Space Weather in Earth’s magnetosphere

Masha Kuznetsova & CCMC/SWRC team

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

Human

Meter (m) (Diameter)
$10^0$ meters

Dodo Bird

Rafflesia

Beach ball

$10^{0.0}$
The Scales of the Universe:
http://htwins.net/scale2/

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

The Sun
$10^9$ m

Luyten's Star

Kapteyn's Star

Distance from Earth to Moon

1,000,000,000,000 m
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 Wind

Dynamic pressure of solar wind

\[ \kappa \rho V^2 = \frac{B^2}{2\mu_0} \]

Magnetic pressure

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

Typical magnetopause standoff distance is 10 – 12 \( R_E \)
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.
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

Magnetic field $B_x, B_y, B_z$

X: Earth to Sun
Z: South to North

Velocity

Density
Solar Wind Speed at ACE for 9 months
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.

http://ccmc.gsfc.nasa.gov/ungrouped/GM_IM/GM_main.php
Magnetosphere
For Steady Solar Wind Conditions

| Run Number          | Vx  | N   | |B|  | IMF Clock Angle | Bx  | By  | Bz  |
|---------------------|-----|-----|-----|-----|-----------------|-----|-----|-----|
| CCMC_CCMC_011006_1  | -400.00000 | 5.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_011006_2  | -400.00000 | 15.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_012006_1  | -400.00000 | 30.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_012006_2  | -400.00000 | 5.00000  | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_012006_3  | -400.00000 | 15.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_012506_1  | -400.00000 | 5.00000  | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_020906_1  | -400.00000 | 15.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_020906_2  | -400.00000 | 30.00000 | 5.00000 | 180.00000 | 0.00000 | 0.00000 | -5.00000 |
| CCMC_CCMC_021606_1  | -400.00000 | 5.00000  | 20.00000 | 180.00000 | 0.00000 | 0.00000 | -20.00000 |
| CCMC_CCMC_021606_2  | -400.00000 | 15.00000 | 20.00000 | 180.00000 | 0.00000 | 0.00000 | -20.00000 |
| CCMC_CCMC_042308_1  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_050808_1  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_050808_2  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_050808_3  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_053006_1  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_053006_2  | -400.00000 | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  | 0.00000  |
| CCMC_CCMC_053106_1  | -400.00000 | 5.00000  | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 5.00000  |
| CCMC_CCMC_053106_2  | -400.00000 | 5.00000  | 5.00000  | 0.00000  | 0.00000  | 0.00000  | 5.00000  |
| CCMC_CCMC_060806_1  | -400.00000 | 5.00000  | 20.00000 | 90.00000  | 0.00000  | 20.00000  | 0.00000  |
| CCMC_CCMC_060806_2  | -400.00000 | 5.00000  | 20.00000 | 90.00000  | 0.00000  | 20.00000  | 0.00000  |
| CCMC_CCMC_060906_3  | -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

Red lines (closed): Magnetic field (MF) lines with both ends connected to the Earth
Black lines (open): MF lines with only one end a 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 a 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

Model at CCMC: BATSRUS
Magnetosphere in Different Cut Planes

- Meridional cut $Y=0$
- Equatorial cut $Z=0$
- Cross-tail cut $X=-15 \, R_E$

- Magnetotail
- Magnetopause
- Bow shock
- Magnetotail current sheet
Magnetosphere:
Quiet vs. Compressed
Geosynch. orbit $R=6.6\ Re$

Magnetopause
Magnetopause Stand-off Distance

Degree of compression of MP
Due to Pdyn of solar wind
(interplanetary shock or HSS)

$\text{r}_0 \leq 6.6 \text{ Re} - \text{model product}$

Events: Apr 5, 2010,
Dec 28, 2010
Jan 6, 2011, 22:30 UT
Non-event: Dec 1 – 7, 2010
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


Threshold Kp>=6

Watch the video

Mysteries of the Sun: Magnetosphere

http://missionscience.nasa.gov/sun/sunVideo_04magnetosphere.html
Inner Magnetosphere
(up to ~ 10 RE)

Van Allen Belts
400 keV – 6 MeV

Plasmasphere
1-10 eV

Ring Current
1-400 keV
Electron Total Flux. Energy 63.3 keV. Color Contour

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

solid line: Fok–RC boundary

dashed: geosynchronous orbit

Model at CCMC: Fok–RC

Equatorial Plane
Magnetopause
Geosynch. Orbit

Earth radius

Sun
Ring Current: Quiet vs. Active
HSS and Radiation Belt Electron Flux Enhancement

Click the check boxes to toggle series visibility.