Energy Flow from the Solar Wind through Magnetosphere and Iono-sphere in Global MHD models.

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Abstract

Due to their different design, global magnetospheric models may at times generate different results for the same solar wind input conditions. In this situation, the average of a quantity obtained from concurrent simulations provides an estimate of the level of geomagnetic activity and the differences between the model results may serve as an estimated error level. We study the shape and location of magnetosphere-solar wind boundaries (bow shock, magnetopause) in simulations with the BATSRUS and UCLA-GGCM models using prescribed and varying solar wind conditions.

We start by studying the possible definitions of the boun dary betweeen solar wind and the magnetosphere system.

Introduction

The magnetopause is an important boundary layer between the magnetospheric plasma and the solar-wind particles in the magnetosheath.

In numerical simulations the magnetopause location can be used to verify model results against satellite measurements.

In this paper:

- Magnetopause – possible definitions
- July 15, 2000 simulations with BATSRUS and UCLA-GGCM

Magnetopheric boundary (possible definitions)

a) Open-closed field line boundary

- defined by magnetic field line connectivity at Earth
- encloses inner magnetosphere
- tail lobes outside of envelope
- irregular shape (“wings” at low-latitude boundaries, tail length variable due to near-Earth reconnection)

b) Solar Wind Flow envelope

- defined by tracing solar wind flow near subsolar point
- surrounds tail lobes, plasma sheet and inner magnetosphere
- regular shape (no wings or disconnected parts)
- exact position not well defined (depend on velocity threshold)

Magnetospheric boundary - continued

c) current sheets

- current sheet not well-defined everywhere (current varies locally, may be absent)
- Current distribution and sheet strength/widths depends on IMF

d) density and pressure gradients

- density or pressure gradients seen throughout magnetosphere (between magnetosphere lobes and plasma sheet as well as magnetosheath
- magnetosheath pressure and density distribution too wide to define a precise boundary

Magnetosphere slices

Velocity envelope intersecting slice:

- White dots: Velocity stream lines
- Stream lines started within 4 R_E of subsolar point at X_S=+20

Magnetic field lines intersecting slices

- Asterisks: closed magnetic field lines

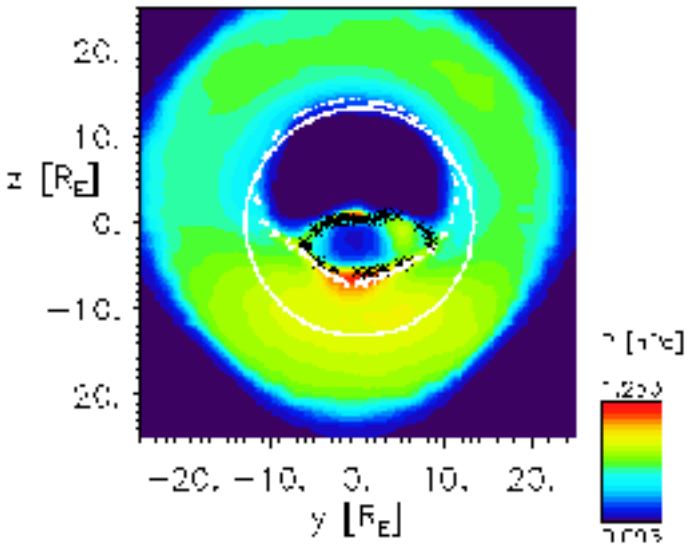
Statistical magnetopause model:

- Solid white circle: Shue et al (1997) model using solar wind conditions in slice.

Position of circle center and subsolar point is determined by solar wind velocity in slice at X (or X_S): $Y_C=X*V_Y/V_X$, $Z_c=X*V_Z/V_X$

Southward IMF B_z 7/15/2000 13:00 UT

Slices through magnetosphere (UCLA-GGCM)



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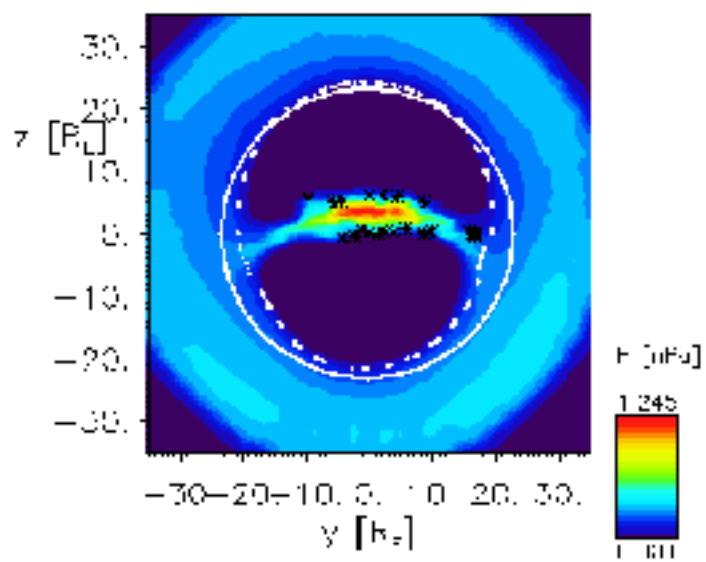
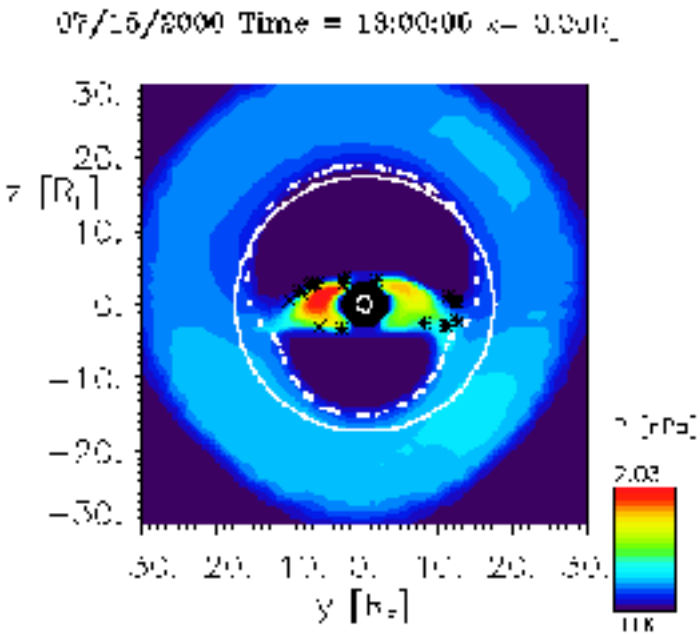
nightside

X=-10





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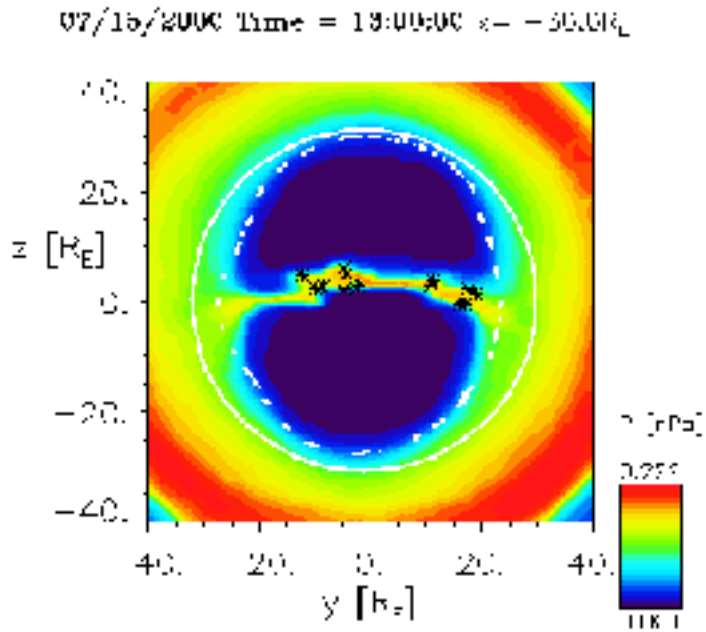
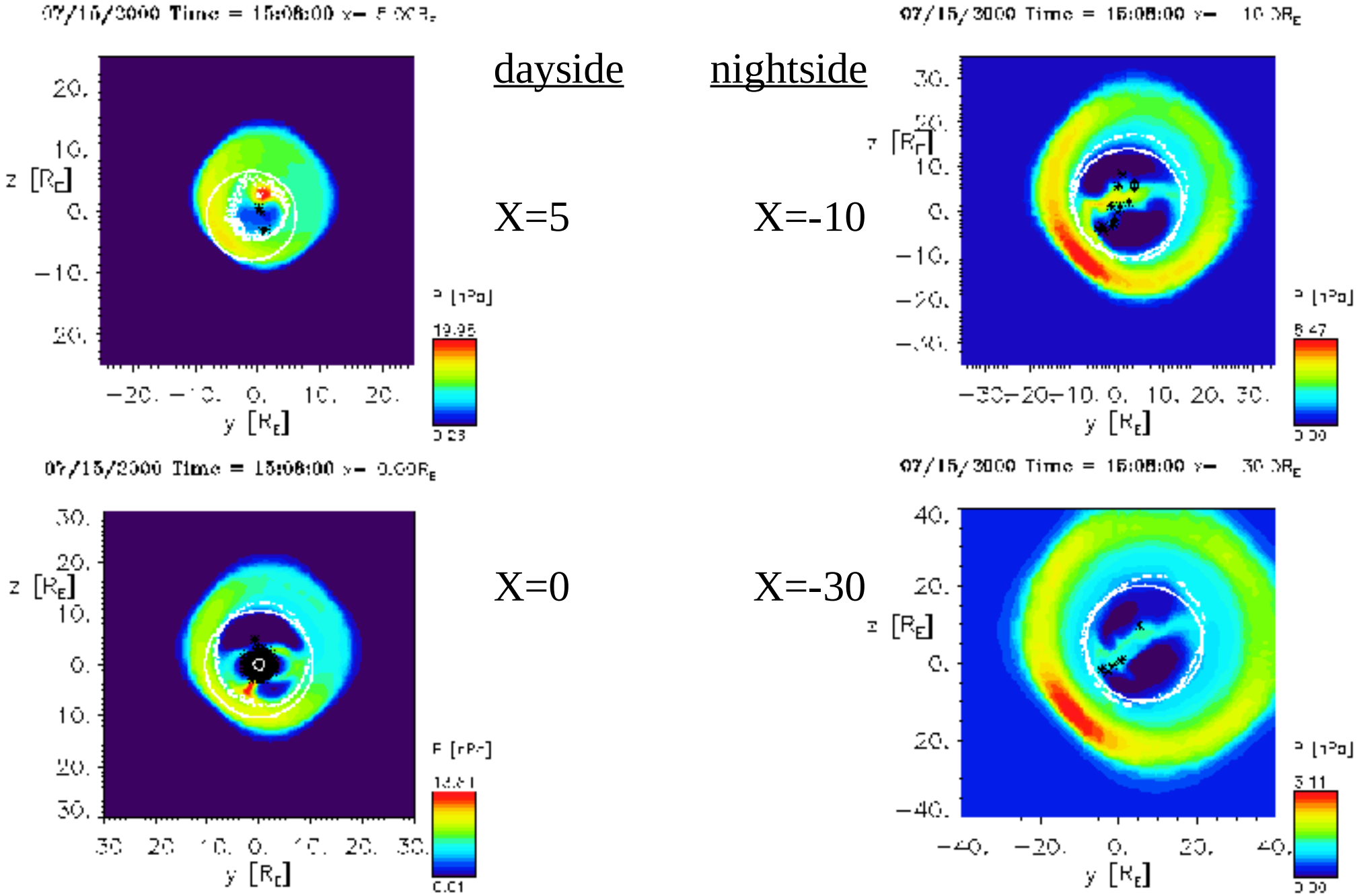
X=-30



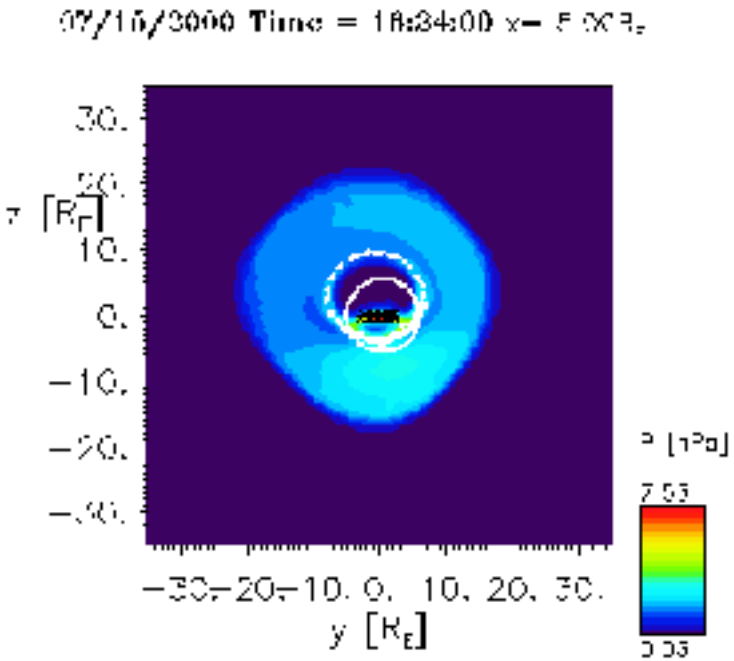
Strong northward IMF Bz

7/15/2000 15:08 UT (UCLA-GGCM)



Strong southward IMF B_z

7/15/2000 16:24 UT (UCLA-GGCM)



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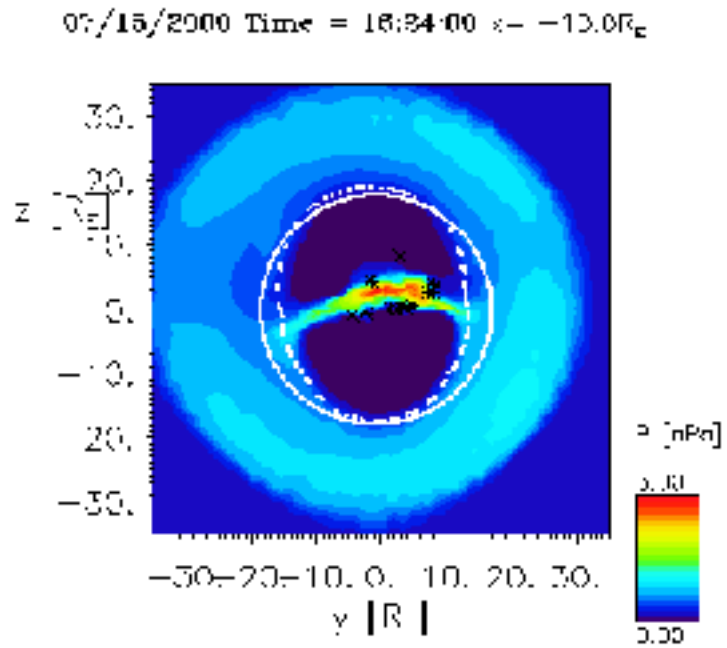
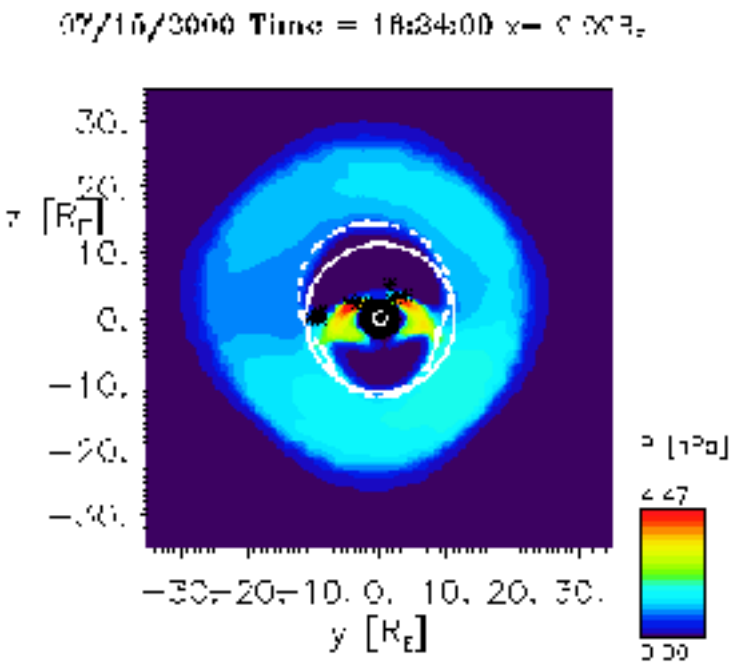
X=5

nightside

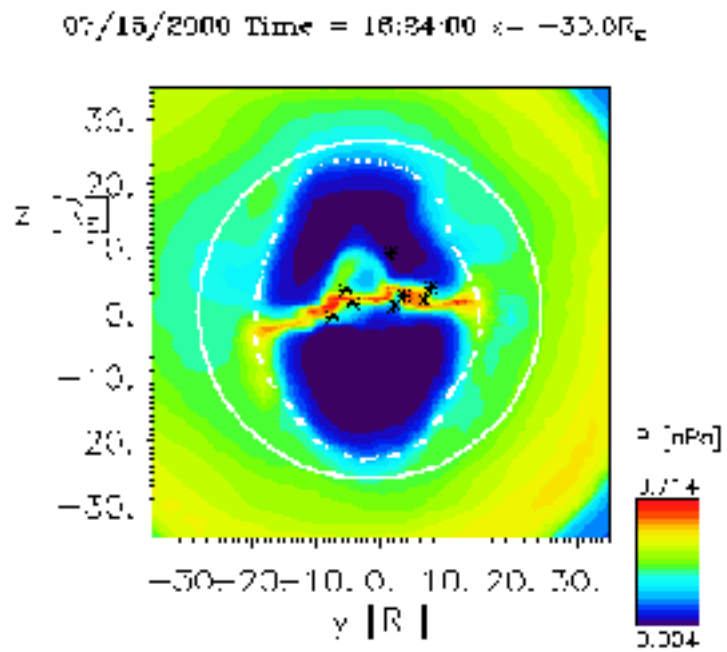
X=-10





X=0

X=-30



Solar Wind Conditions **July 15, 2000**

13:00 – 14:40 UT:

$N = 5\text{-}7\ cm^{-3}$ $V_x = -600$ km/s

$B_z = -5$ nT $B_y = 0$ nT

14:40 – 15:08 UT:

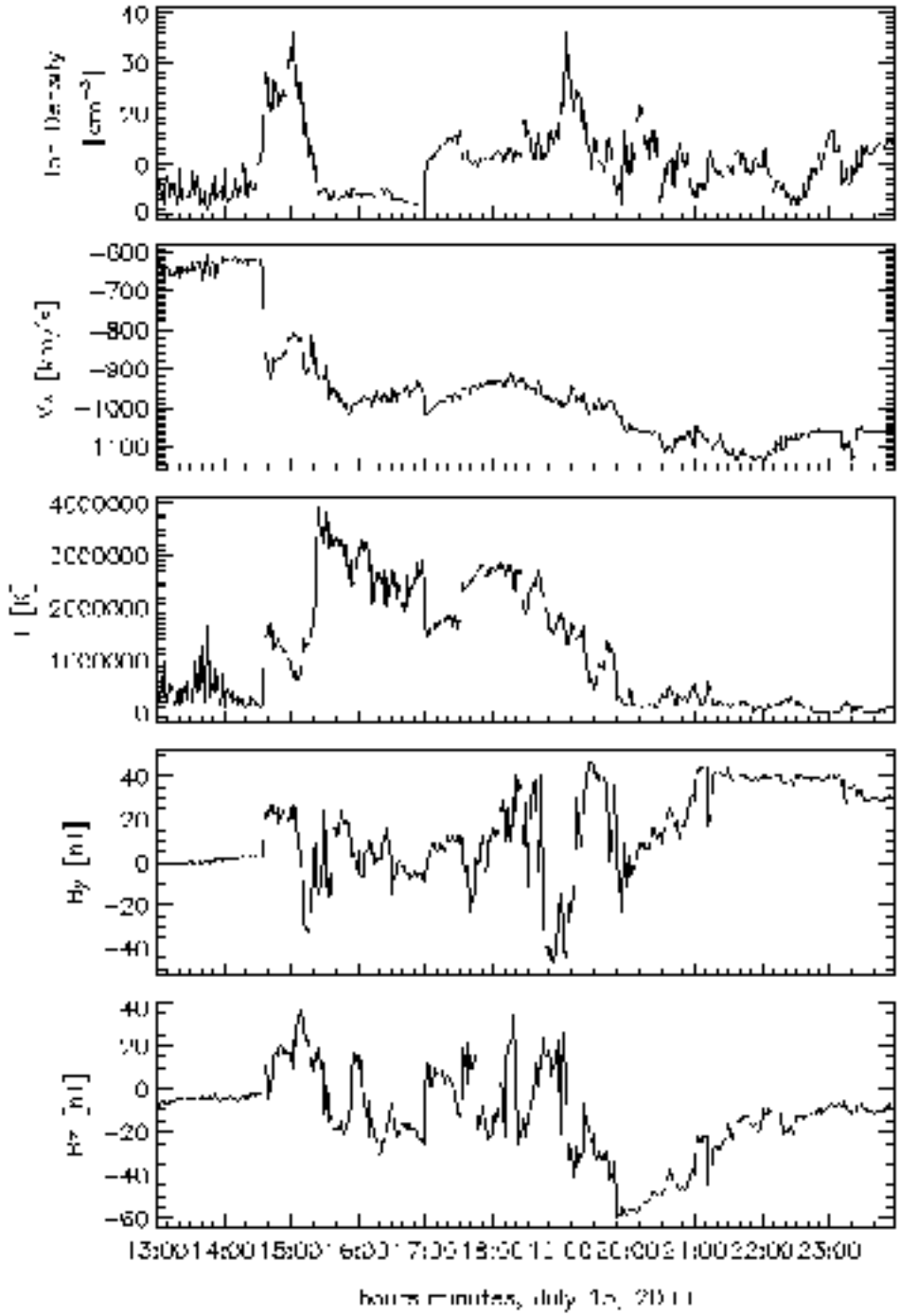
$N = 25\ cm^{-3}$ $V_x = -900$ km/s

$B_z = +20$ to 30 nT $B_y = +20$ nT

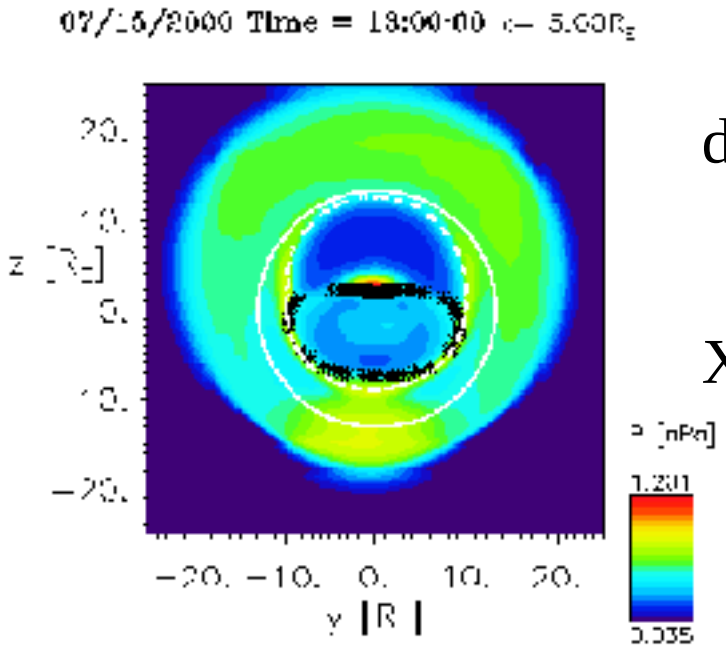
16:00 – 16:24 UT:

$N = 5\ cm^{-3}$ $V_x = -1000$ km/s

$B_z = -15$ to -20 nT $|B_y| < 10$ nT



Weak southward IMF B_z
13:00 UT - BATSRUS

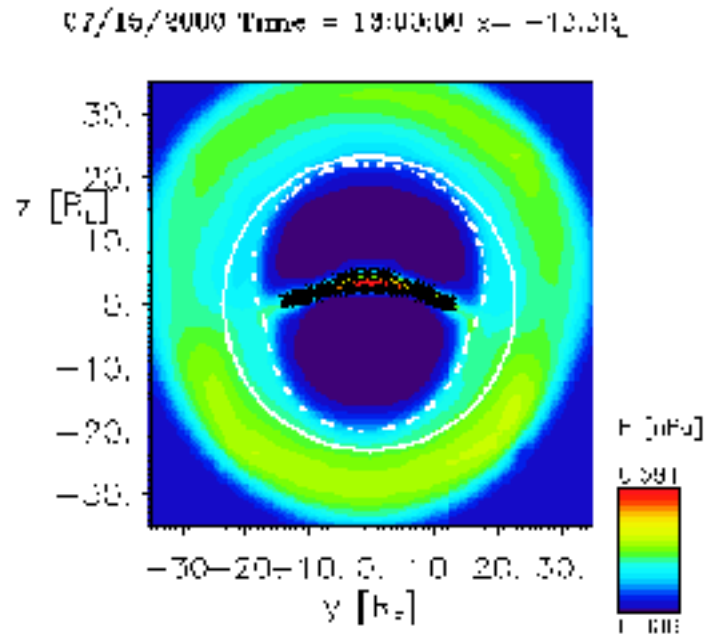


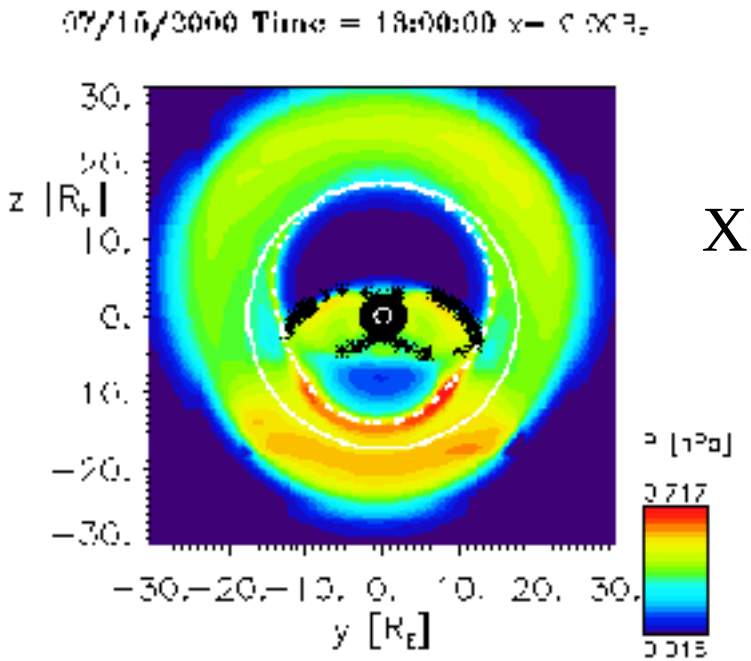
dayside

X=+5

nightside

X=-10

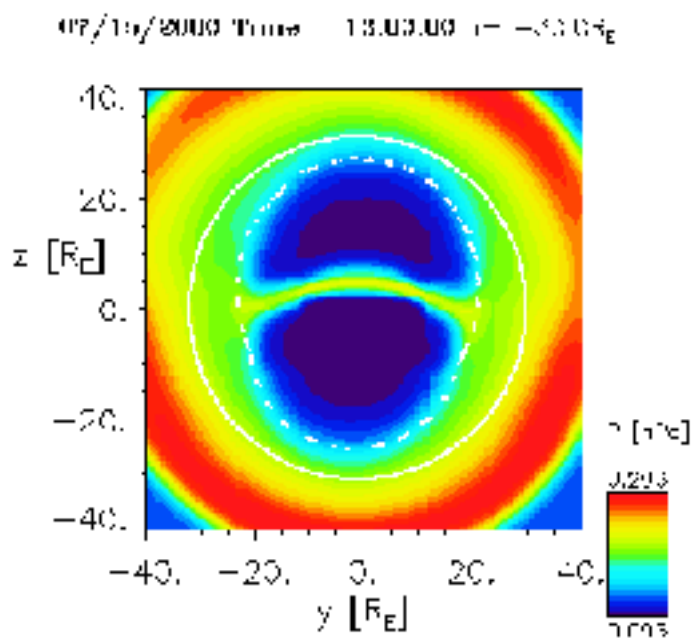




X=0

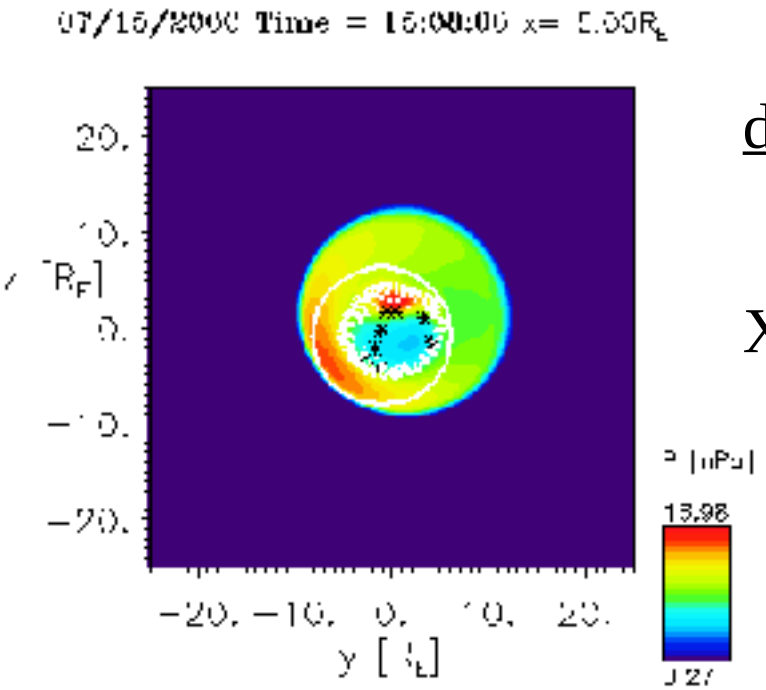
X=-30

Closed field lines end between X=-20 and X=-30



Strong northward IMF Bz

7/15/2000 15:08 UT (BATSRUS)

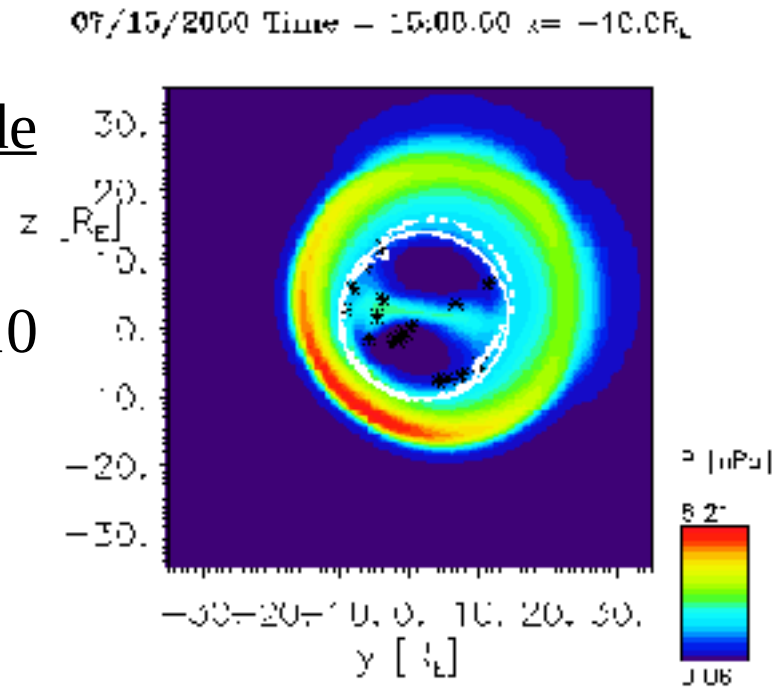


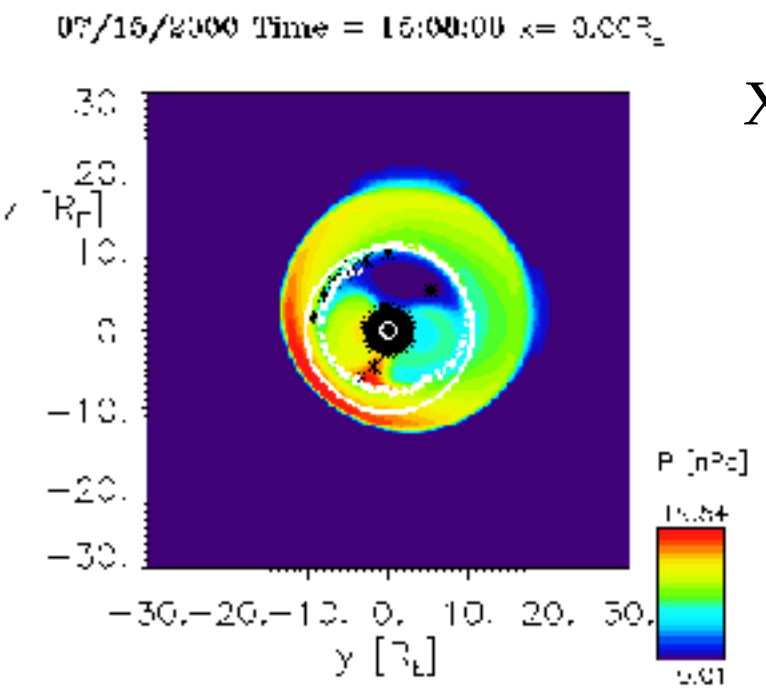
dayside

X=+5

nightside

X=-10

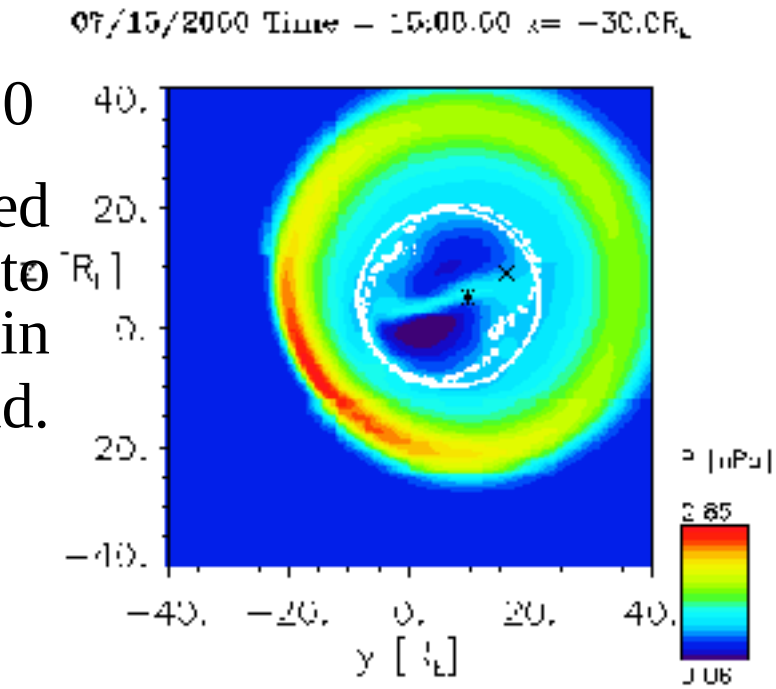




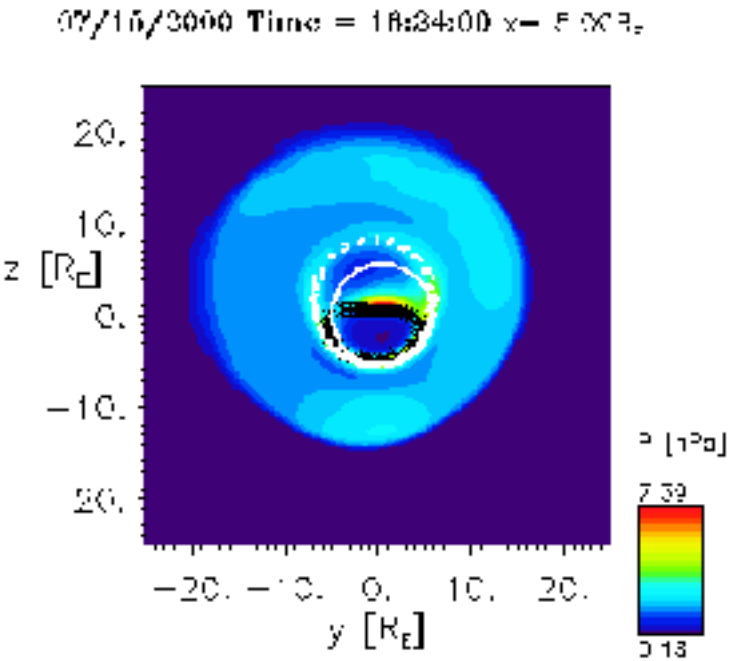
X=0

X=-30

Tail axis is displaced from X-axis due to strong V_Y and V_Z in the solar wind.



Southward Bz
16:24 UT (BATSRUS)

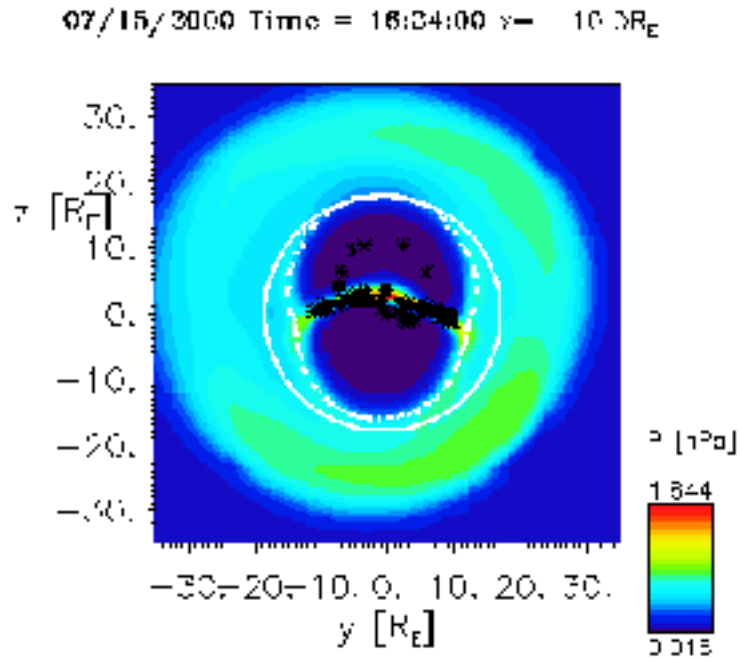


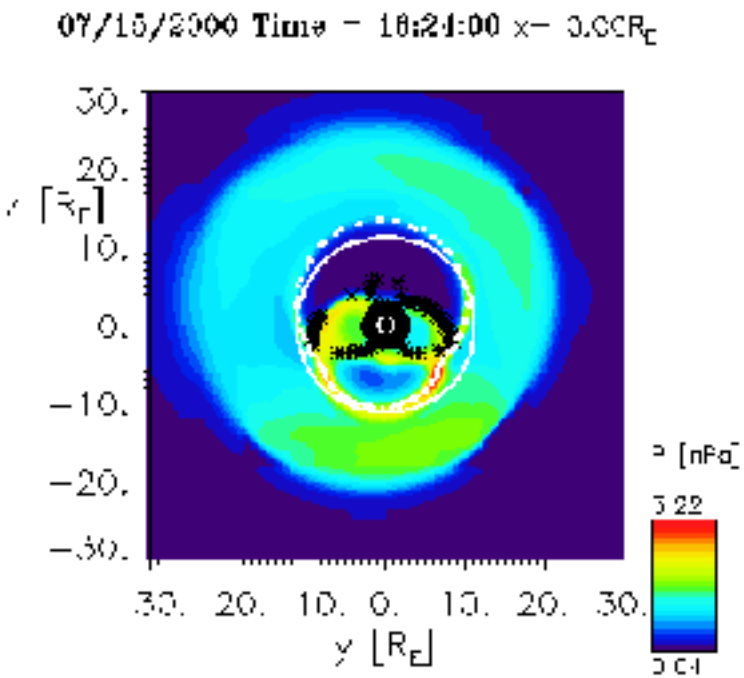
dayside

X=+5

nightside

X=-10





X=0

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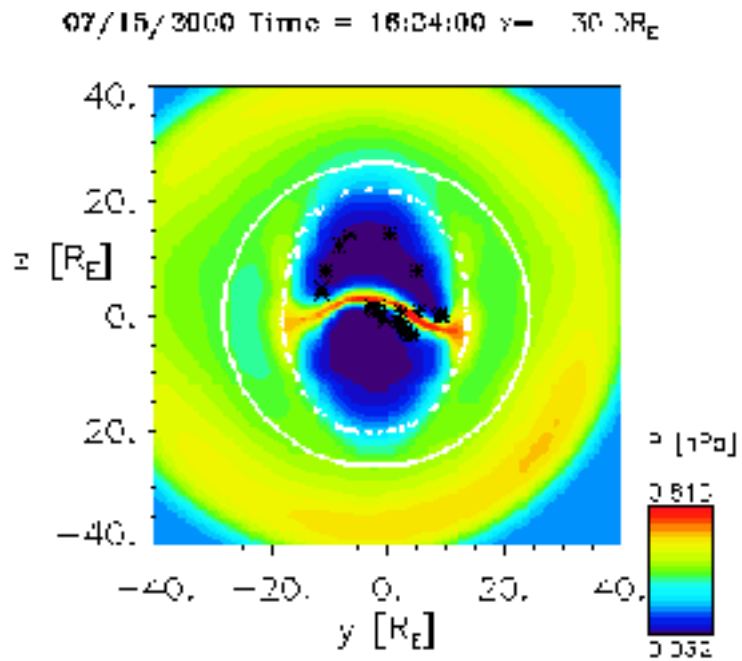
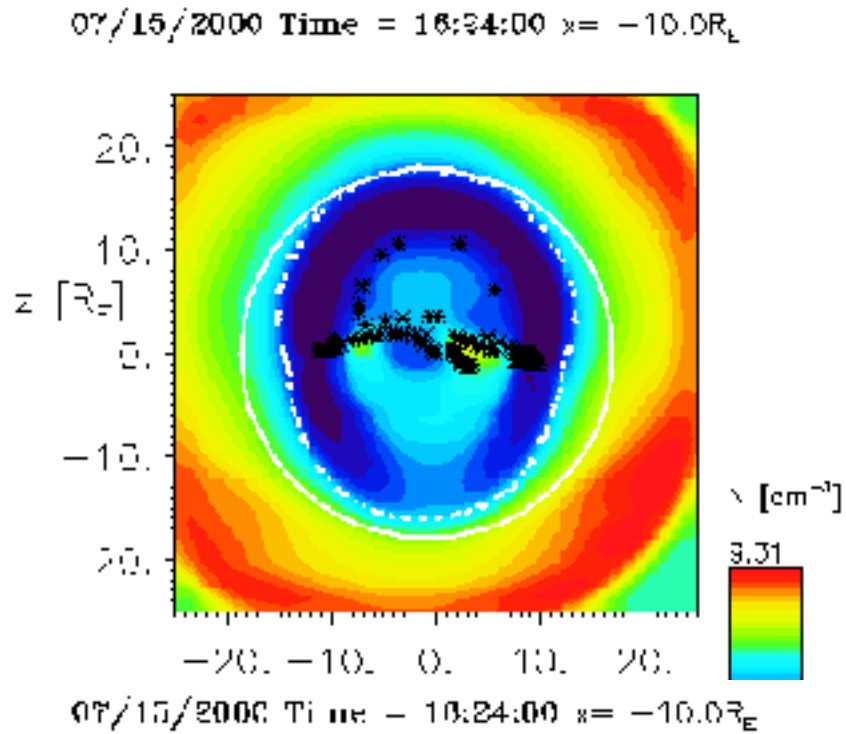
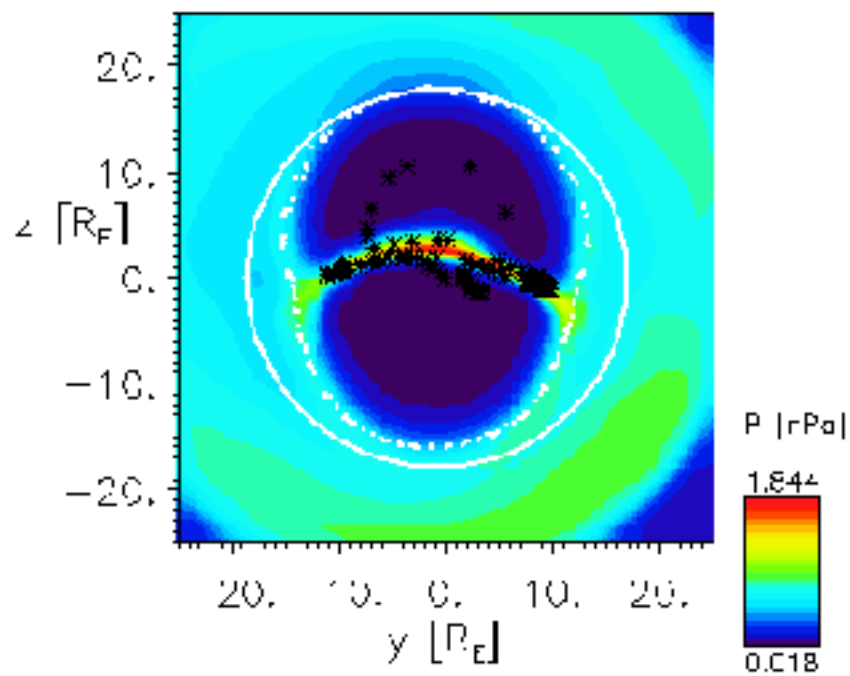


Magnetosheath at flow envelope

- **Magnetosheath** density is seen outside of flow envelope,
- **pressure gradient** seen across or just inside envelope
- **Low-latitude boundary** at plasma sheet may eliminate well-defined gradients



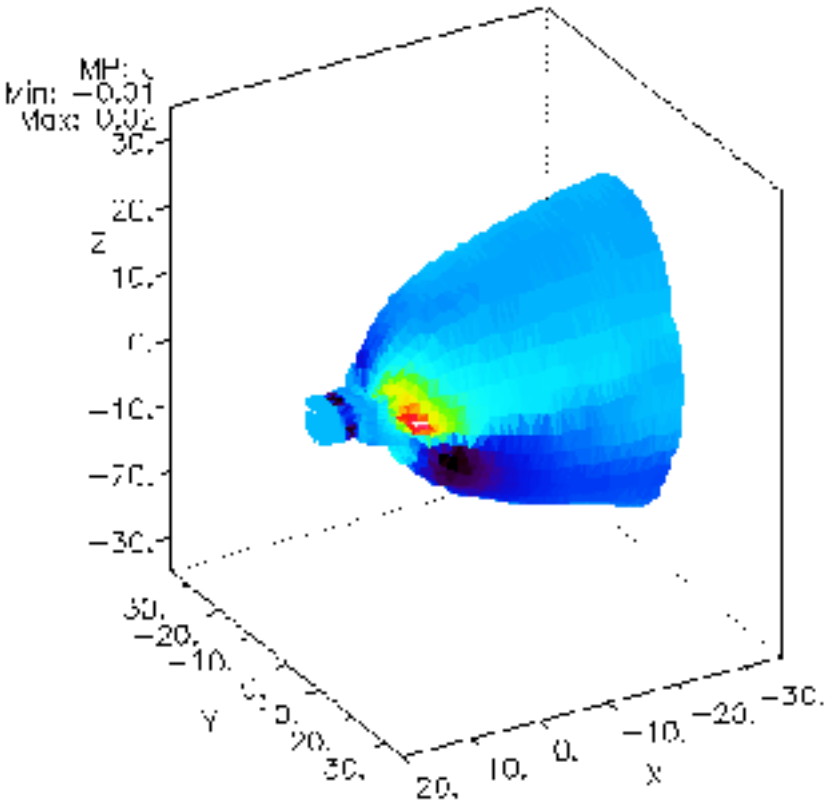
- **Currents** exist only on **part of** the flow **surface** (see surface plots).

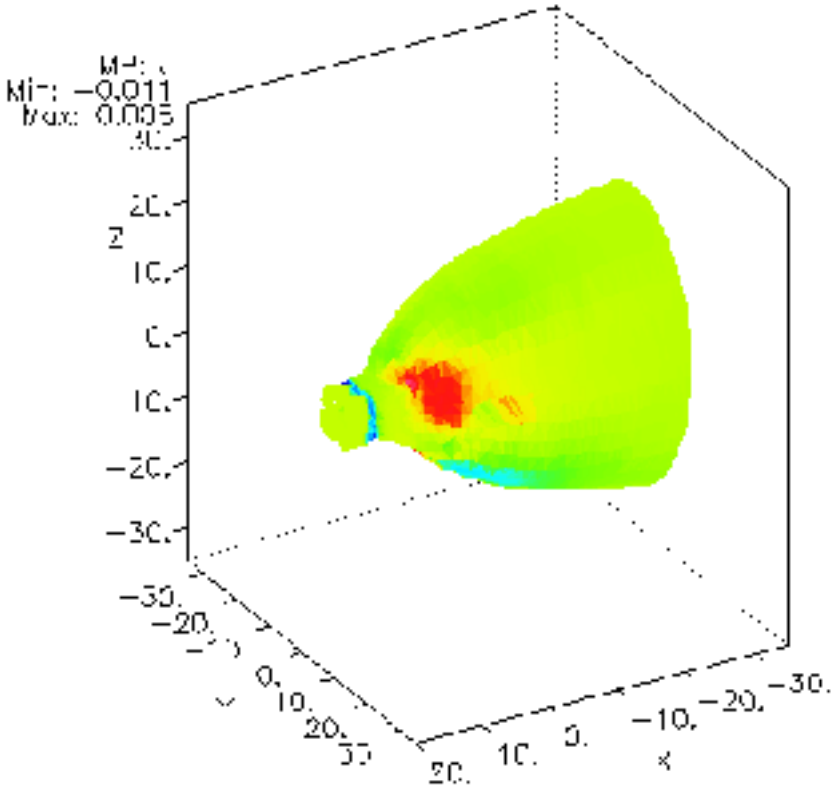


Currents on flow surface

UCLA-GGCM 16:24 UT BATSRUS

-0.01 < J < 0.02 range -0.11 < J < 0.008





Summary - magnetopause definitions

Velocity envelope:

- **coincides well** with inner edges of **pressure and density gradients** in the magnetosheath,
- velocity is still significant (non-zero) on surface,
- many **parameters describing energy transport** on the surface are **zero by definition** (e.g., ExB, V_n=0 => no quantity transported with the flow crosses the boundary)
- appears outside of closed field line regions.

Statistical magnetopause model (Shue et al., 1997):

- **Good agreement with location of flow envelope** in the tail with distance of center from the X-axis determined by the solar wind velocity in cut slice (X=constant).
- Circle **center positioning** using solar wind flow **essential**.
- **Less agreement in dayside** (dipole tilt, reconnection erosion,…)

Summary - continued

Closed magnetic field lines

- enclose a **much smaller** area then either of the other approaches,
- usually are located **well inside** of both the Shue et al. **magnetopause location** and **velocity envelope**,
- define structures in the **near-Earth** magnetosphere (cusp, plasma sheet),
- may not reach as far downtail as plasma sheet is seen.
- Shape **much more variable** with constant solar wind conditions due to intermittent reconnection in the tail.

Outlook

Given suitable and reliable definitions of the magnetosphere boundary in simulations:

- The energy fluxes across the magnetospheric boundaries can be studied in relation to the energy dissipation in the ionosphere and the mapping of open and closed field lines into the ionosphere.
- The results will be complementary to a similar study performed with the GUMICS-4 model (M. Palmroth, JGR **108,** 1048, 2003) where energy transfers were found to follow solar wind parameters in a power-law relation.
- Parameters of this functional relation and correlation coefficients can be calculated for the two models used in this study in a similar manner.
- Results can verify models' performance in comparison with ground and satellite observations.