Unusual Solar Wind Associated with Global Sawtooth Oscillations: CCMC Simulations of the Magnetosphere

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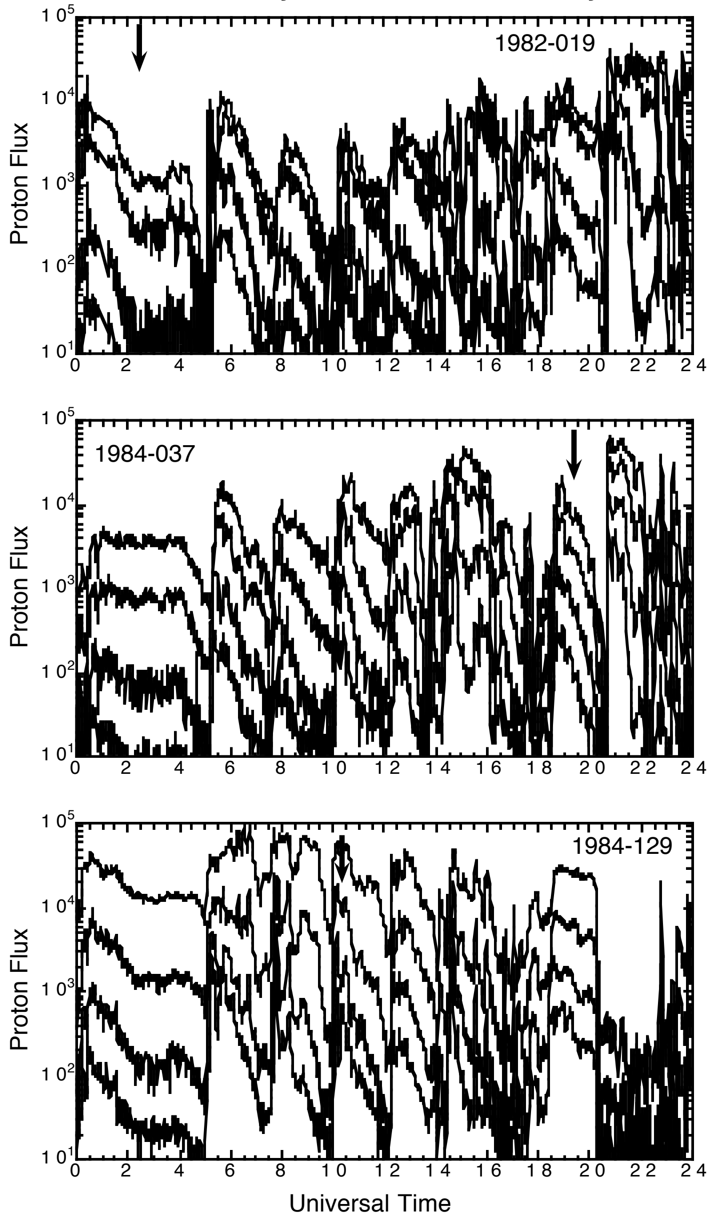
1) What Global Sawtooth Oscillations Are.

2) Statistics of the Solar Wind for Sawtooth Times.

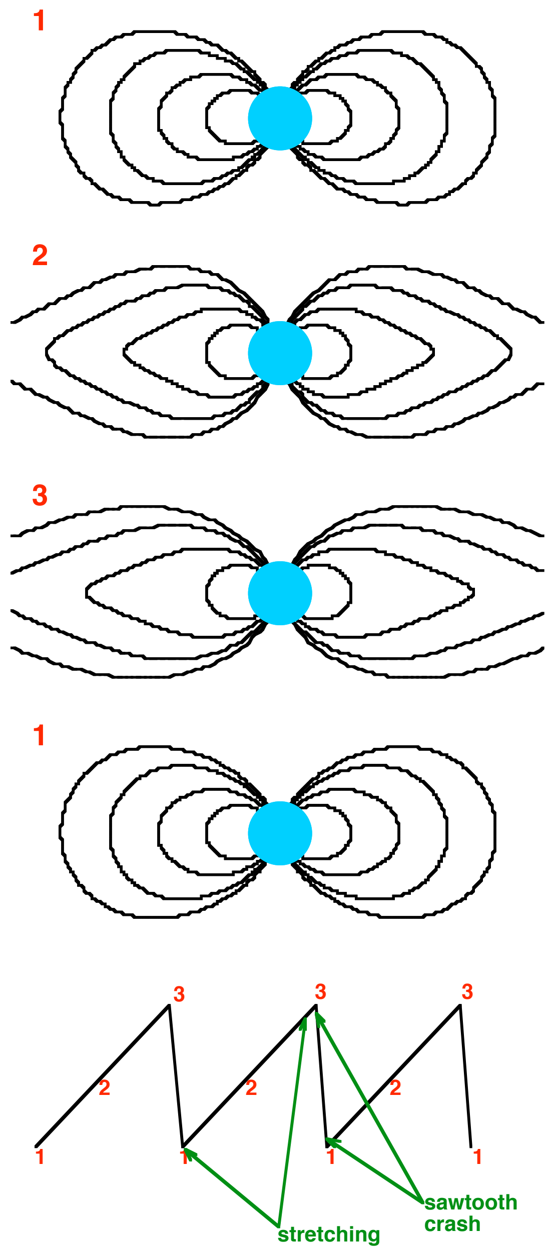
3) Perform Simulations of the Magnetosphere for "Sawtooth Solar Wind".

4) What Is Learned. What is Outstanding.

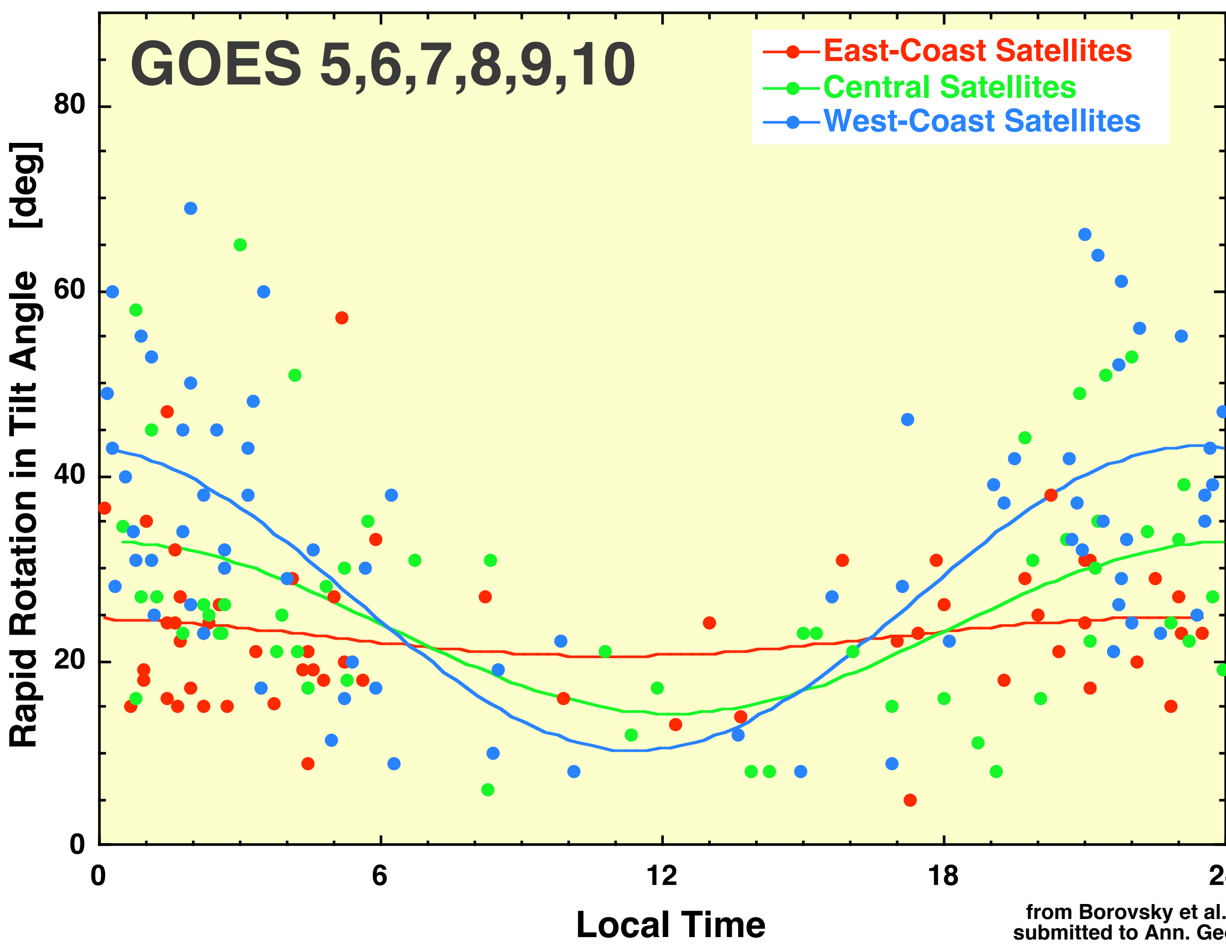
CPA Fluxes at Geosynchronous February 8, 1986



volution of the Dipolar Magnetosphere
During a Global Sawtooth Cycle



Size of Sawtooth Crash Versus Local Time



from Borovsky et al., 2003
submitted to Ann. Geophys.

Properties of Global Sawtooth Oscillations

✓ Global: Signatures appear at all local times

✓ Geosynchronous E-P fluxes ~dispersionless

✓ Geosynchronous field stretches and dipolarizes

✓ Lobe can be encountered at geosynchronous equator

✓ Sawtooth period is 2-4 hours
- Slow Stretching
- Fast Crash (~5 minutes)

✓ Sawtooths occur during storms
- Kp 6.2 ± 1.4
- Dst -127 ± 72 nT

✓ Sawtooth has a signature in Dst
- Crash corresponds to 20 - 50 nT drop in |Dst|
- Symmetric perturbation
- No ionospheric current wedge with crash

✓ Might require geosynchronous plasma □ > 1

Statistical Properties of the Solar Wind during Global Sawtooth Oscillations of the Magnetosphere

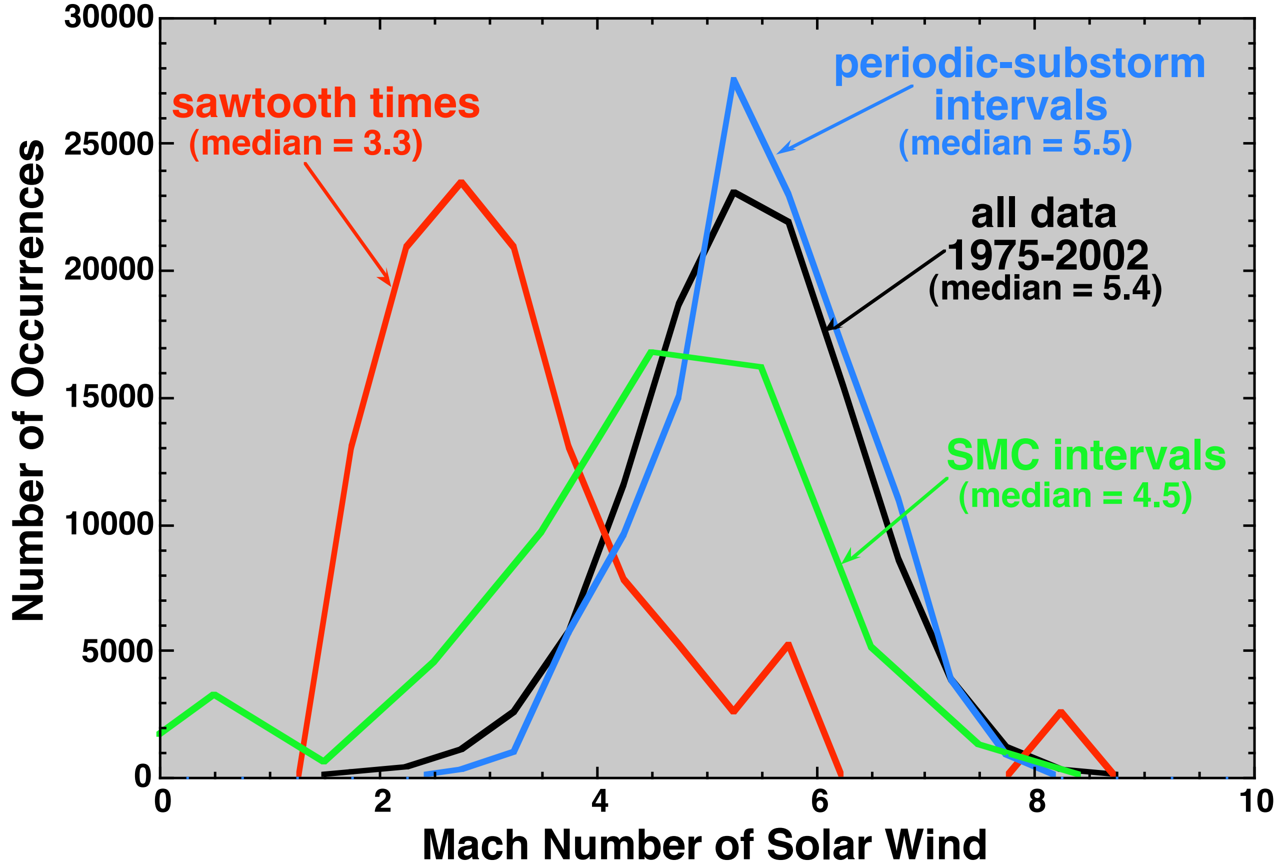
Statistical Analysis of the Solar Wind Finds:

- **B is large**
- ① **n is low**
- ④ **v is medium to fast**
- → **P_{ram} is average**
- ❺ **IMF is southward**
- ❻ **□B/B is anomalously low**

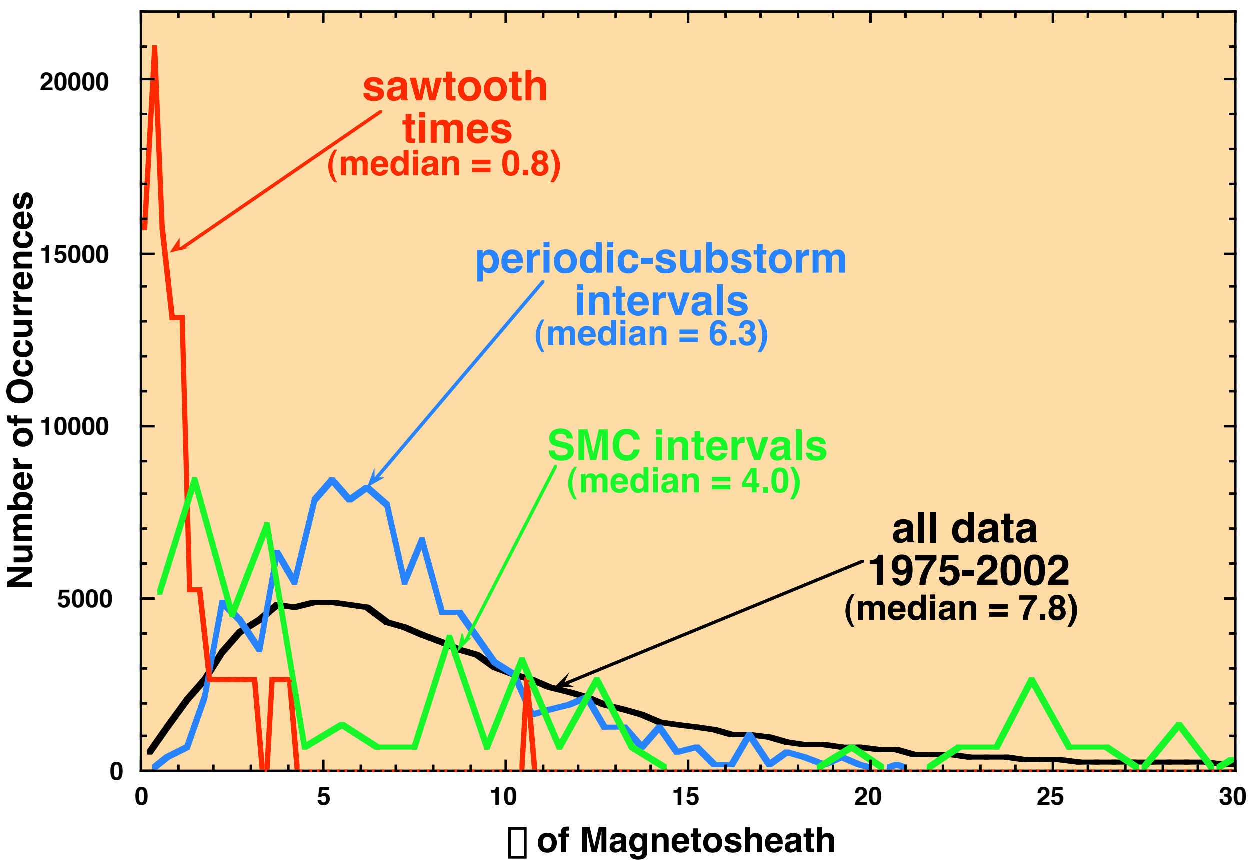
These parameters combine to yield:

- ☞ **A low-Mach-number solar wind.**
- ☞ **A magnetosheath flow that has very low beta.**

Distributions of Solar-Wind Magnetosonic Mach Numbers



Distributions of Magnetosheath □



CCMC Simulations of the Magnetosphere for "Sawtooth Solar Wind"

Utilize the BATSRUS code, with verification by the UCLA code.

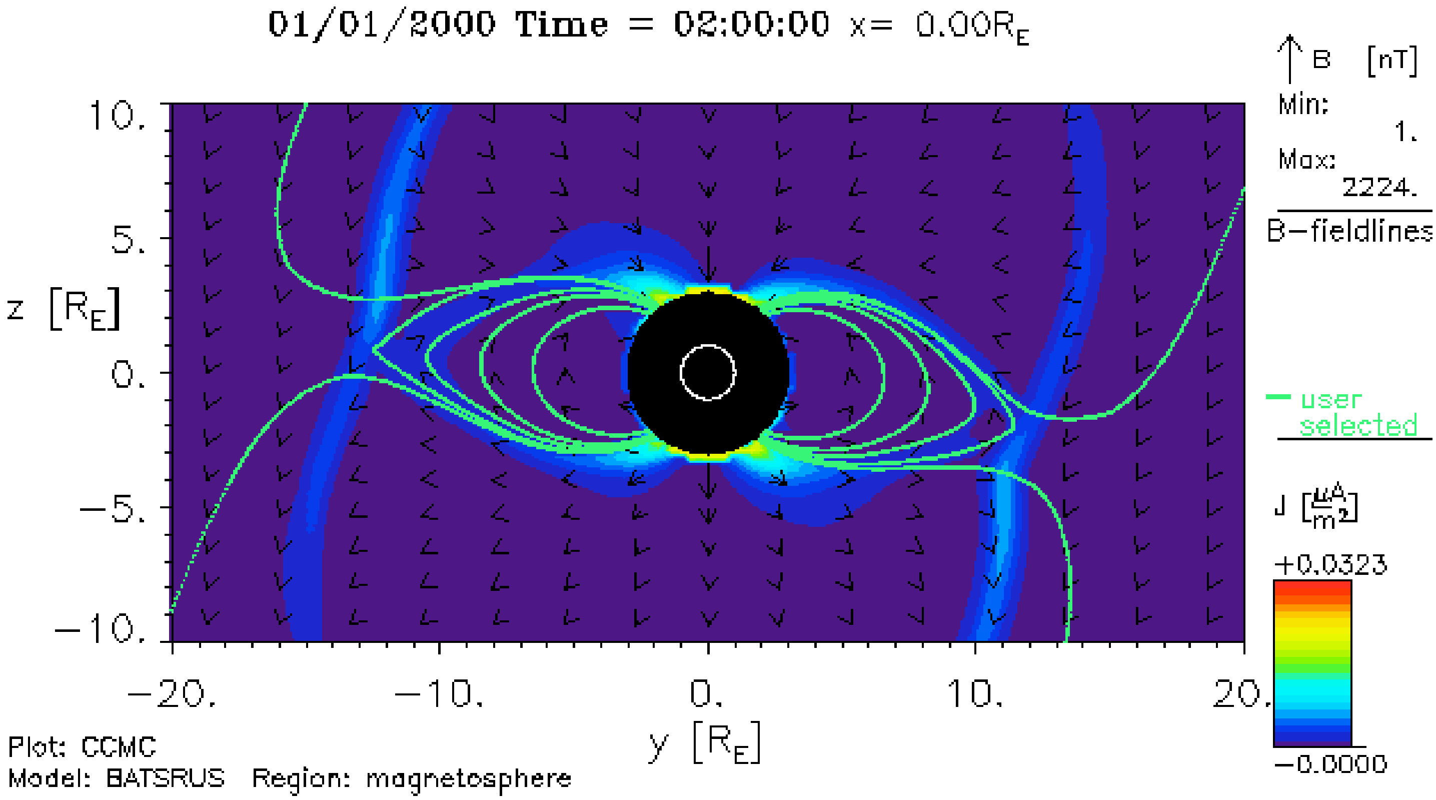
The MHD simulations do not exhibit sawtooth oscillations.

Analysis of simulations focuses on the stretching of B in the dipole regions of the magnetosphere.

The fiducial "sawtooth solar wind" run has:

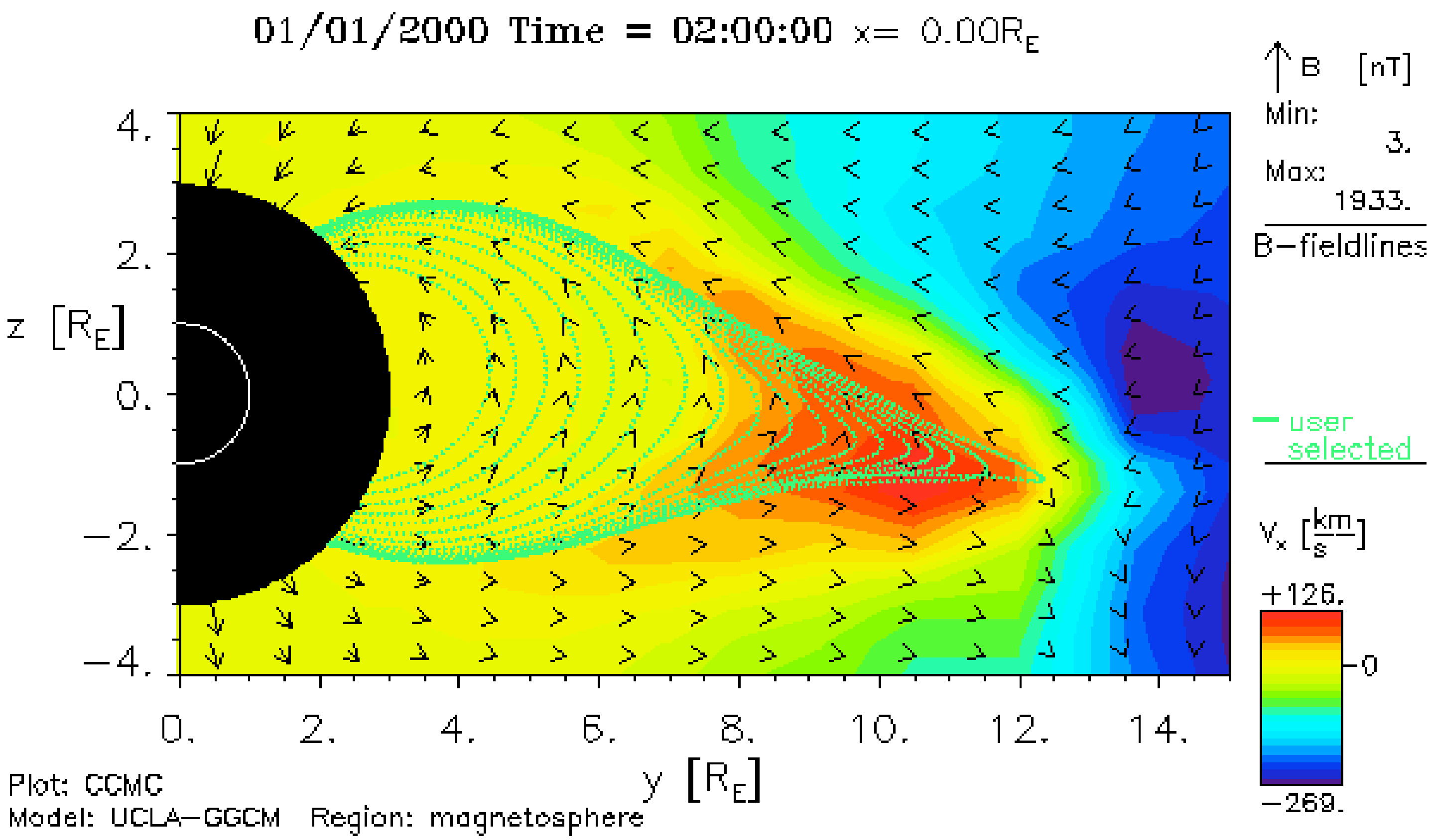
$B = 19.6$ nT $(B_x,B_y,B_z) = (6.6,-8.6,-16.3)$nT
$n = 3.4$ cm^{-3}
$v = 408$ km/sec
$T = 8.6$ eV
$M_{ms} = 1.74$
$\beta_{sheath} \sim 0.15$

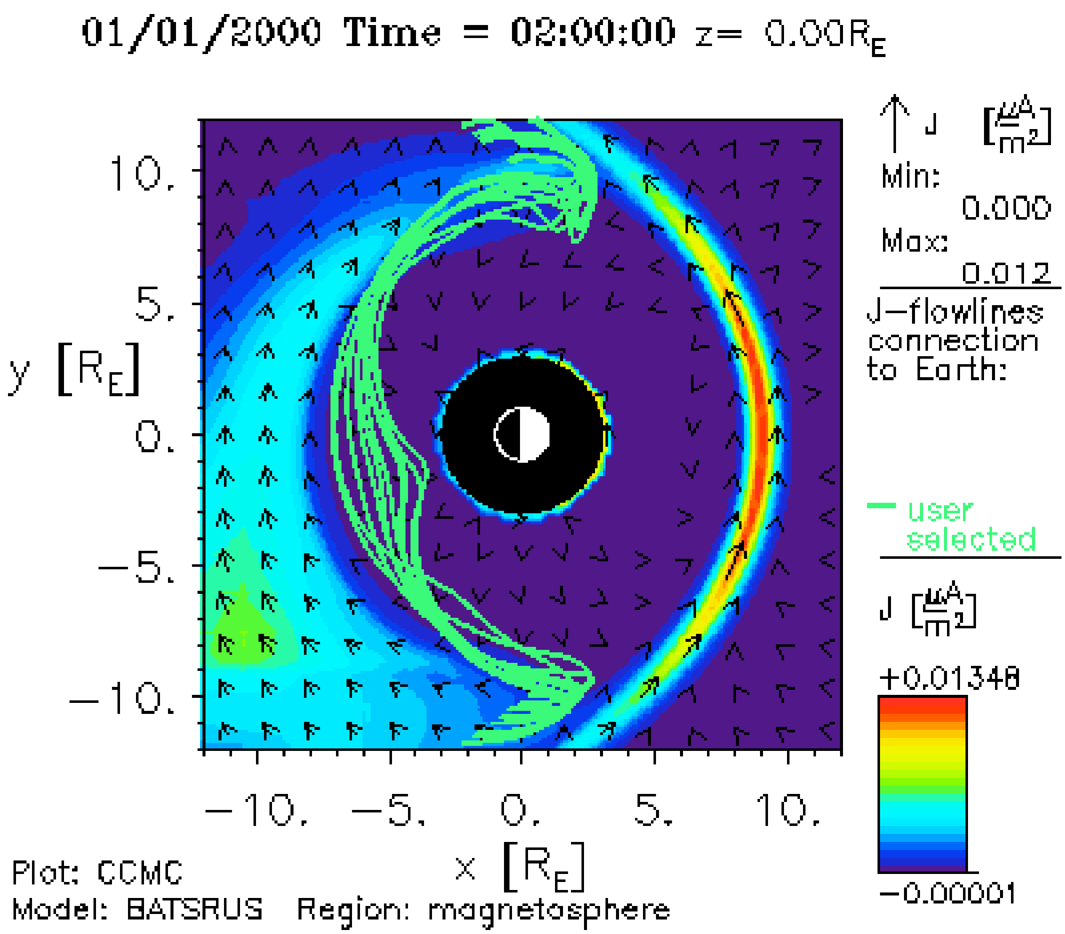
Look at the effects of varying the solar wind (one parameter at a time) on the field stretching in the dipole.



Stretching Regions in the Dipole Are Associated with:

- ★**Sunward flow of hot plasma from the magnetotail**
- ★**High plasma pressure**
- ★**Weakened field strength |B| near the equator**
- ★**High plasma** β
- ★**A horseshoe of toroidal current in the equator**


01/01/2000 Time = 02:00:00 x= 0.00R_E
B [nT]
Min:
3.
Max:
1933.
B-fieldlines
user selected
V_x [km/s]
+126.
0
-269.
z [R_E]
4.
2.
0.
-2.
-4.
0.
2.
4.
6.
8.
10.
12.
14.
y [R_E]
Plot: CCMC
Model: UCLA-GGCM Region: magnetosphere


01/01/2000 Time = 02:00:00 z= 0.00R_E
y [R_E]
x [R_E]
10.
5.
0.
−5.
−10.
−10.
−5.
0.
5.
10.
J [μA/m²]
Min:
0.000
Max:
0.012
J−flowlines connection to Earth:
user selected
J [μA/m²]
+0.01348
−0.00001
Plot: CCMC
Model: BATSRUS Region: magnetosphere

Effects of Varying Solar-Wind Parameters on the Field Stretching in the Dipole

Type of Variation	*Effect on Stretching at Terminator*
B weak	**stretching gone**
n high	**stretching gone**
v high	**stretching maintains**
v low	**stretching reduced**
northward IMF	**stretching gone**
sideways IMF	**stretching weakens**
southward-northward switching (15 min)	**stretching gone**
rapidly varying southward IMF	**stretching maintains**
ionospheric conductivity forced low	**stretching gone**
ionospheric conductivity forced high	**stretching maintains**

CCMC simulations support two causes for stretching at the terminator:

❶ Internal pressure from presence of hot plasma

① Squeezing by lobe magnetic flux

Summary, Outstanding Question, and Future Work

Summary: What Causes the Stretching in the Dipole?

- Build up of pressure in equator and lowering of B there.
- Squeezing from the lobe field lines.

Question: What Causes this Stretching to Collapse?

- Interchange or ballooning instability in dipole?
- Reconnection around the dipole?
  - Radial motion of the ring current??
  - Thinning/thickening of the ring current??
  - Reduction of the ring current??

Future Plans

- Look for sawtooth oscillations and causes with coupled CSEM (BATSRUS + Rice-Convection-Model) simulations.

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