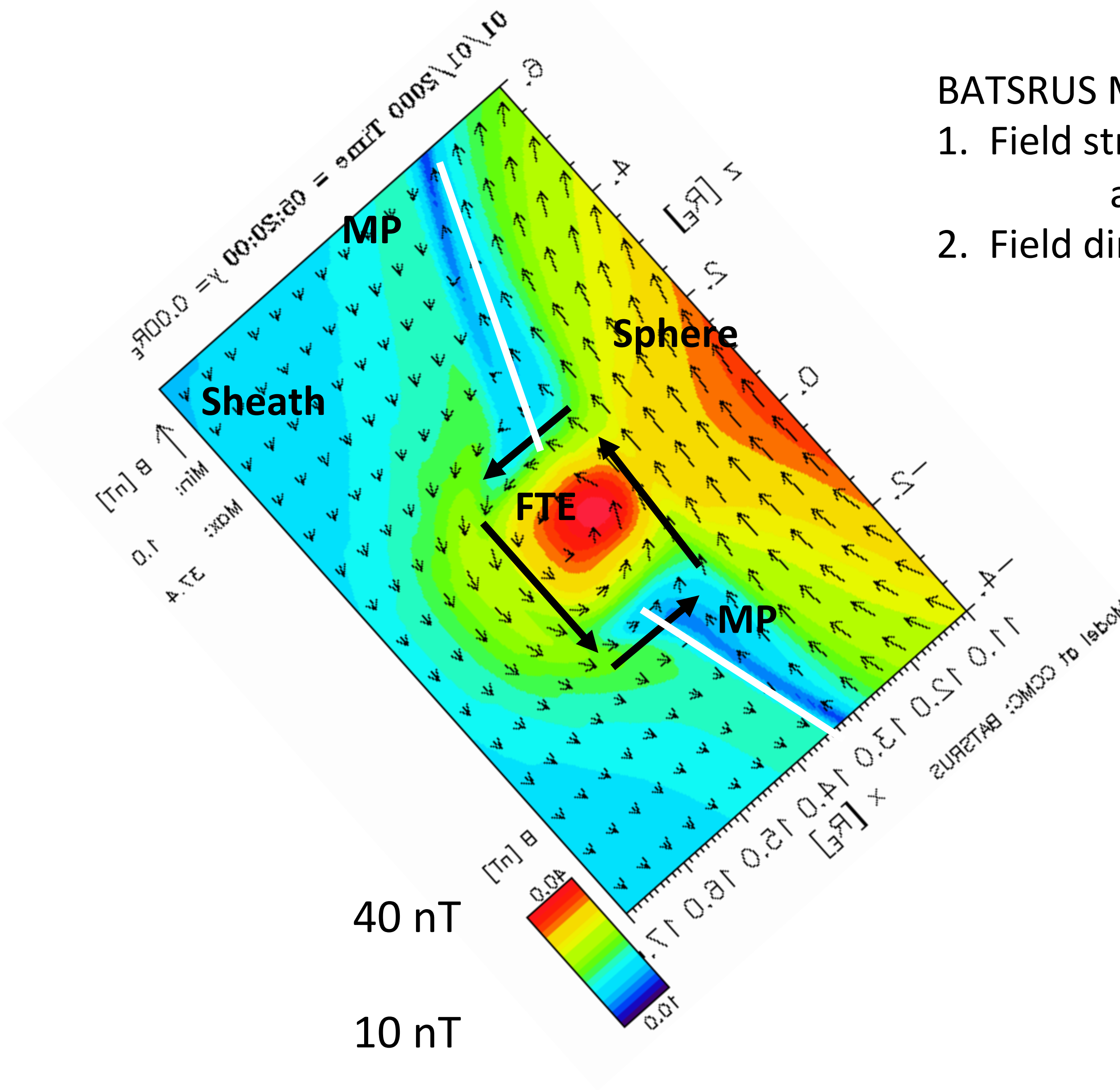
Use Tsyganenko model magnetic field (red) as this baseline.

The pulsations deflect the magnetic field away from its statistical mean.

We interpreted the pulsations in terms of drift-bounce resonances [Sibeck et al., 2012]



Sibeck:
Can We Predict the Structure of FTEs?

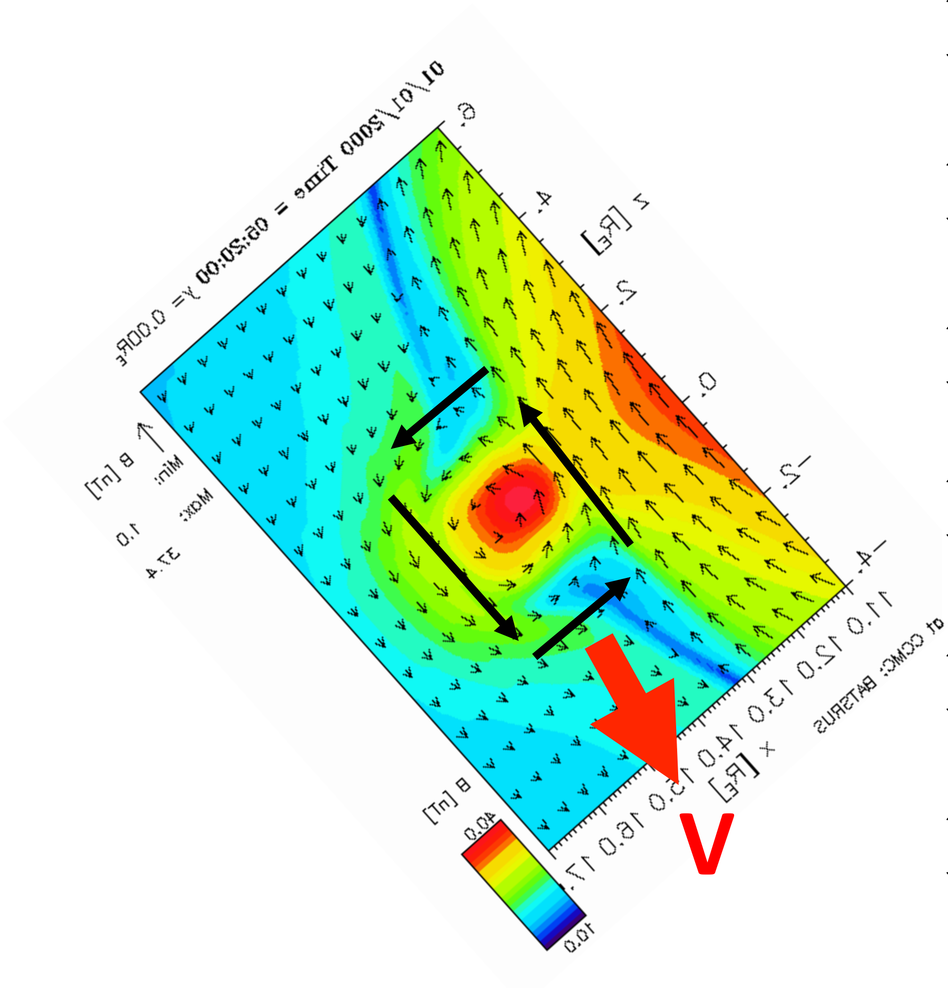


BATSRUS Model, IMF ~ By, May 20, 2007
1. Field strengths (colors)
   and
2. Field directions (arrows)

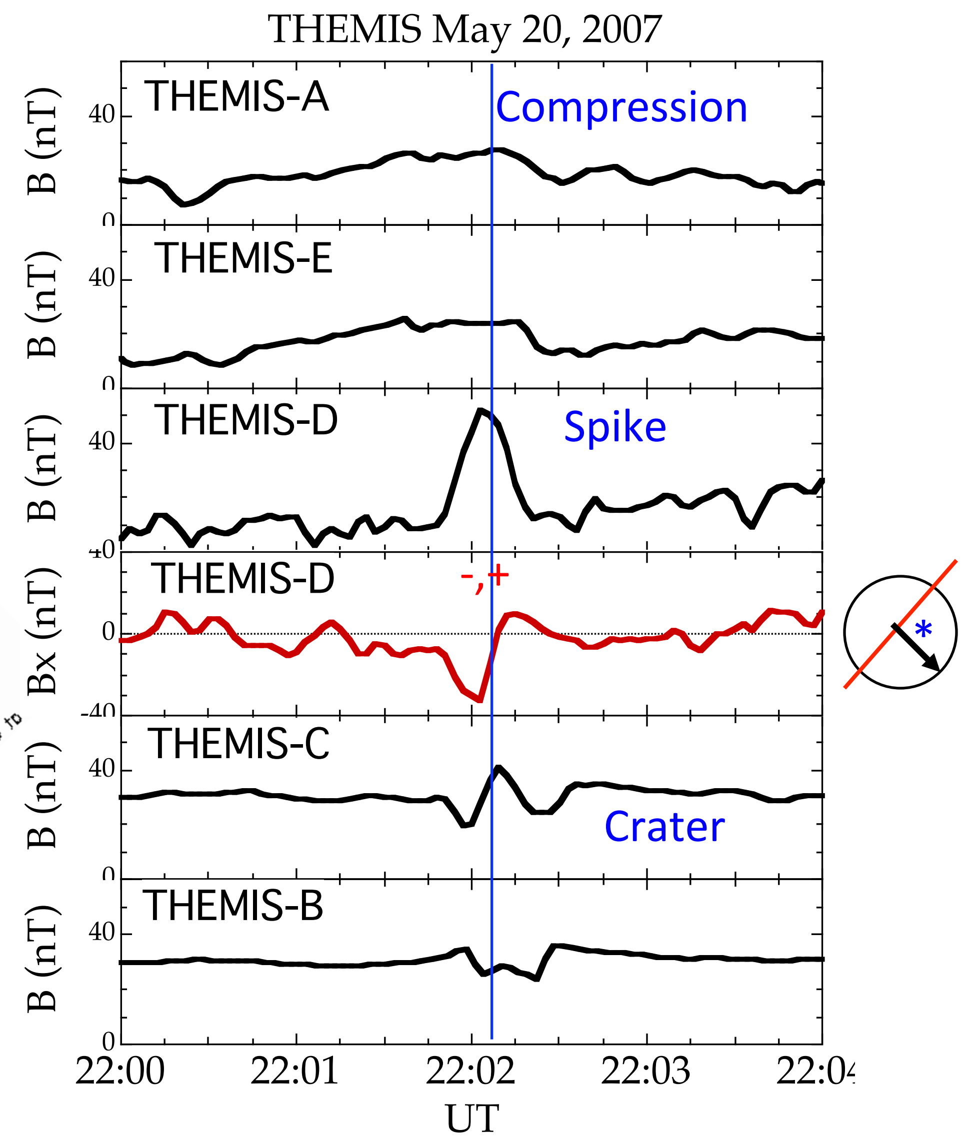
FTE flux rope with
Strong core field
Straddles the weak
Magnetic field region
of the magnetopause.

Flux Transfer Events

Model

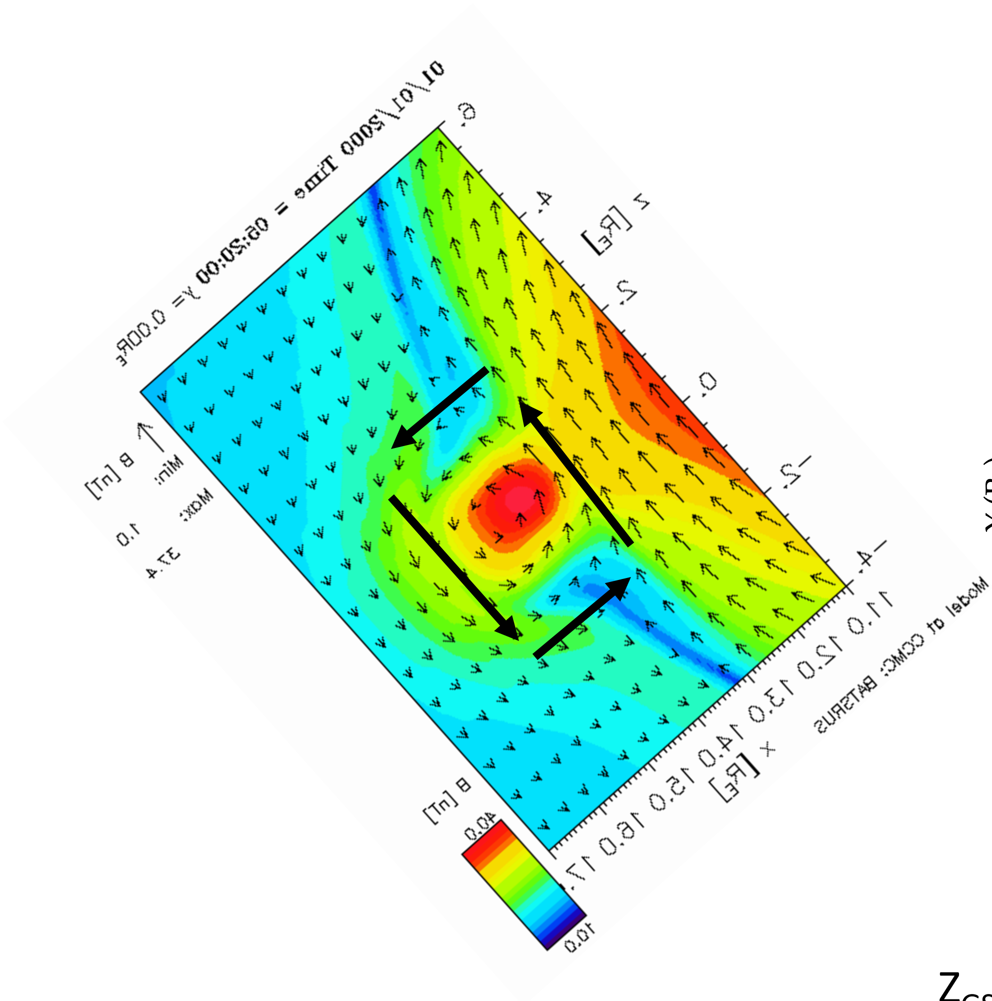


Multipoint Observations (IMF ~+By)

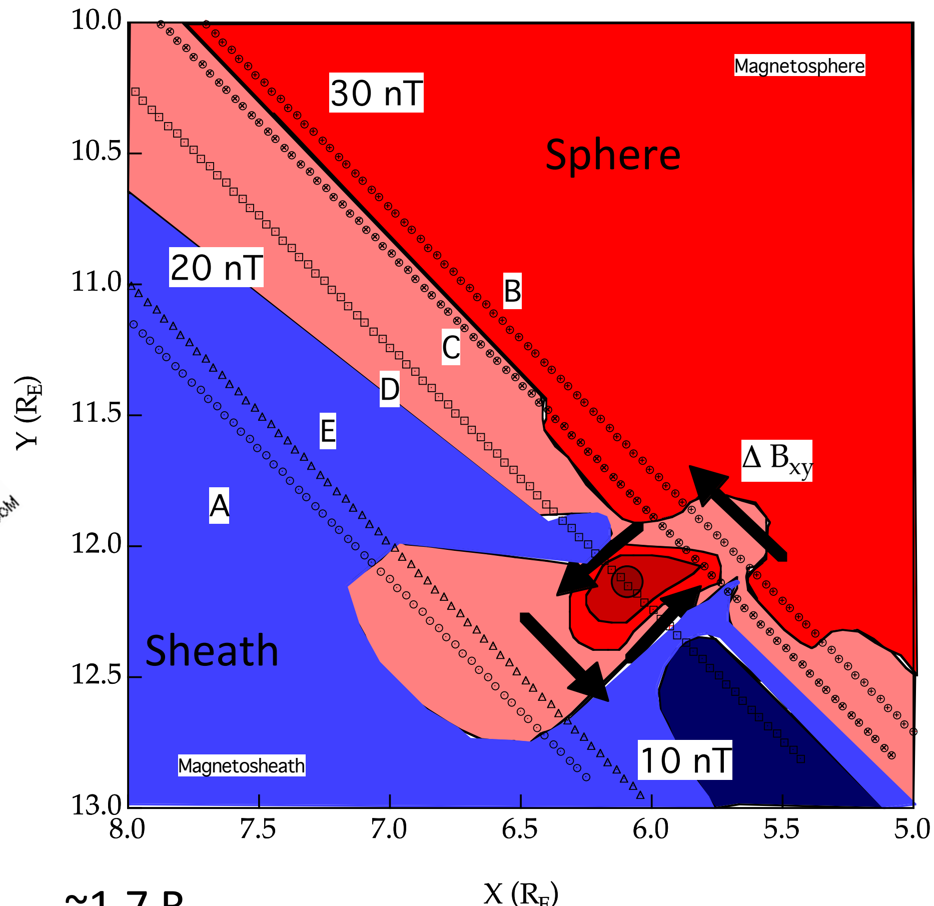


Flux Transfer Events

Model



Reconstruction (B contours)

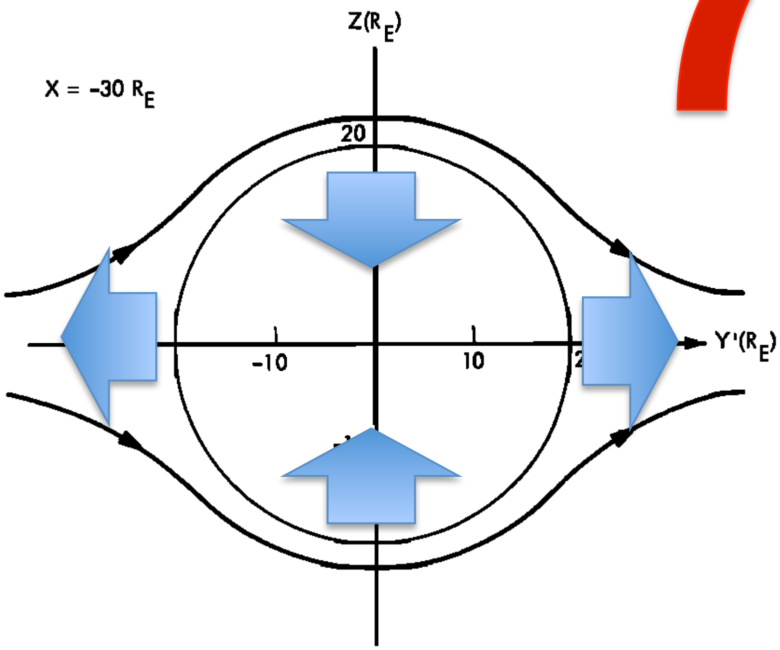


Z_{GSM} ~1.7 R_E

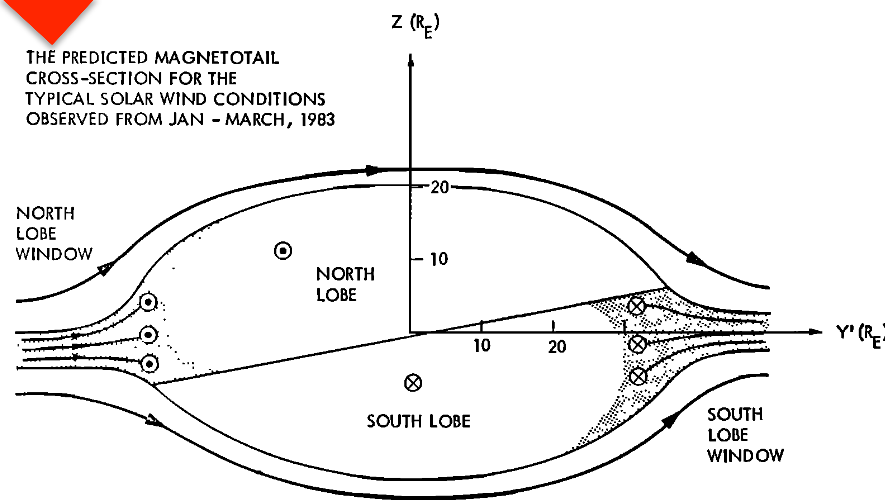
Sibeck:
Magnetotail Cross-Section

Anisotropic Pressure
Transforms

Near-Earth



Distant Magnetotail



The anisotropic pressure of draped magnetosheath magnetic field lines flattens the circular near-Earth magnetotail cross-section into an elliptical distant tail cross-section

Theory Predicts

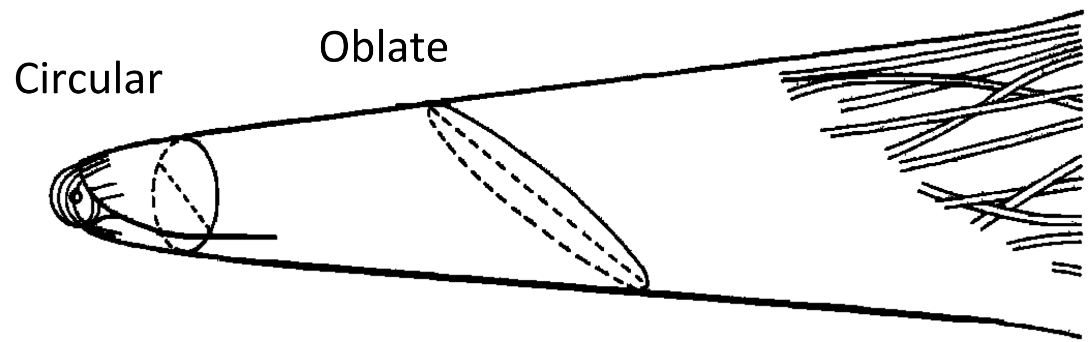
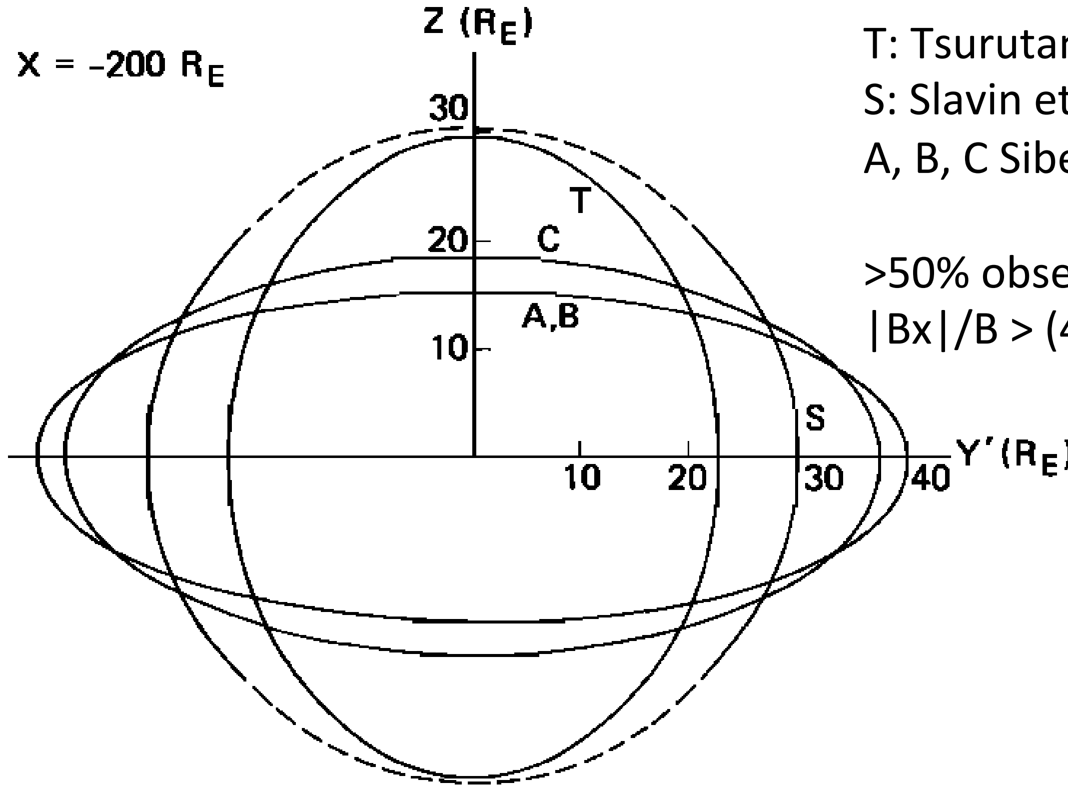


Fig. 2. Schematic of the magnetospheric tail showing (from left) the earth and near magnetosphere, the cylindrical portion of the tail and neutral sheet giving the 'theta' cross section, the flattening of the tail into an elliptical cross section, and the postulated breakup of the tail into individual flux tubes.

Michel and Dessler [1970]

ISEE-3 Observations Confusing

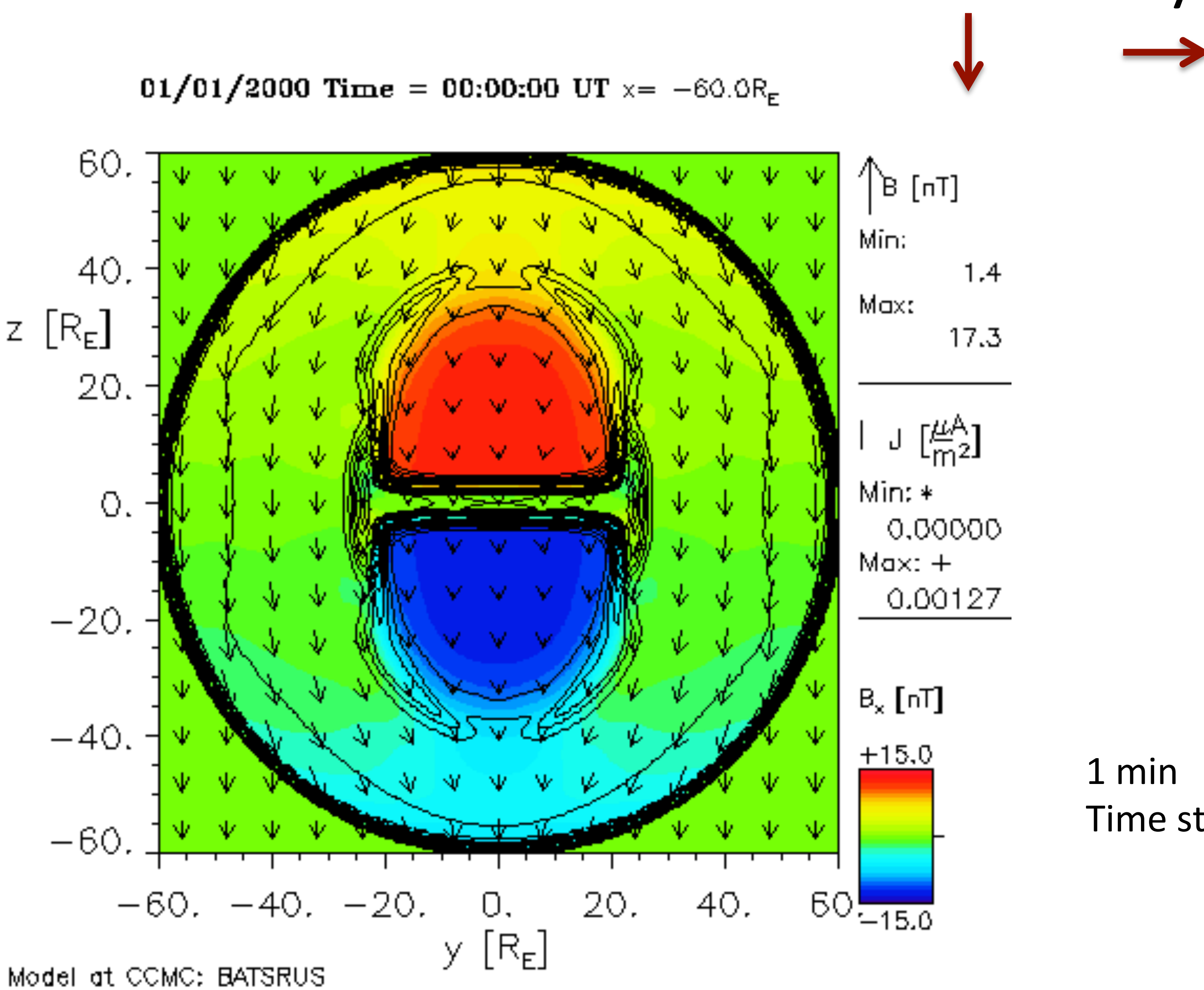


Observed and model magnetotail cross-sections

T: Tsurutani et al. [1984]
S: Slavin et al. [1983]
A, B, C Sibeck et al. [1986]

>50% observations with $|Bx|/B > (4/5)^{1/2}$

Time-Dependent Response of Magnetotail Cross-Section when IMF Rotates from –Bz to +By



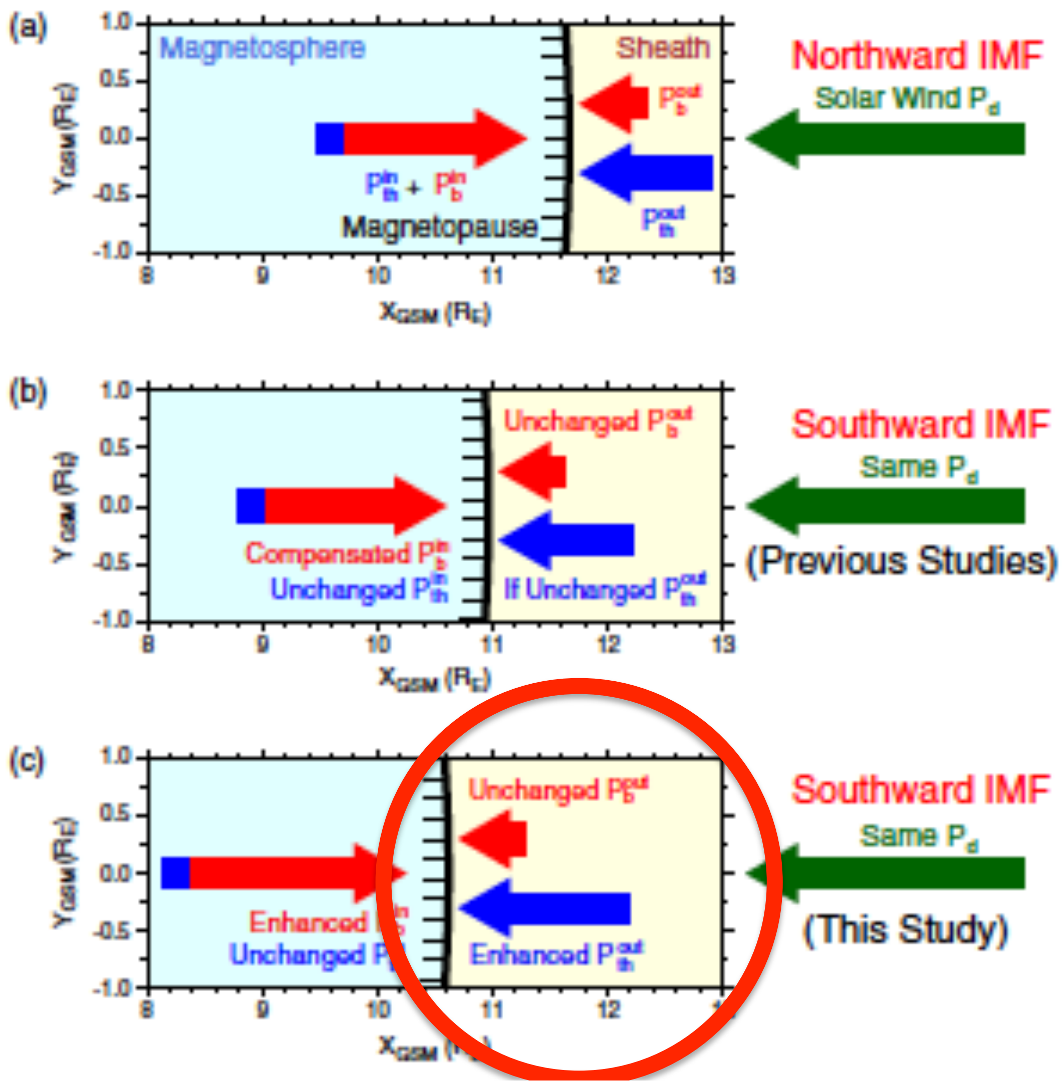
Published Sibeck et al. [JGR, 2014]

1 min Time steps

Sibeck
Pressure Balance at the Magnetopause

- Shue and Chao [2013] report that pressures applied to the subsolar magnetopause increase when the IMF turns southward.
- Really? Lets ask the MHD models.

The Claim (Part 1):
IMF Bz Controls Pressure Applied to Magnetopause Near the Sun-Earth Line [Shue and Chao; 2013]



Standard View

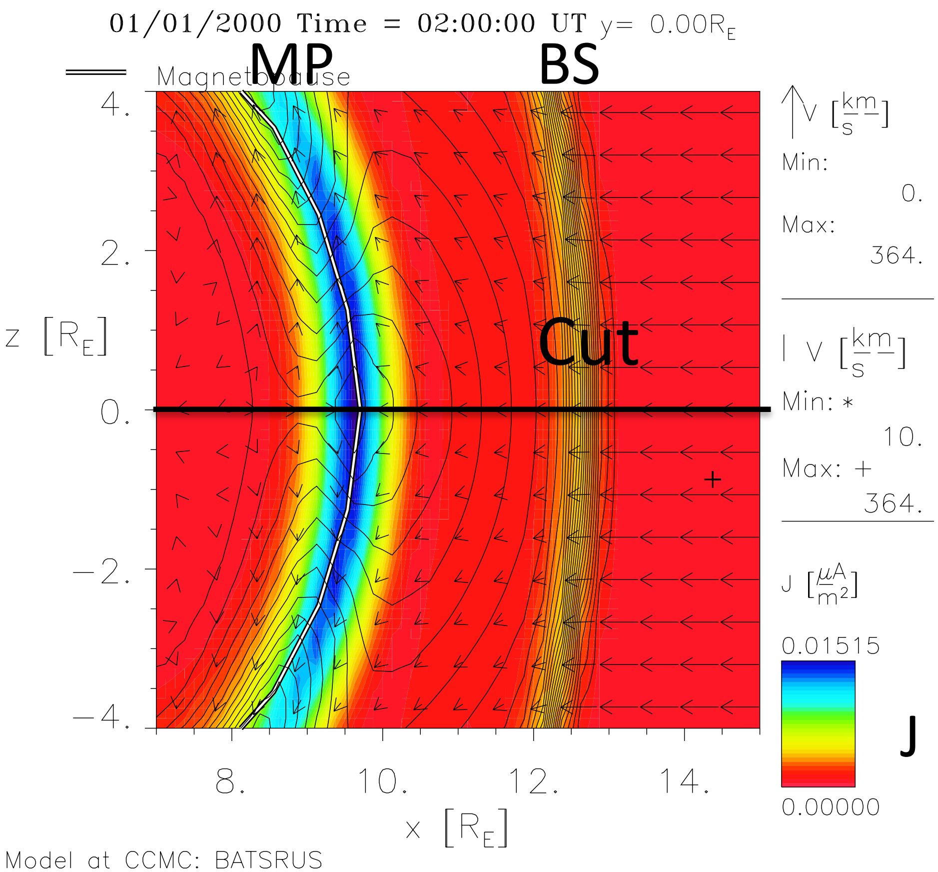
Standard View

IMF Bz

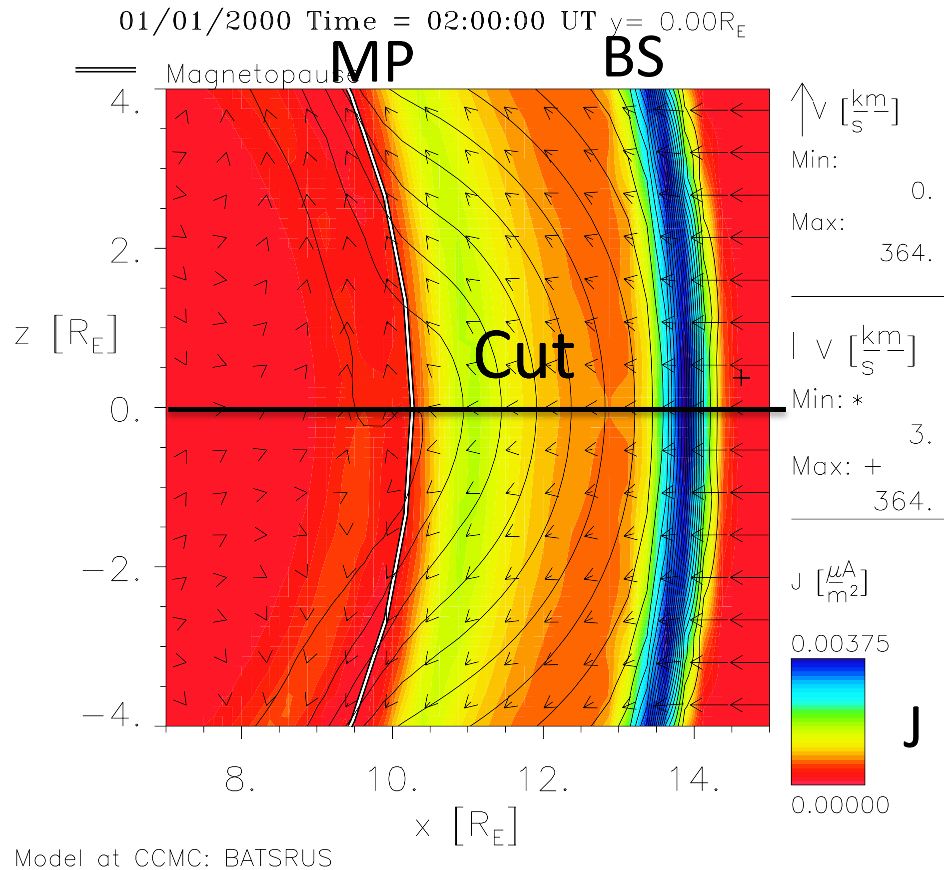
Shue View
Pressures increase for Bz < 0

MHD Simulations: Cut Along X-axis

IMF Bz < 0
Magnetopause Current Strong



IMF Bz > 0
Bow Shock Current Strong



Profiles along the Sun-Earth Line

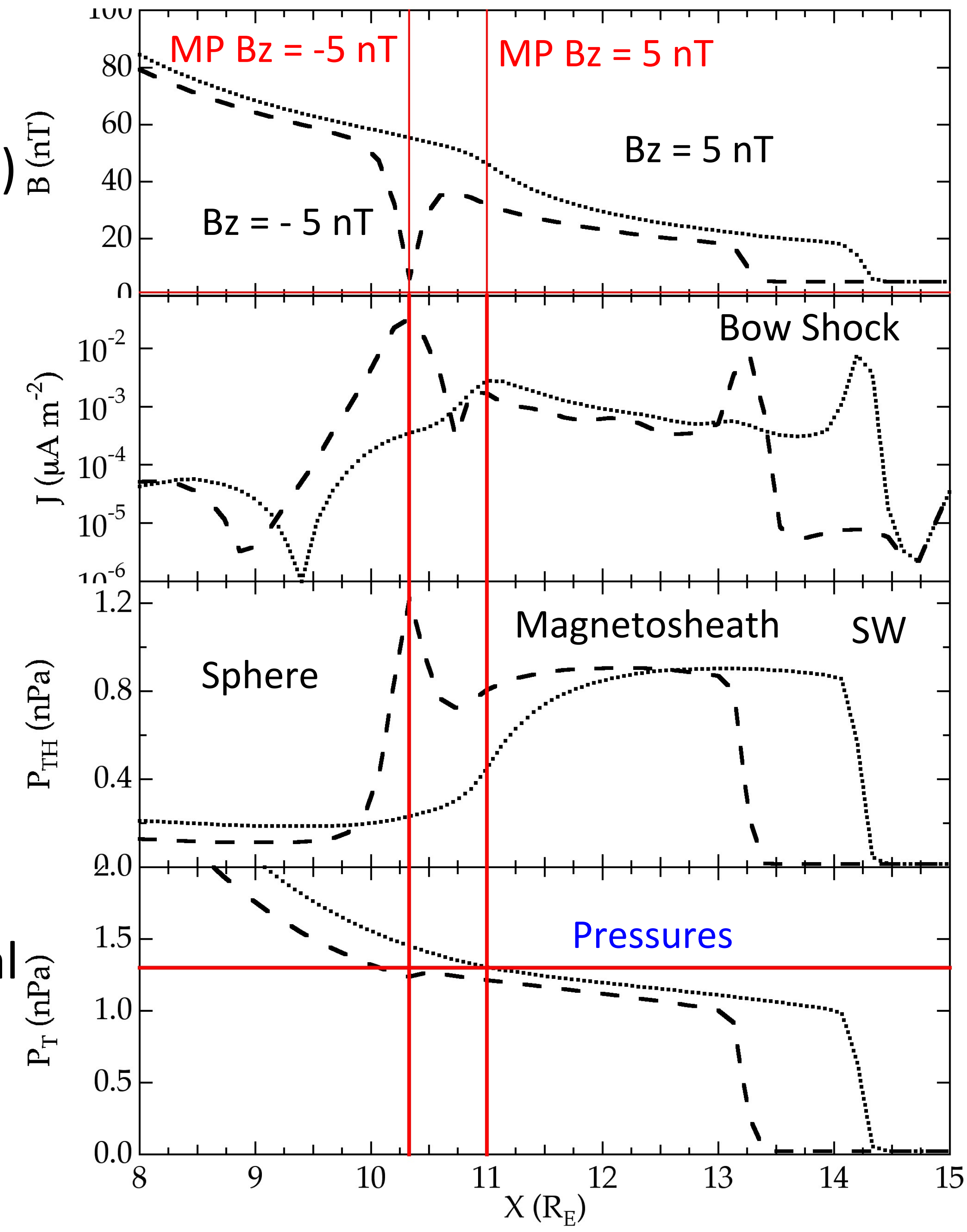
Use current peaks to find magnetopause, compare pressures at Bz > 0, <0 magnetopause.

B (nT)

J

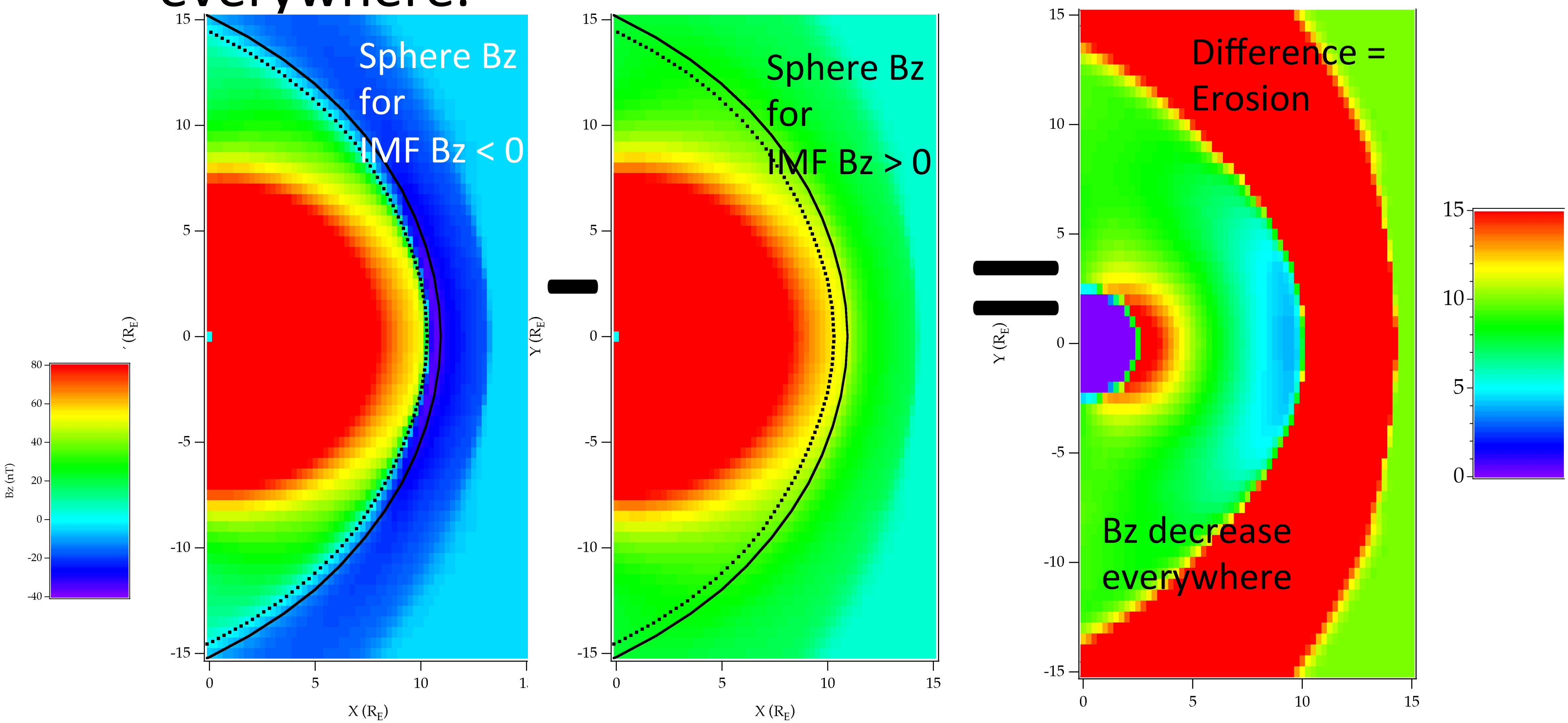
Pth (nPa)

Ptotal (nPa)



How About Deeper in the Magnetosphere?

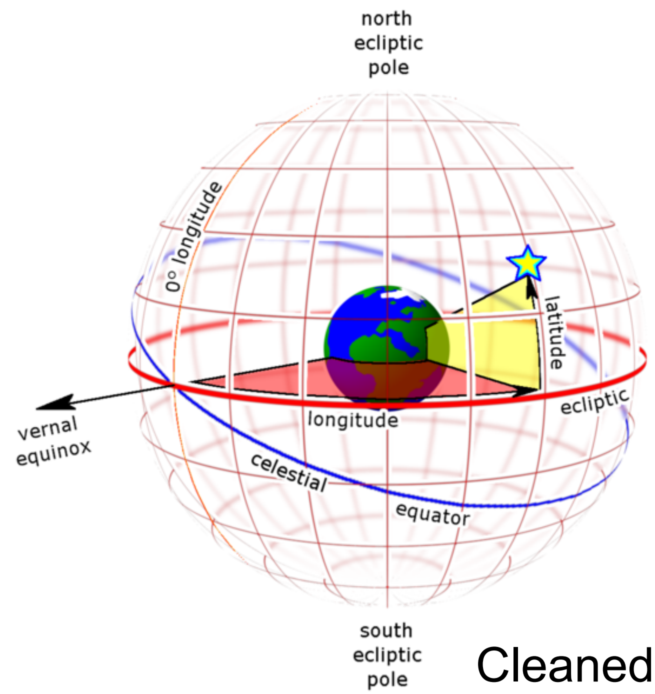
- Compare distributions of equatorial magnetospheric Bz for IMF Bz > 0 and <0… to show that Bz decreases everywhere.

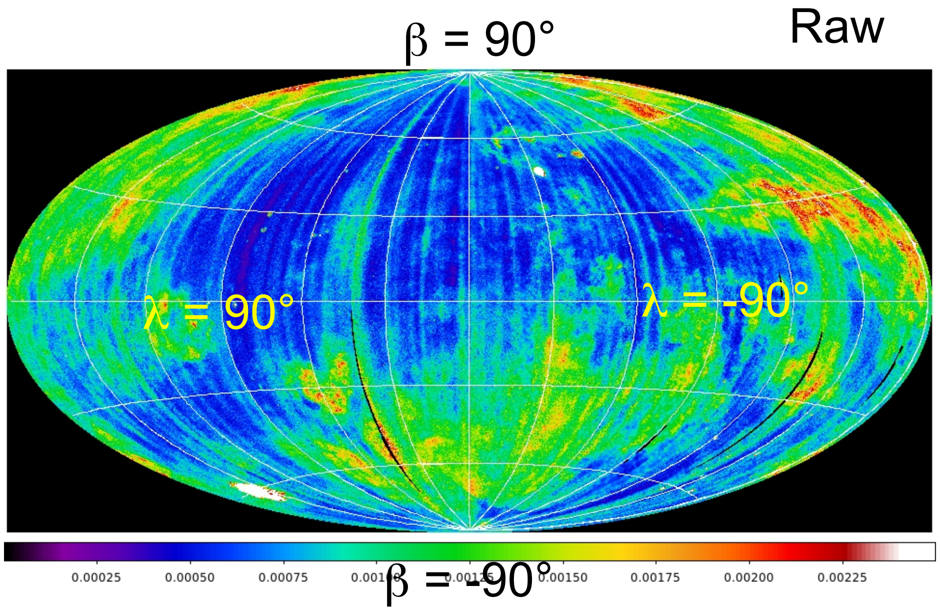


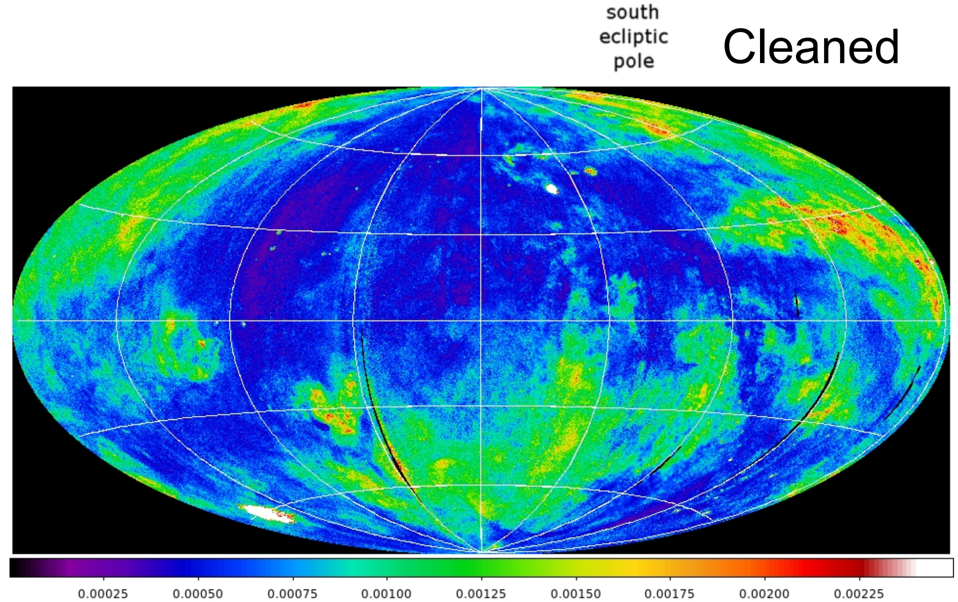
Sibeck:
Mission Planning

- Want to develop and fly a soft x-ray imager
- Need to determine signal to noise
- Need to determine best orbit

Magnetosheath emissions frequently obstructed low altitude spacecraft ROSAT's all-sky soft (0.1-2 keV) X-ray survey from 7/90-8/91







Streaks contaminate ROSAT views through the terminator magnetosheath.

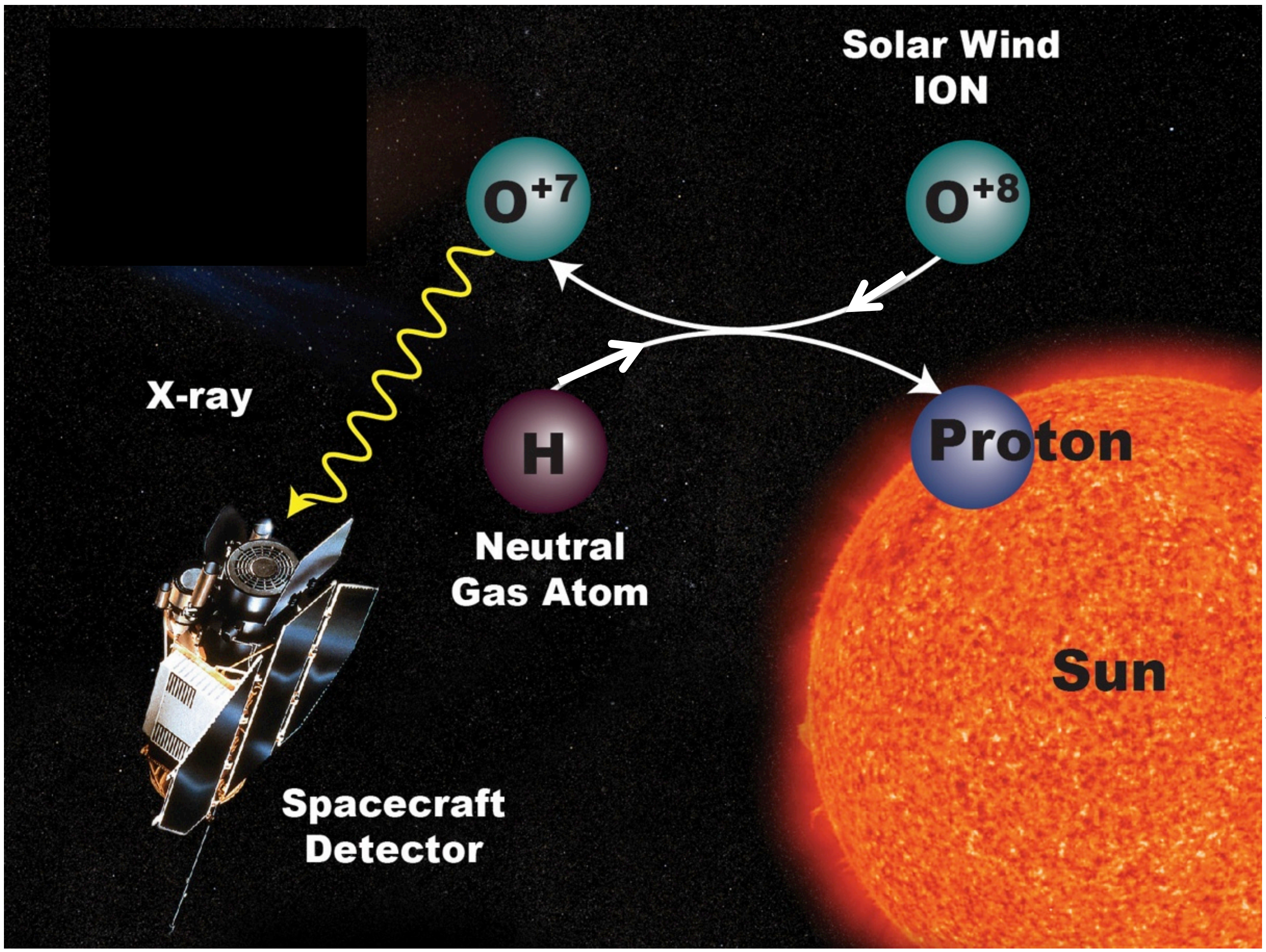
With magnetosheath 'contamination' removed, background is well-determined

Snowden et al. [1997]

Charge Exchange Generates Soft X-Rays In the Magnetosheath and Cusp: High Charge State Solar Wind Ions and Exospheric Neutrals

$O^{8+} + H \rightarrow O^{7+} + H^{+}$ + Soft X-rays

$C^{6+} + H \rightarrow C^{5+} + H^{+}$ + Soft X-rays



The soft X-rays are emitted isotropically, and can be seen from a wide range of locations

Integrated line of sight intensity is given by:

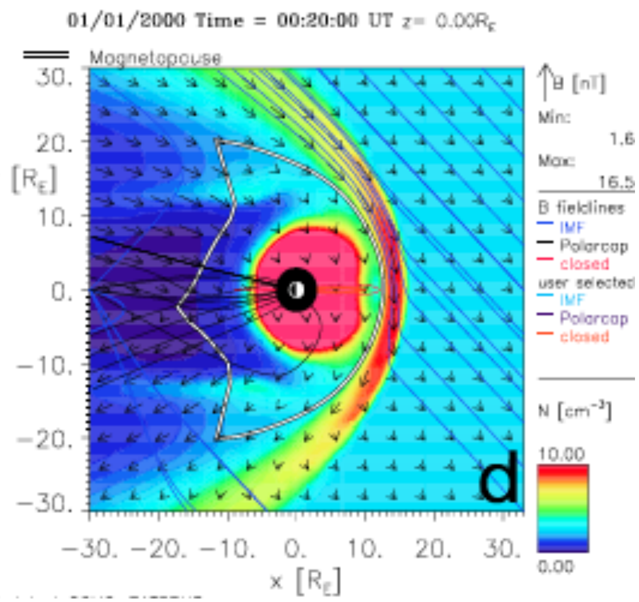
$$J_{x\text{-}ray} = \int \delta r \; n_{ion} V_{eff} \sigma n_H$$

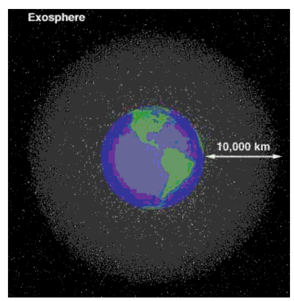
$$V_{eff} \sim (V_{th}^2 + V_{bulk}^2)^{1/2}$$

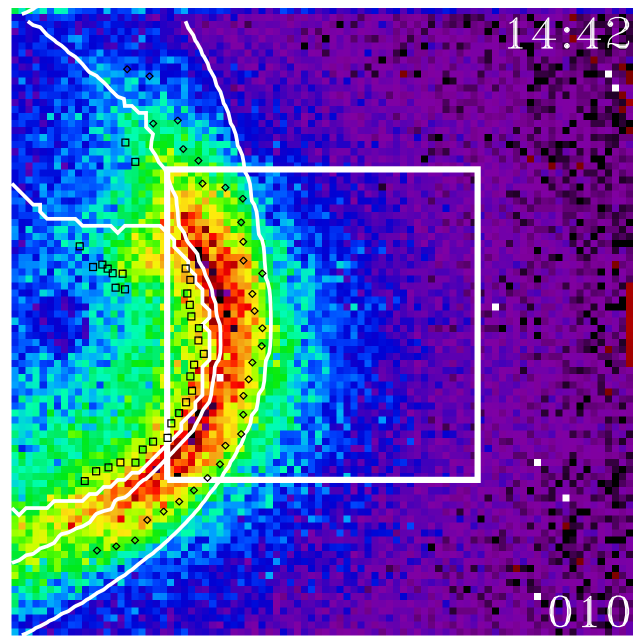
We Want to Look from the Outside-In

- Cross-section of the magnetosphere, exosphere imposed, lines of sight integrations,

Magnetosphere + Exosphere = Soft X-ray Emissions







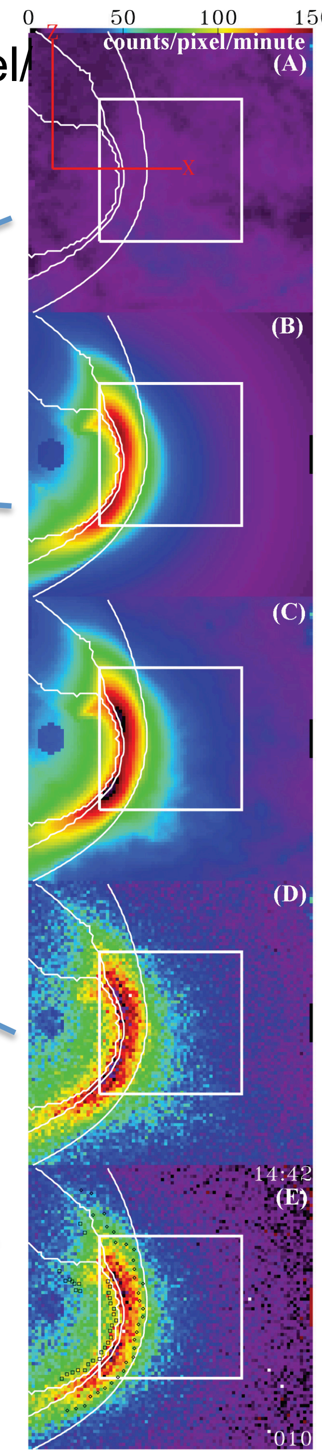
...and test boundary extraction routines on simulated observations

- A. Nominal soft x-ray background
- B. Integrated LOS emissions
- C. A+B
- D. A+B+Poisson Noise
- E. D-A

- Observer at
  (x,y,z) = (10, -30, 0) R_E
  Counts/0.5° x 0.5° pixel - minute

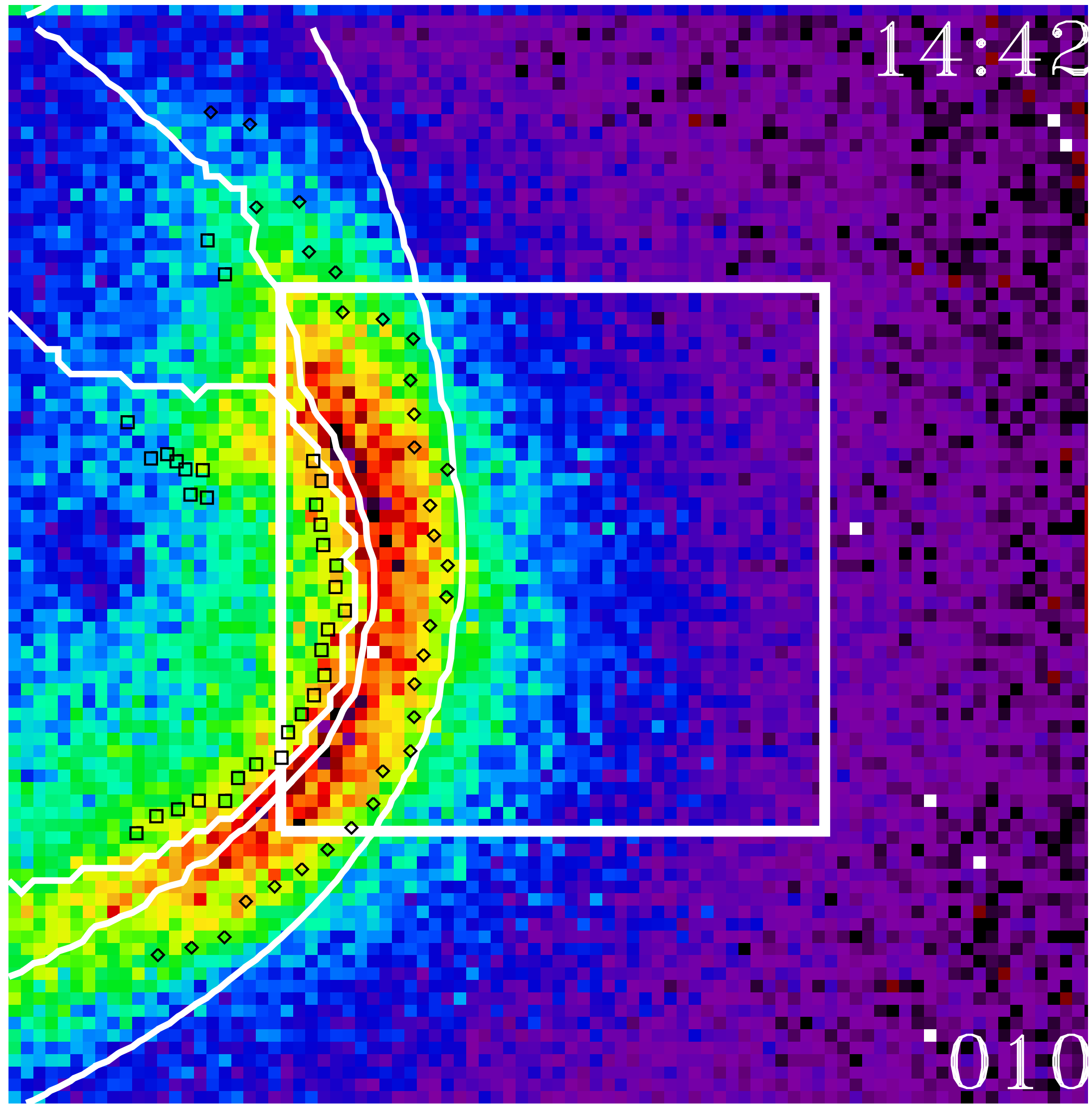
Calculations made using BATS-R-US MHD (courtesy CCMC) and Hodges exospheric models

Counts/pixel/min



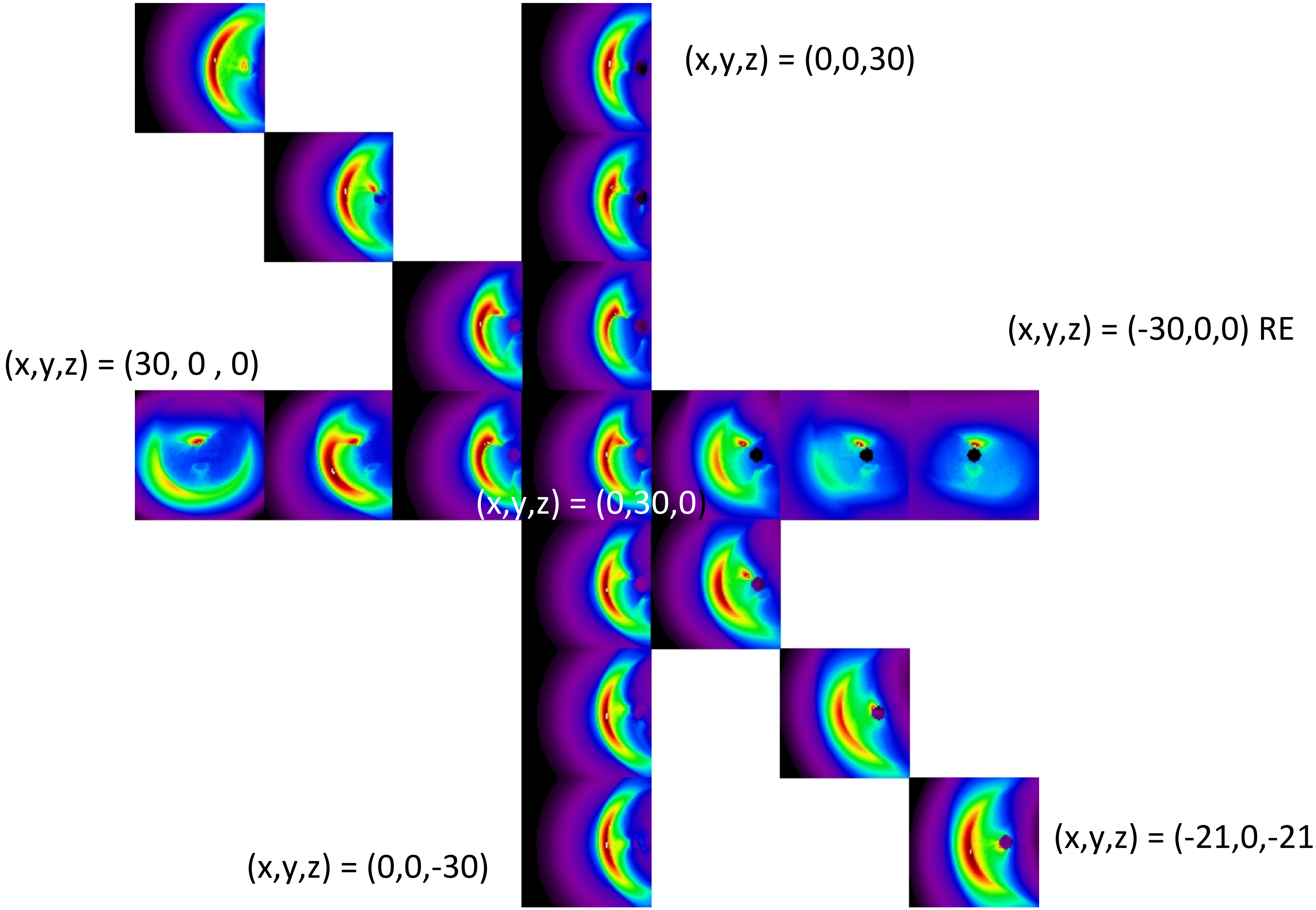
We have to show that we can use automated routines to extract physical boundaries

- Automatically extracted magnetopause (squares) and bow shock (diamonds) shapes match line of sight tangents to these boundaries (white curves)



23°x23° FOV from 30 RE
N = 22 cm-3, V = 930 km/s
By = 26 nT, Bz = -1 nT

Different Views from 30 R_E Orbits



Summary

- This talk demonstrates that the tools we need to do great science and mission planning are already available.
- CCMC staff respond rapidly to requests for special services.
- However, we have encountered one problem: We need more disk space to store results from multiple high resolution runs.