# Geomagnetism and SWPC Report of Solar and Geophysical Activity

**Introduction**: The Space Weather Prediction Center *Report of Solar and Geophysical Activity* (SWPC RSGA) issued each day at 2200 UTC includes a 24-h Geophysical Activity Summary covering from 2100 the previous day to 2100 the current day and a Geophysical Activity Forecast covering the next 3-d period.

The RSGA frequently contains terms and phrases of space weather observations such as "*ACE spacecraft*" and magnetic measurements by ACE of "*southward Bz*" and "*Bt*". RSGA also frequently mentions "*greater than 2 MeV electron flux at geosynchronous orbit*" and occasionally mentions "*solar sector boundary crossing*" and "*geomagnetic crochet*". Below is a brief discussion of these report elements.

SWPC resources:

- SWPC homepage: http://www.swpc.noaa.gov/
- RSGA webpage: http://www.swpc.noaa.gov/ftpmenu/forecasts/RSGA.html

**ACE spacecraft**: The Advanced Composition Explorer (ACE) spacecraft has orbited the L1 libration (Lagrangian) point since 1997. L1 is a point between Earth and Sun where the gravitational pulls of the two bodies cancel. The distances are about 1.5 million km from Earth (240$R_E$) and 148.5 million km from the Sun. The spacecraft moves in a Lissajous orbit around this point and is kept there by active maneuvering. ACE monitors many parameters including the solar wind characteristics, interplanetary magnetic field (IMF, also called the solar wind magnetic field) and higher energy particles accelerated by the Sun toward Earth. Image right courtesy of NASA.

Because the spacecraft location is between Earth and Sun, it provides advance warning of space weather moving toward Earth from the Sun. The advance warning time depends on the solar wind speed. The average solar wind speed is around 470 km/s, and it covers the 1.5 million km distance in about 55 min. Of particular interest are potentially hazardous geomagnetic storms resulting from solar activity such as Earth-directed flares, coronal mass ejections (CME) and coronal hole high-speed streams (CHHSS).

The IMF is a vector field, which is broken into three directional components *Bx*, *By* and *Bz*. The total (vector sum) is designated *Bt*. The component *Bx* lies along the Sun-Earth line and *By* is at a right-angle such that the two form a plane parallel to the ecliptic. *Bz* is perpendicular to the ecliptic roughly parallel to Earth's spin axis. *Bz* is created by waves and other disturbances in the solar wind. This component couples the IMF and geomagnetic field when the direction of *Bz* is opposite, or anti-parallel, to Earth's field, resulting in the transfer of energy, mass, and momentum from the solar wind flow to the magnetosphere. The strongest coupling and the most dramatic magnetospheric effects occur when *Bz* is oriented southward. The IMF's amplitude near Earth varies from 1 to 37 nT, with an average value of about 6 nT.

The RSGA Summary often reports the amplitude and direction of *Bz*. For example, a report may read "*Observations from the ACE spacecraft observed a period around 06/1350Z of southward Bz to –5nT*".

This example gives the measurement day/time (the Z suffix is Zulu, or UTC, time reference) and indicates the amplitude of *Bz* is slightly less than average and is in a direction that can couple with Earth's field. Note: For reporting purposes ACE was replaced by DSCOVR spacecraft in late 2016. DSCOVR provides the same functions.

Resources:

- http://www.srl.caltech.edu/ACE/
- http://xuv.byu.edu/docs/previous_research/euv_imager/documentation/part3/3IMF.html

**Electron flux**: Electron flux is reported in RSGA because of its potentially deleterious effects on spacecraft and satellites. Enhanced fluxes of charged particles, such as electrons and protons, for an extended period of time have been associated with deep dielectric charging anomalies in satellite electronic equipment and have caused satellite upset events.

Electron flux is the rate of electron flow through a surface area. It has energy associated with it and is measured in units of electrons per square centimeter per second per steradian (electrons/$cm^2$-s-sr). A convenient unit is the energy an electron obtains when accelerated through 1 volt of electric potential difference (1 eV).[1] A similar unit is the proton flux unit, or pfu, in protons/$cm^2$-s-sr. The solar wind or plasma cloud moving away from the Sun consists of charged particles of varying energy, but of interest here are high-energy relativistic particles (> 2 MeV). A relativistic particle has a speed that is a significant fraction of the speed of light and correspondingly increased mass.

When the RSGA Summary mentions the "*greater than 2 MeV flux at geosynchronous orbit*", it refers to measurements made by the Geosynchronous Operational Environmental Satellites (GOES), which are placed in geostationary orbit about 35,800 km above Earth's surface. GOES 5-minute averaged integral proton flux is measured for energy thresholds of ≥10, ≥50 and ≥100 MeV. SWPC's proton event threshold is 10 protons/$cm^2$-s-sr at ≥10 MeV.

SWPC issues an "*Electron Alert when the greater than 2 MeV GOES electron flux exceeds $10^3$ pfu level in a day when no values on the previous day were above that threshold. The event continues for each subsequent day where the flux meets or exceeds the threshold. Event end occurs when a complete UT day passes where the electron flux never meets the threshold.*"[2]

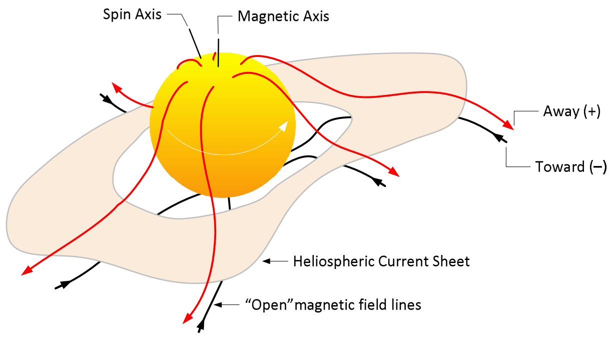
Resources:

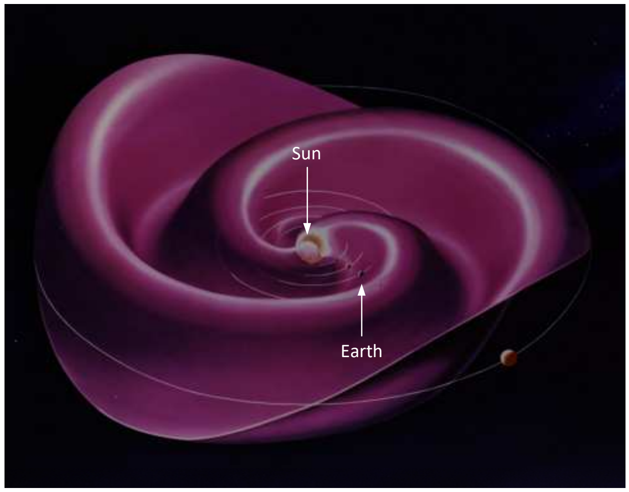
- http://www.oso.noaa.gov/goes/
- http://www.swpc.noaa.gov/info/Satellites.html
- http://www.swpc.noaa.gov/info/Satellite.pdf
- [Ukhorskiy] Ukhorskiy, A. Y., Sitnov, M. I., Sharma, A. S., Anderson, B. J., Ohtani, S., and Lui, A. T. Y., Data-derived forecasting model for relativistic electron intensity at geosynchronous orbit, Geophysical Research Letters, Vol. 31, L09806, doi:10.1029/2004GL019616, 2004

[1] The basic units of potential difference, or voltage, are joules/coulomb, or energy per electric charge. The electron has unit charge of ~$1.6 \times 10^{-19}$ coulombs, so the energy of 1 eV = ~$1.6 \times 10^{-19}$ joules.

[2] Personal communication from Larry Combs, SWPC, on 16 April 2011.

- **Solar Sector Boundary Crossing (SSBC)**: The RSGA occasionally includes something like "*Measurements by the ACE spacecraft show a solar sector boundary crossing occurred at 28/1445Z.*" As the solar wind flows away from the Sun, the IMF is carried with it. The solar wind has a spiral shape as it extends out from the Sun due to the Sun's rotation. Along the solar magnetic equator the opposite polarity field lines are parallel, creating a current sheet between them called the *heliospheric current sheet*, or HCS (see image upper-right, adapted from [Smith 1978]. The current sheet is warped and develops folds, or sectors, because the Sun's rotational and magnetic axes are not always aligned (image lower-right, courtesy of Stanford Solar Center, adapted). Along the ecliptic plane, the IMF generally has 2 or 4 sectors per solar rotation (27 d). When Earth, in its orbit around the Sun, crosses one of these folds there is a change in the solar wind's magnetic orientation, or polarity, and this is called a solar sector boundary crossing. A well-defined sector boundary crossing has a uniform field direction for about 4 d before and after the crossing.

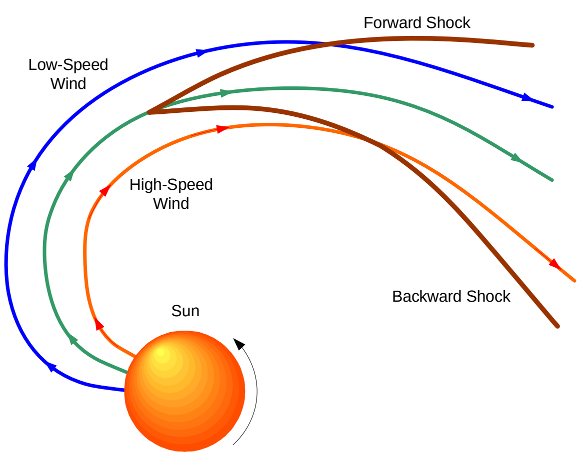



Resources:

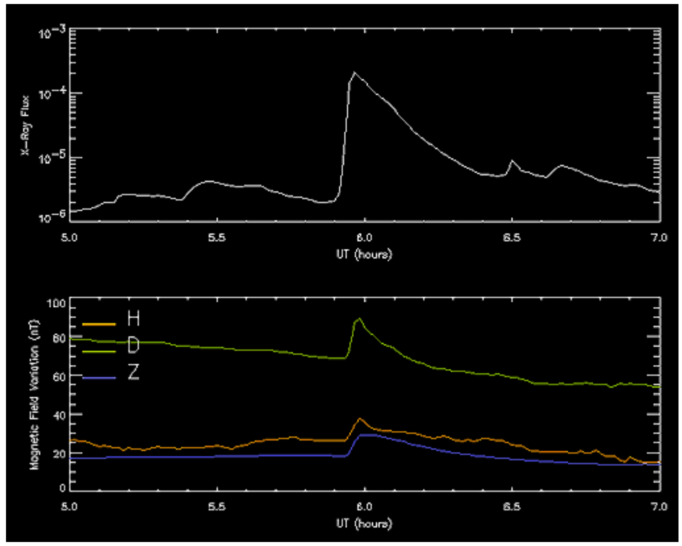
- http://wso.stanford.edu/SB/SB.html
- [Smith 1978] Smith, E and Tsurutani, B., Observations of the Interplanetary Sector Structure up to Heliographic Latitudes of 16°: Pioneer 11, Journal of Geophysical Research, Vol. 83, No. A2, February 1, 1978

**Corotating Interaction Region (CIR)**: The solar wind speed depends on many factors associated with the sunspot cycle. During the descending and minimum phases of the sunspot cycle, the solar wind is dominated by coronal hole high-speed streams with speeds in the range of 500 – 800 km/s. The solar wind also has a denser low-speed component with a speed of around 300 km/s associated with the equatorial coronal streamer belt. The overall average speed is in



the vicinity of 470 km/s.

The high- and low-speed components form alternating streams in the solar wind flow. They move outward into inter-planetary space in a spiral due to the Sun's rotation. As the streams travel away from the Sun, the high-speed streams overtake the slow-speed flows and create regions of enhanced density and magnetic field called *corotating interaction regions* (CIR) (image bottom-right of previous page).




**Geomagnetic Crochet**: A magnetic crochet is caused by the increased ionization in the ionosphere's D- and E- layers (60 to 100 km altitude) due to the massive increase in x-ray radiation generated by a large impulsive solar flare. This increases the conductivity allowing electric currents to flow more easily in the ionosphere. The sudden increase in the currents produces a jump in Earth's magnetic field. As the flare subsides, the ionospheric layers quickly return to their previous state and the electric currents and magnetic field return to normal. Unlike geomagnetic disturbances that arrive with CMEs 2 to 9 days after a flare, a magnetic crochet occurs while the flare is in progress. Magnetic crochets are observed only during very powerful flares that rise to a peak very quickly and where the observer is on the sunlit side of Earth. The upper panel in the image above (from http://www.ips.gov.au/Educational/3/1/1) shows the rapid rise in x-ray flux over time during a large solar flare, which resulted in a magnetic crochet, and the lower panel shows the resulting changes in the geomagnetic field components H, D and Z. The crochet shown here is upward (sudden increase) but downward crochets also occur.

Resources:

- http://www.ips.gov.au/Educational/3/1/1

**Document Information:**

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