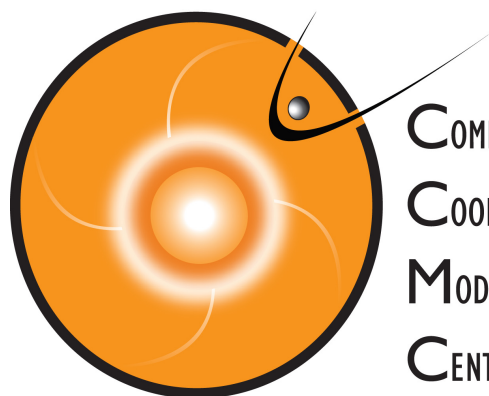




<http://ccmc.gsfc.nasa.gov>



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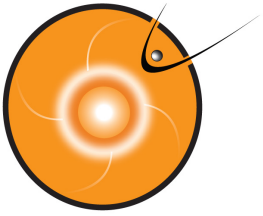
# Space Weather in Earth's magnetosphere



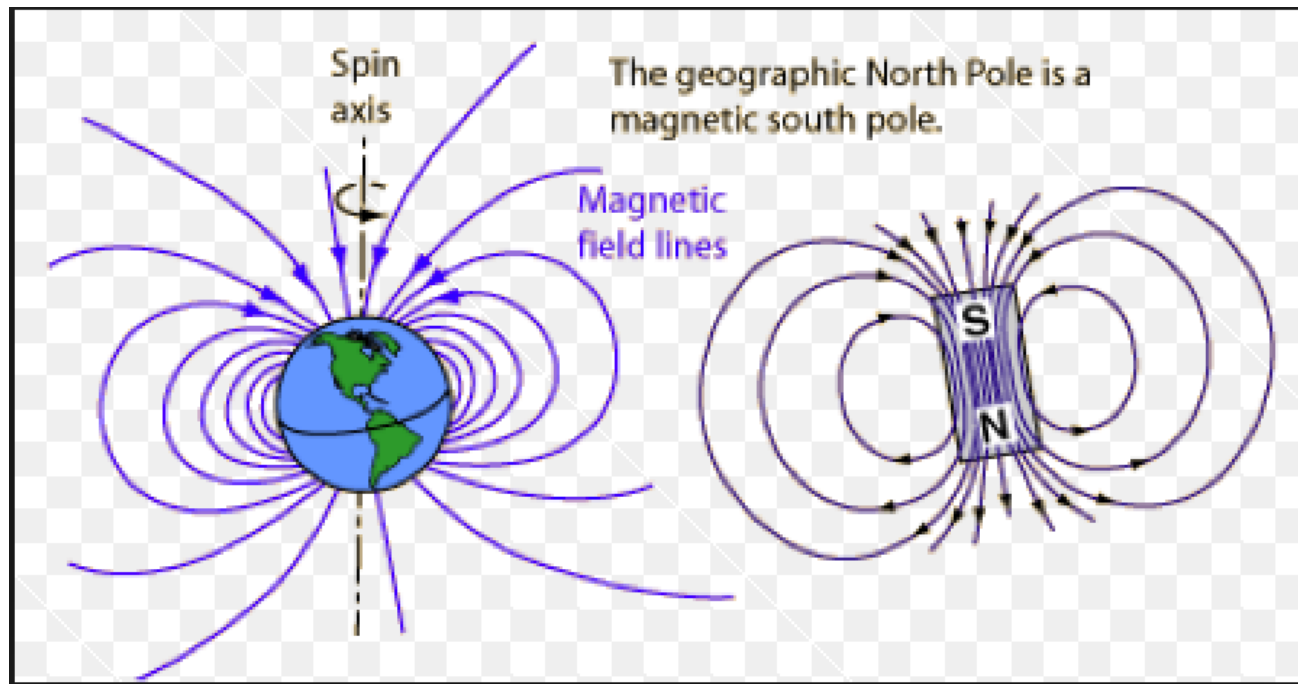
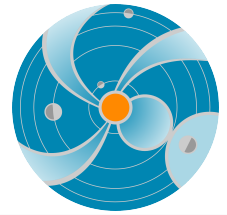
Space  
Weather  
Research  
Center

*Masha Kuznetsova  
& CCMC/SWRC team*

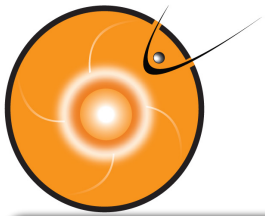
**MODELS • DATA • TOOLS • SYSTEMS • SERVICES • INNOVATIVE SOLUTIONS**



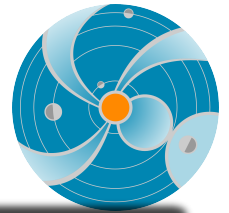
# Magnetic Field of the Earth



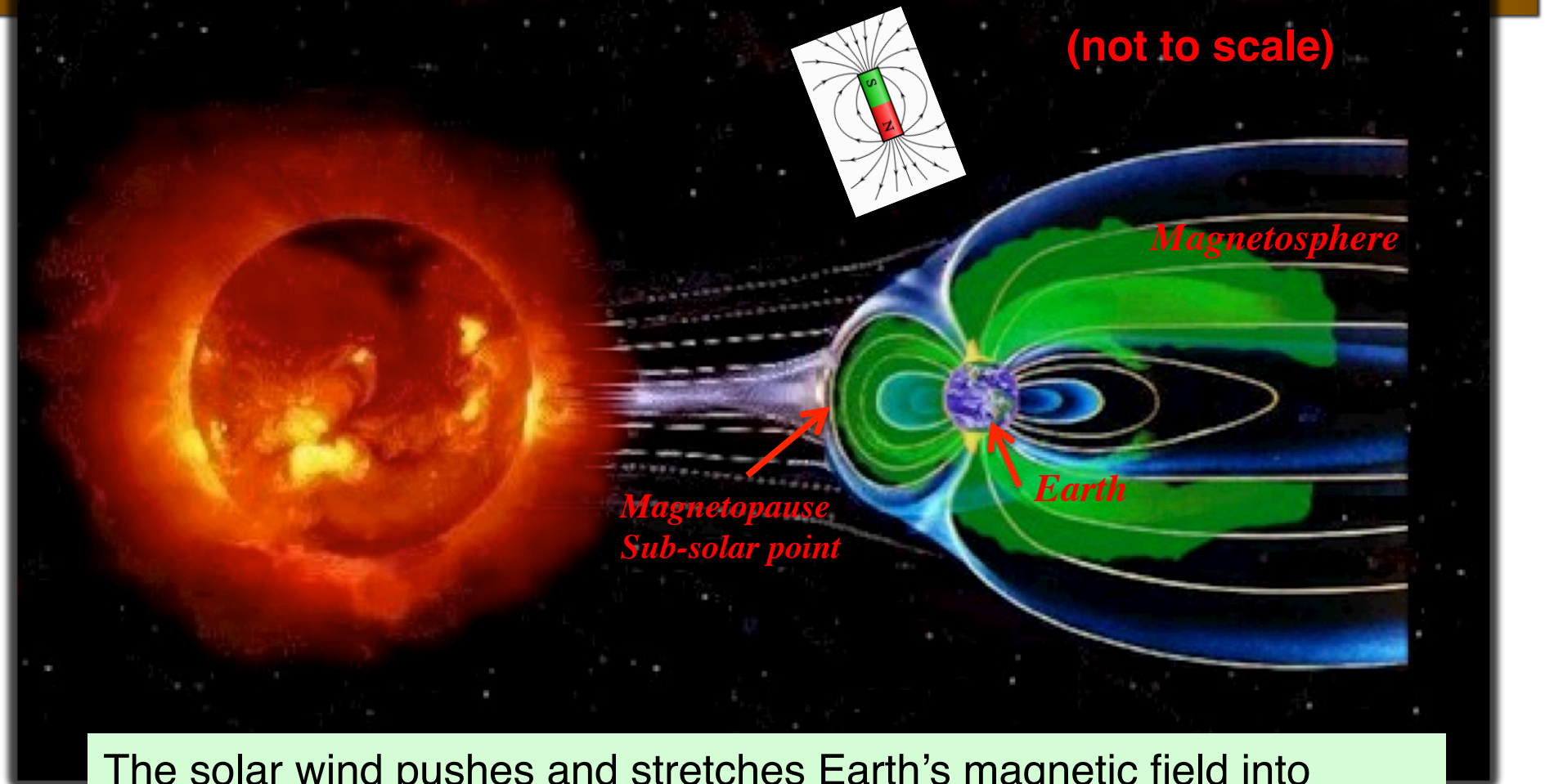
The Earth's magnetic field is similar to that of a bar magnet.  
The magnitude varies over the surface of the Earth in the range 0.3 to 0.6 Gauss.



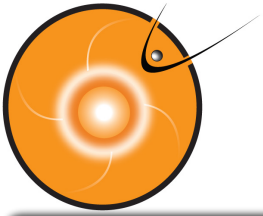
## Earth's Magnetic Field – Solar Wind Interaction



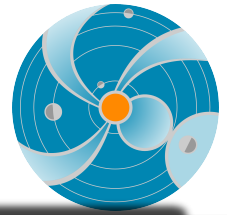
(not to scale)



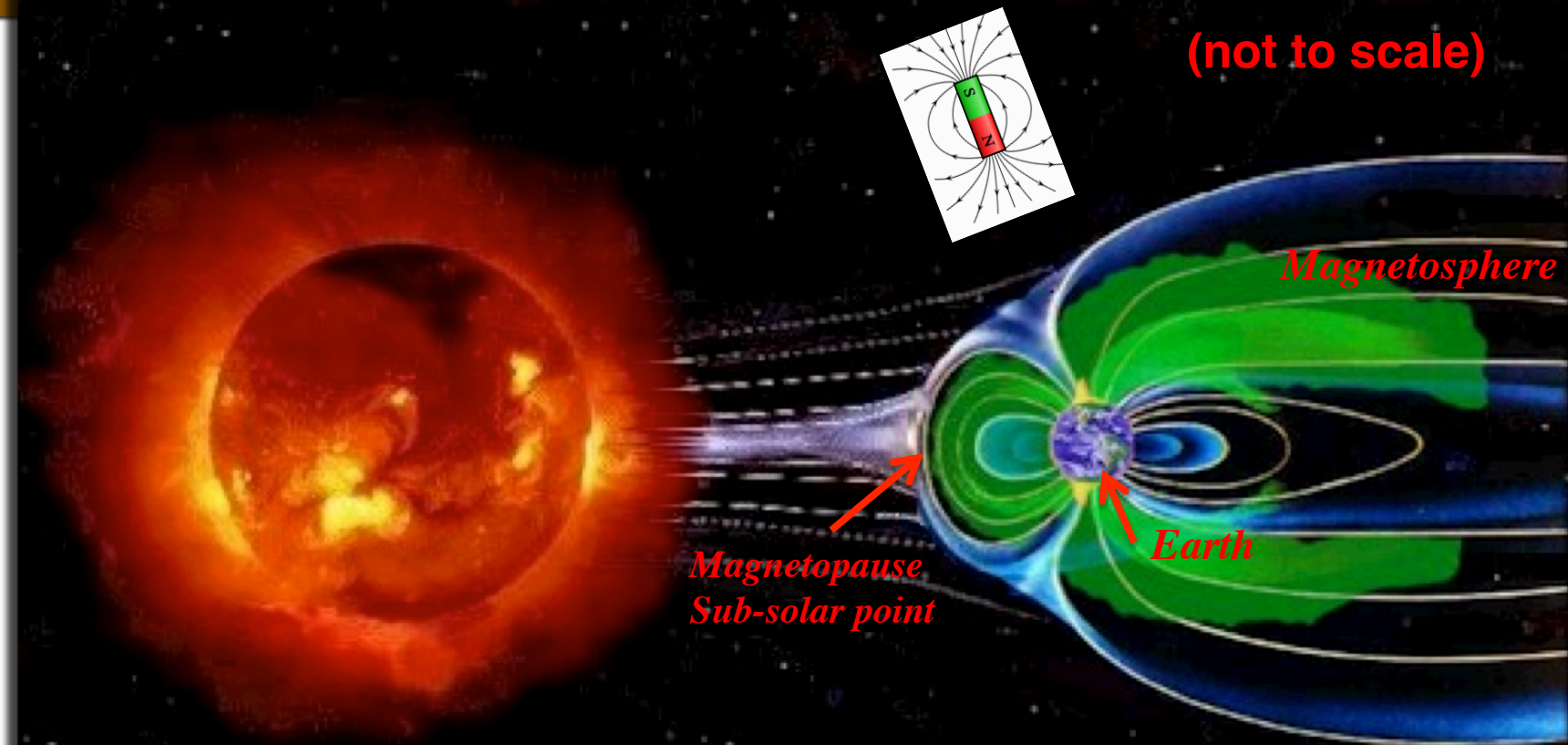
The solar wind pushes and stretches Earth's magnetic field into comet-shaped region called the magnetosphere. The magnetosphere and Earth's atmosphere protect us from the solar wind and other kinds of solar and cosmic radiation.



## Earth's Magnetic Field – Our Shield

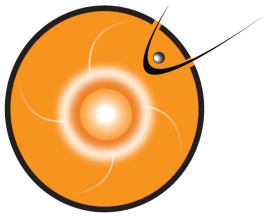


(not to scale)



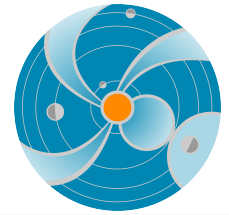
- The magnetosphere is the shield that protects the Earth from the solar plasma particles because they have difficulty in moving across the magnetic field lines.





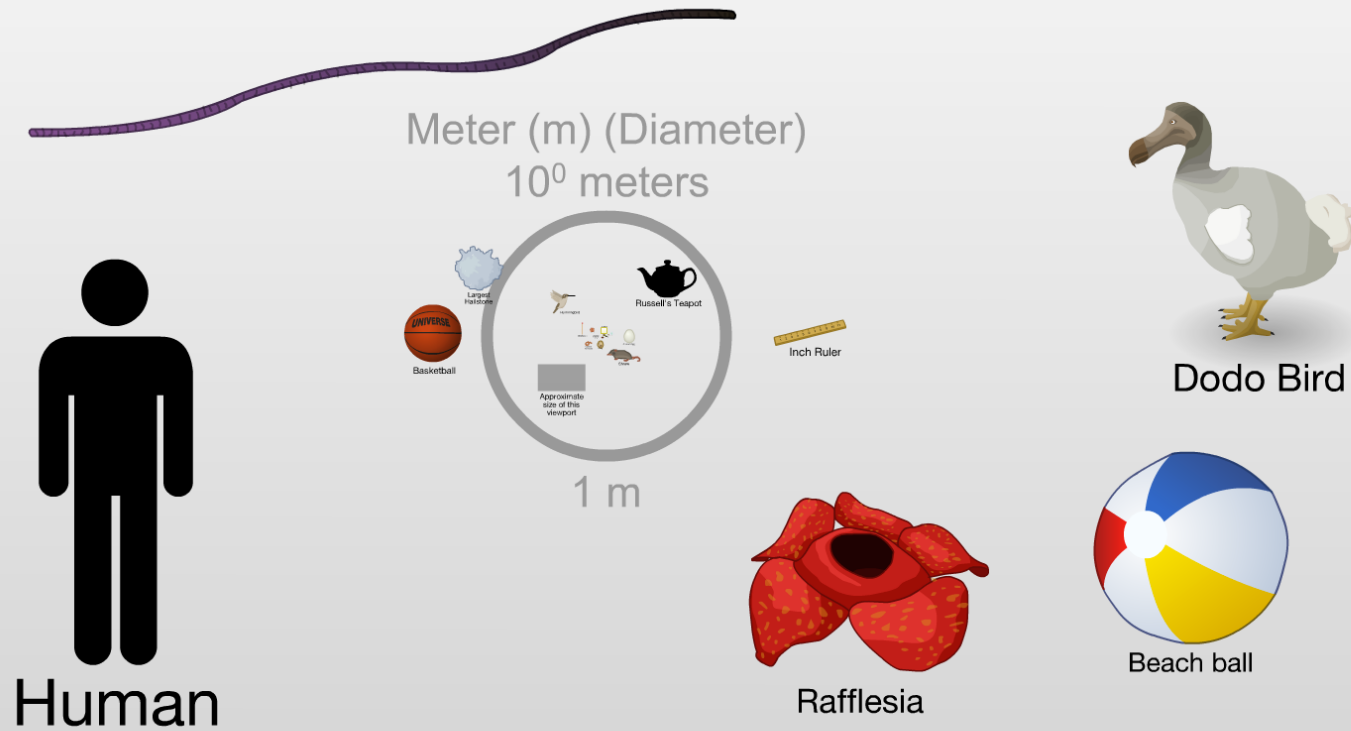
# The Scales of the Universe:

<http://htwins.net/scale2/>

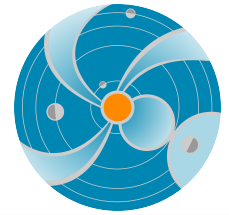
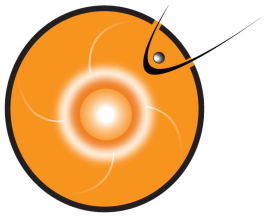


Human scale: (an order of magnitude) 1 meter

## Giant Earthworm



$10^{0.0}$



# The Scales of the Universe:

<http://htwins.net/scale2/>

Gigameter (Gm) (Diameter)  
 $10^9$  meters



Luyten's Star



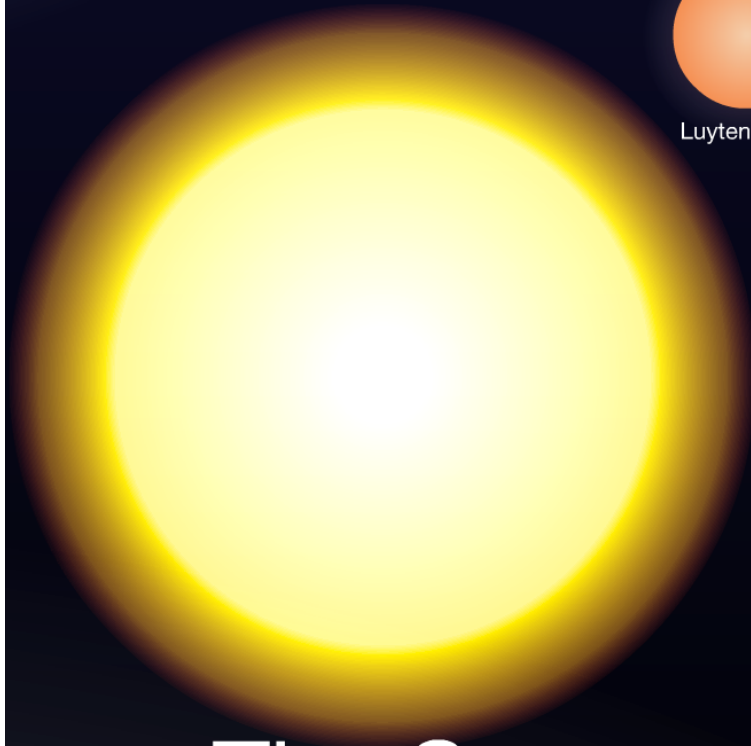
Distance from  
Earth to Moon



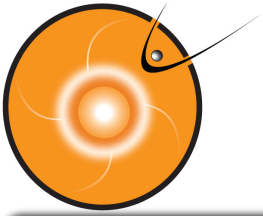
Kapteyn's Star

1,000,000,000 m

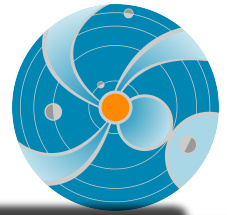
$10^9$  m



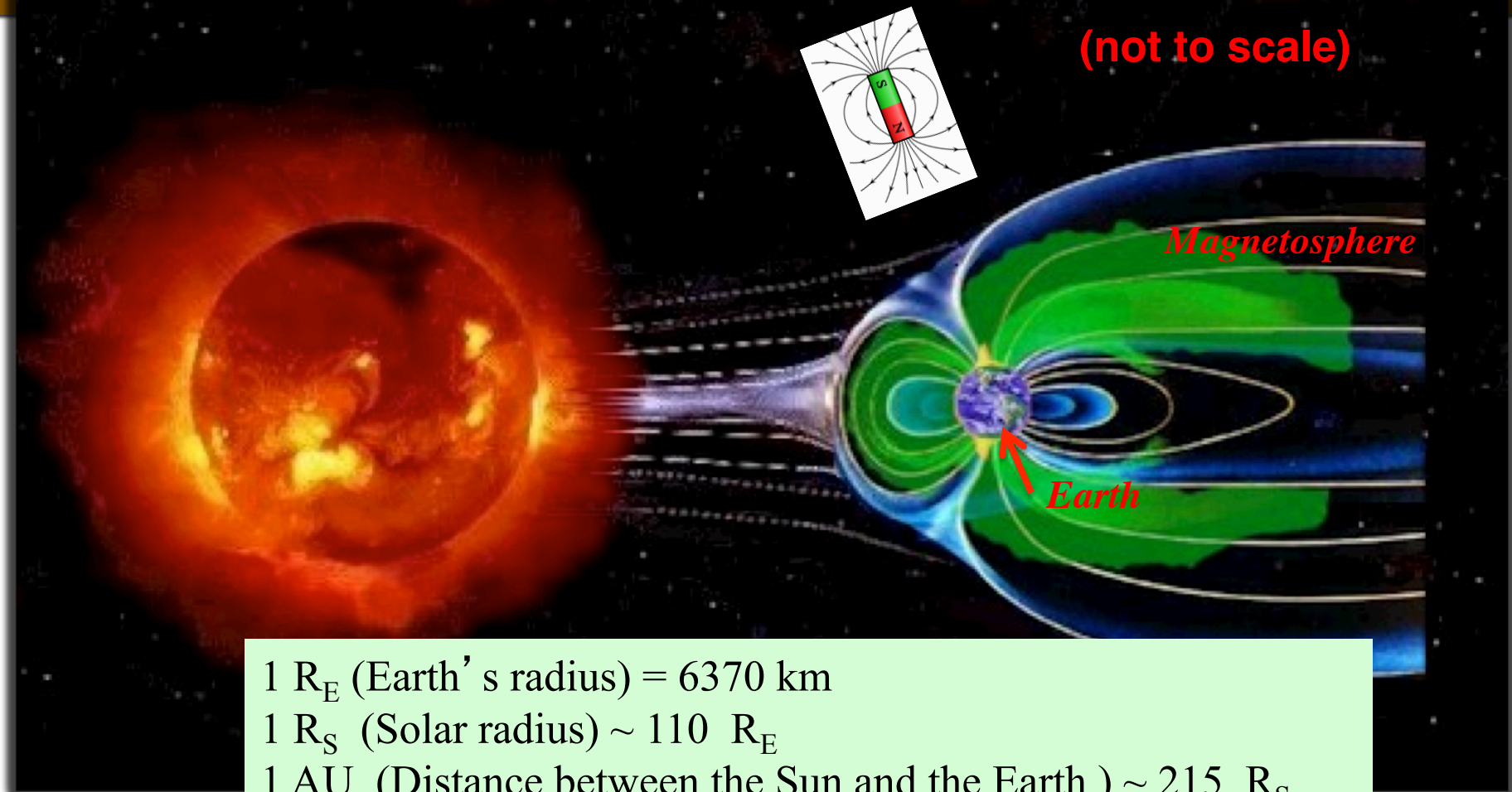
The Sun



## Spatial Scales in Heliosphere



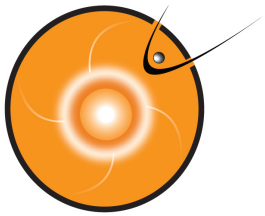
(not to scale)



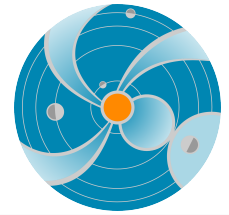
1  $R_E$  (Earth's radius) = 6370 km

1  $R_S$  (Solar radius)  $\sim 110 R_E$

1 AU (Distance between the Sun and the Earth)  $\sim 215 R_S$



# Structure and Dynamics of Magnetosphere Depend on Conditions in Solar Solar Wind



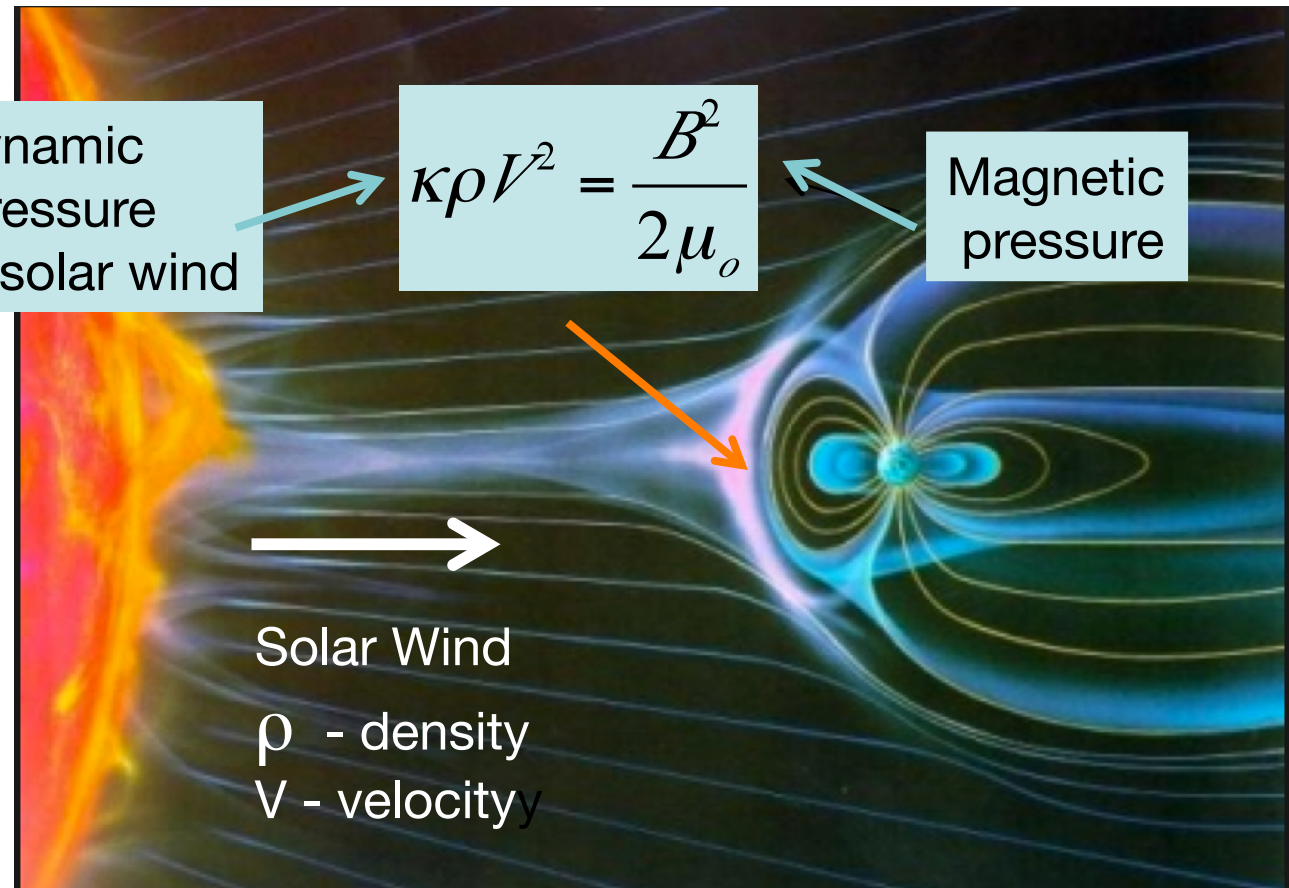
Dynamic  
pressure  
of solar wind

$$\kappa \rho V^2 = \frac{B^2}{2\mu_o}$$

Magnetic  
pressure

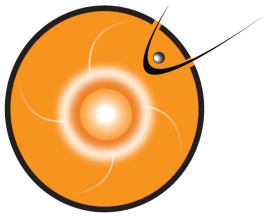
Typical quite  
solar wind:  
 $\rho = 5 \text{ ncc}$   
 $V = 400 \text{ km/s}$   
 $B = 5 \text{ nT}$

Solar Wind  
 $\rho$  - density  
 $V$  - velocity

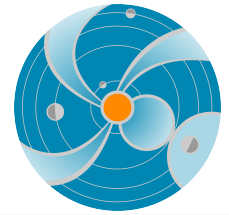


Typical magnetopause standoff distance is 10 – 12  $R_E$

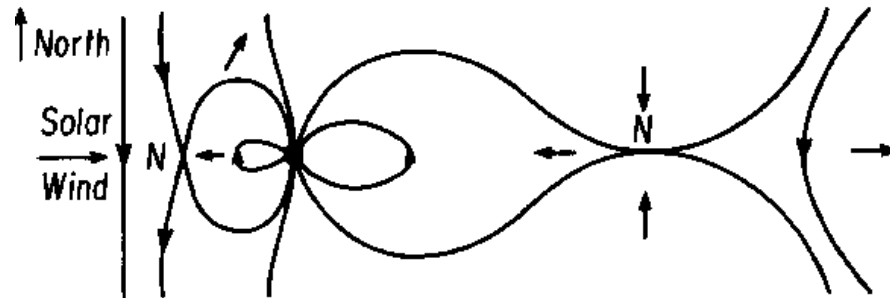




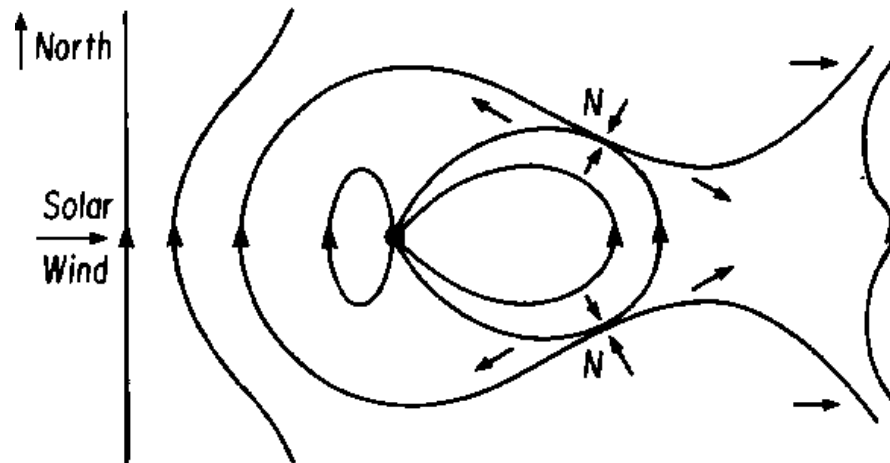
## Magnetosphere for Southward and Northward IMF Orientation



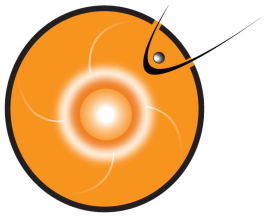
Interplanetary Field Southward



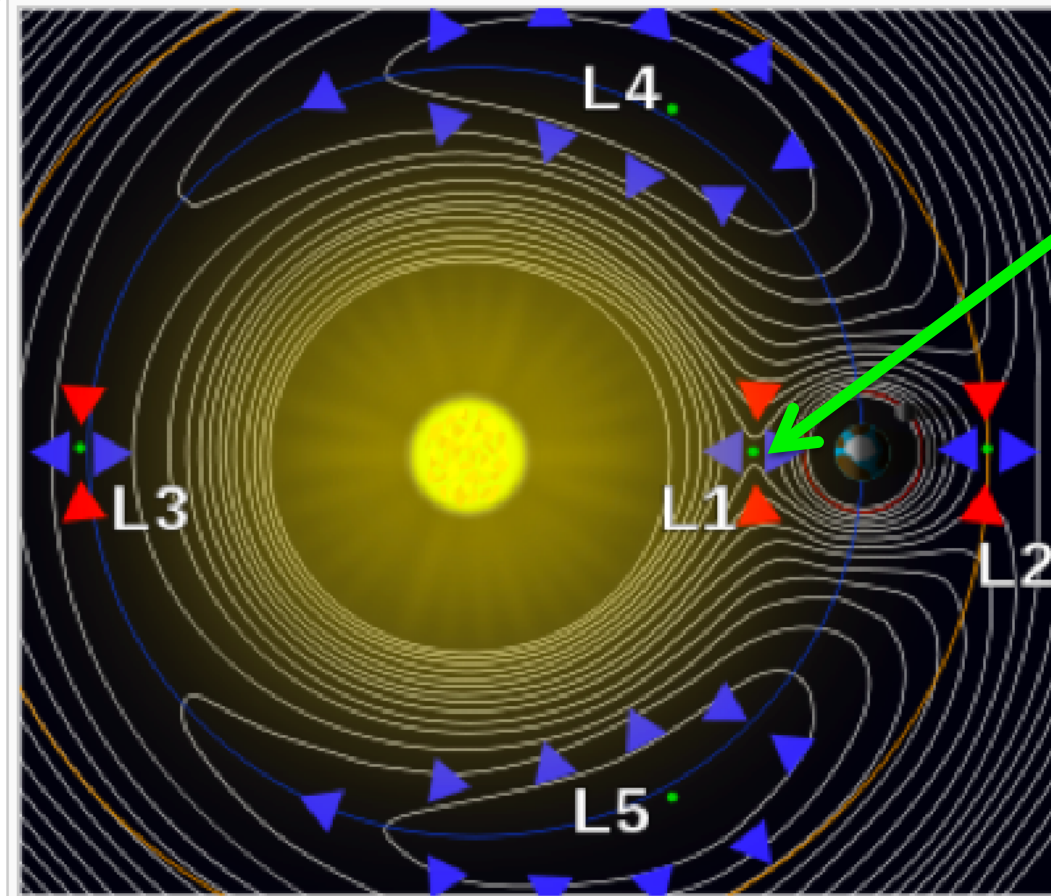
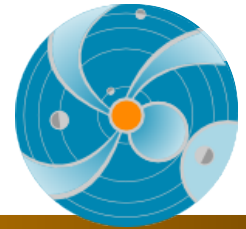
Interplanetary Field Northward



Structure and dynamics of the magnetosphere is strongly depends on orientation of magnetic field in solar wind (Interplanetary Magnetic Field – IMF) with respect to the Earth's dipole field

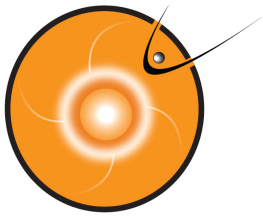


# Solar Wind Monitor at Lagrangian Point – L1



Advanced  
Composition  
Explorer

**L1** (Solar Wind Monitor ACE location):  $\sim 200 R_E$  sunward  
You can fit 1 Sun between the Earth and L1.  
 $2 R_S$  (Solar diameter)  $\sim 220 R_E$

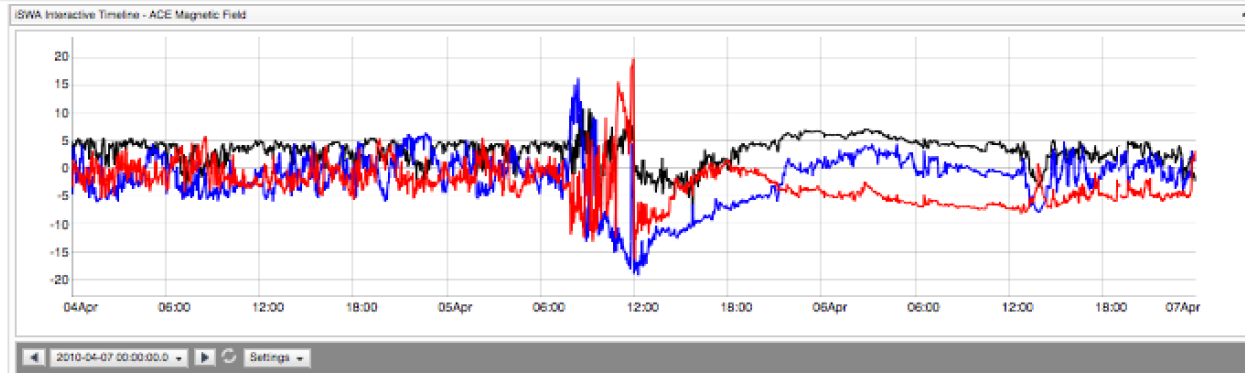


# Solar Wind Parameters at ACE

on 04/05/2010



nT



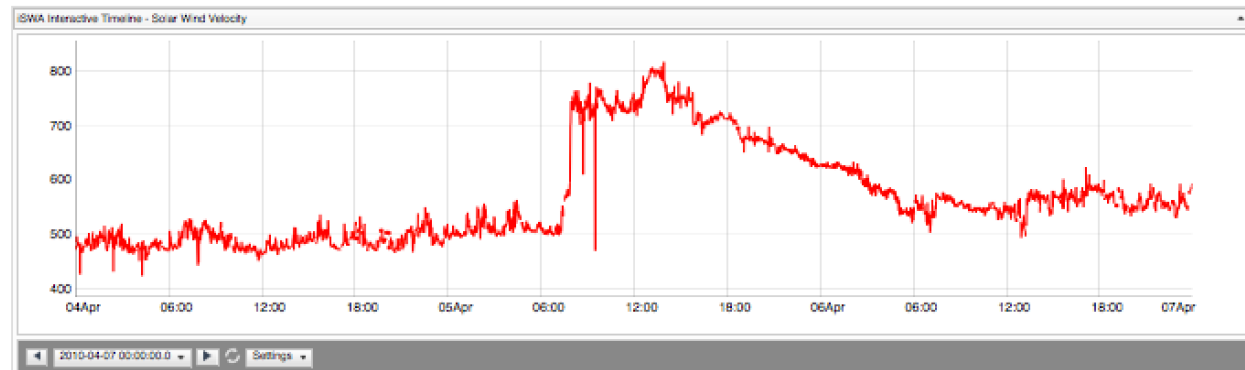
Magnetic field

$B_x$ ,  $B_y$ ,  $B_z$

X: Earth to Sun

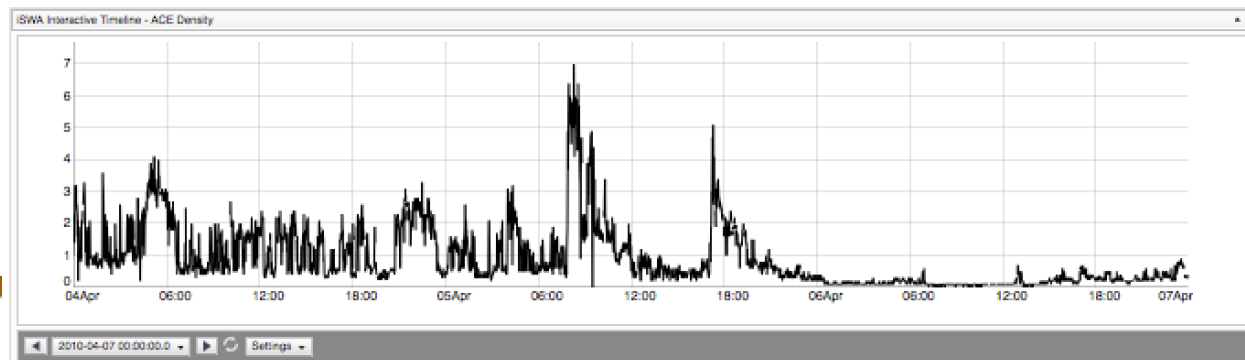
Z: South to North

km/s

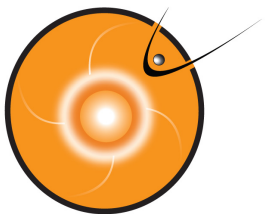


Velocity

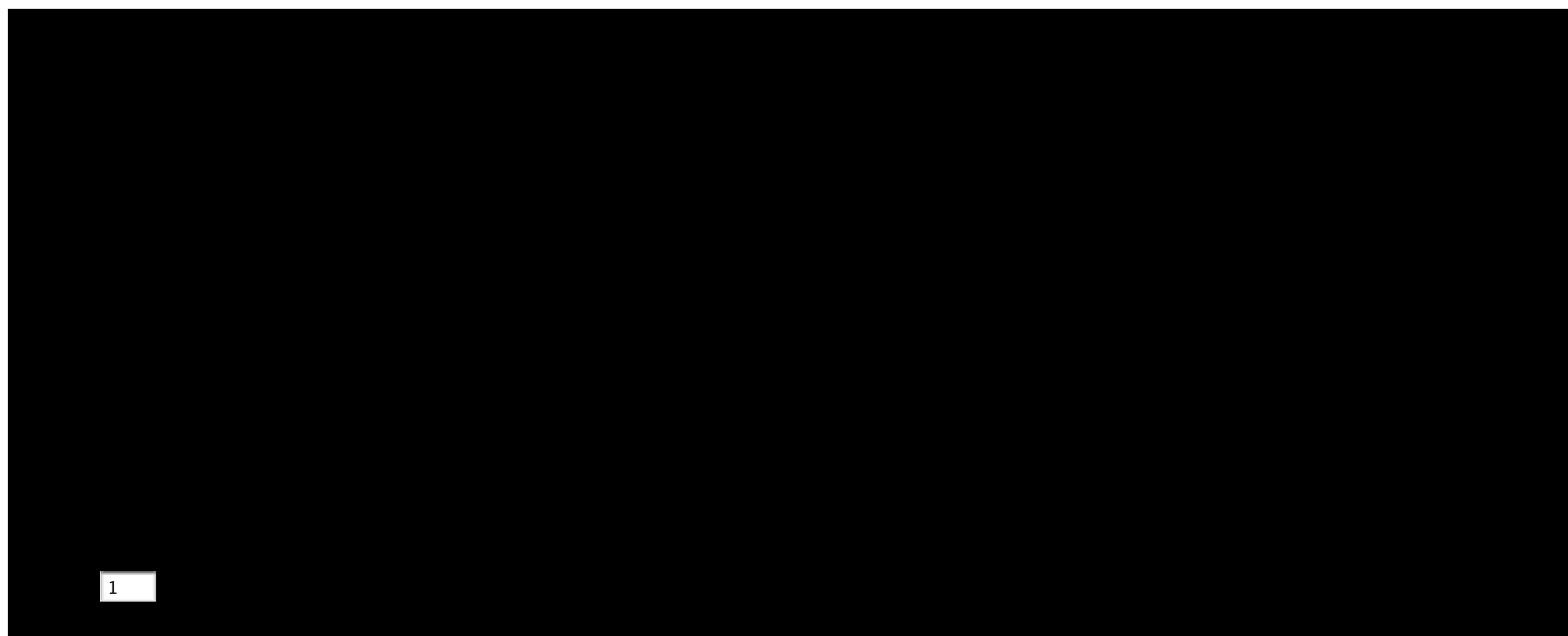
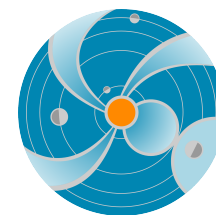
part/cm<sup>3</sup>



Density

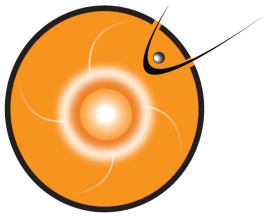


## Solar Wind Speed at ACE for 9 months

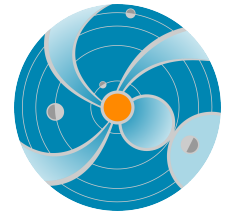


☒ Bulk Speed Zoom: [In](#) [Out](#) [full](#) Pan: [left](#) [right](#)





# Magnetosphere in Global MHD Simulations



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[http://ccmc.gsfc.nasa.gov/  
ungrouped/GM\\_IM/GM\\_main.php](http://ccmc.gsfc.nasa.gov/ungrouped/GM_IM/GM_main.php)

ed Links

About

Models at CCMC

Request A Run

View Results

Instant Run

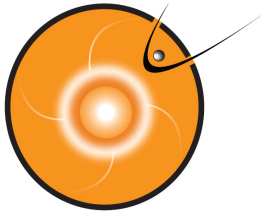
Metrics and Validation

## Global Magnetosphere Simulation Results

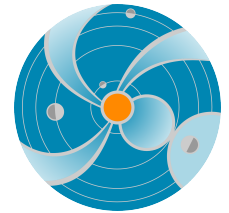
- View ALL Runs on Request
- View simulations with MODELED conditions
- View simulations of REAL EVENTS
- View general purpose runs for education and research

SEARCH database for string(s):

*At present, we do not support multiple string search, so please only enter one string*



# Magnetosphere For Steady Solar Wind Conditions

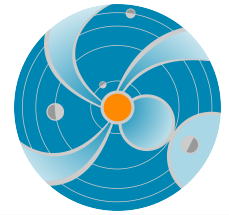
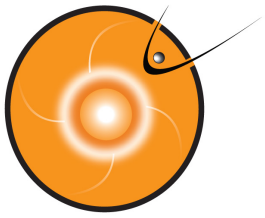


**Sort by:**

Total Number of Runs in the Database: 3739

Number of Educational Runs in this Database: 37

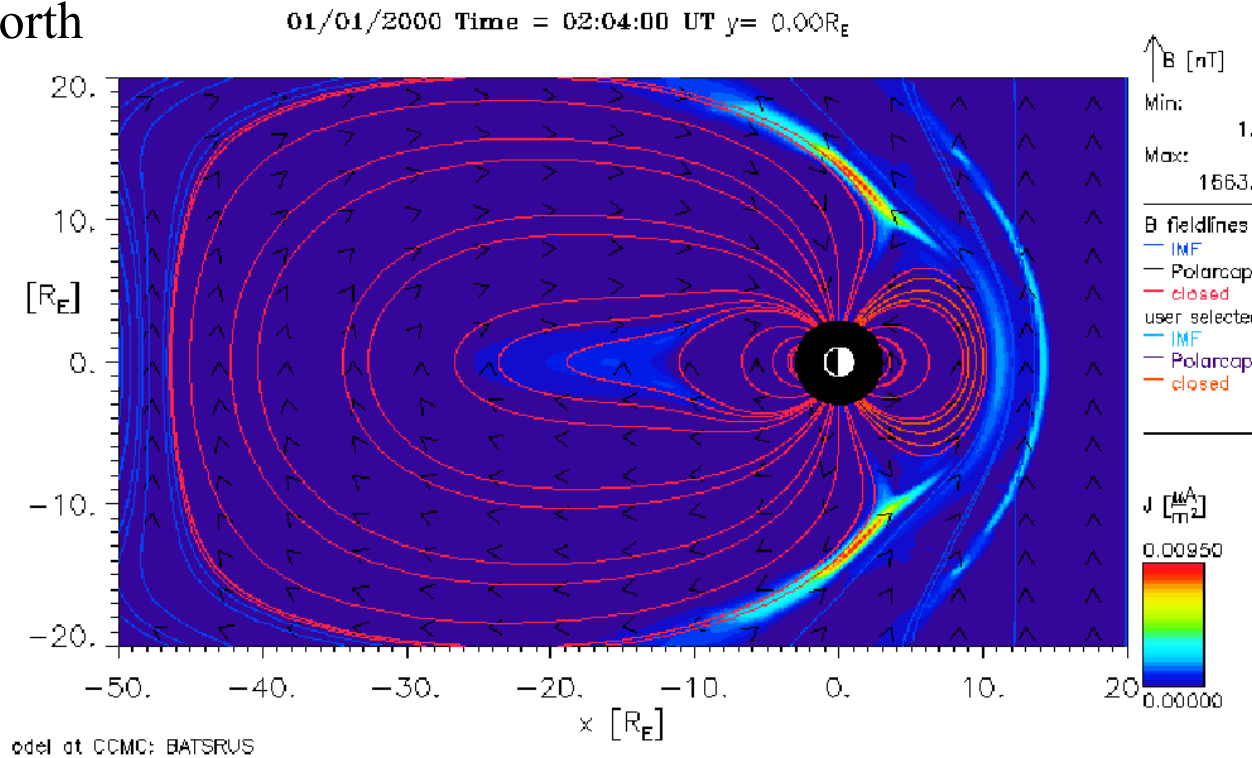
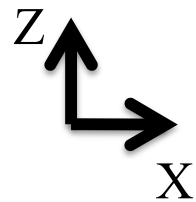
Run Number	V <sub>x</sub>	N	B	IMF Clock Angle	B <sub>x</sub>	B <sub>y</sub>	B <sub>z</sub>
<a href="#">CCMC_CCMC_011006_1</a>	-400.00000	5.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_011006_2</a>	-400.00000	15.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_012006_1</a>	-400.00000	30.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_012006_2</a>	-700.00000	5.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_012006_3</a>	-700.00000	15.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_012506_1</a>	-1000.00000	5.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_020906_1</a>	-1000.00000	15.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_020906_2</a>	-1000.00000	30.00000	5.00000	180.00000	0.00000	0.00000	-5.00000
<a href="#">CCMC_CCMC_021606_1</a>	-400.00000	5.00000	20.00000	180.00000	0.00000	0.00000	-20.00000
<a href="#">CCMC_CCMC_021606_2</a>	-400.00000	15.00000	20.00000	180.00000	0.00000	0.00000	-20.00000
<a href="#">CCMC_CCMC_042308_1</a>	-400.00000	5.00000	0.00000	0.0	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_050808_1</a>	-400.00000	5.00000	0.00000	0.0	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_050808_2</a>	-400.00000	5.00000	0.00000	0.0	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_050808_3</a>	-400.00000	5.00000	0.00000	0.0	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_053006_1</a>	-400.00000	5.00000	0.00000	0.00000	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_053006_2</a>	-400.00000	5.00000	0.00000	0.00000	0.00000	0.00000	0.00000
<a href="#">CCMC_CCMC_053106_1</a>	-400.00000	5.00000	5.00000	0.00000	0.00000	0.00000	5.00000
<a href="#">CCMC_CCMC_053106_2</a>	-400.00000	5.00000	5.00000	90.00000	0.00000	5.00000	0.00000
<a href="#">CCMC_CCMC_060806_1</a>	-400.00000	5.00000	20.00000	90.00000	0.00000	20.00000	0.00000
<a href="#">CCMC_CCMC_060806_2</a>	-400.00000	5.00000	20.00000	90.00000	0.00000	20.00000	0.00000
<a href="#">CCMC_CCMC_060906_3</a>	-400.00000	5.00000	40.00000	180.00000	0.00000	0.00000	-40.00000



# Magnetosphere: Northward IMF

X: Earth to Sun

Z: South to North

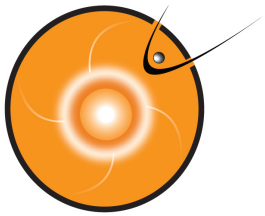


Sun

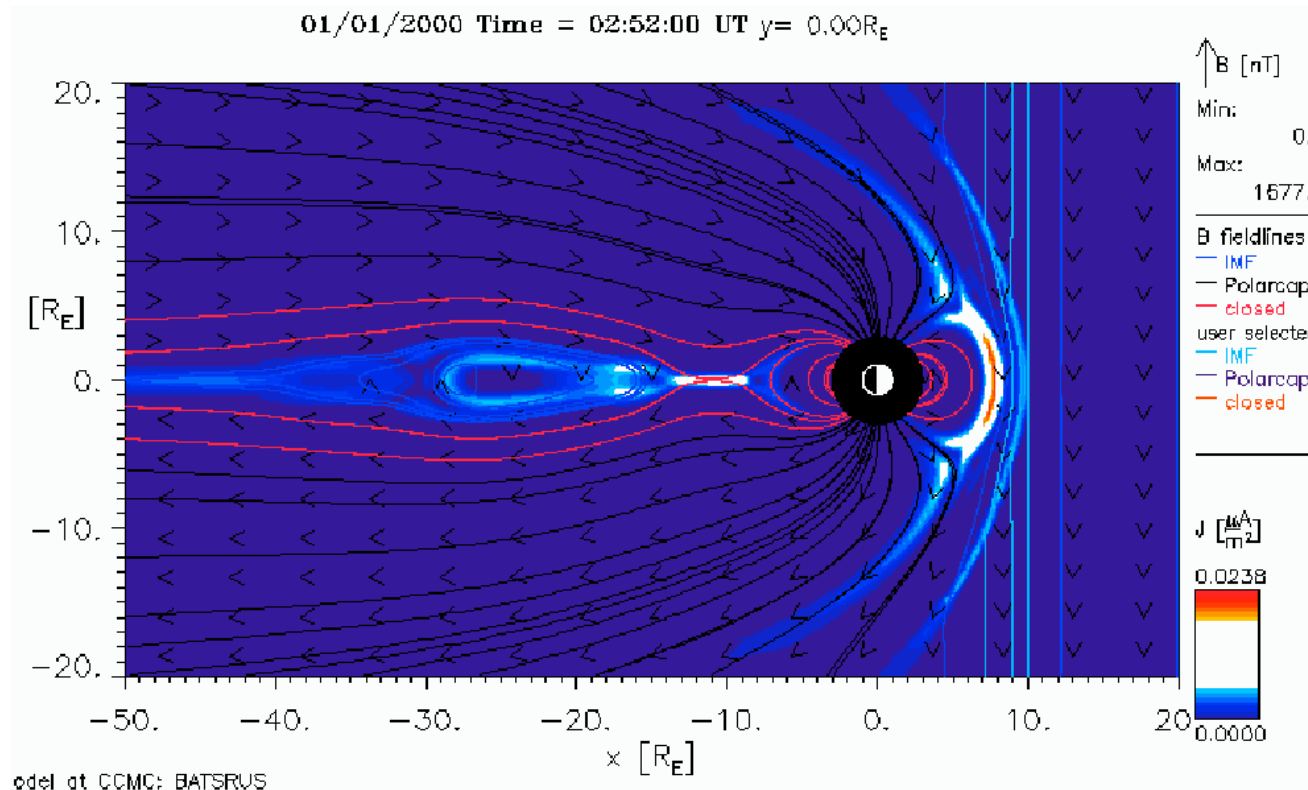
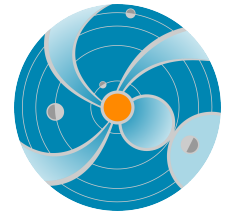
**Red lines** (closed): Magnetic field (MF) lines with both ends connected to the Earth

**Black lines** (open): MF lines with only one end at the Earth

**Blue lines** (interplanetary): MF lines with both ends in the interplanetary space



# Magnetosphere: Southward IMF

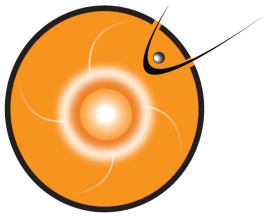


**Red lines** (closed): Magnetic field (MF) lines with both ends connected to the Earth

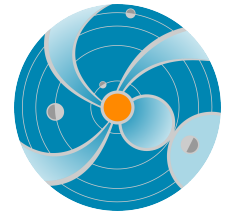
**Black lines** (open): MF lines with only one end at the Earth

**Blue lines** (interplanetary): MF lines with both ends in the interplanetary space

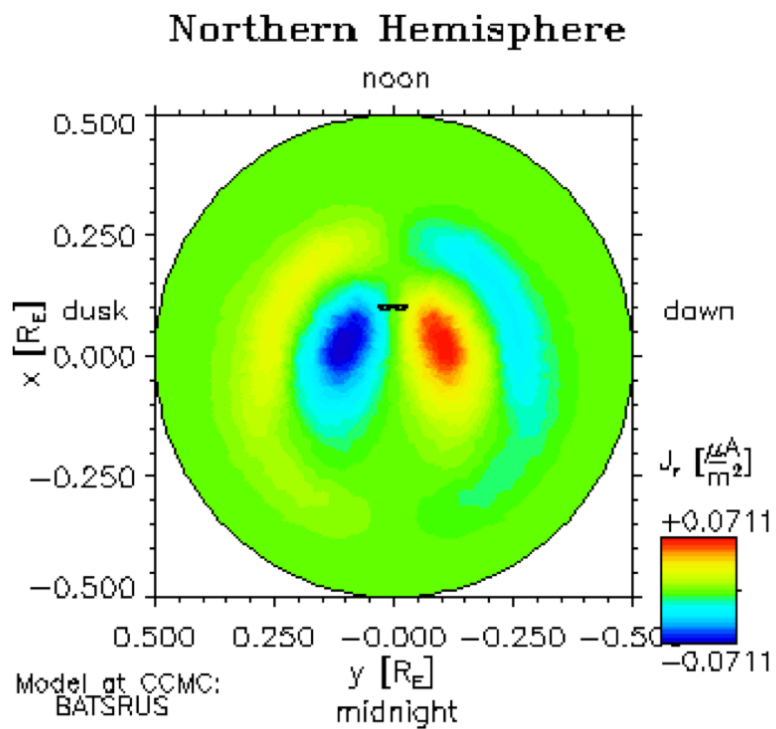




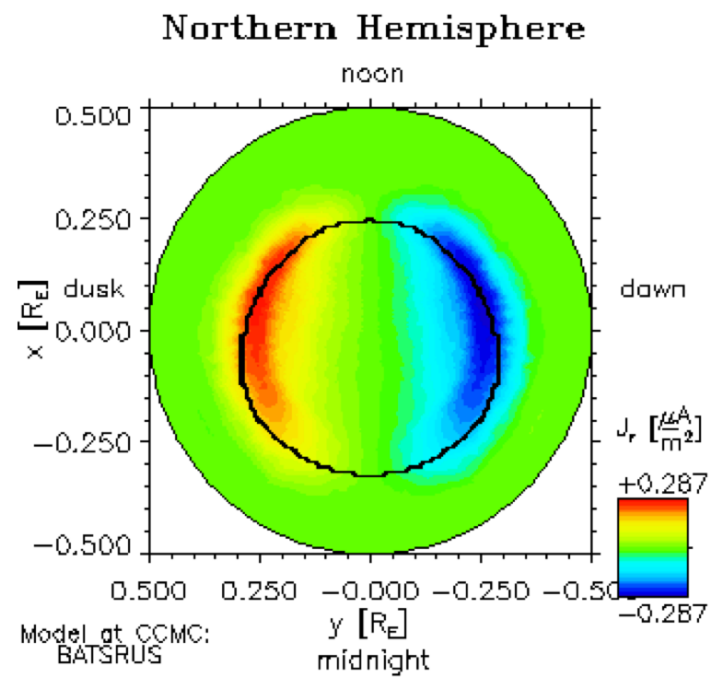
# Currents into Ionosphere & Polar Cap

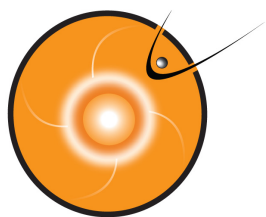


## Northward IMF

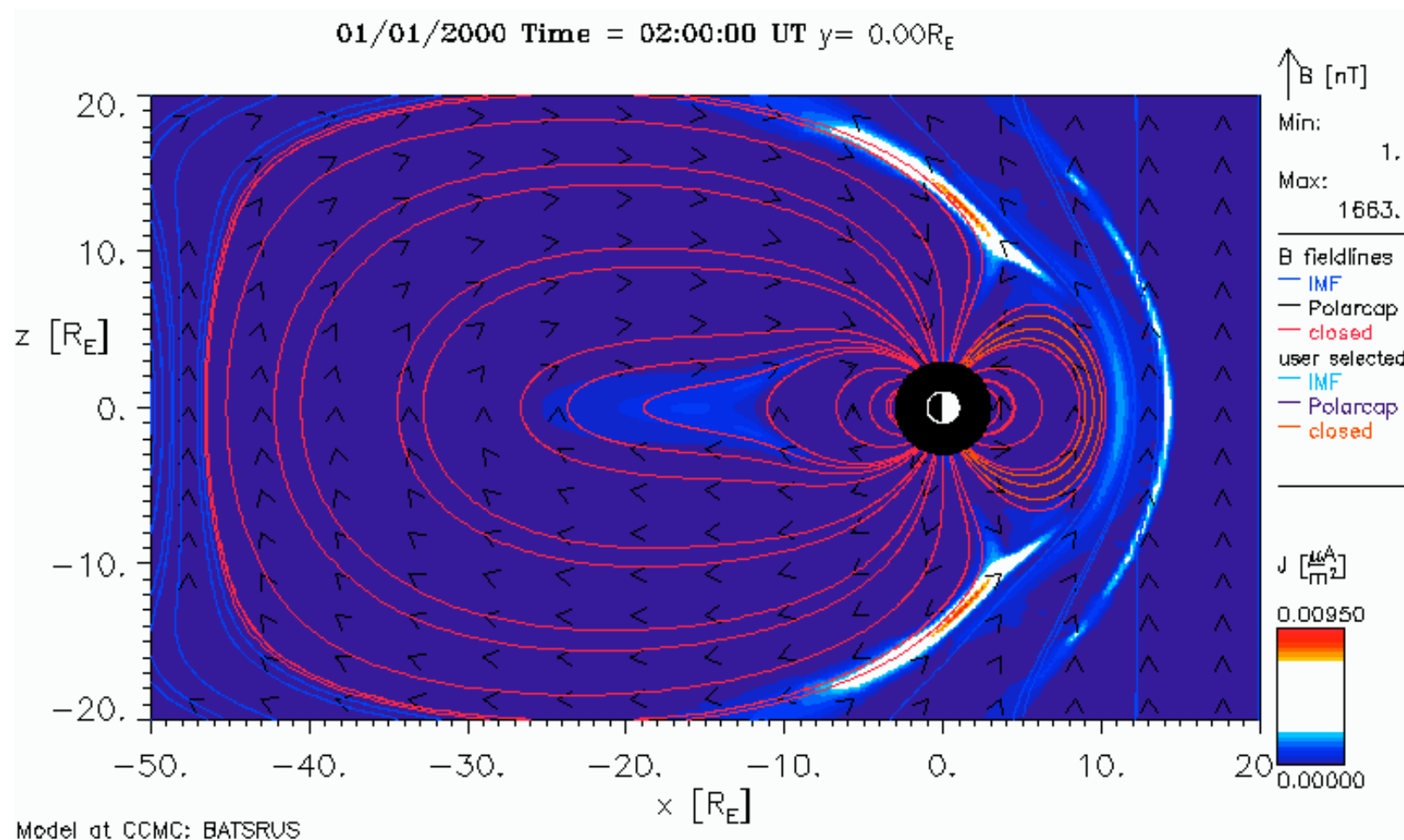


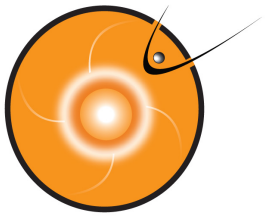
## Southward IMF



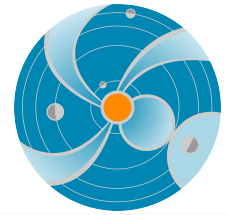


# Magnetosphere: North to South Turning



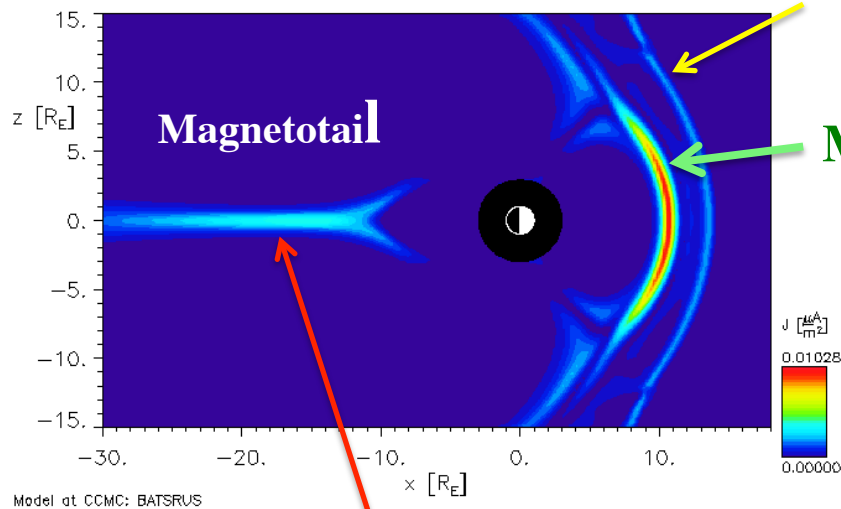


# Magnetosphere in Different Cut Planes



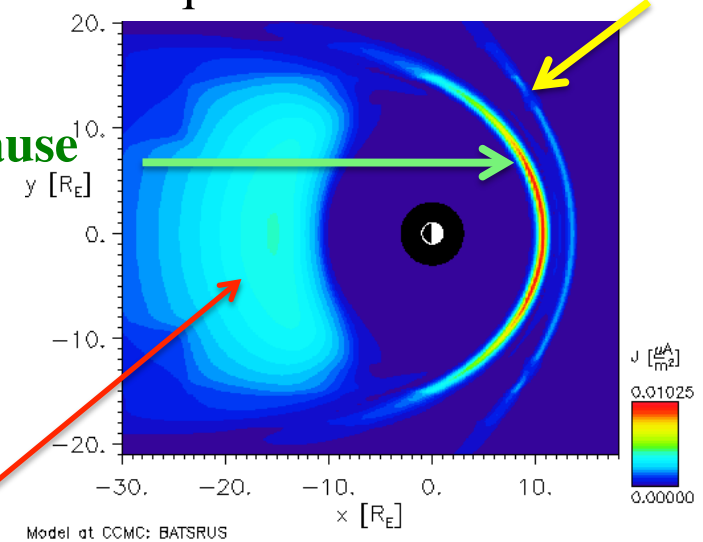
meridional cut  $Y=0$

Bow shock

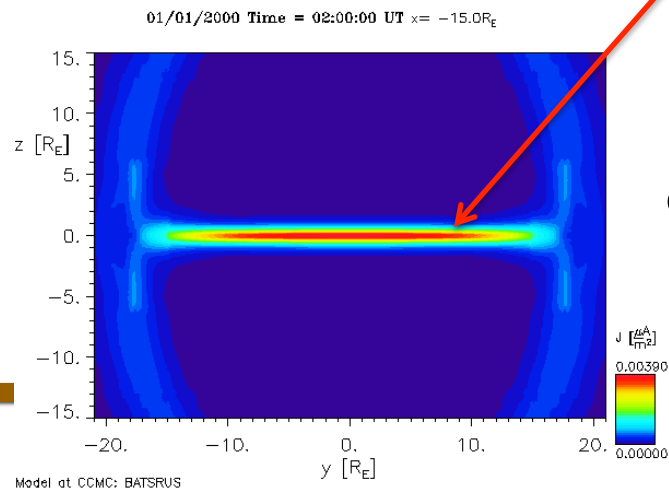


equatorial cut  $Z=0$

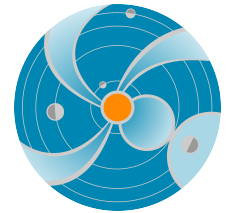
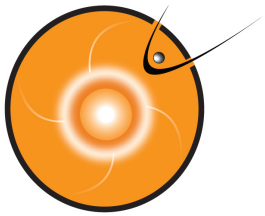
Bow shock



Magnetotail current sheet

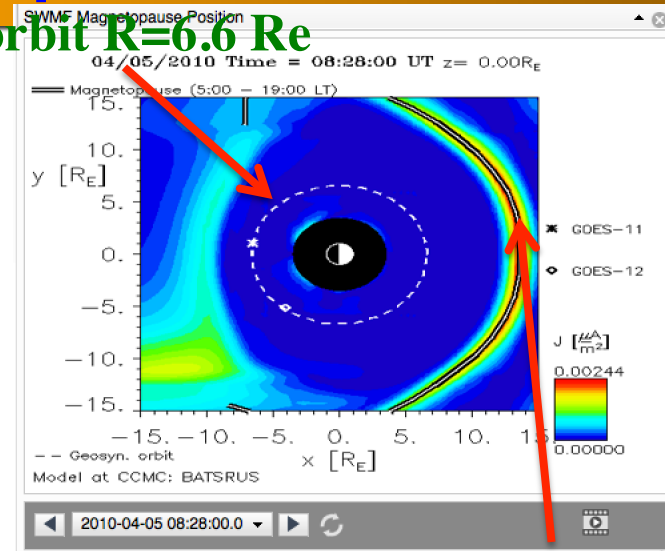
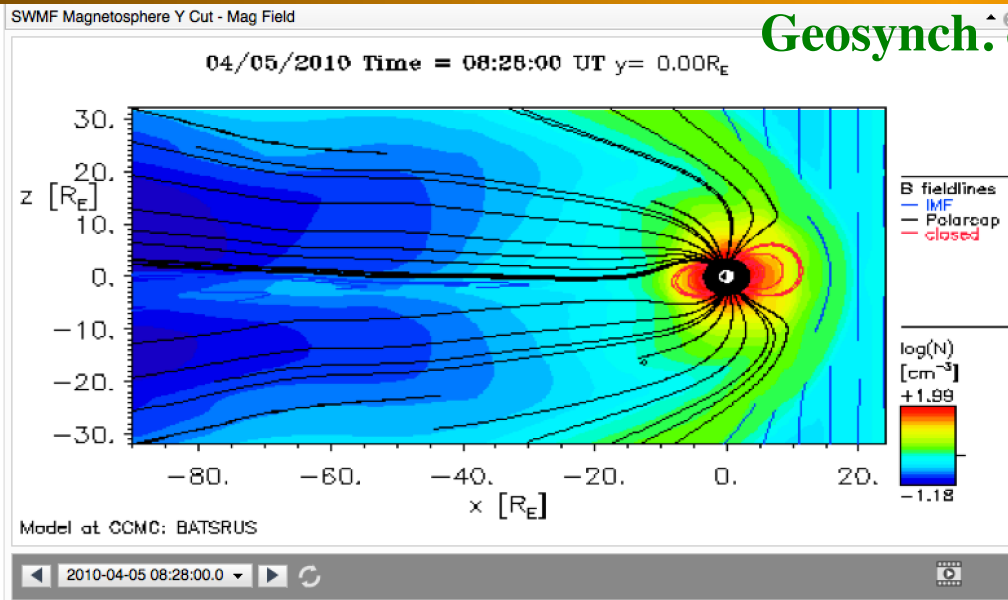


cross-tail cut  $X = -15 R_E$

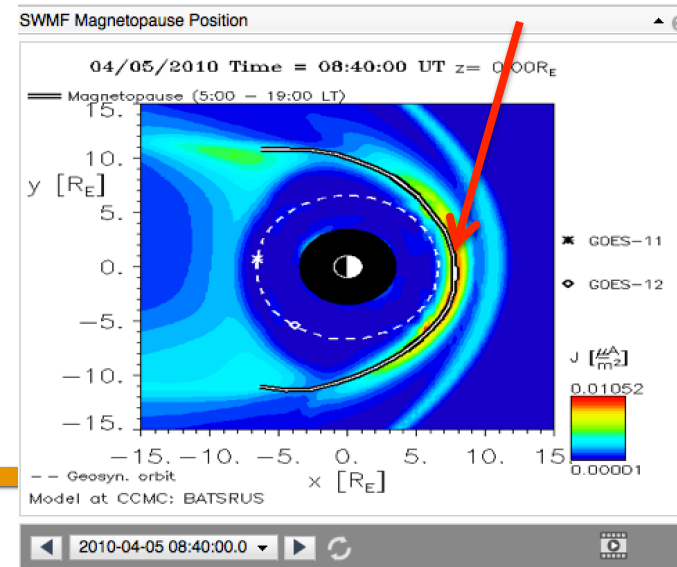
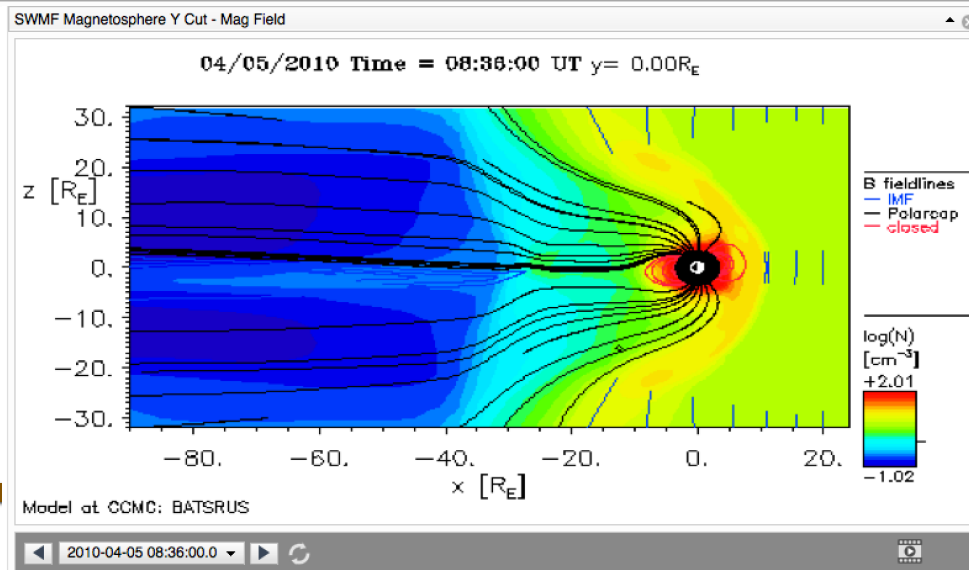


# Magnetosphere: Quiet vs. Compressed

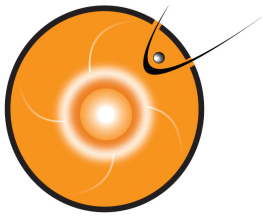
Geosynch. orbit  $R=6.6 R_E$



Magnetopause







# Magnetopause Stand-off Distance



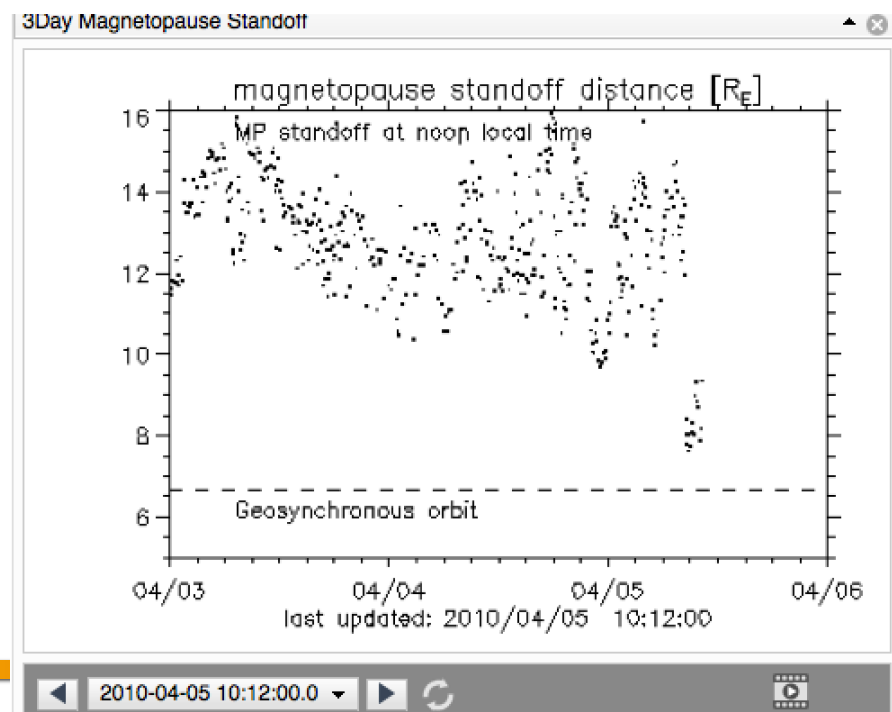
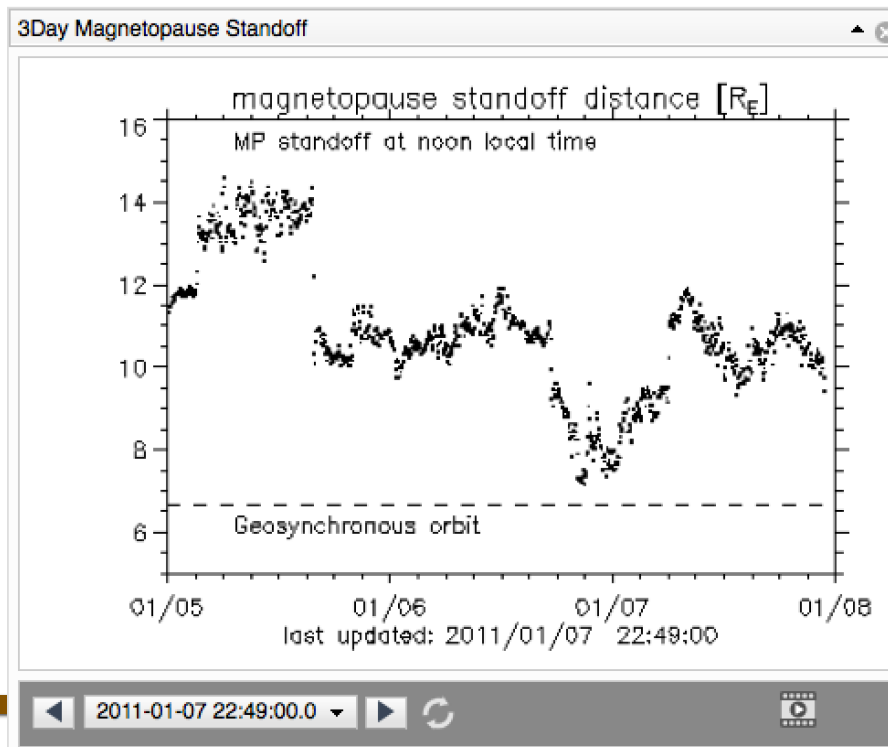
Degree of compression of MP  
Due to  $P_{\text{dyn}}$  of solar wind  
(interplanetary shock or HSS)

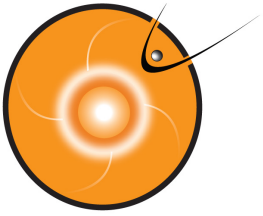
$r_0 \leq 6.6 R_E$  – model product

Events: Apr 5, 2010,  
Dec 28, 2010

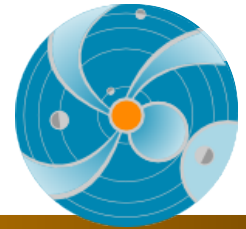
Jan 6, 2011, 22:30 UT

Non-event: Dec 1 – 7, 2010





# Kp

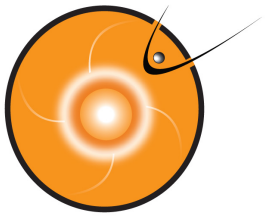


"planetarische Kennziffer" (= planetary index).

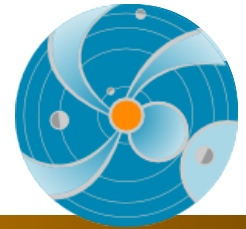
- Geomagnetic activity index  
range from 0-9 disturbance levels of  
magnetic field on the ground - currents
1. Non-event - period of 12/01/2010 – 12/7/2010
  2. Moderate event – April 5, 2010
  3. Extreme event - Oct 29 – Oct 31, 2003

[http://bit.ly/Kp\\_layout](http://bit.ly/Kp_layout)

Threshold  $Kp \geq 6$

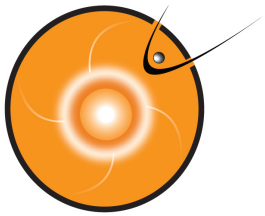


**Watch the video**

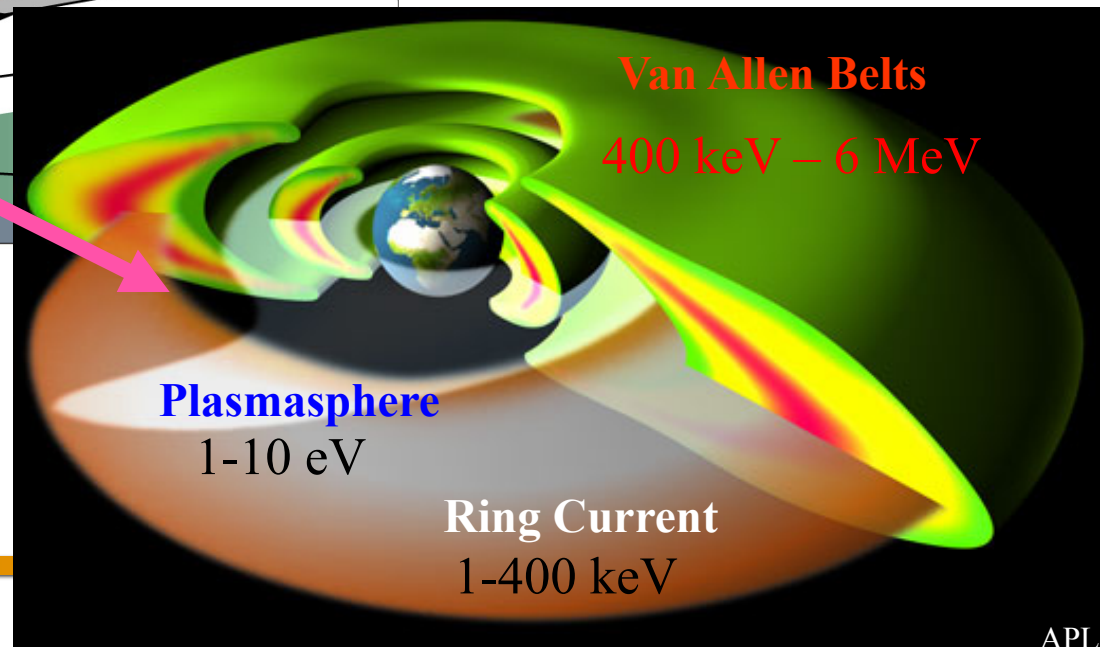
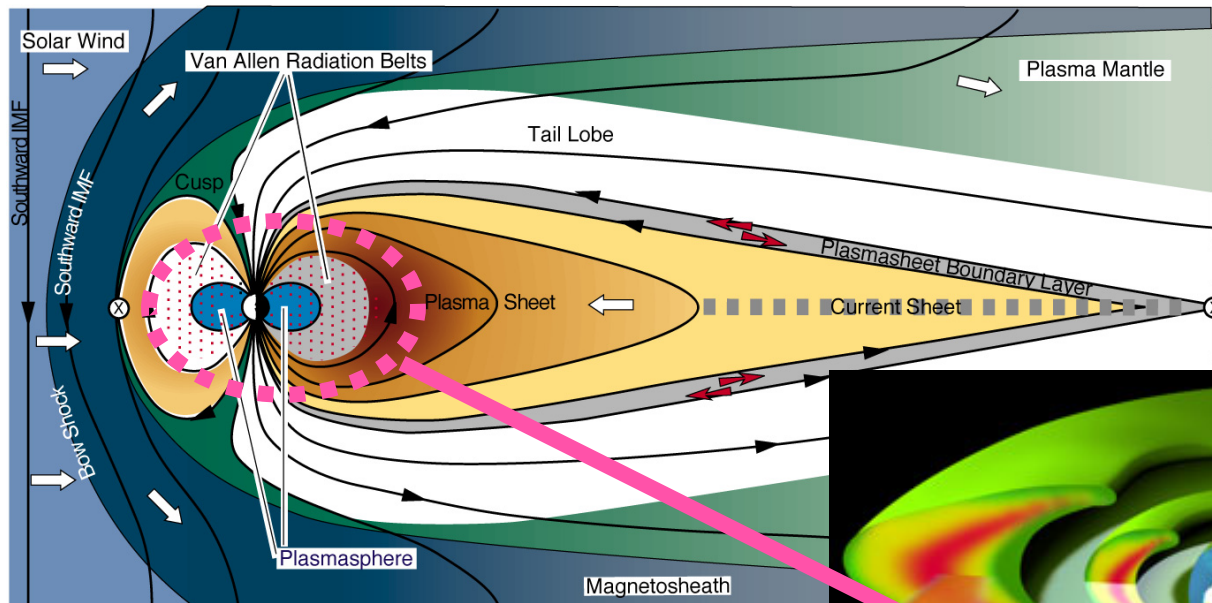


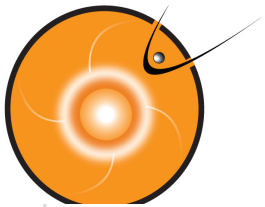
Mysteries of the Sun : Magnetosphere

[http://missionscience.nasa.gov/sun/  
sunVideo\\_04magnetosphere.html](http://missionscience.nasa.gov/sun/sunVideo_04magnetosphere.html)

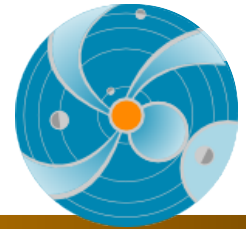


## Inner Magnetosphere (up to $\sim 10$ RE)

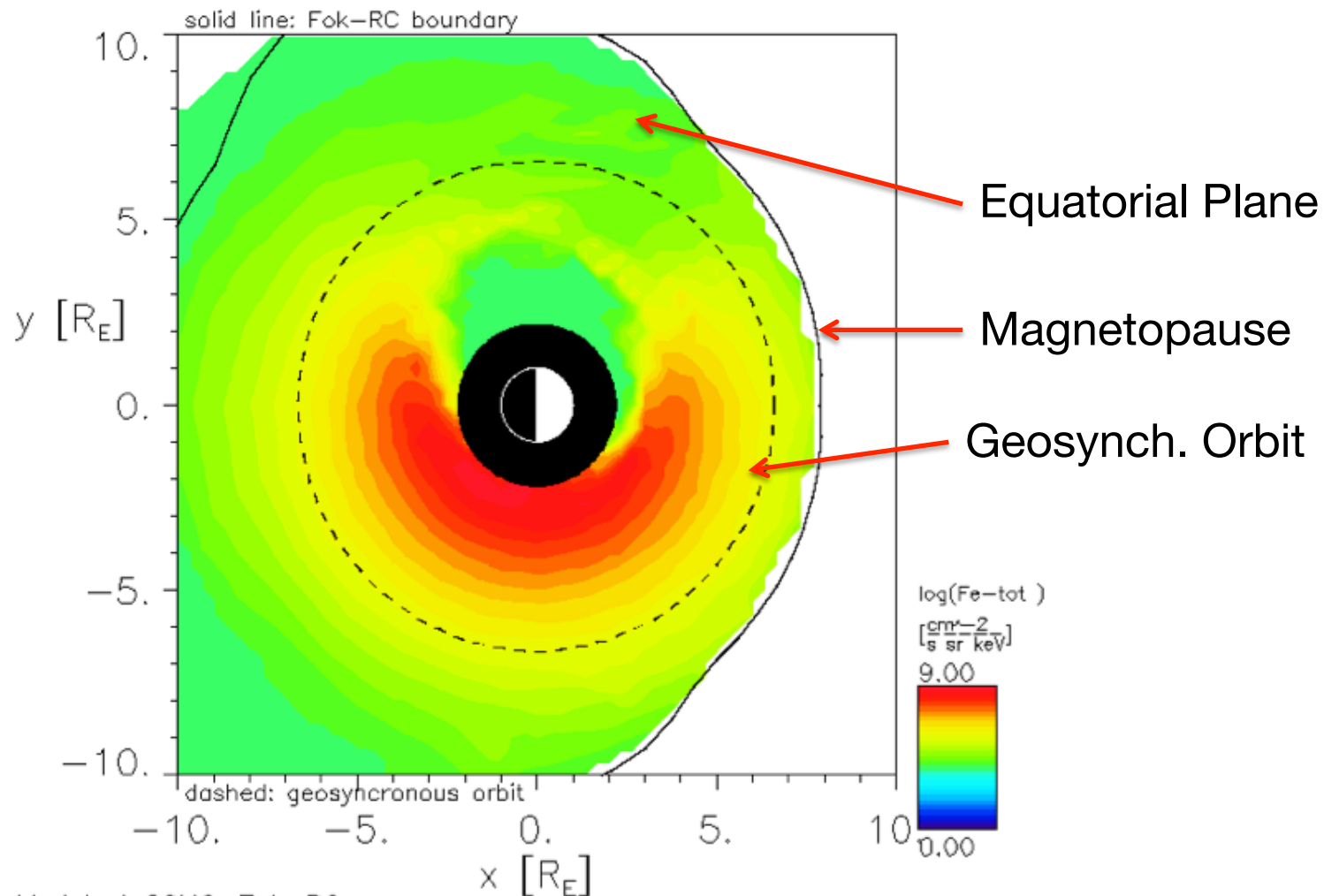




# Electron Total Flux. Energy 63.3 keV. Color Contour



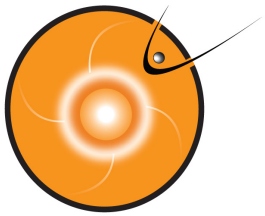
01/01/2000 Time = 04:55:58 UT En.= 63.3keV



→  
**Sun**

Model at CCMC: Fok-RC

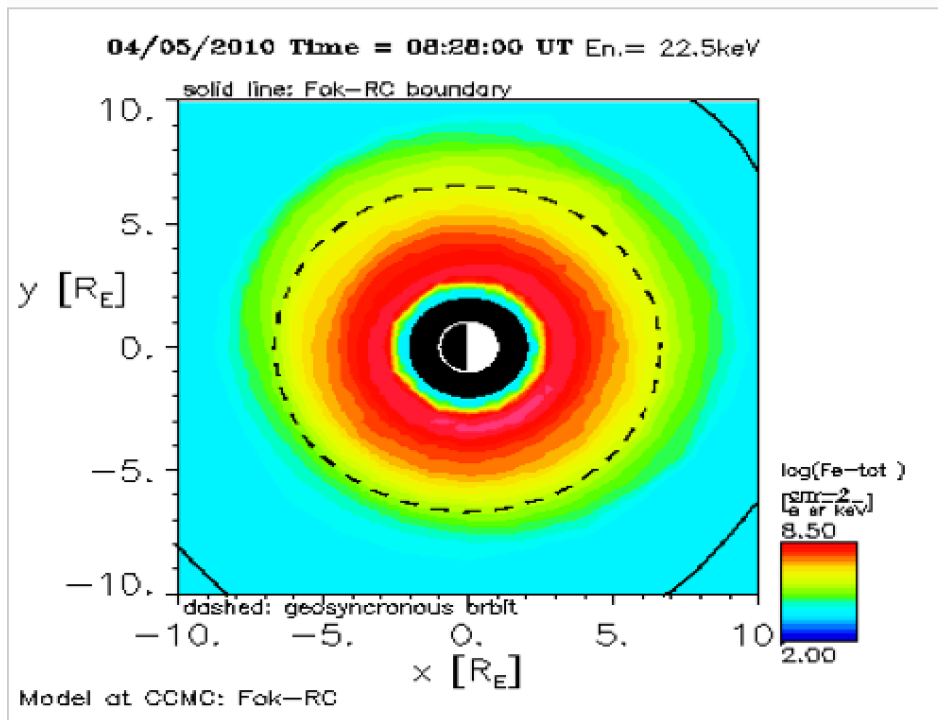
Earth radius



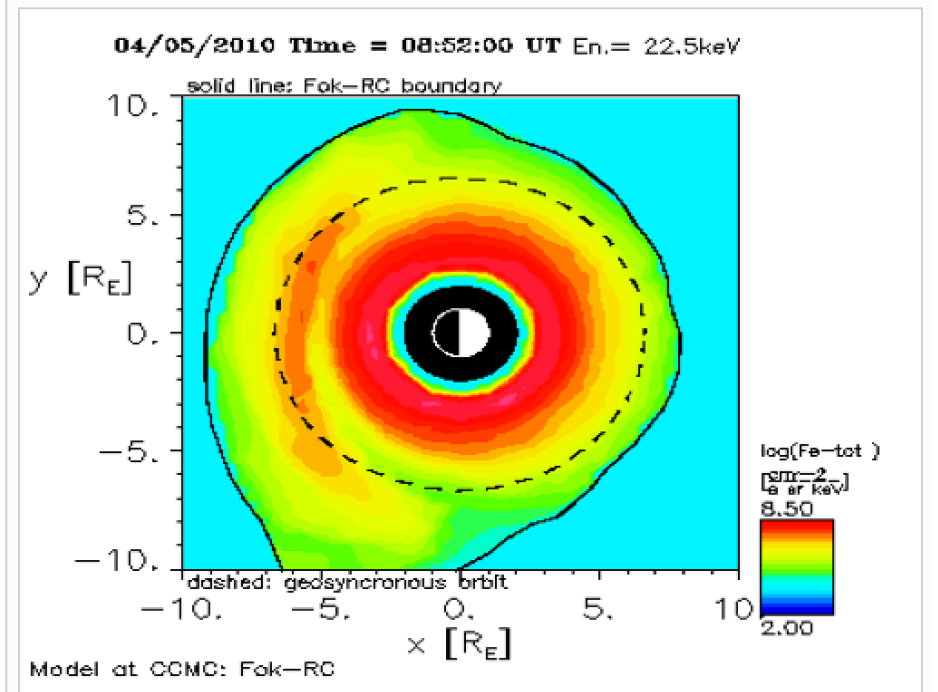
# Ring Current: Quiet vs. Active



Fok Ring Current electrons at 22.5 keV



Fok Ring Current electrons at 22.5 keV



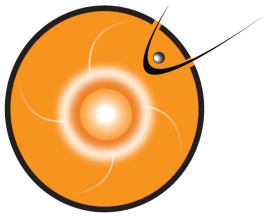
2010-04-05 08:28:00.0



2010-04-05 08:52:00.0



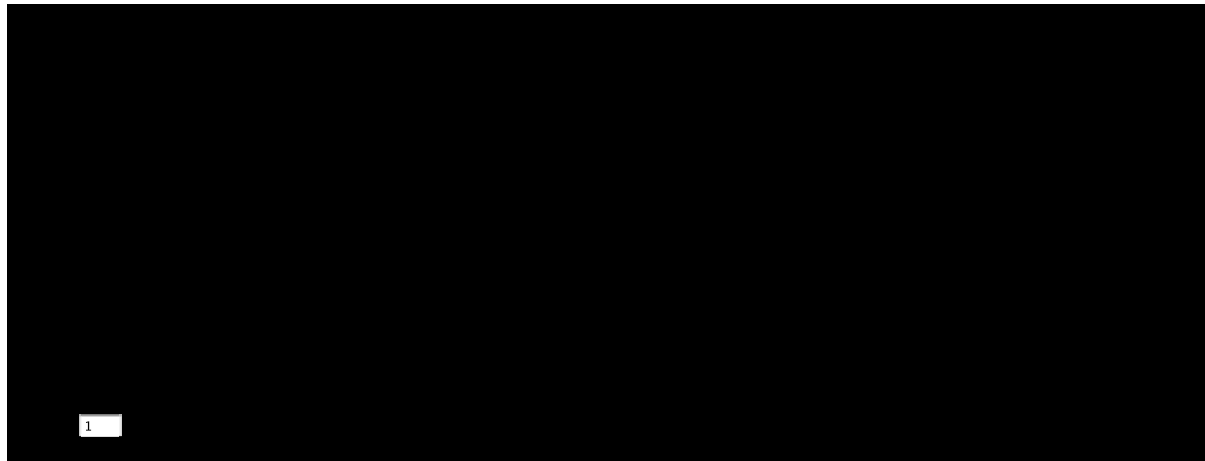




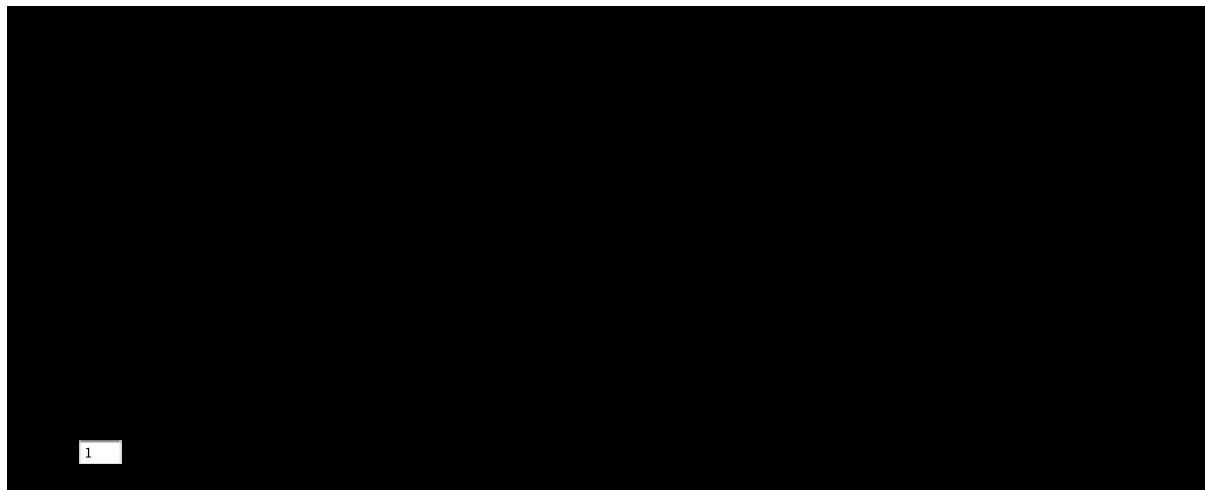
# HSS and Radiation Belt Electron Flux Enhancement



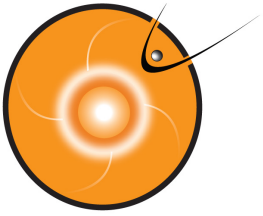
Click the check boxes to toggle series visibility



☒ E > 0.8 MeV ☒ E > 2.0 MeV Zoom: [In](#) [Out](#) [full](#) Pan: [left](#) [right](#)

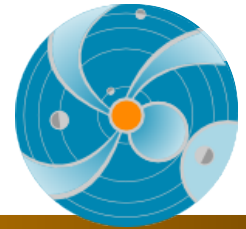


☒ Bulk Speed Zoom: [In](#) [Out](#) [full](#) Pan: [left](#) [right](#)



# iSWA Layout:

## 04/05/2010



<http://iswa.gsfc.nasa.gov/IswaSystemWebApp/index.jsp?>

i\_1=327&l\_1=9&t\_1=2130&w\_1=1372&h\_1=403&s\_1=2010-04-07%2000:00:00.0!3!  
&i\_2=335&l\_2=32&t\_2=300&w\_2=800&h\_2=400&s\_2=2010-04-06%2022:30:00.0!3!  
&i\_3=41&l\_3=878&t\_3=734&w\_3=495&h\_3=416&s\_3=2010-04-05%2010:00:00.0\_0\_10\_3&i\_4=51&l\_4=858&t\_4=1209&w\_4=509&h\_4=477&s\_4=2010-04-05%2010:00:00.0\_1\_80\_3&i\_5=337&l\_5=836&t\_5=300&w\_5=800&h\_5=400&s\_5=2010-04-07%2000:00:00.0!3!  
&i\_6=323&l\_6=8&t\_6=2552&w\_6=1370&h\_6=390&s\_6=2010-04-07%2000:00:00.0!3!  
&i\_7=325&l\_7=6&t\_7=1700&w\_7=1380&h\_7=408&s\_7=2010-04-07%2000:00:00.0!3!  
&i\_8=125&l\_8=390&t\_8=2965&w\_8=646&h\_8=418&s\_8=2010-04-06%2023:56:00.0\_0\_10\_3&i\_9=39&l\_9=175&t\_9=1226&w\_9=493&h\_9=409&s\_9=2010-04-05%2010:00:00.0\_0\_10\_3&i\_10=43&l\_10=33&t\_10=722&w\_10=792&h\_10=468&s\_10=2010-04-05%2010:00:00.0\_0\_10\_3