Space Weather

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[1] ICSWSE
[2] KNCT

Outline

Overview of Space Weather

I. Space disasters

II. Space weather

III. Sun

IV. Solar wind (interplanetary space)

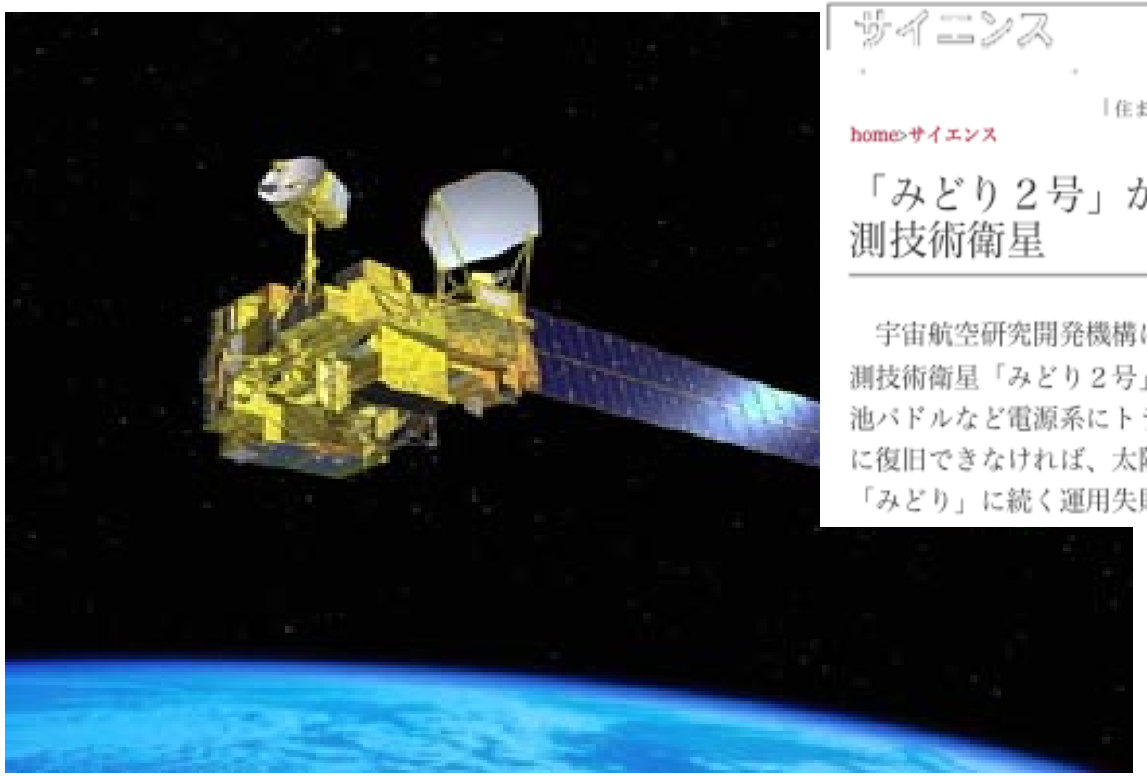
V. Magnetosphere

VI. Recent Space Weather

I. Space disasters

■Satellite breakdown（24/10/03)

Japanese satellite “Midori 2” disappeared on 24 Oct. 2003 because of intense solar activity.



asahi.com

CNN 世界情勢をいつでもどこ

天気 辞書 地図 サイト案内 アクセスTop

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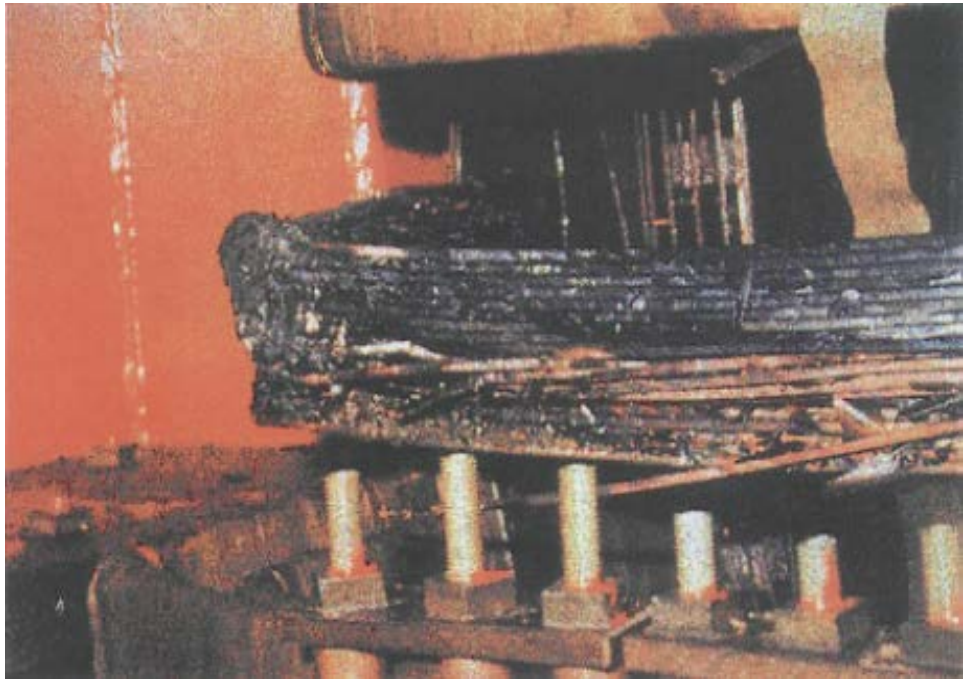
「みどり２号」からの信号途絶える　環境観測技術衛星

宇宙航空研究開発機構は２５日、昨年１２月に打ち上げた環境観測技術衛星「みどり２号」からの信号が途絶えたと発表した。太陽電池パドルなど電源系にトラブルが起きた可能性が高いという。数日中に復旧できなければ、太陽電池パドルの破断で機能が停止した先代の「みどり」に続く運用失敗になる。

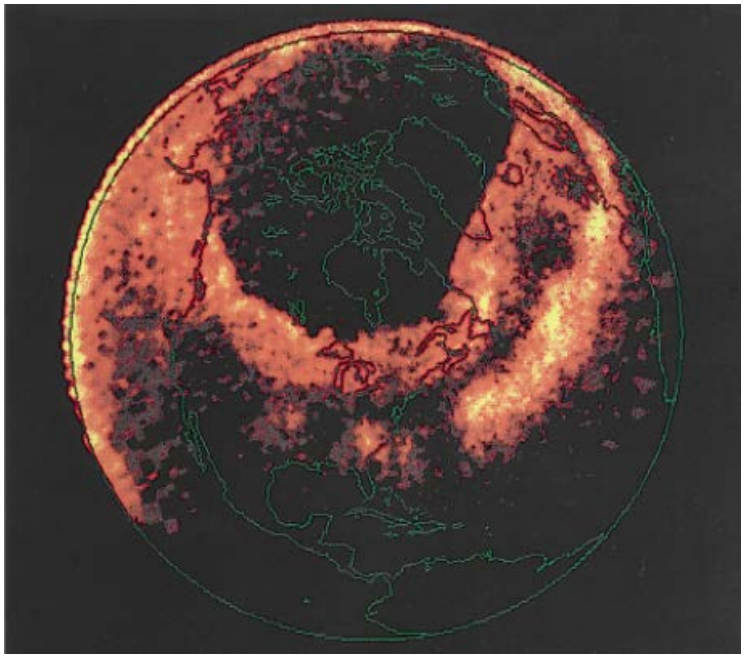
I. Space disasters

- Transformer fault (13 Mar. 1989, Quebec, Canada)

  Large-scale power failure occurred on 13 Mar. 1989 at Canada because the intense aurora flowed inductive current in the electric power line and a transformer broke down.



Broken transformer



At that time, intense Aurora was observed by a satellite Dynamics Explorer-1

I. Space disasters

- Train accident
  （5 Feb. 1986, Canadian Rockies)

Radio communication was disrupted, railway signaling failed, and so train accident occurred.

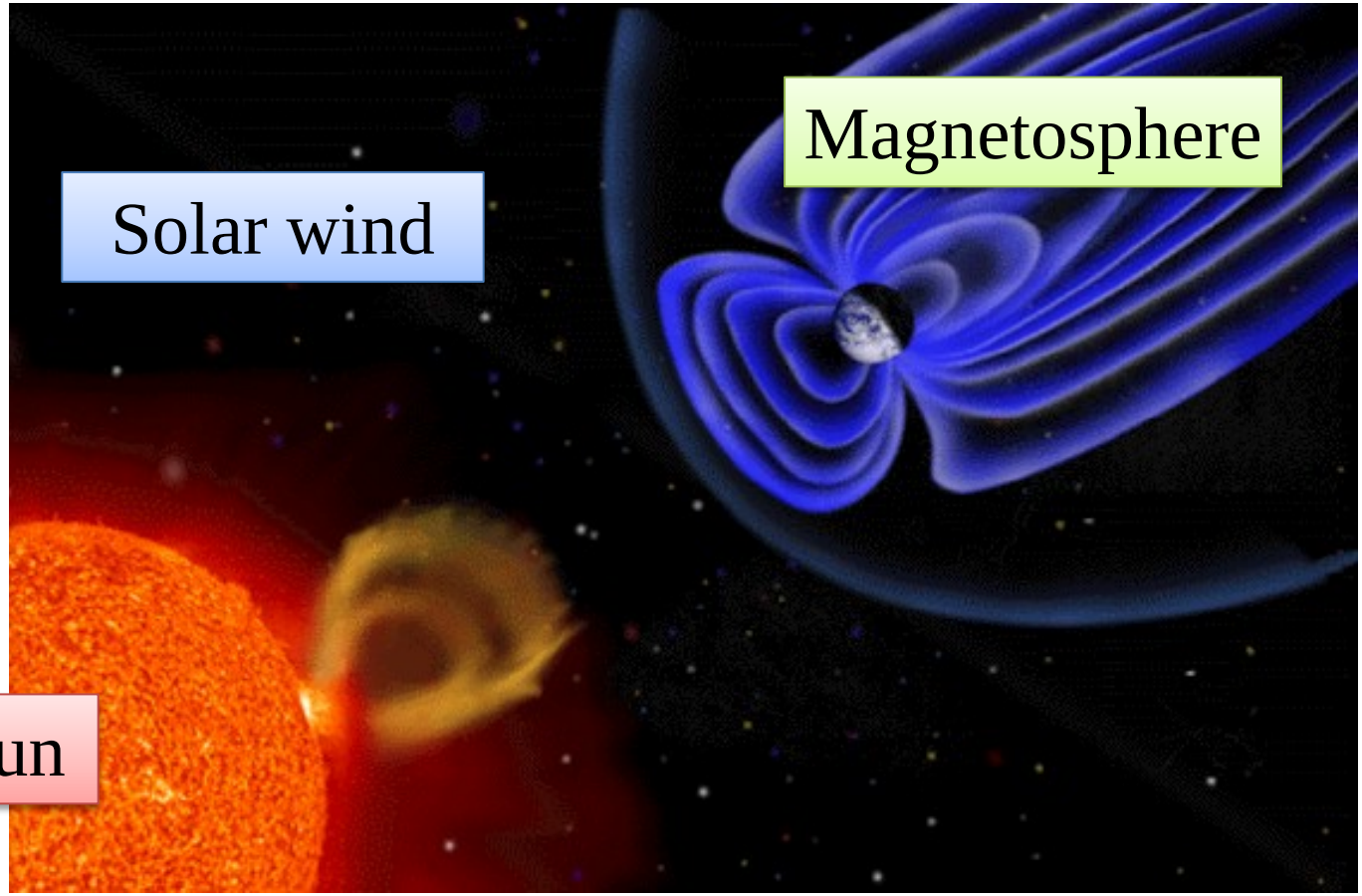
http://danger-ahead.railfan.net/

II. Space weather

- Recently, human activities intensify in the space environment. It becomes more important that we have a better understanding of the disturbances occur in space, and have a space weather forecasting system to prevent space disasters.

- Space environment for space weather is the space between the Sun and Earth and in the Earth's vicinity.

II. Stage of Space weather



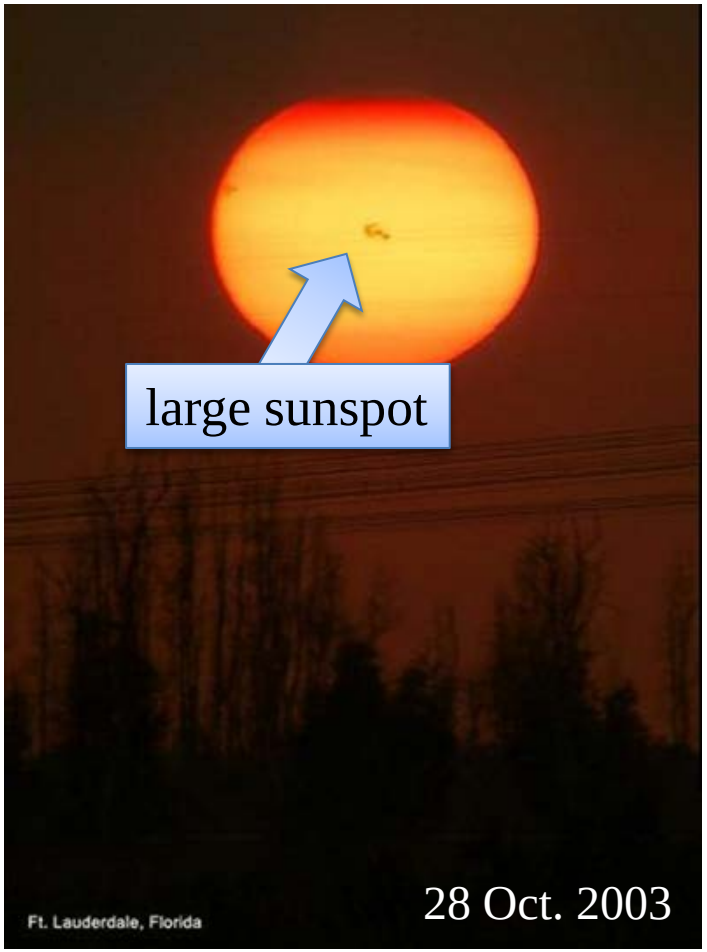
Nasa

The sun - Solar wind (interplanetary space) - magnetosphere

III. Sun

- An enormous amount of energy is constantly being radiated from the Sun and into space in the form of electromagnetic waves such as visible light, ultraviolet and infrared emissions. At the same time, solar atmosphere (corona) create outward flow of plasma (solar wind) which fills all regions of space surrounding the Sun.

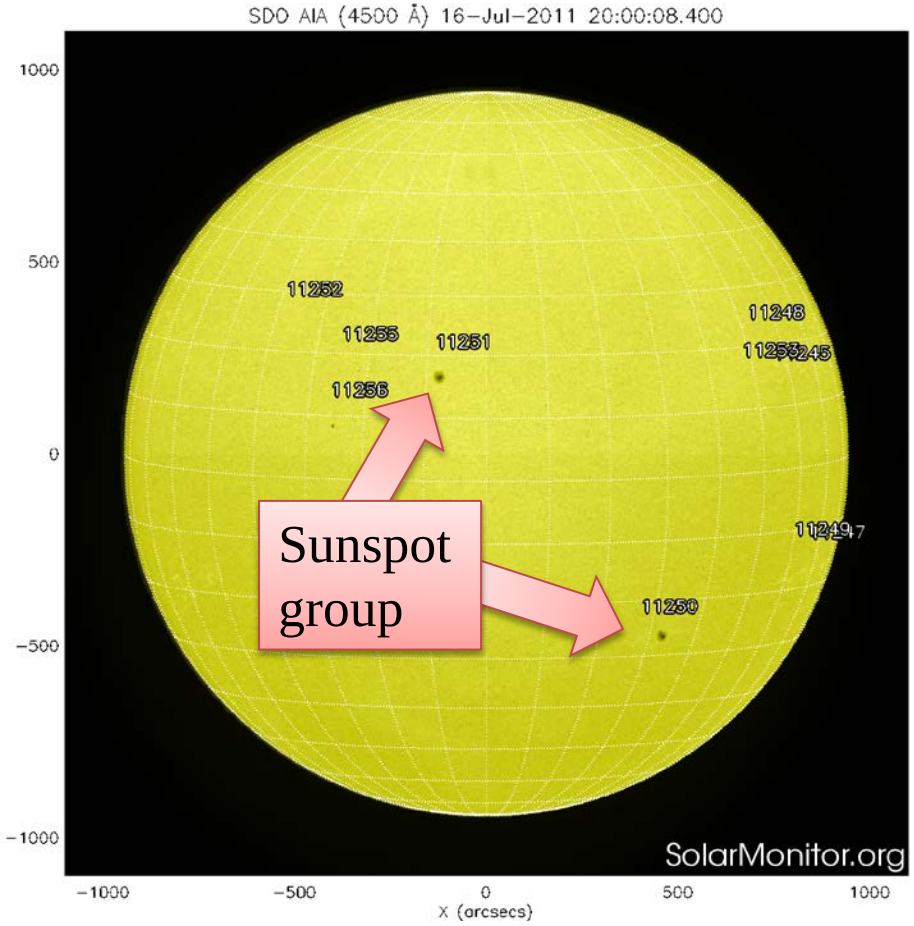
- The sun occasionally radiates energy through burst-like phenomena called solar flares and coronal mass ejections (CME), and these events produce drastic changes in the space environment.



III. Sun

Active regions (sunspot groups)

16 Jul. 2011



Optical wave length image

- Sunspots are dark spots on the solar surface.
- The scale size of large sunspots are larger than that of the Earth. They consists of a cold central umbra with very strong local magnetic fields.
- The relative sunspot number is one of a commonly used index.

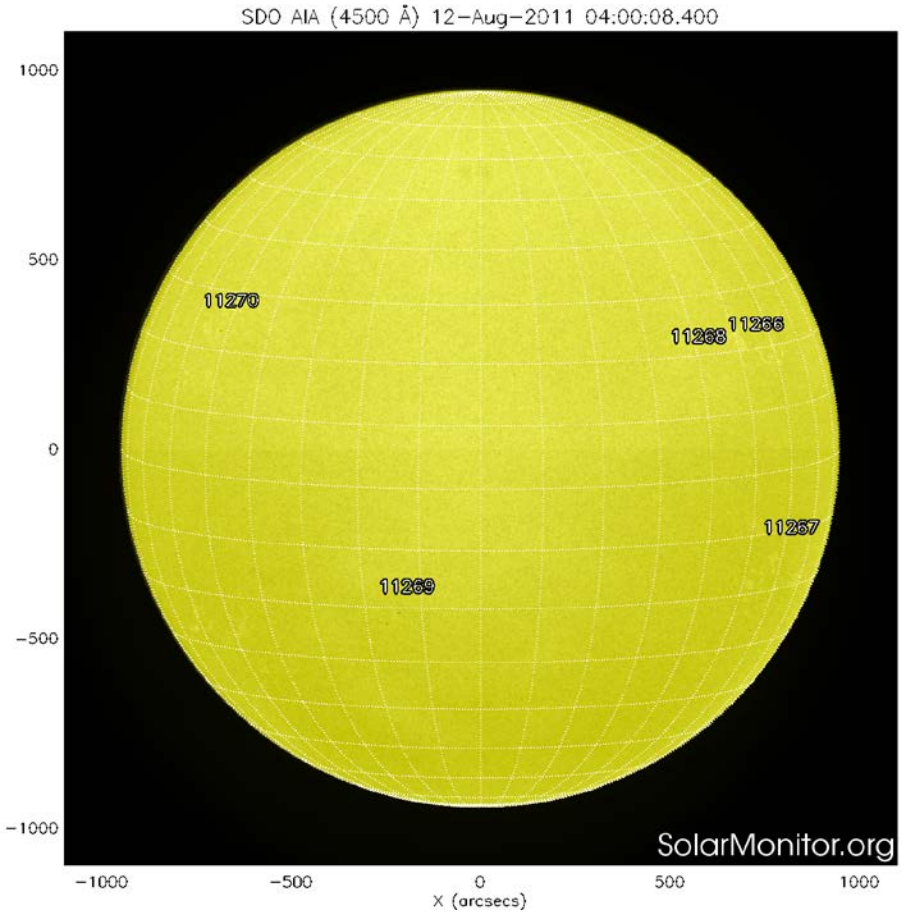
$$R=k(10g+f)$$

R:Sunspot number
k :coefficient to adjust for differences in the observer or telescope
g : number of sunspot groups
f : total number of individual sunspots

III. Sun

Active regions (sunspot groups)

12 Aug. 2011



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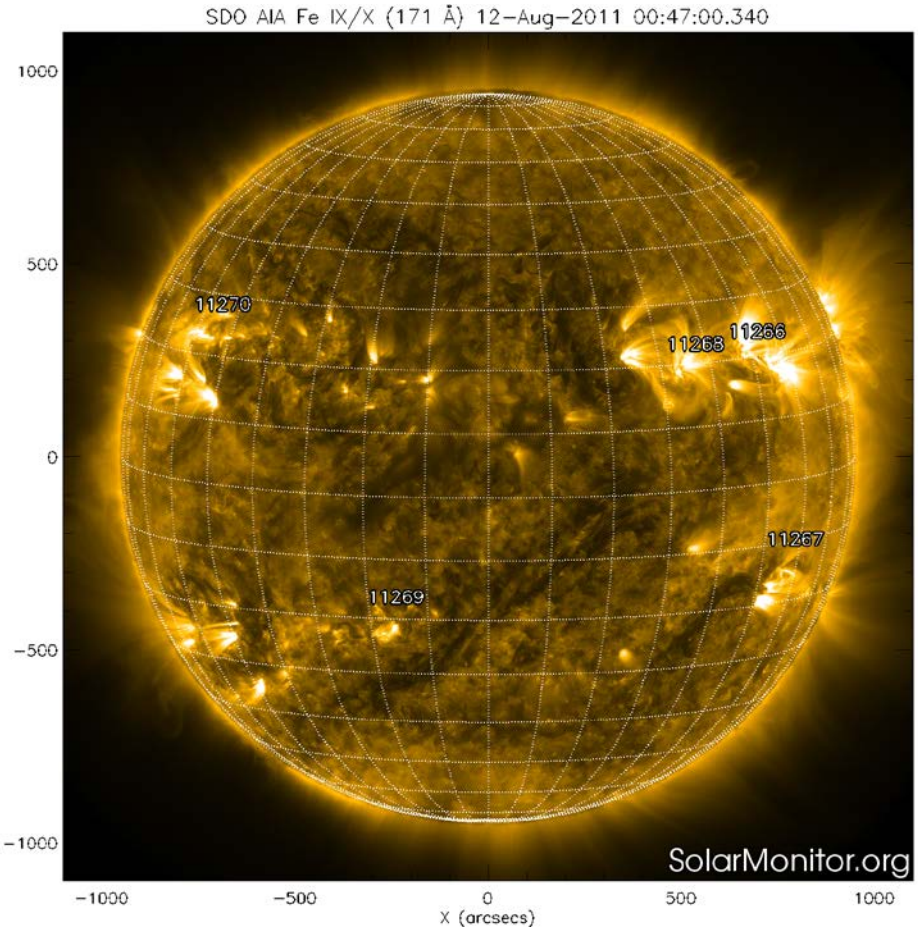


X-ray image

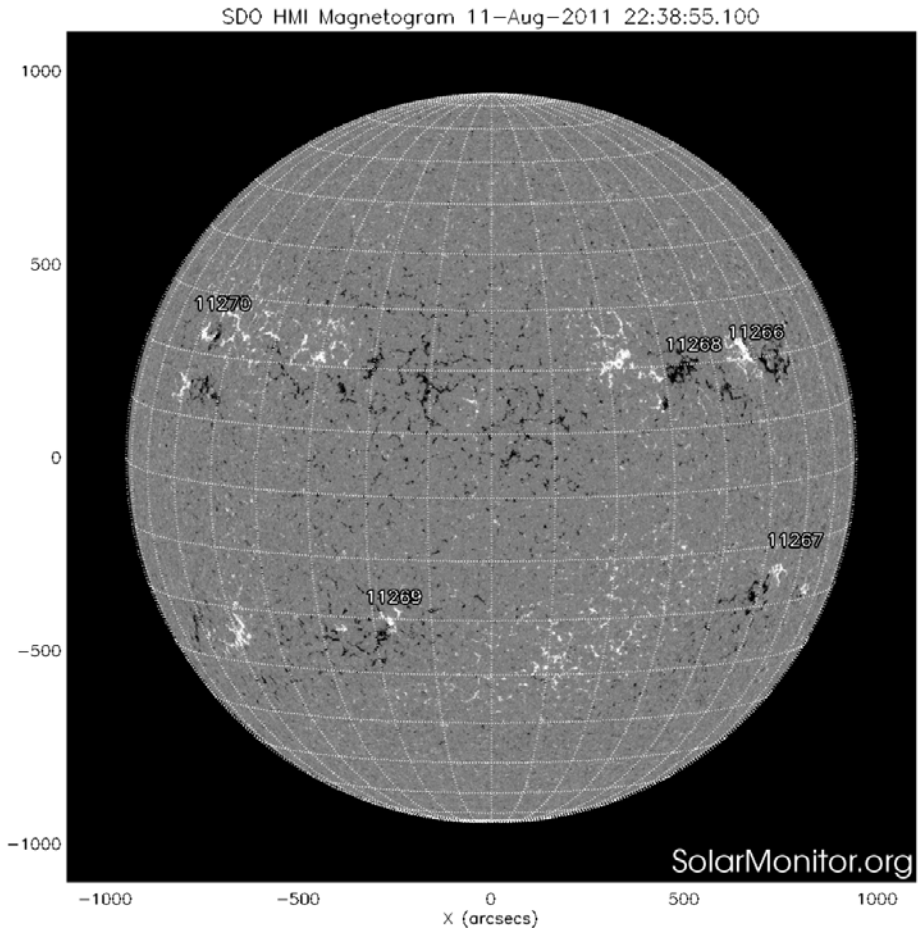
The left panel shows the sun taken by X-ray. We can see bottom of the solar corona.

- In the image, the sunspot groups are blight. The bright region is a called "active region" which is the group of sunspots.

III. Sun

Active regions (sunspot groups)

12 Aug. 2011



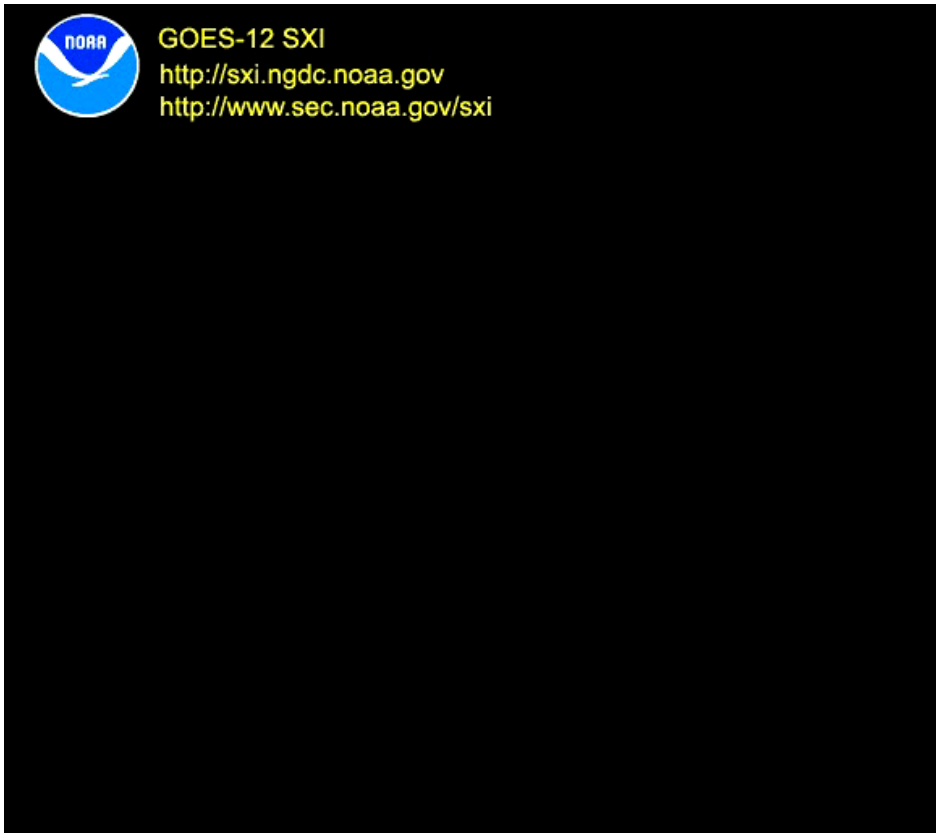
Magnetic field image

- Sunspots are dark spots on the solar surface that can be as large as 10^5 km. They consists of a cold central umbra with very strong local magnetic fields.

III. Sun

Flares

29 Oct. 2003

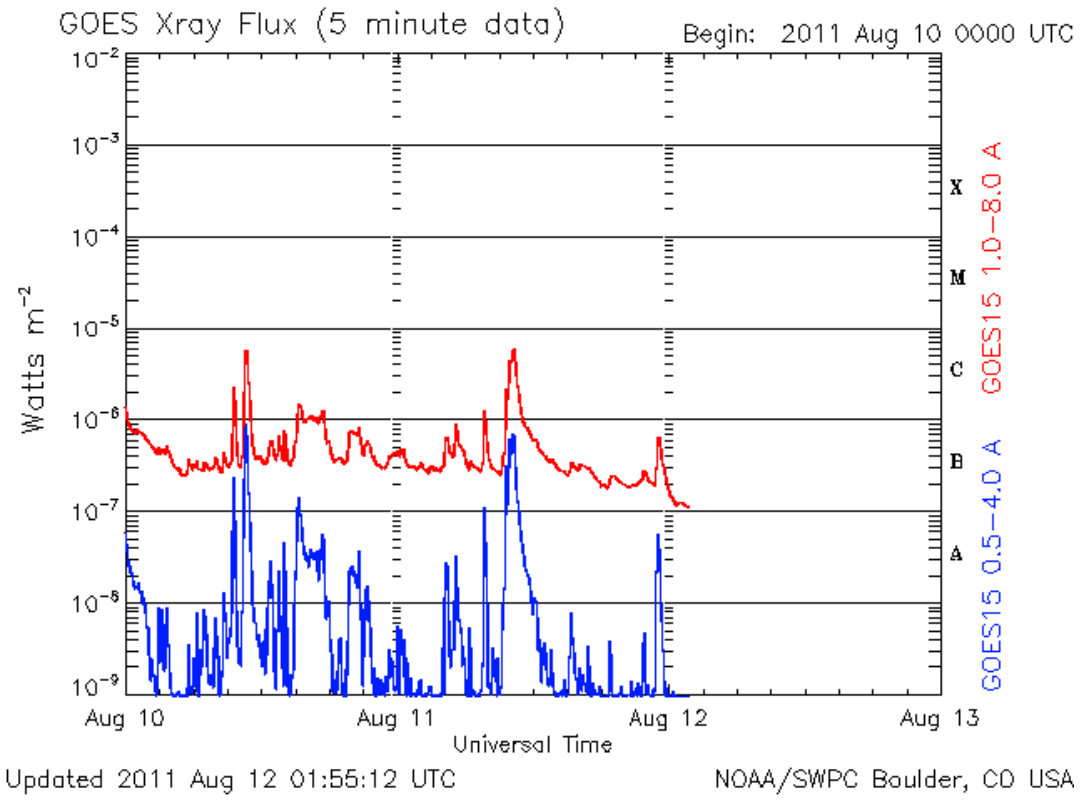


- A solar flare is a localized explosive release of energy that appears as a sudden, short lived brightening of an area in the chromosphere.
- Large flares eject large amounts of energetic particles.
- Flares are essentially high-energy particles.

III. Sun

X ray flux

X-ray intensity(10-12 Aug. 2011)

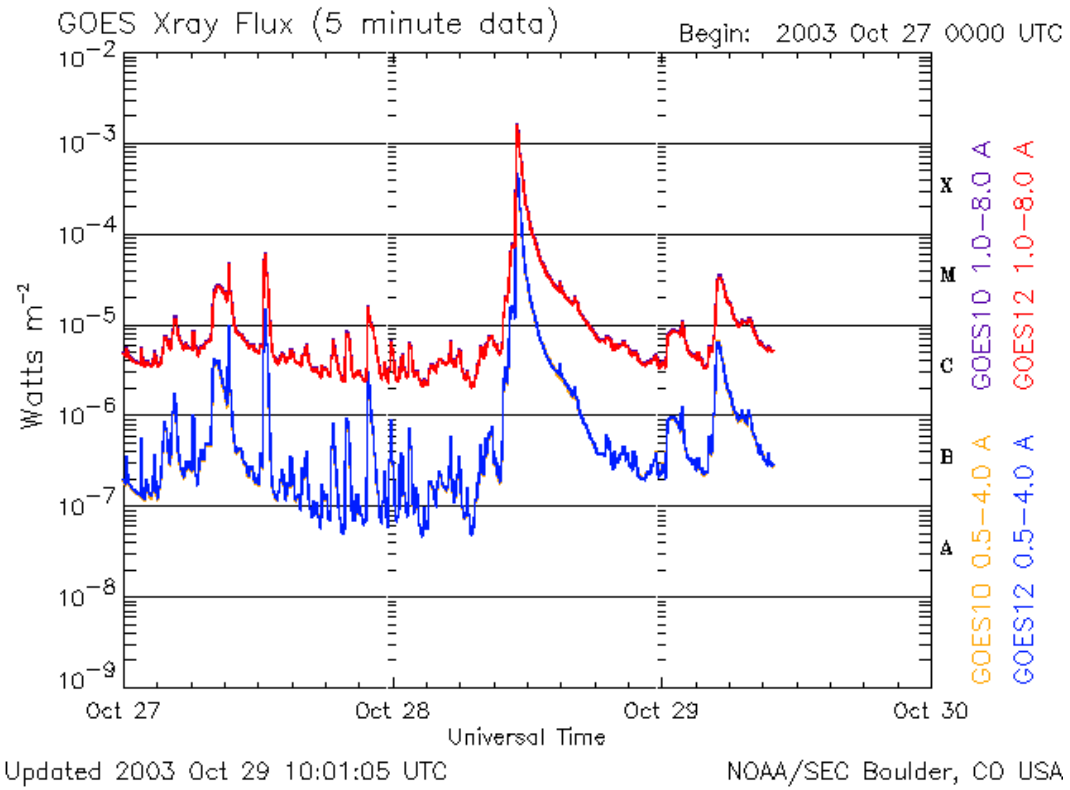


- Solar flares occur as explosive releases of energy in the outer atmosphere of the Sun, and radiate electromagnetic emissions that extend across the spectrum from γ- and X-rays, to the radio wave range.
- The enhancement of X-ray flux is observable around the Earth.
- The flares which are exceed “C class” are alarming phenomenon.

III. Sun

X ray flux

X-ray intensity(27-29 Oct. 2003)



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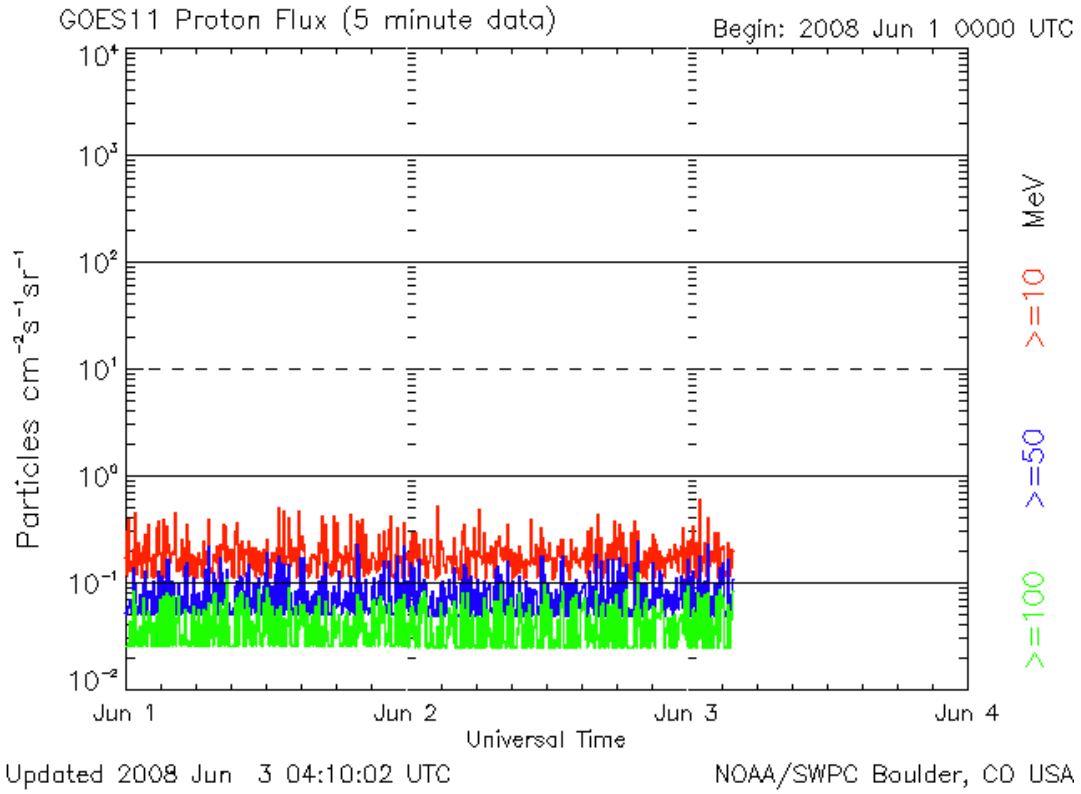
III. Sun

High-energy particles (Proton Flux)

Proton Flux (10-12 Aug. 2011)

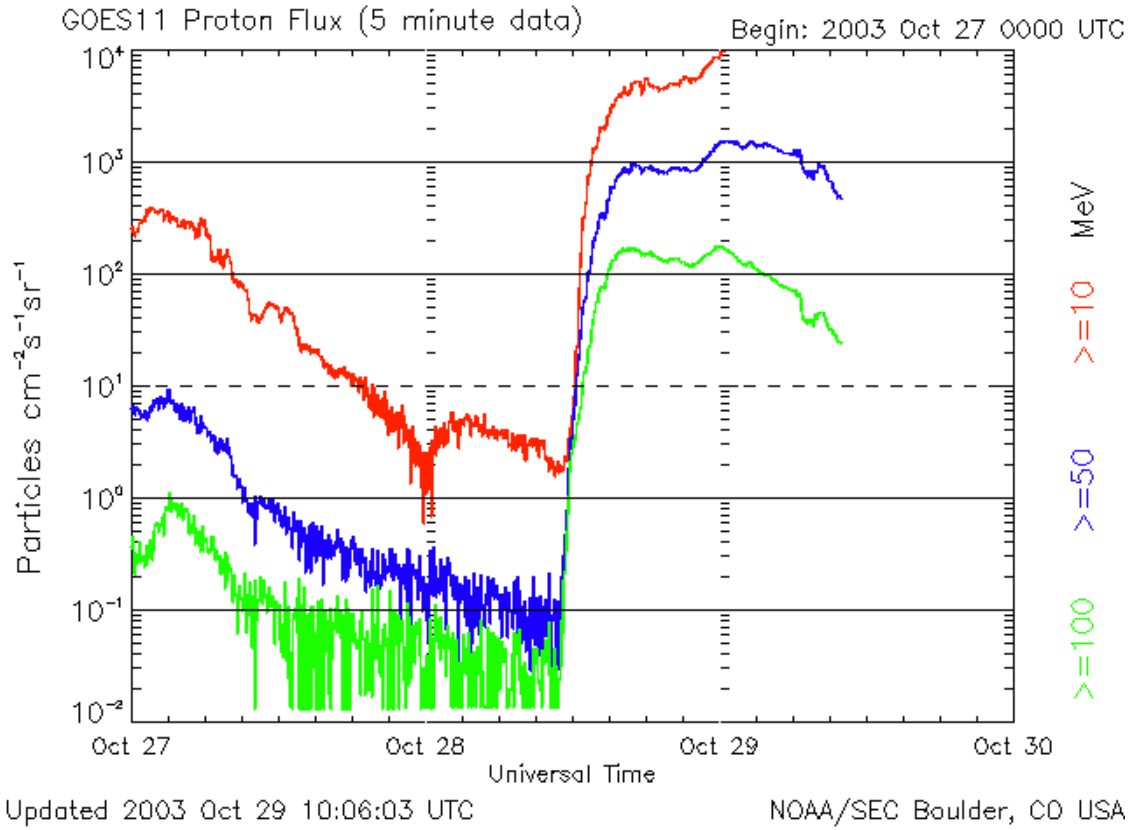


- High-energy particles are observable when large flares (or CMEs) occur.
- If density of the high-energy particles exceed the dashed line, It is “Proton event”. We need to alarm.

III. Sun

High-energy particles (Proton Flux)

Proton Flux (27-29 Oct. 2011)



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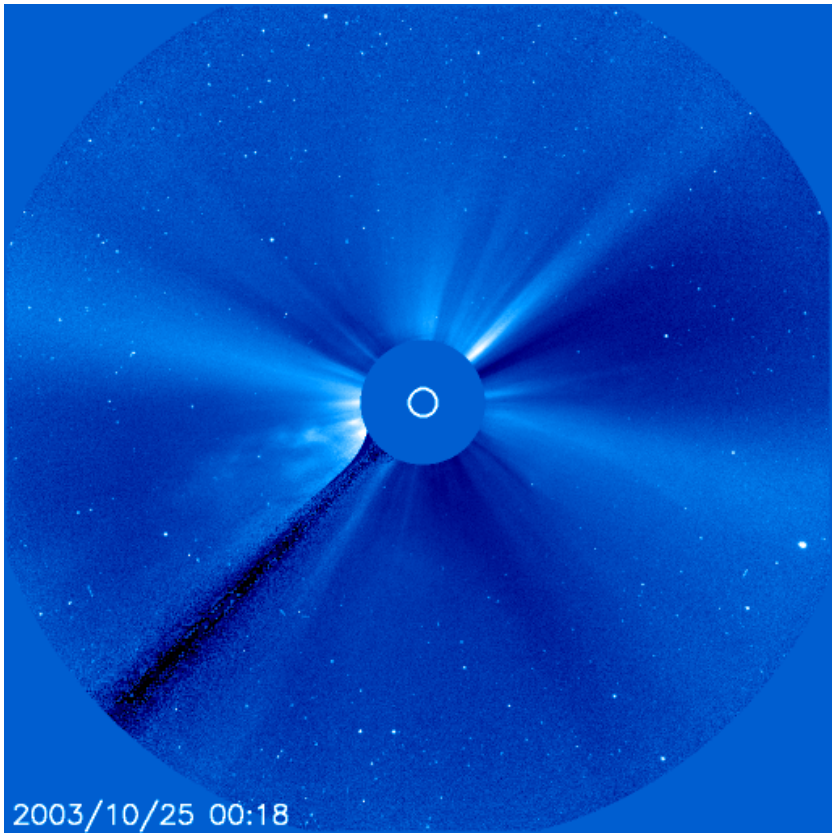
III. Sun

Coronal mass ejection (CME)

25-31 Oct. 2003



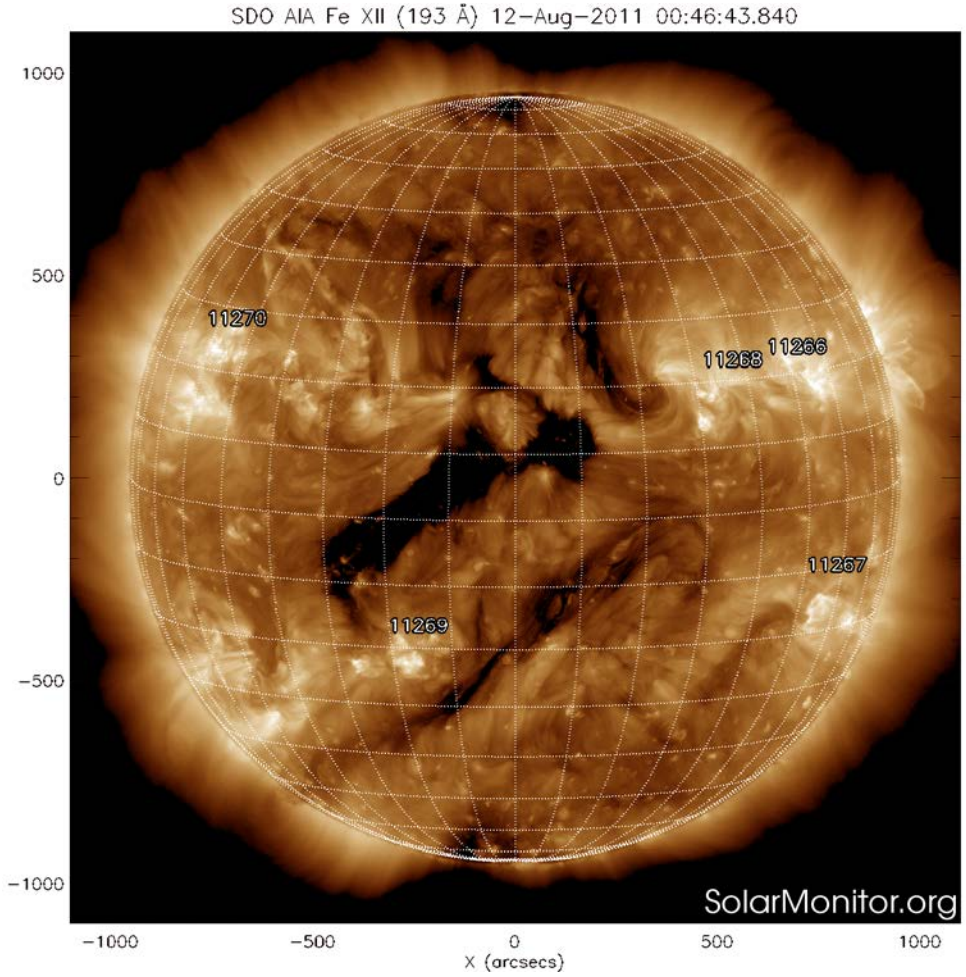
Coronagraph

- CMEs events originate in closed field regions in the corona, where magnetic field is strong enough to constrain the plasma from expanding outward.
- CMEs often occurs with flares, however CMEs are not generated by solar flares (The origin of CMEs not clear).
- CMEs mainly produce plasma.

III. Sun

Coronal holes

12 Aug. 2011



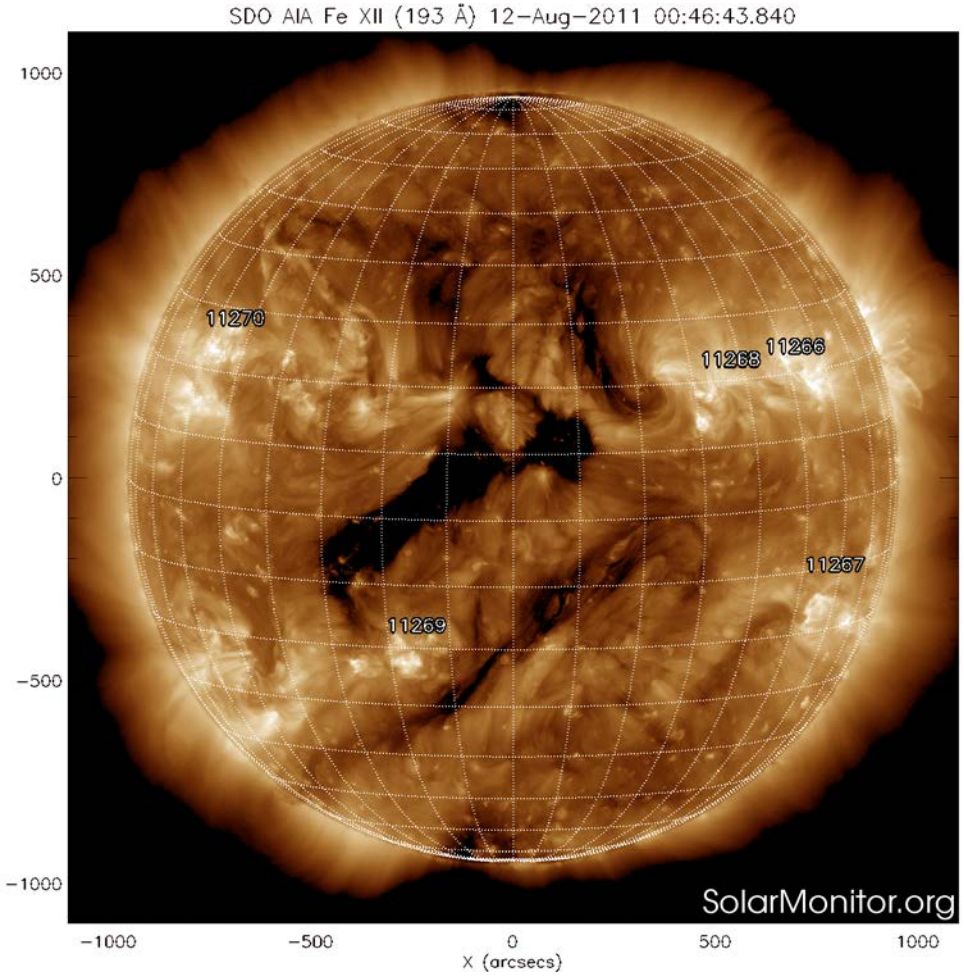
Extreme UV image

- Extreme UV images shows us the the upper corona.
- At this wavelength range, we observe the emission line spectrum produced by the heavy ions in the corona.
- The regions surrounding sunspots and other active regions are areas where the magnetic field is strong.
- The dark region in the X-ray image is called “coronal holes” ,where intensities of magnetic fields are weaker than those in active region.

III. Sun

Coronal holes

12 Aug. 2011



Extreme UV image

- The magnetic fields in the coronal holes are open and extending far out into interplanetary space.
- Life times of coronal holes can be as long as several months. Therefore the coronal holes reappear in the Sun's 27-day rotation cycle.
- High-speed solar wind flows from coronal holes and causes disturbance in the earth's magnetosphere.

IV. Solar wind (interplanetary space)

- The Sun radiates a stream of plasma we refer to as the "solar wind". The solar wind provides the energy that largely determines conditions within the space environment surrounding the Earth.

- The solar wind consists of a stream of plasma, and also carries the magnetic field of the solar corona into interplanetary space. The magnetic field is called the interplanetary magnetic field (IMF).

IV. Solar wind (interplanetary space)

Solar wind

2 Jun. 2008

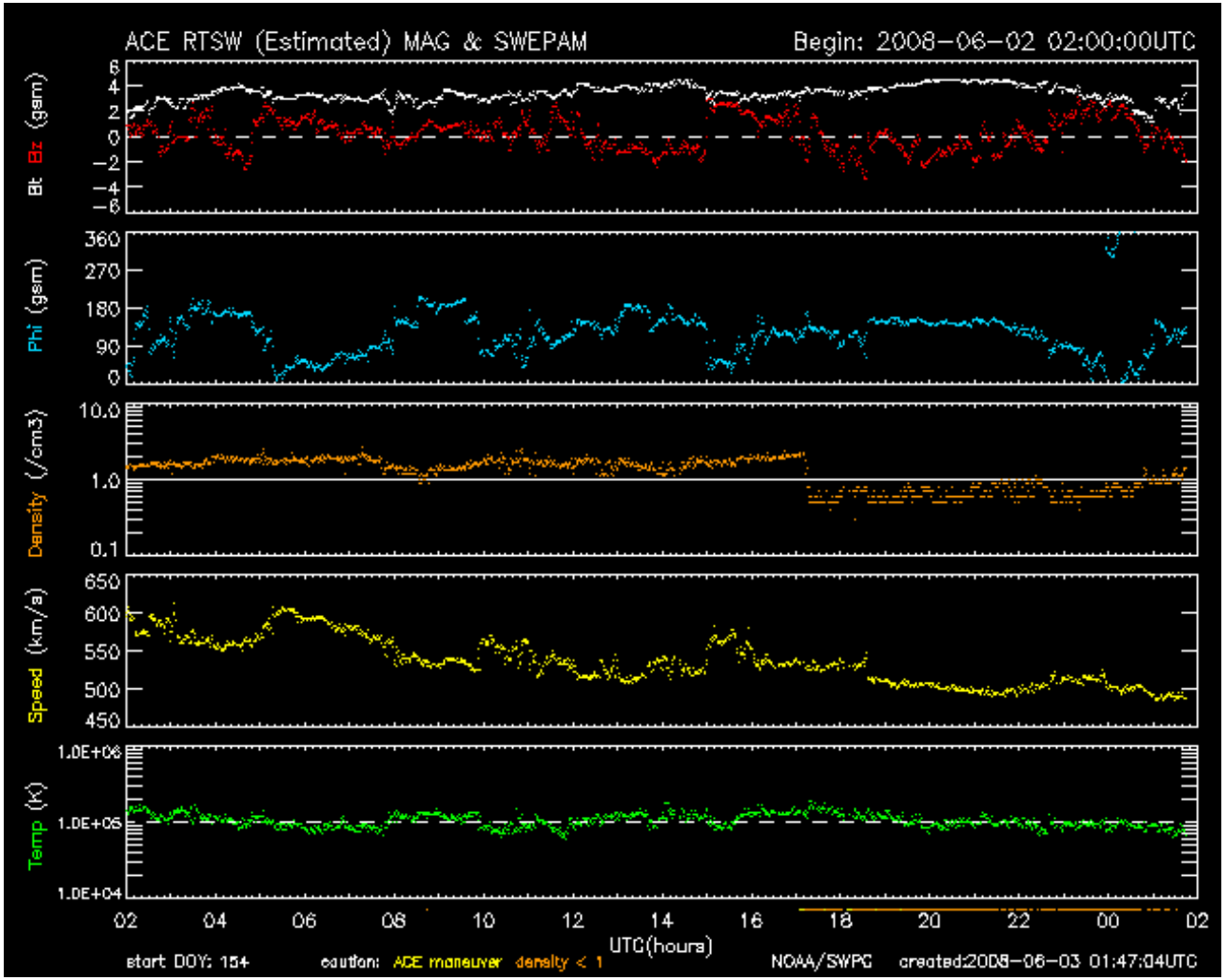
Magnetic field: Bt, Bz (nT)

Magnetic field: Phi (degree)

Density: (/cm3)

Speed: (km/s)

Temperature: (k)



IV. Solar wind (interplanetary space)

Solar wind

2 Jun. 2008

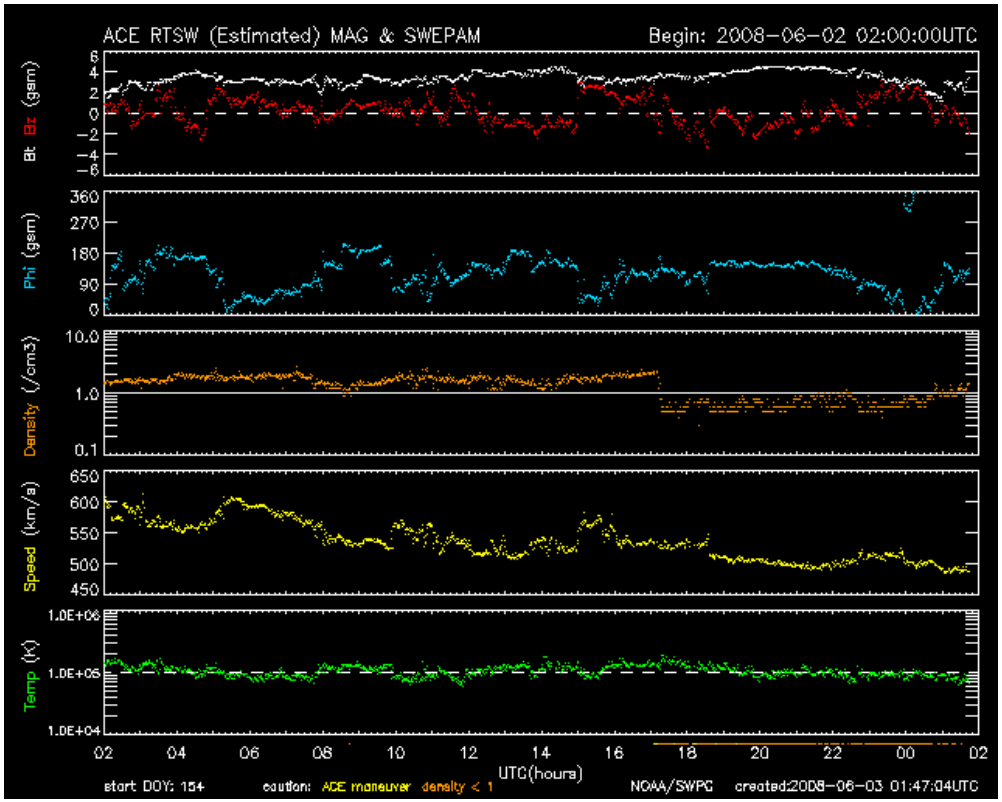
Bt,
Bz (nT)

Phi
(degree)

Density:
(/cm3)

Speed:
(km/s)

Temp.
(k)



UT

- We take particular note of variation of Bz, density(N), and speed(v).

  Bz → Storm, substomrs

  N → formation of the magnetosphere

  V → formation of the magnetosphere

- Near the Earth, typical values are as follows;
  V=450km/s, n=5/cc, T=10^5k and B=5nT

IV. Solar wind (interplanetary space)

Effect of coronal holes

Solar wind velocity (18 Apr. 2011 – 3 Aug. 2011)

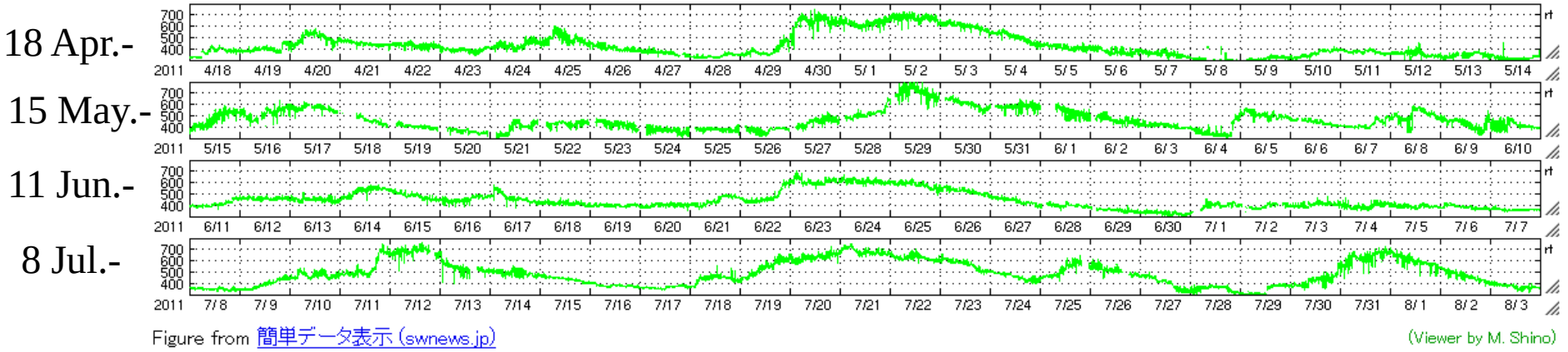


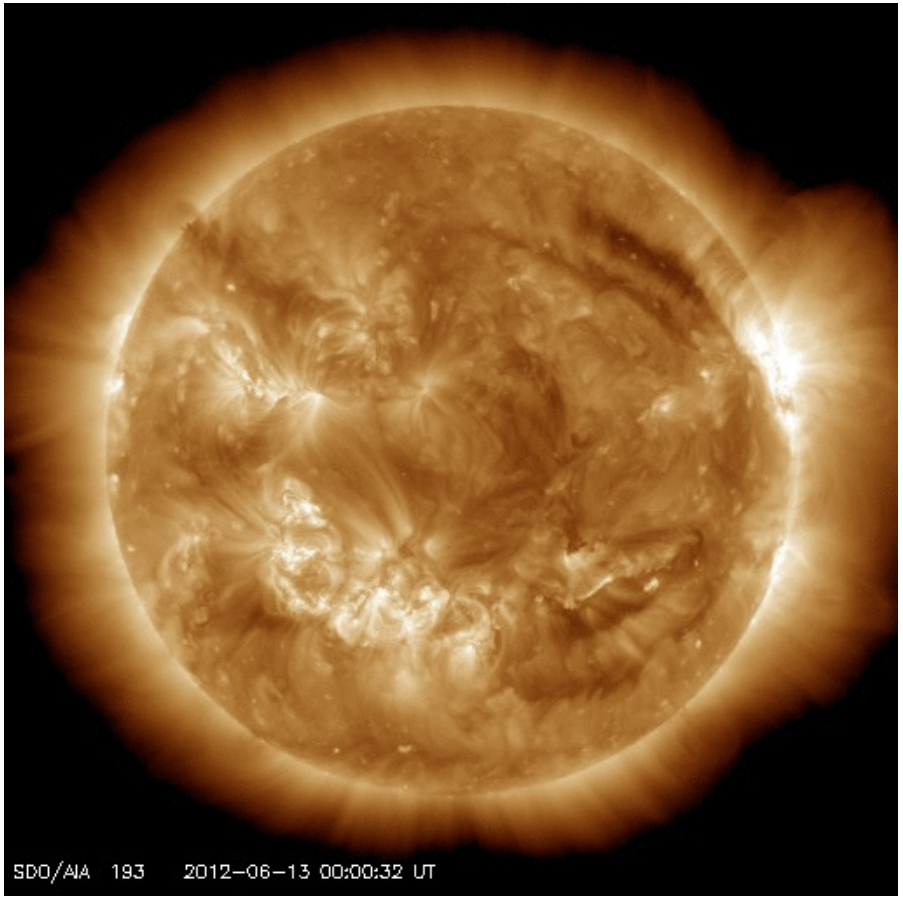
Figure from 簡単データ表示 (swnews.jp) (Viewer by M. Shino)

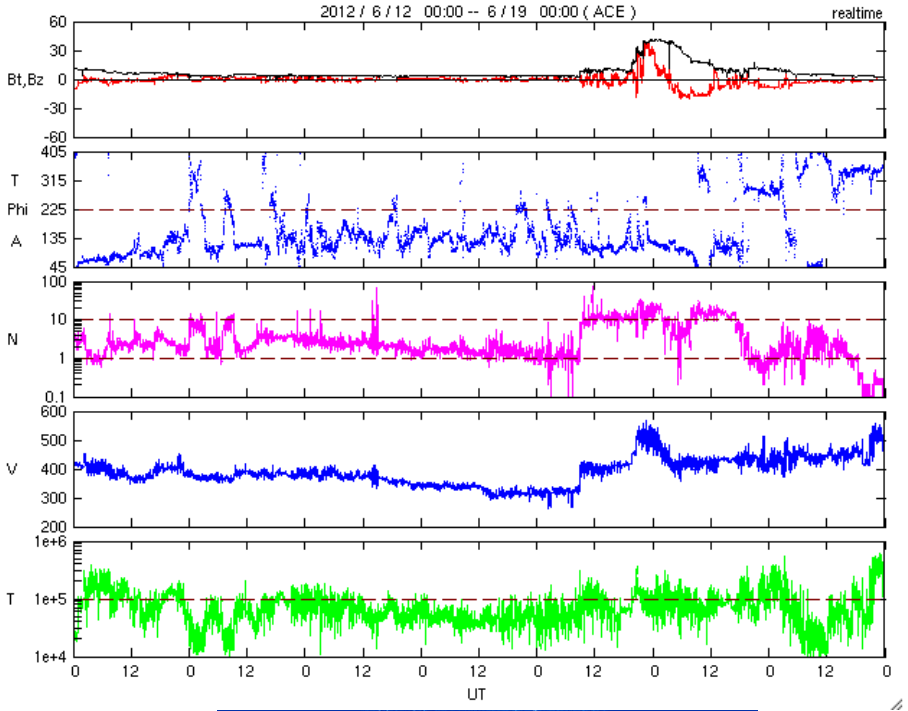
The period of the sun's rotates is 27 days, therefore the solar wind shows 27-day variations. Thus High-speed solar wind (from coronal holes) is observable periodically.

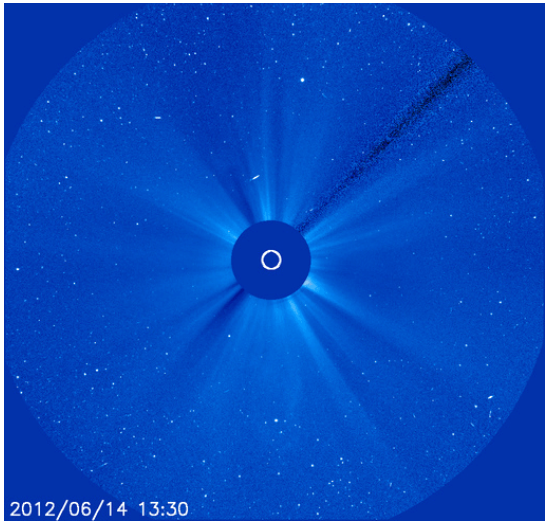
CME-type variation

- CME causes a increase of Bt, N, and V.
- CME-type variation is characterized by simultaneous increase of Bt, N, and V

6/12-14 CME
6/16 21:15UT- 6/17 13:00UT







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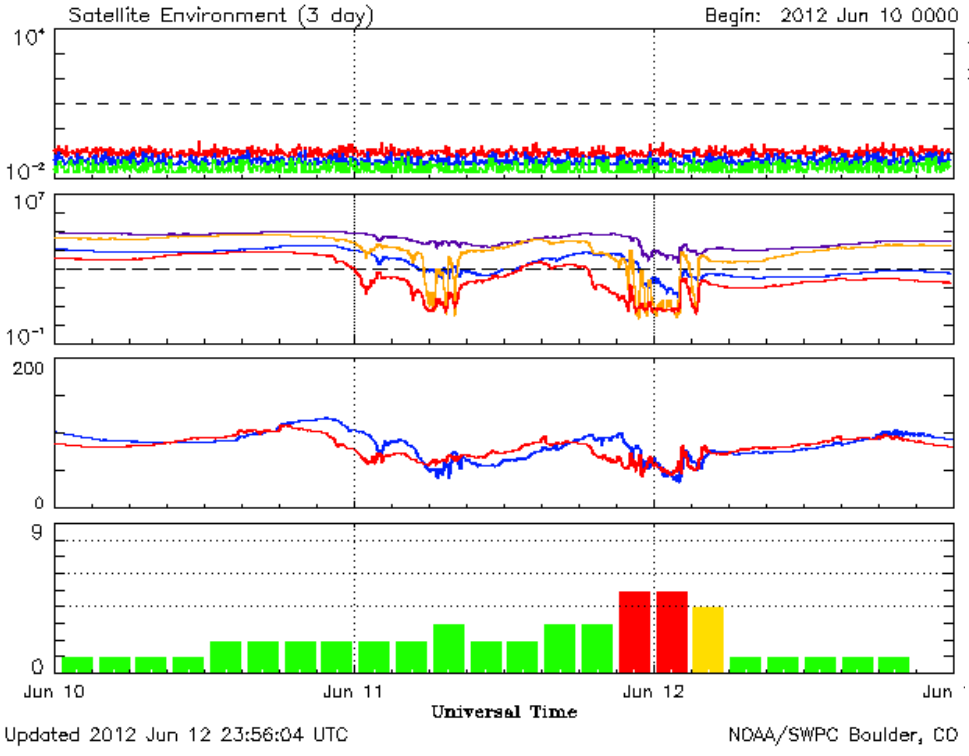
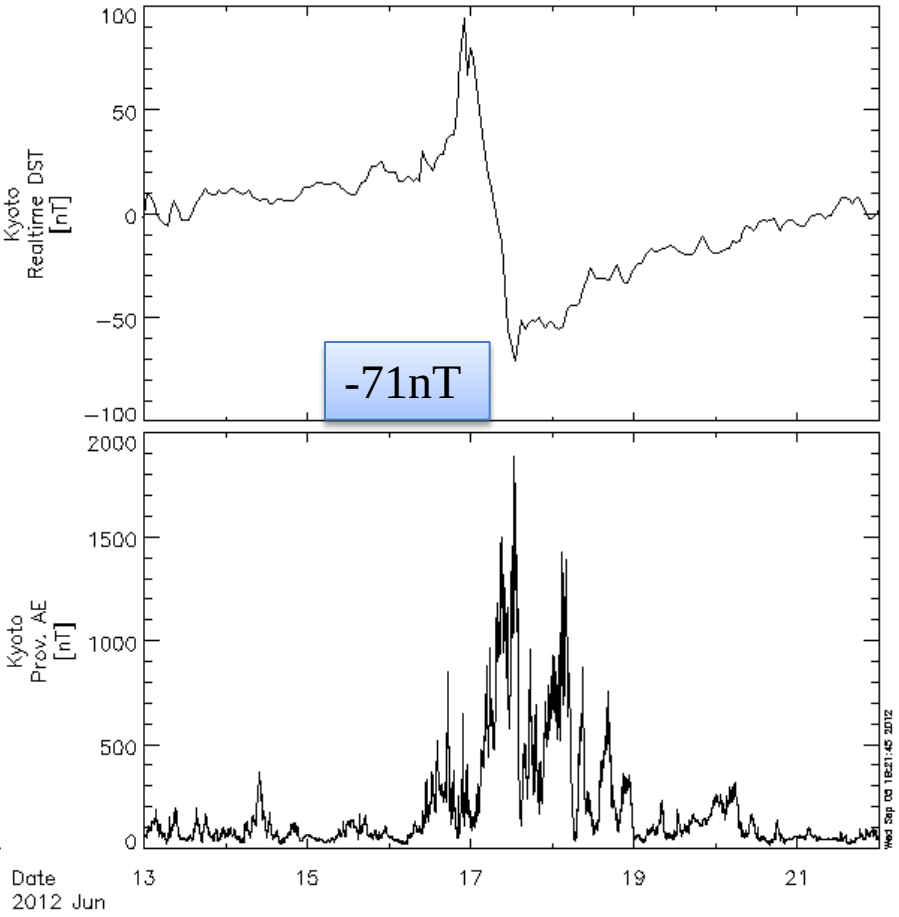
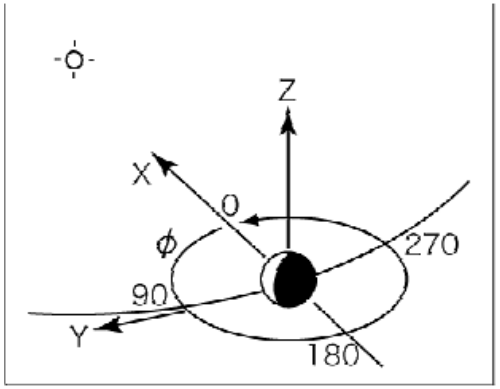




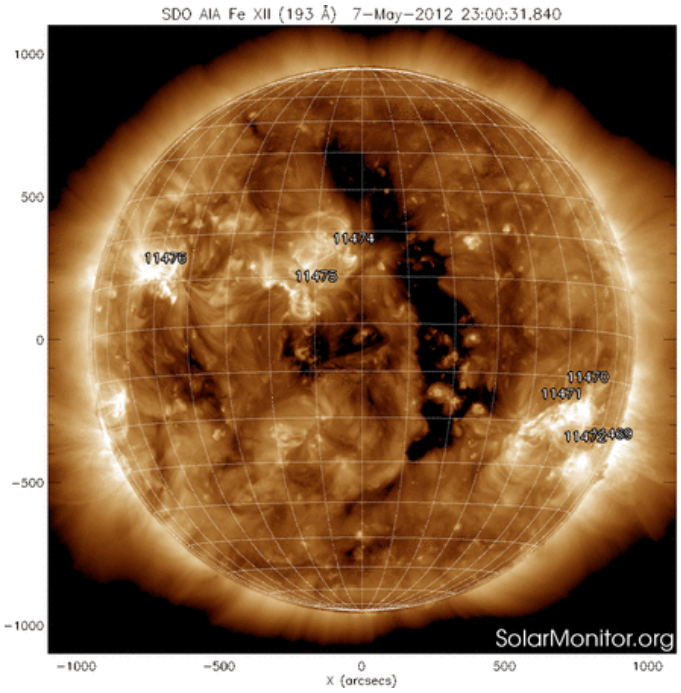
- CIR-type variation is caused by high-speed solar wind which is radiated from coronal holes.

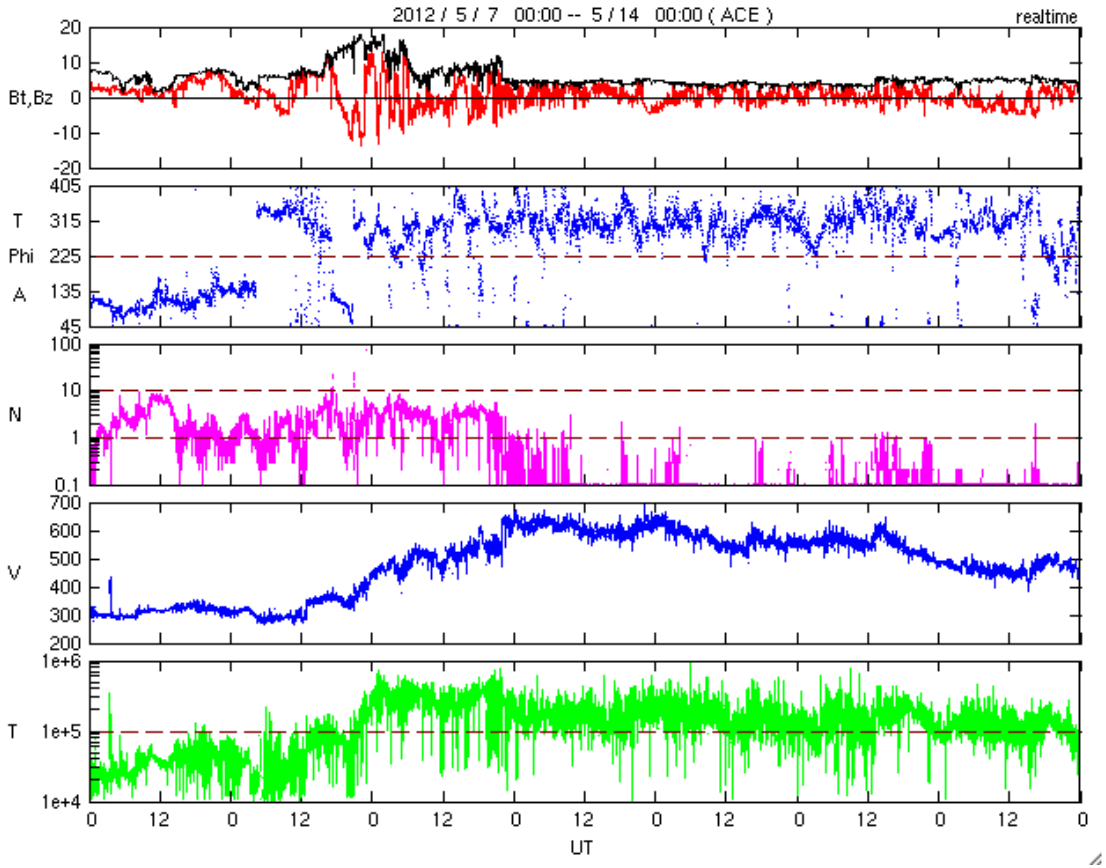
- In the case of CIR-type, Bt and N increases before high-speed flow arrives.



05/07-13

CIR-type variation





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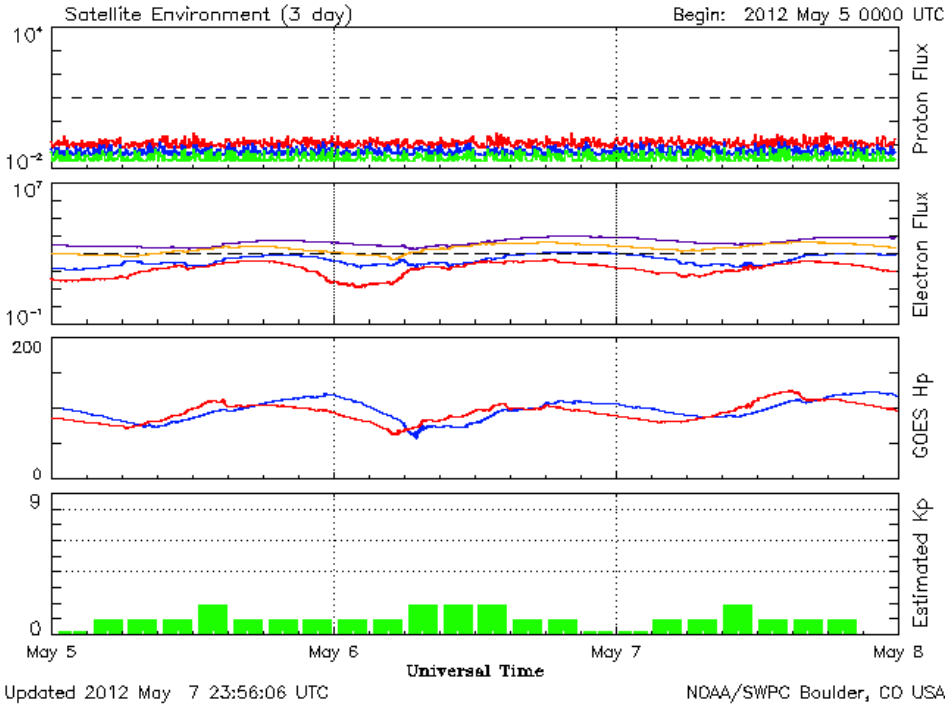
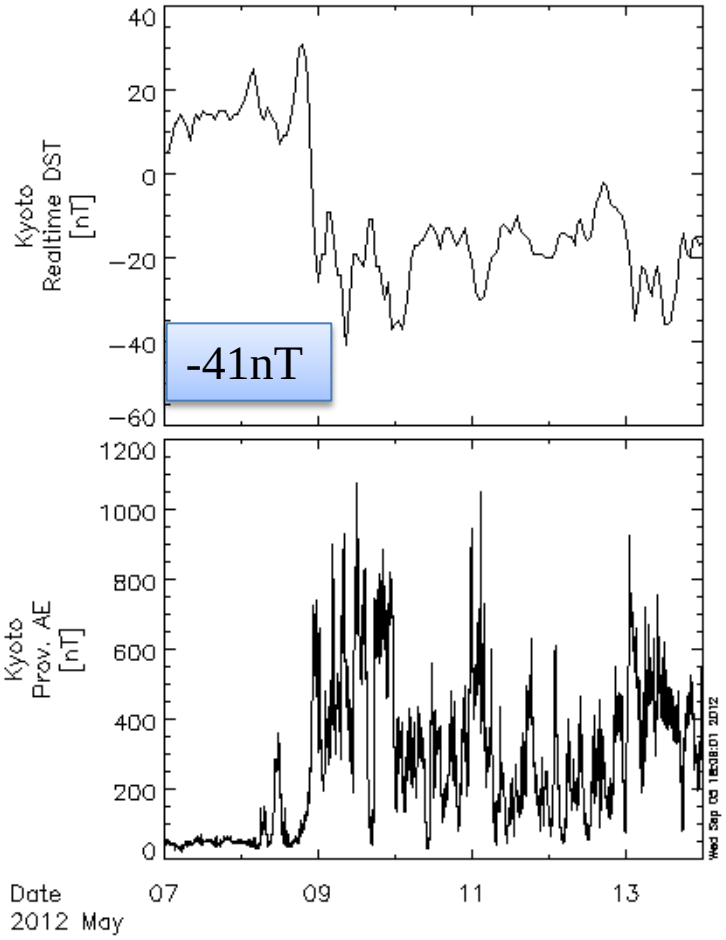
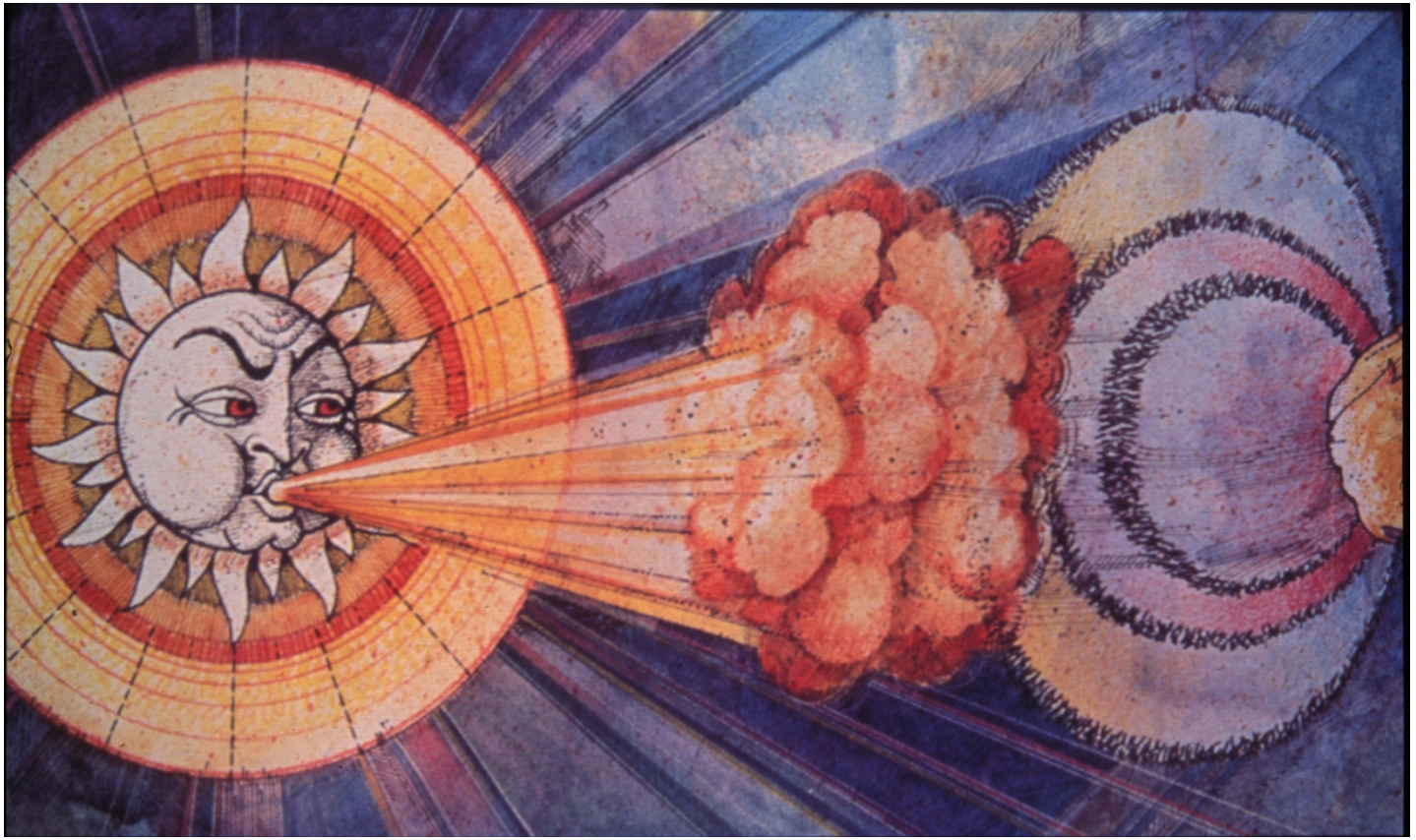




V. magnetosphere

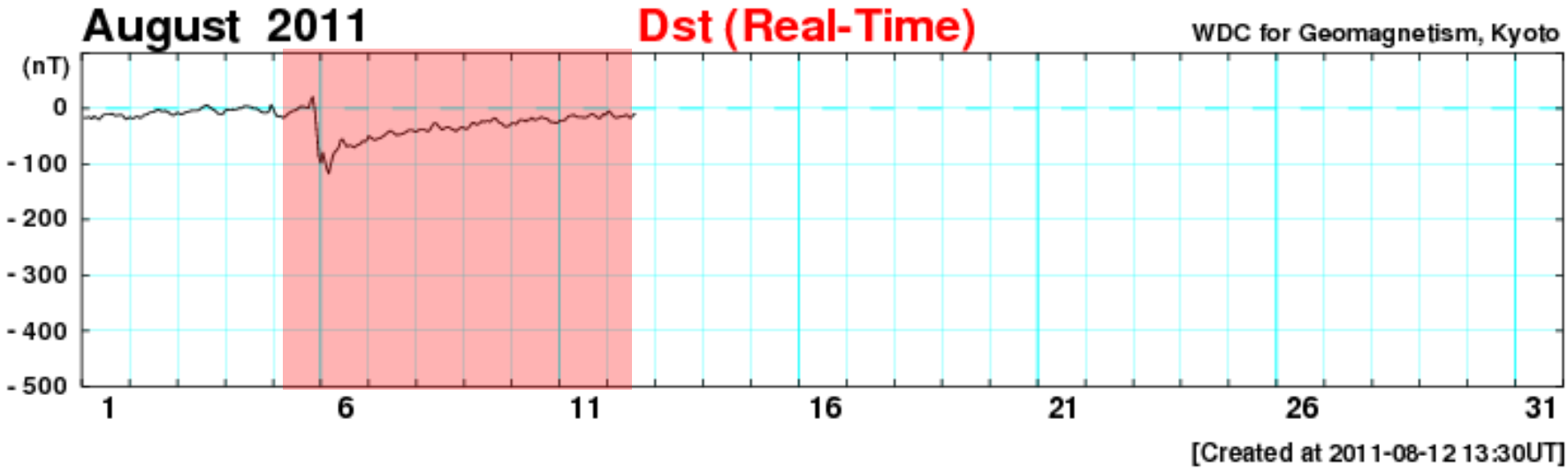
- The magnetosphere is surrounded by solar wind, therefore the magnetosphere is controlled by the sun.



- Here we show two famous index; Dst index and AE index. They are useful for the “space whether” to know Storm and Substorm (aurora).

V. magnetosphere

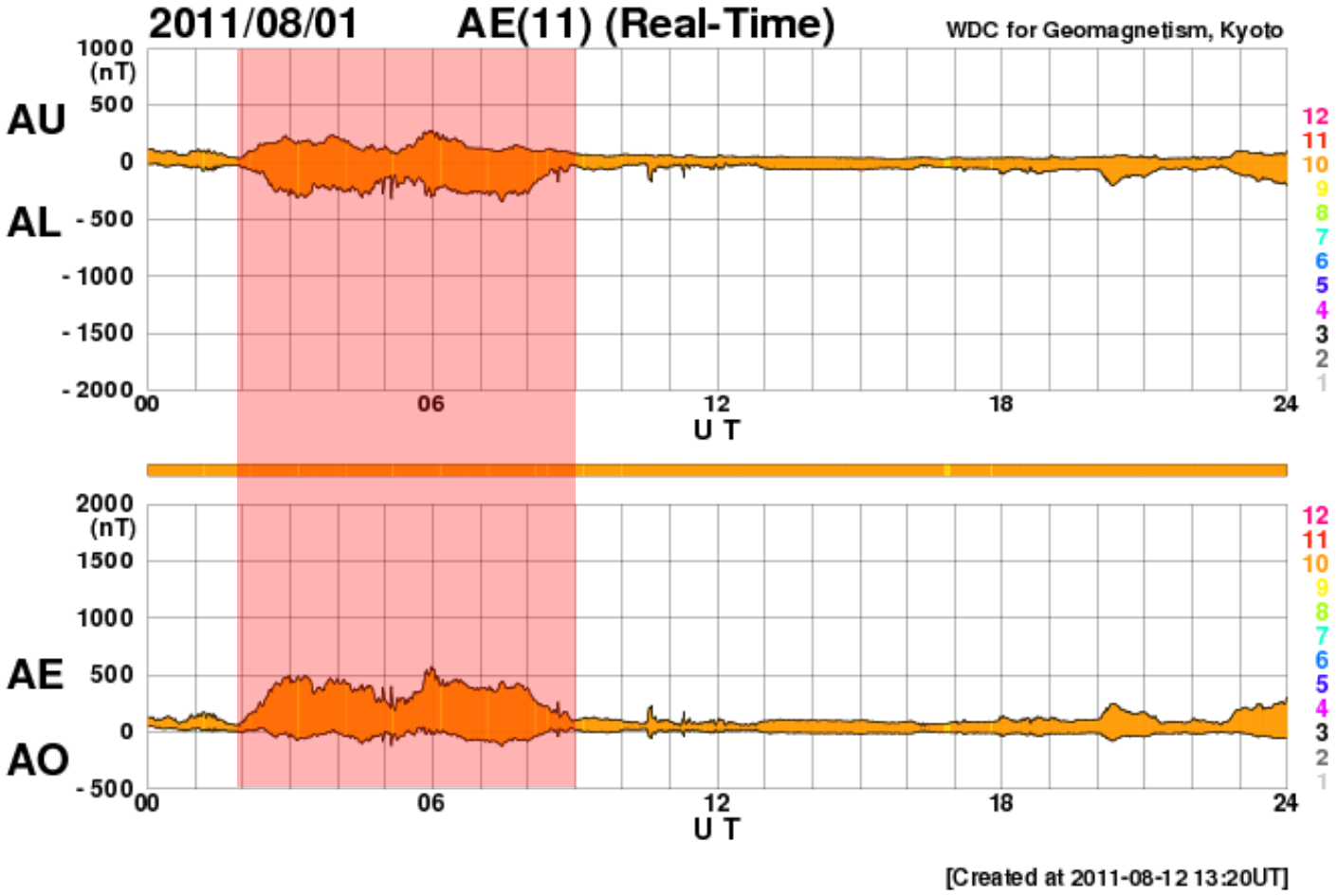
Dst index



Dst commonly uses as index of the magnetic disturbances.
Especially we cans see magnetic storms because DST index reflects effect of the ring current.
Magnetic storm started on 5 Aug. with negative DST index of less than -100 nT

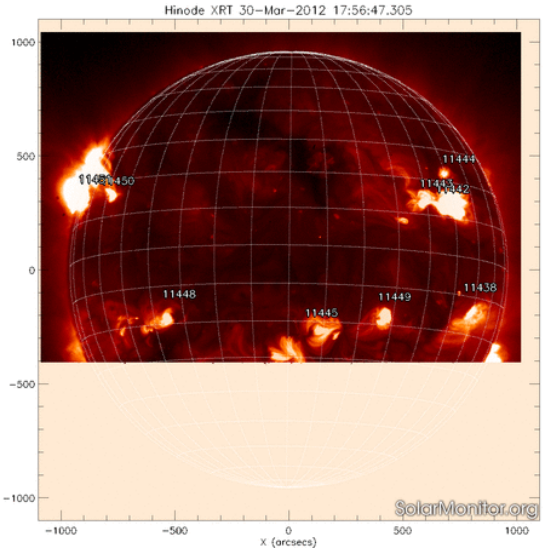
V. magnetosphere

AE index



AE index is for substorms. When substorms occur, AE enhances because of auroral electro jet.

VI. Recent Space Weather
Recent Sunspot number



[Noaa Sunspot Number]

Hinode XRT

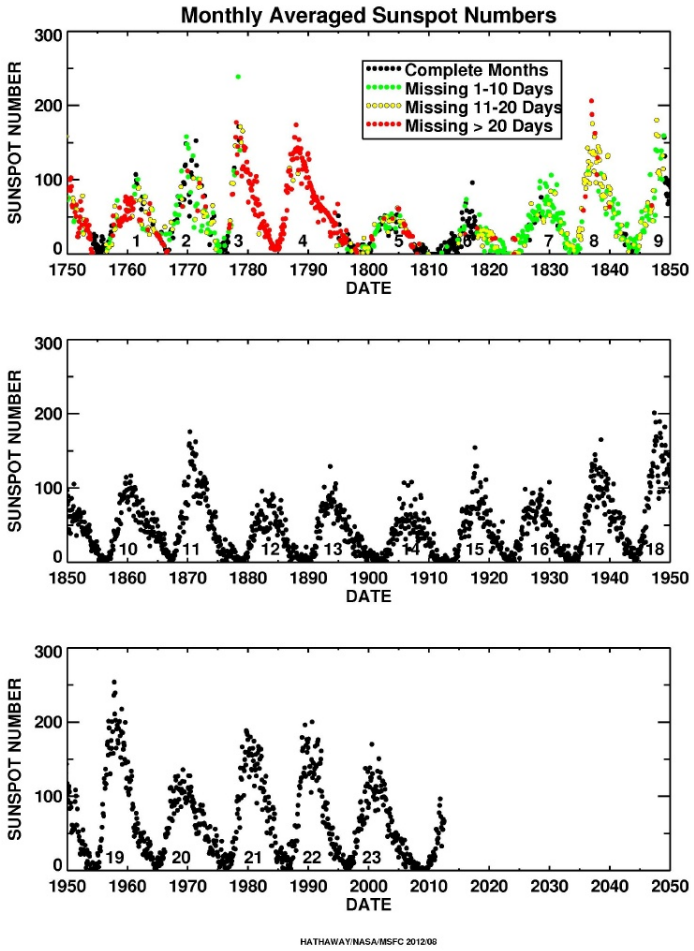
White:0, Skyblue: less than 40, Green: 40-80, Yellow: 80-120, Red: greater than 120

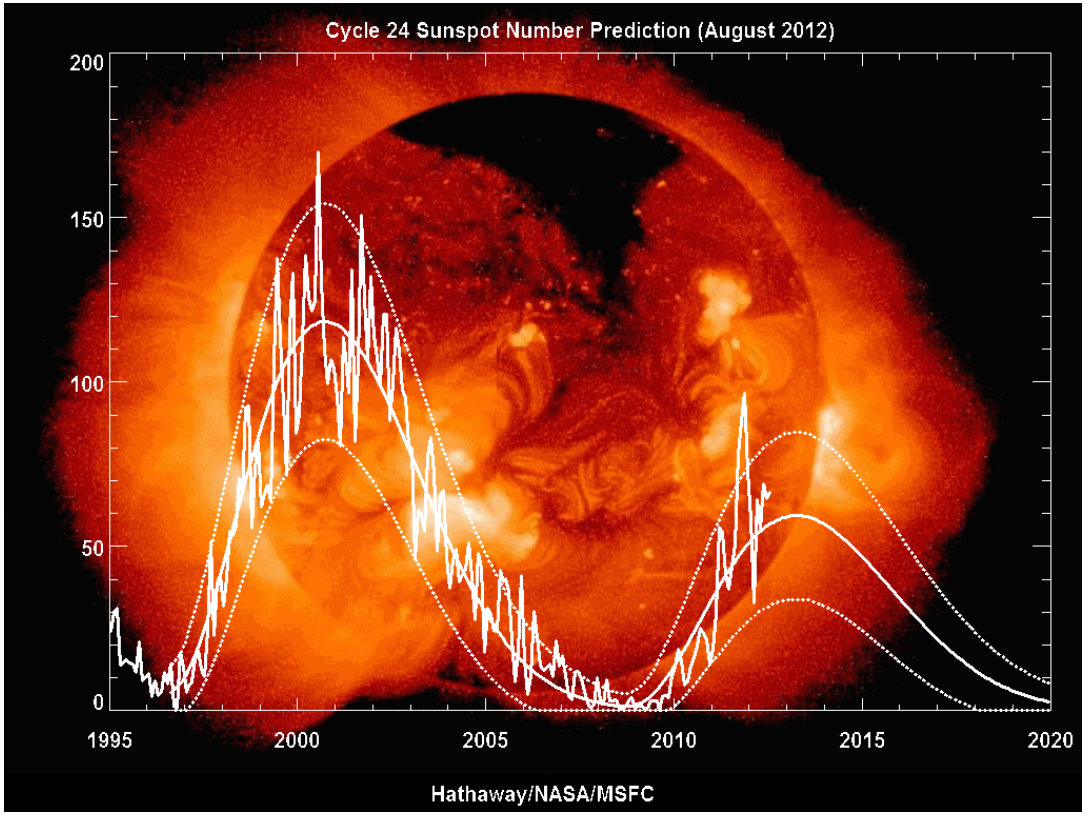
2012/03/07	102	86	96	89	103	89	80	75	85	104	89	54	58	74	62	86	74	65	84	56	63	70	100	93	96	50	67
2012/04/03	62	60	50	39	38	25	24	24	28	50	50	65	77	86	78	96	122	162	147	118	158	169	137	117	99	118	114
2012/04/30	104	99	96	107	101	88	104	79	90	79	93	102	85	138	156	125	122	114	118	110	124	120	95	91	96	86	70
2012/05/27	83	87	73	78	76	151	113	133	155	154	131	98	90	107	127	98	132	134	114	113	110	96	66	64	29	13	13
2012/06/23	13	24	14	28	79	73	97	90	137	165	136	129	122	131	127	113	137	122	94	132	112	120	134	89	87	59	39
2012/07/20	55	50	29	60	66	66	77	91	108	79	106	116	118	126	160	140	107	108	96	99	124	105	98	76	62	46	32
2012/08/16	34	42	56	69	52	64	65	49	69	70	78	85	73	95	118	144	120	108	156								

http://www2.nict.go.jp/aeri/swe/swx/swcenter/sunspot.html

Recent Sunspot number

http://solarscience.msfc.nasa.gov/images/ssn_predict_l.gif



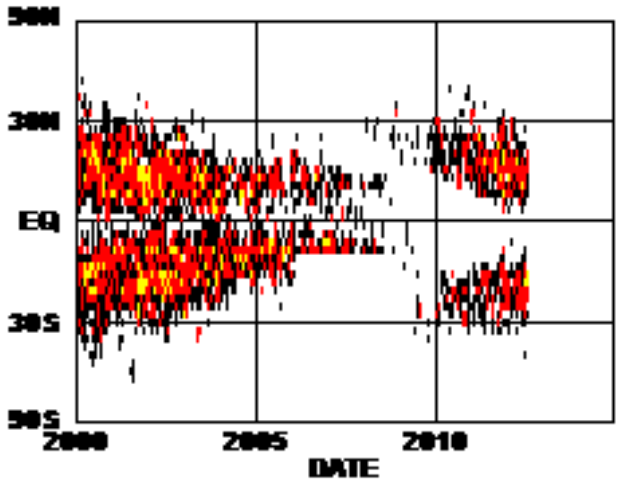


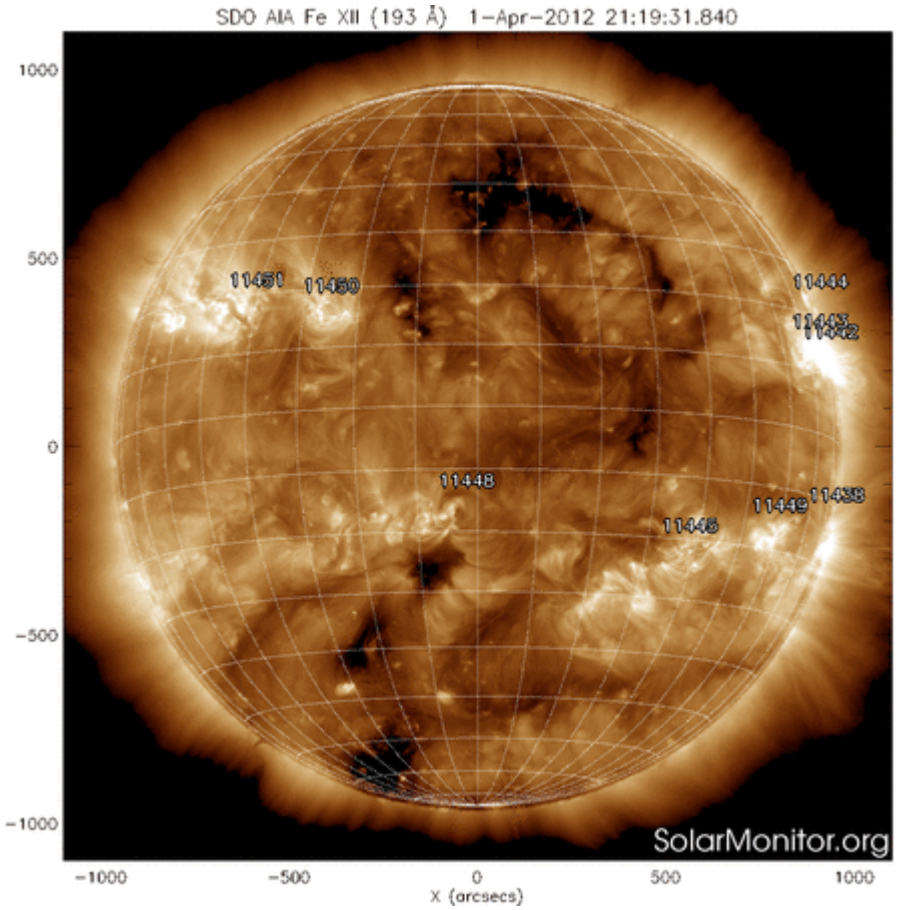
http://solarscience.msfc.nasa.gov/images/Zurich_Color_Small.jpg

Recent Solar Surface

Solar Dynamics Observatory/
Atmospheric Imaging Assembly

Apr., 2012 – Sept., 2012

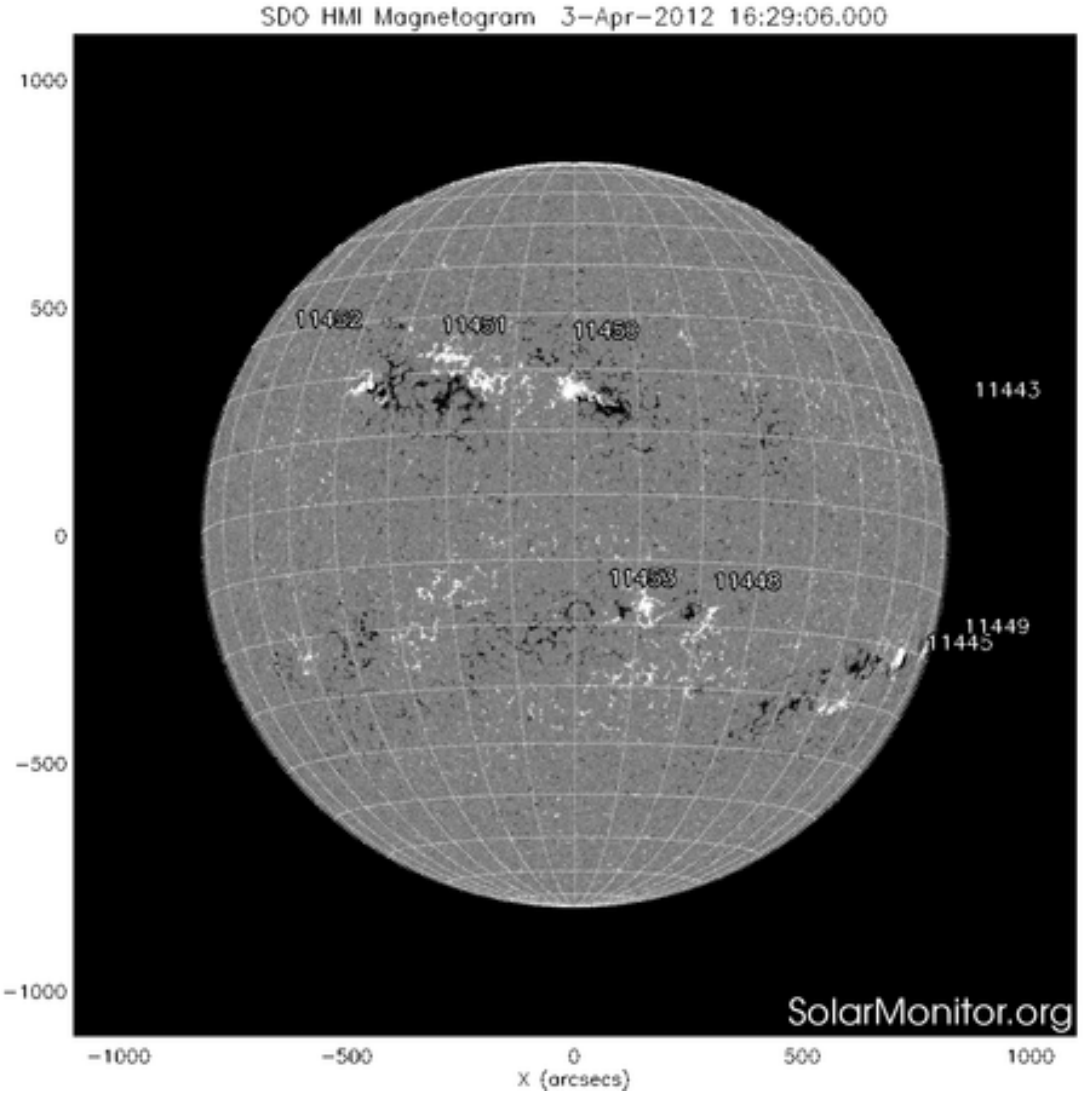




http://solarscience.msfc.nasa.gov/images/bfly_recent.gif

Recent Solar Surface

SDO MHI Magnetograms Apr., 2012 – Sept., 2012



Recent X-ray Activity

Apr., 2012 – Sept., 2012

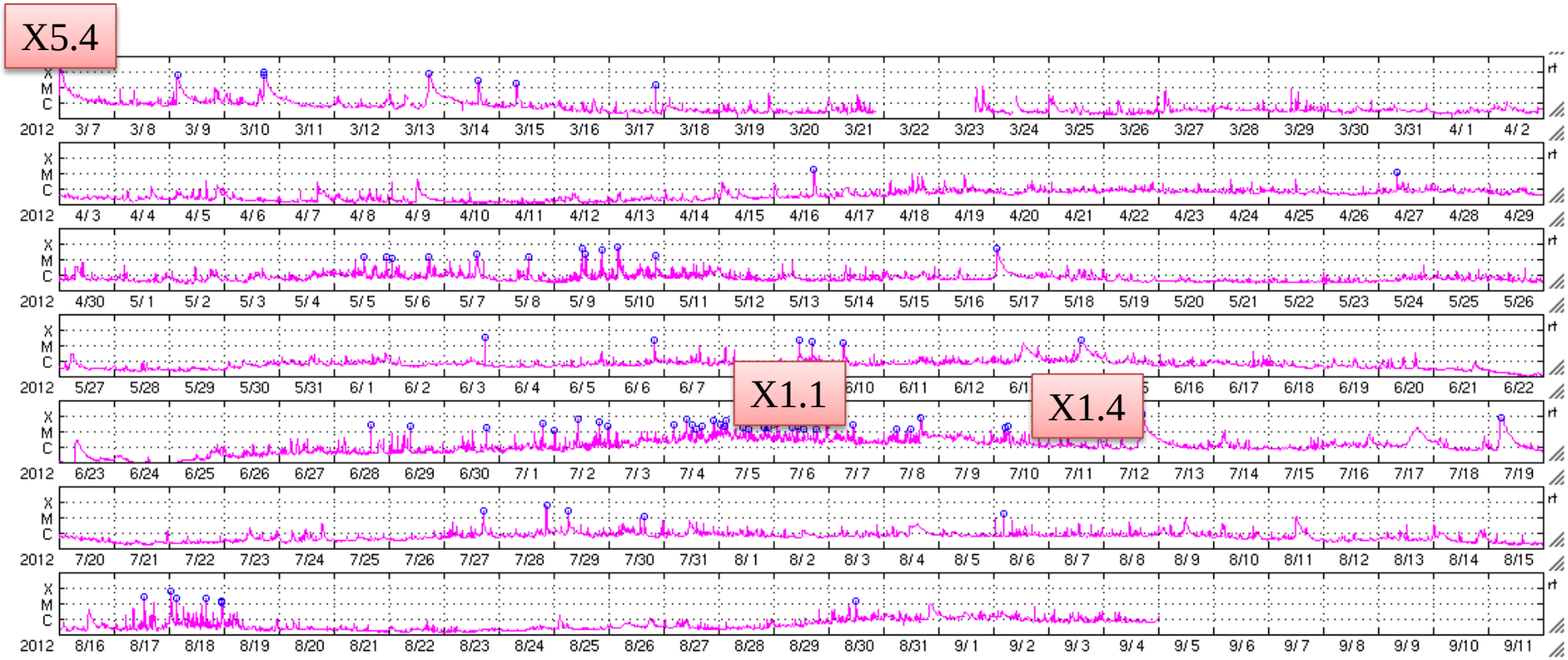


Figure from 簡単データ表示 (swnews.jp)

(Viewer by M. Shino)

Recent Solar Proton Activity

Apr., 2012 – Sept., 2012

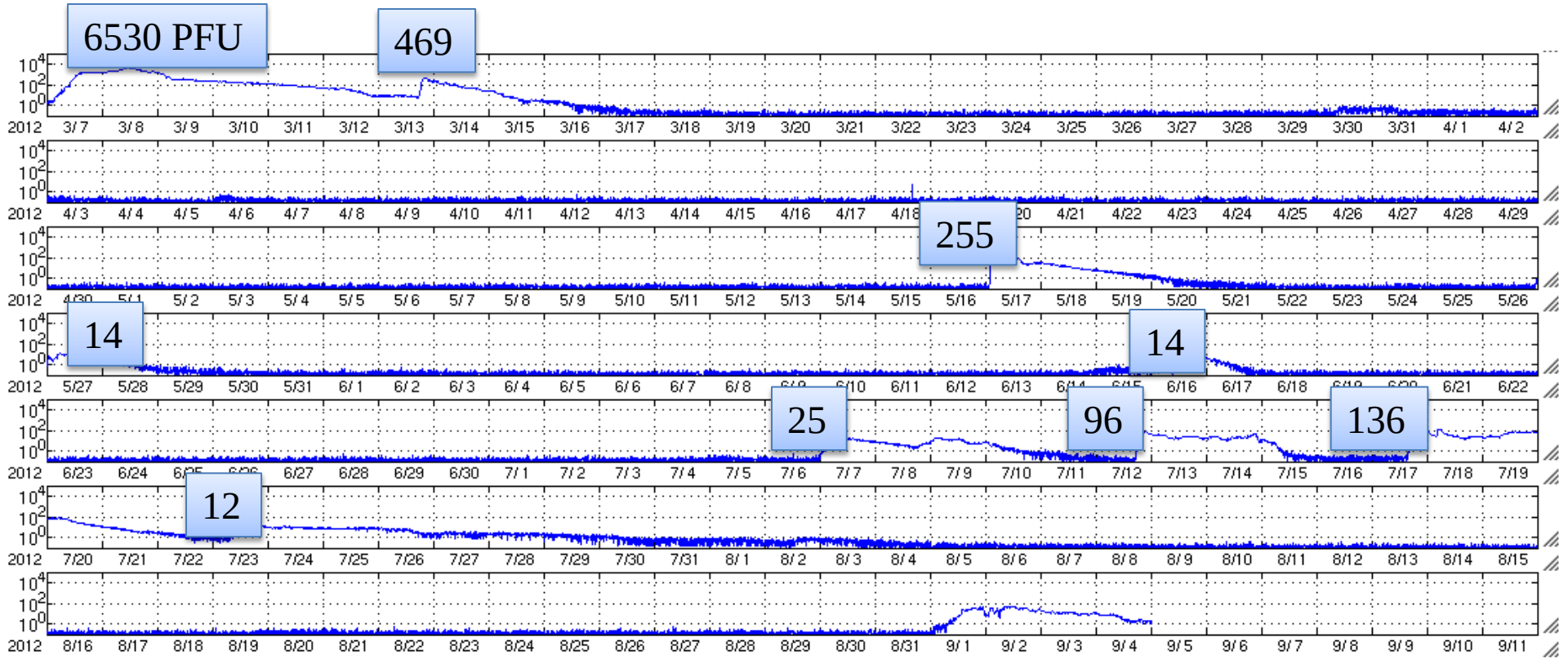


Figure from 簡単データ表示 (swnews.jp)

(Viewer by M. Shino)

Recent Solar Proton Activity

Apr., 2012 – Sept., 2012

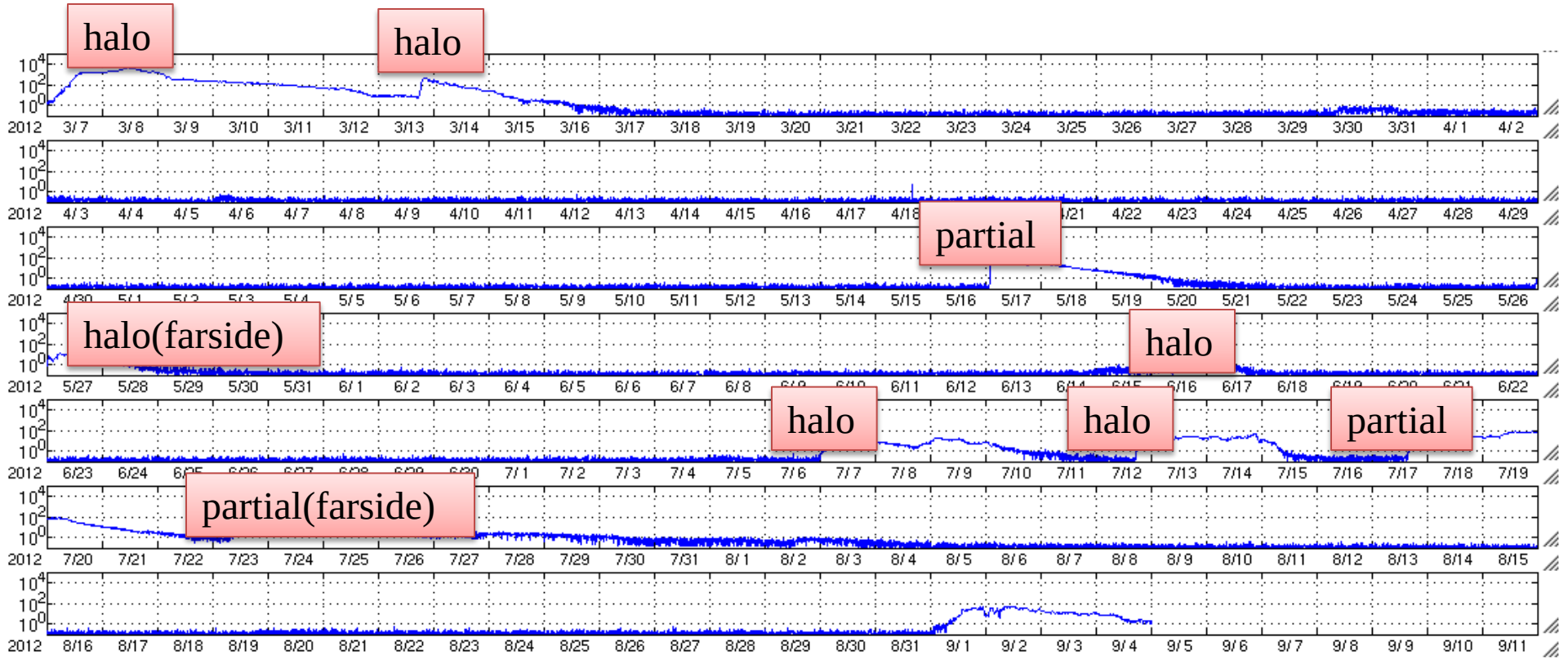


Figure from 簡単データ表示 (swnews.jp)

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Recent Solar Proton Activity

Apr., 2012 – Sept., 2012

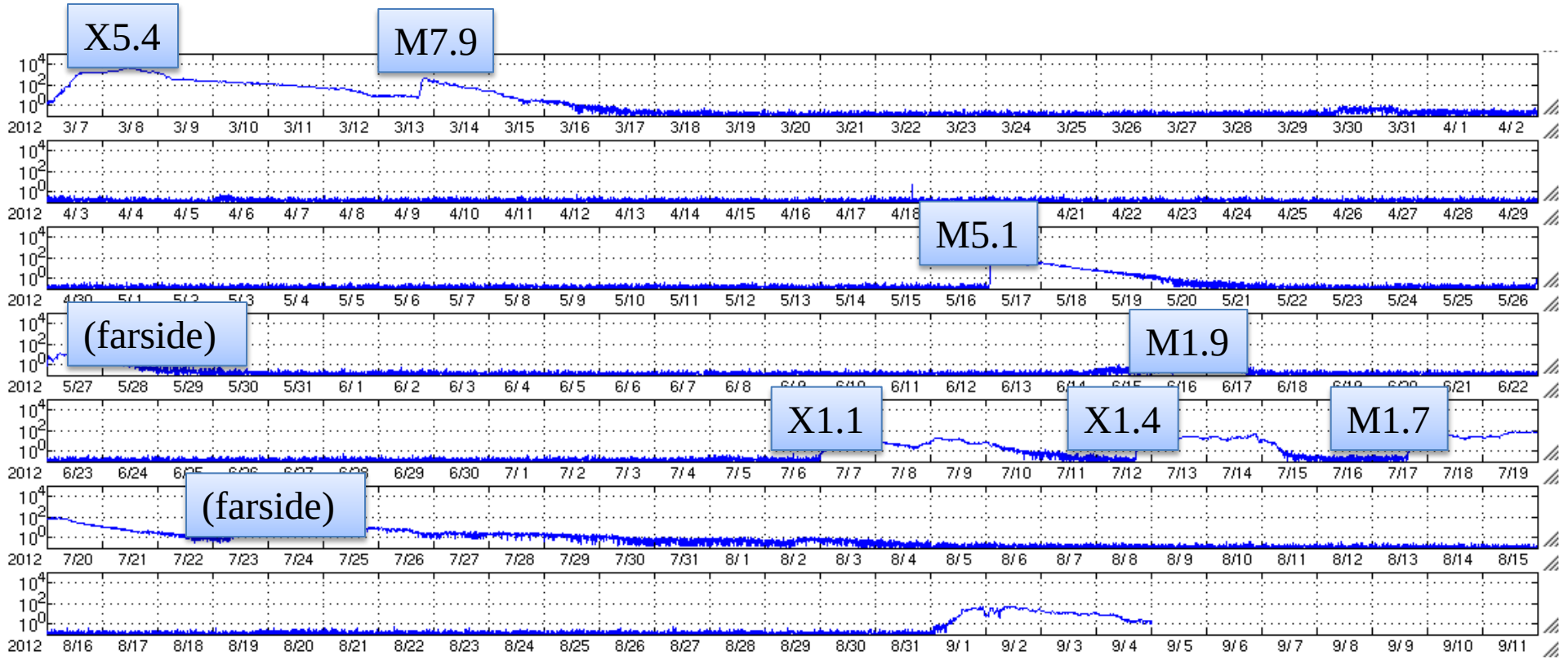


Figure from 簡単データ表示 (swnews.jp)

(Viewer by M. Shino)

Recent Solar Wind Velocity by ACE

Apr., 2012 – Sept., 2012

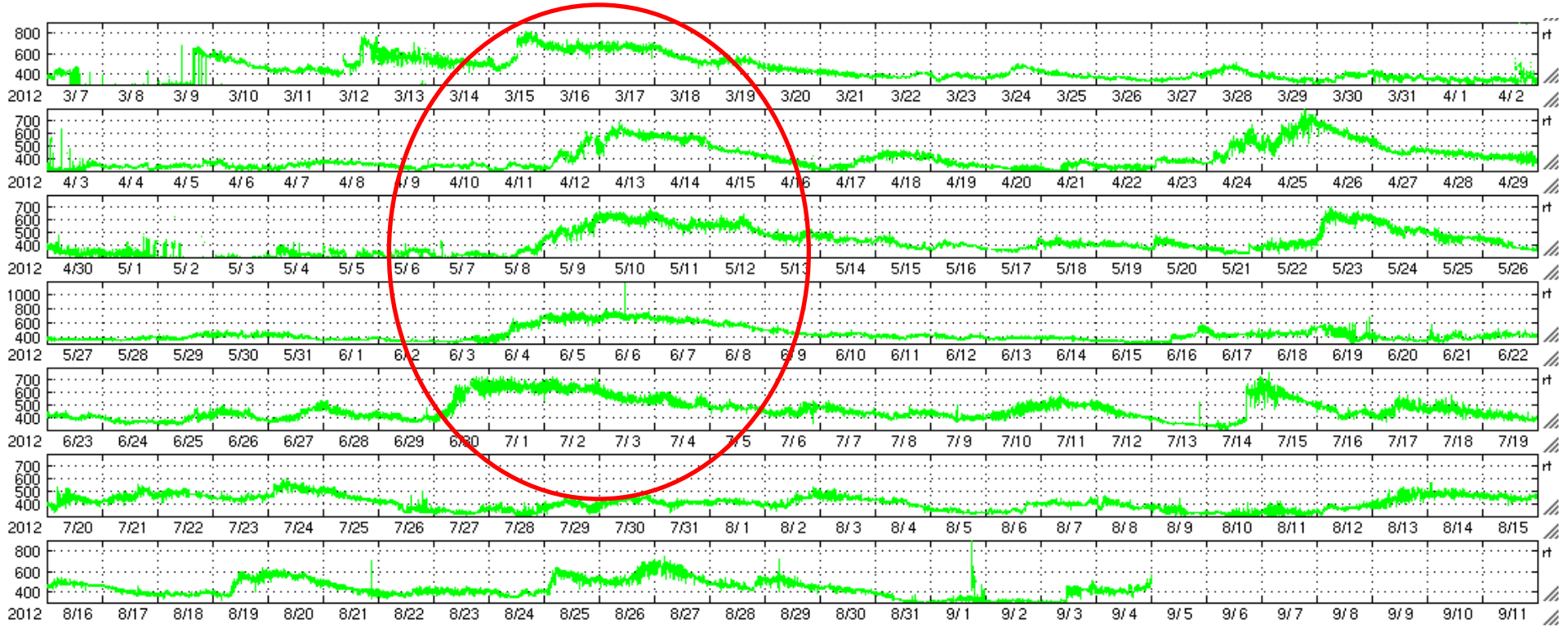


Figure from 簡単データ表示 (swnews.jp)

(Viewer by M. Shino)

Recent Interplanetary Field Activity

Apr., 2012 – Sept., 2012

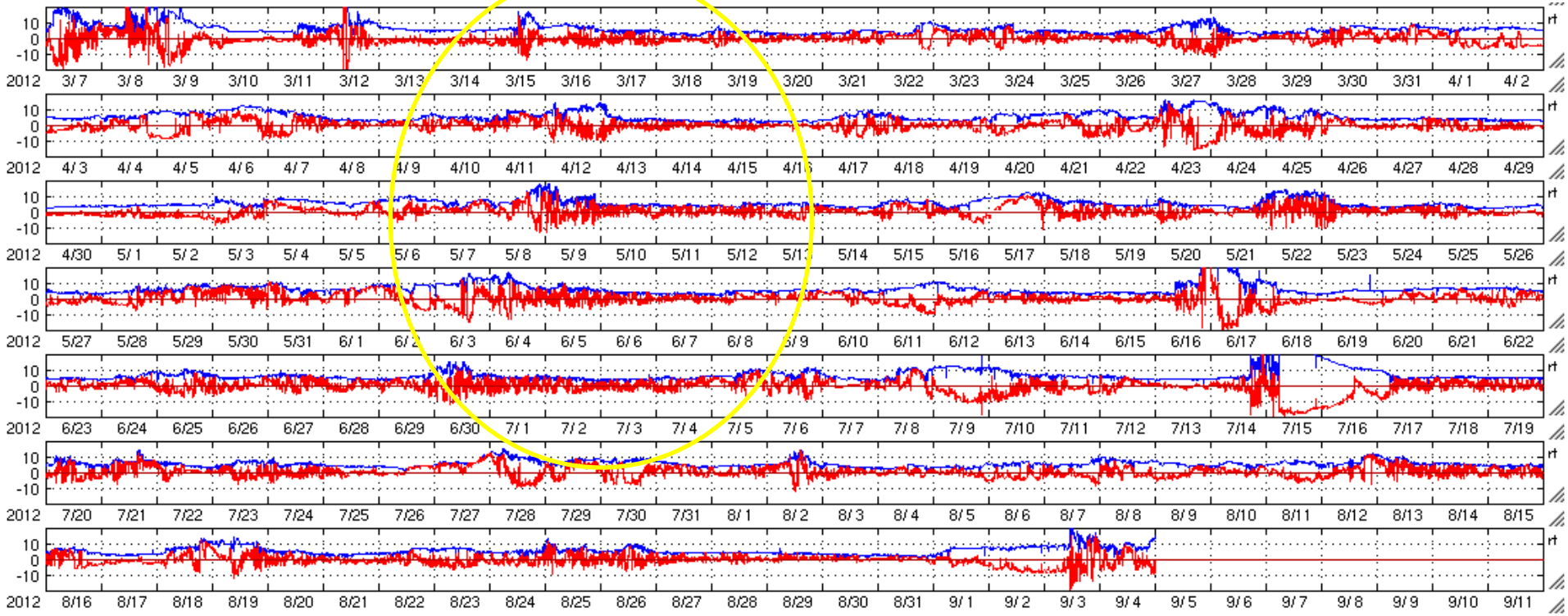
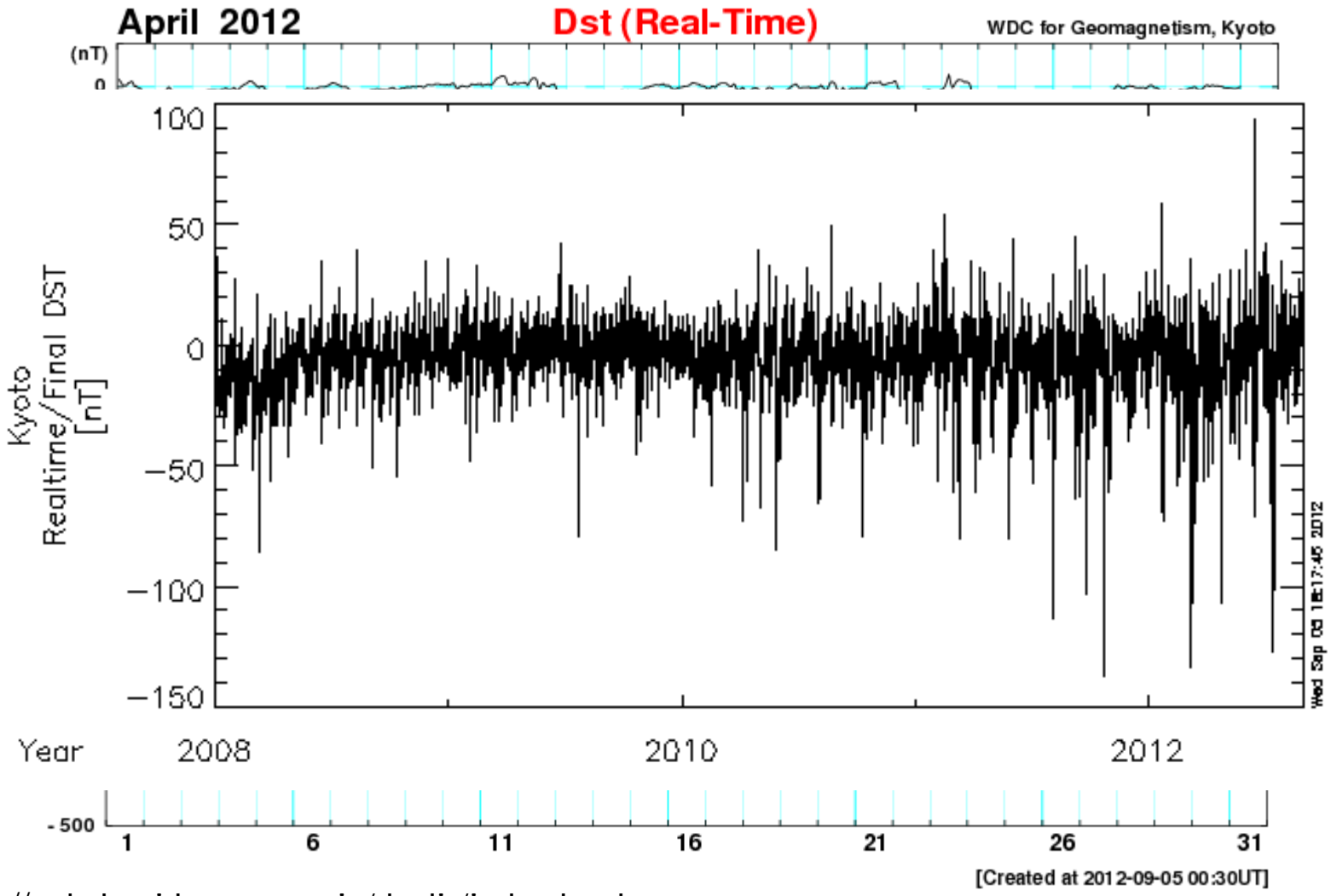


Figure from 簡単データ表示 (swnews.jp)

(Viewer by M. Shino)

Recent Dst Index

Apr., 2012 – Sept., 2012



http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html

Recent Space Weather Event

2012 March /02-16

Flare List

3/4 M2.0/1N LDE CME

3/5 X1.1/2B LDE CME

3/7 X5.4/3B CME、X1.3/SF CME

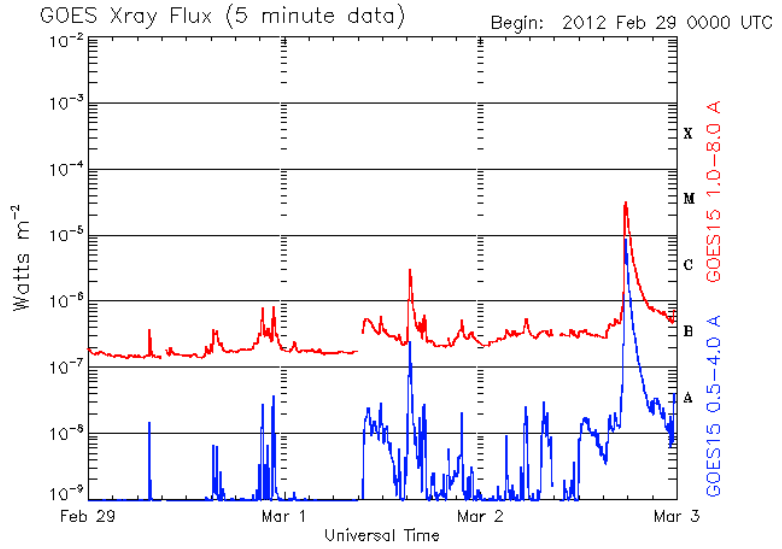
3/9 M6.3 CME

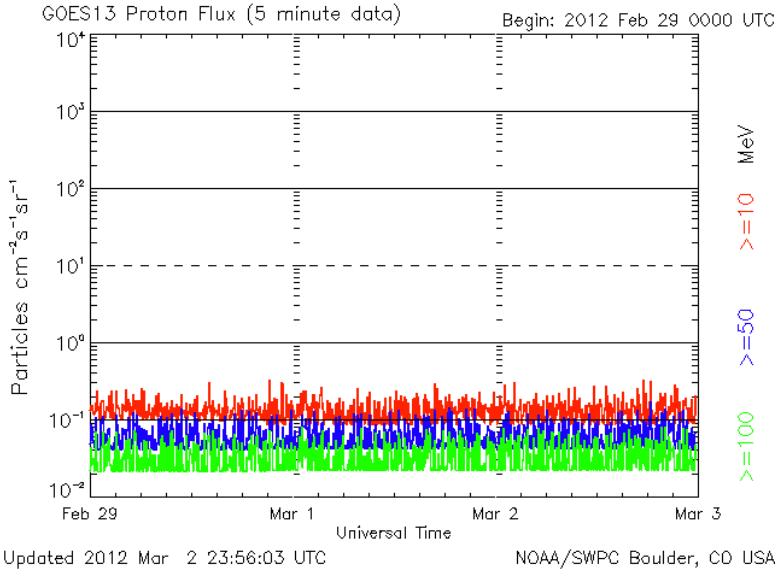
3/10 M8.4 LDE CME

Proton Event:

3/7 05:00UT- 3/12 21:00UT

(max. 6530 PFU at 3/8 11:15UT)





Recent Space Weather Event

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Flare List

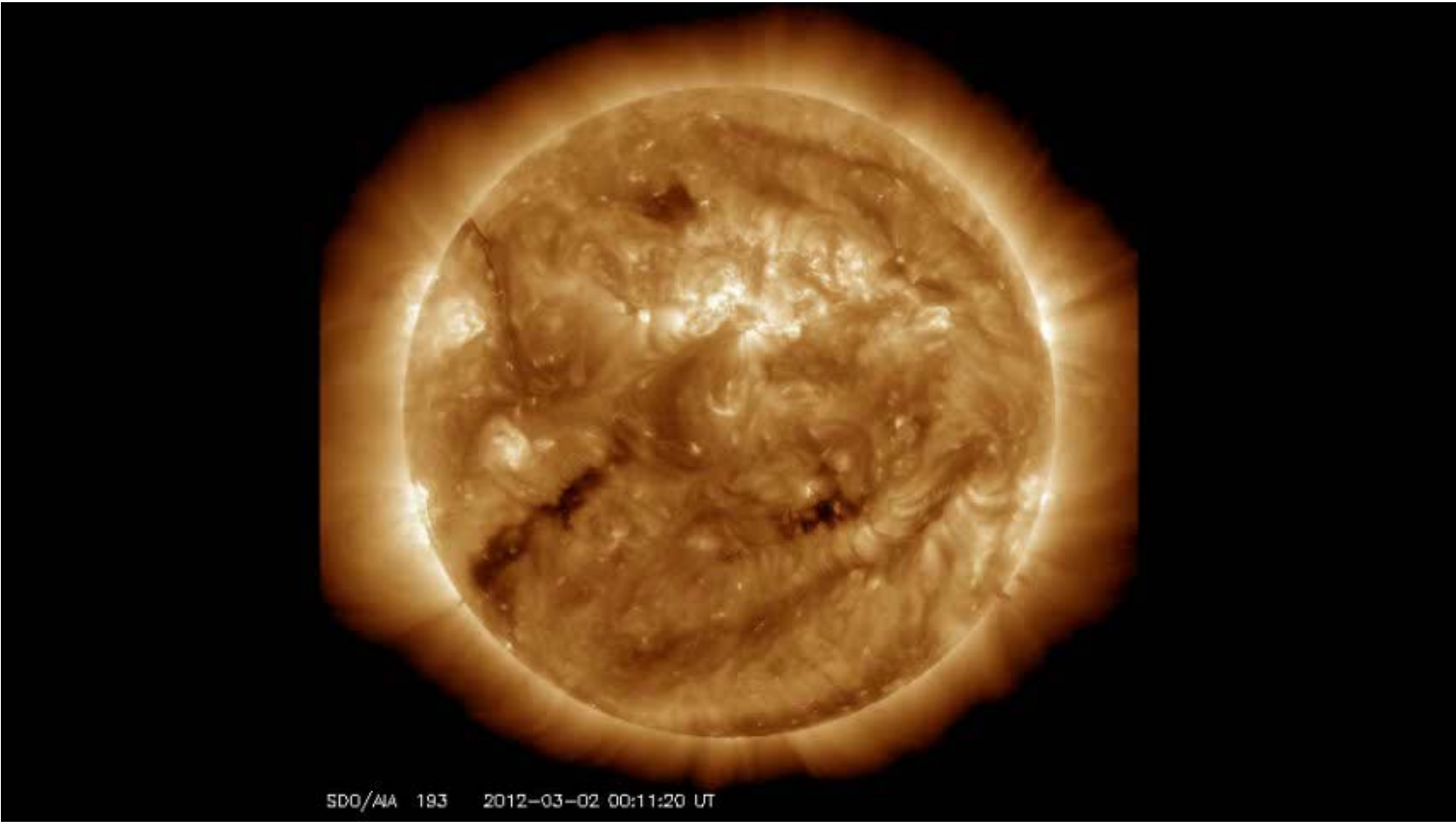
3/4 M2.0/1N LDE CME

3/5 X1.1/2B LDE CME

3/7 X5.4/3B CME、X1.3/SF CME

3/9 M6.3 CME

3/10 M8.4 LDE CME



Recent Space Weather Event

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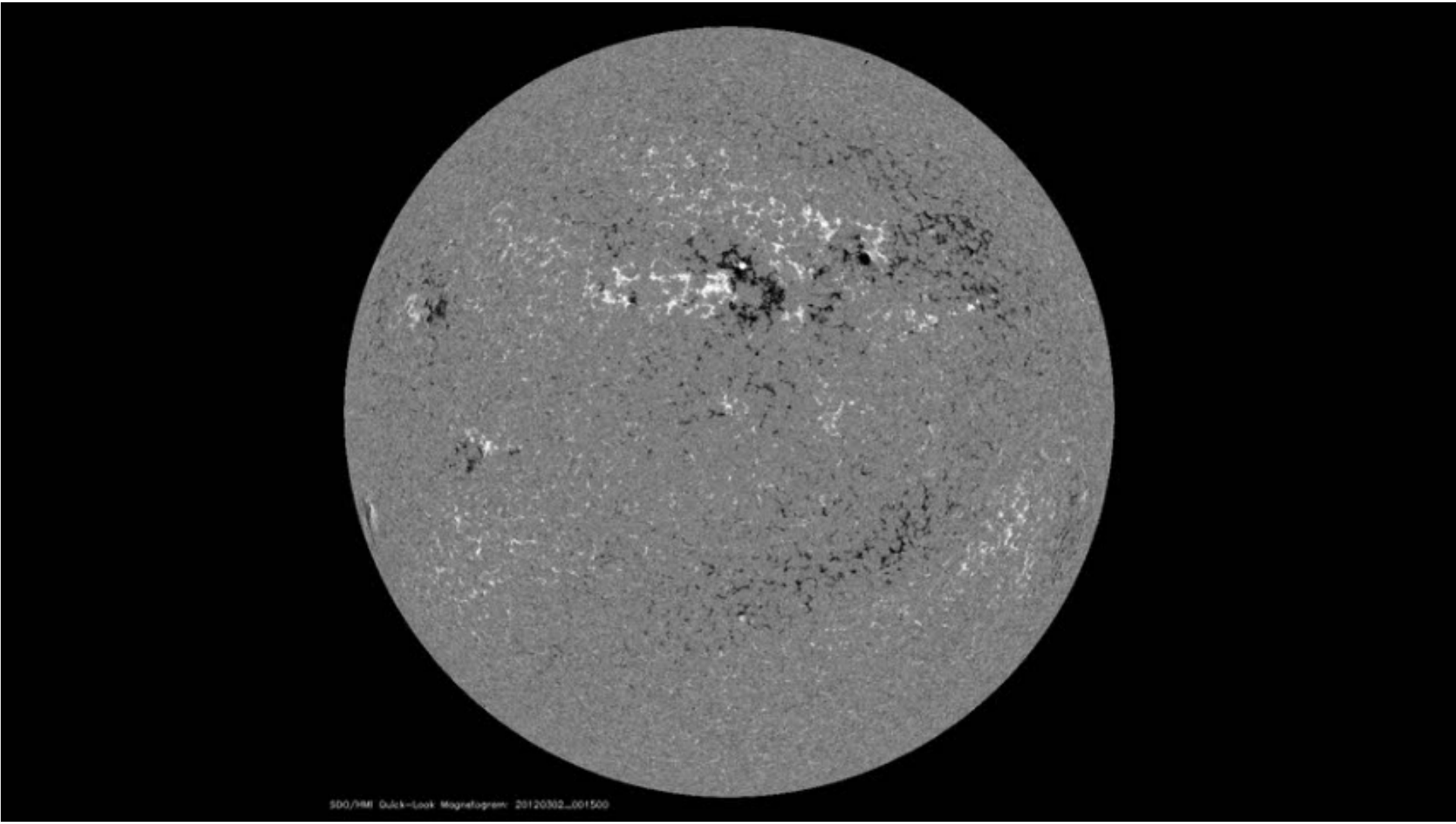
3/4 M2.0/1N LDE CME

3/5 X1.1/2B LDE CME

3/7 X5.4/3B CME、X1.3/SF CME

3/9 M6.3 CME

3/10 M8.4 LDE CME



Recent Space Weather Event

2012 March /02-16

Flare List

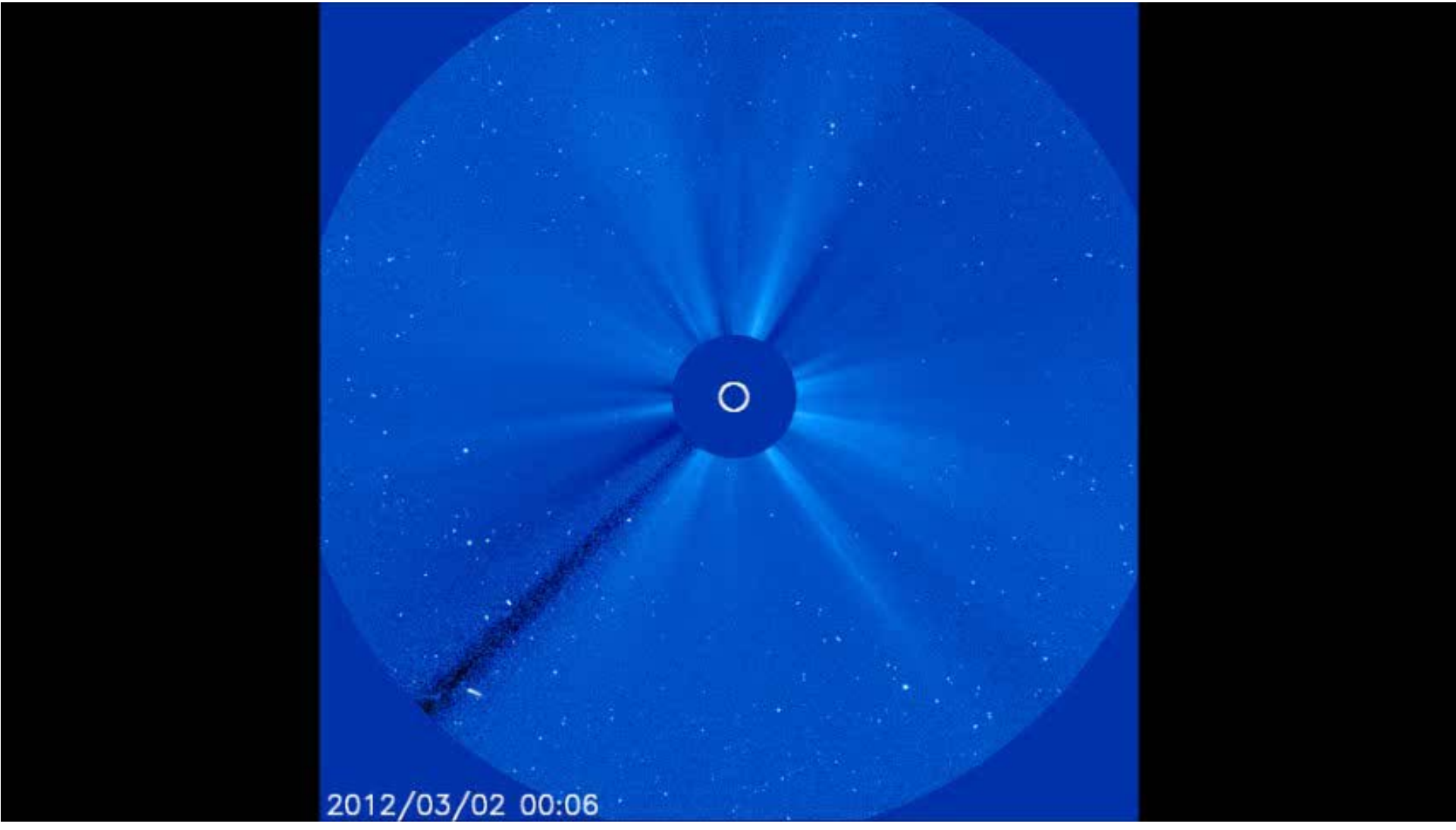
3/4 M2.0/1N LDE CME

3/5 X1.1/2B LDE CME

3/7 X5.4/3B CME、X1.3/SF CME

3/9 M6.3 CME

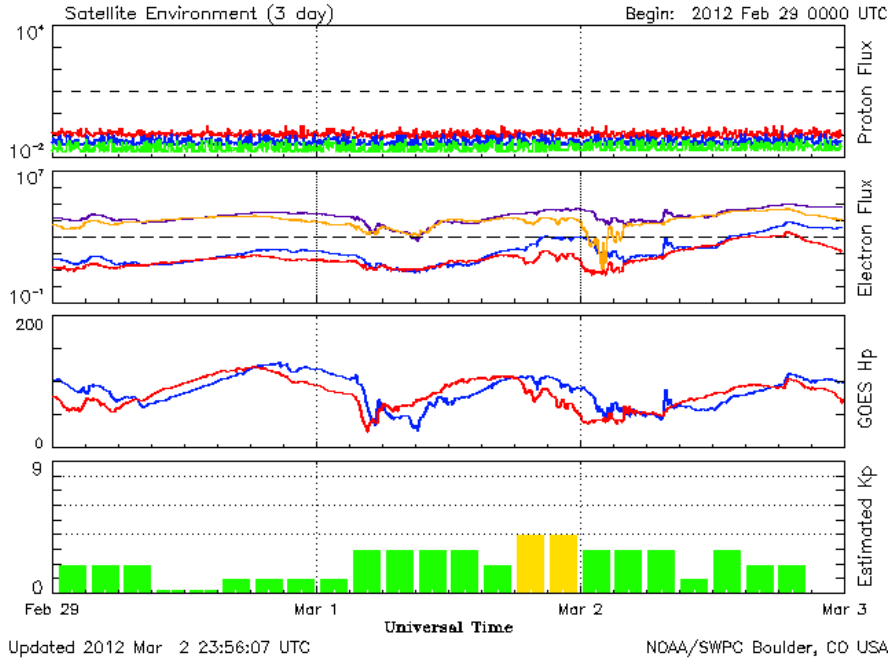
3/10 M8.4 LDE CME

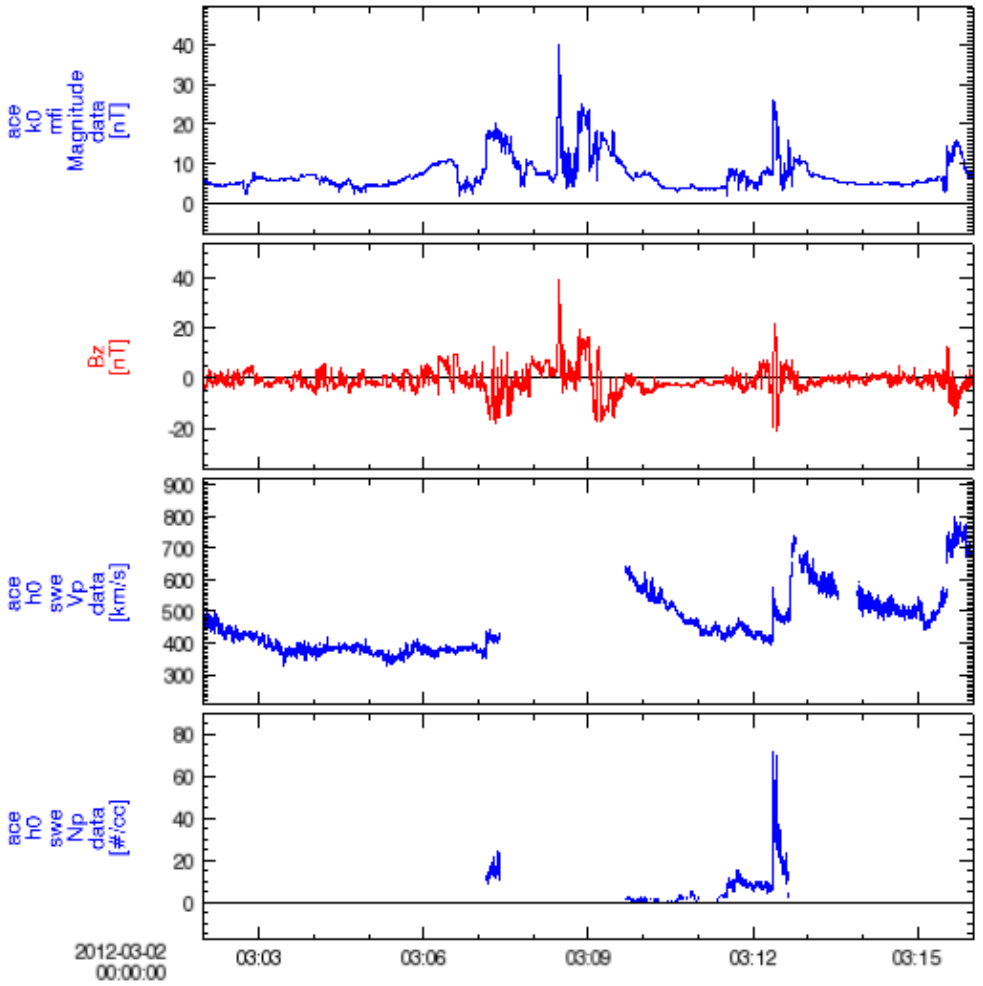


Recent Space Weather Event

2012 March /02-16

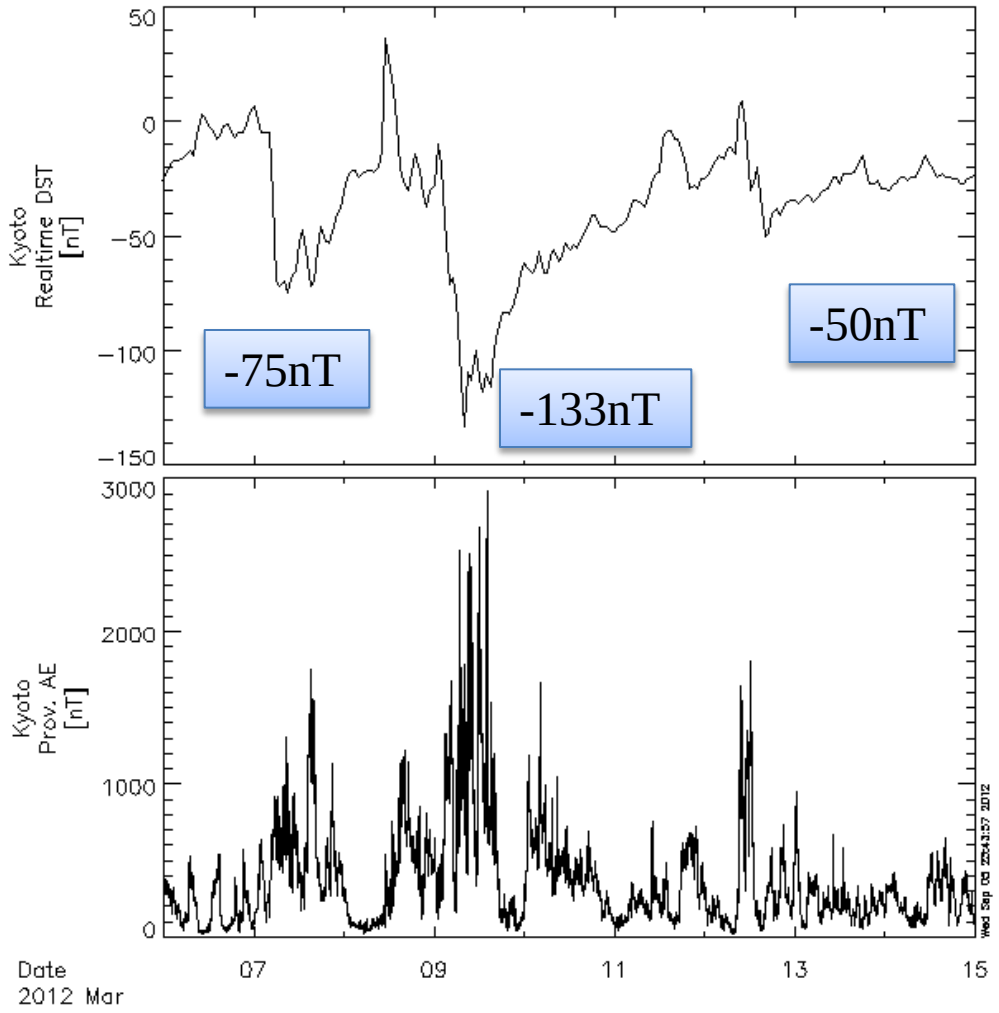
IMF and Geosynchronous Orbit





Recent Space Weather Event

2012 March /02-16
- 3/7 04:19UT- 3/8 00:00UT
- 3/8 11:03UT- 3/10 19:00UT
- 3/12 09:14UT- 3/13 00:00UT



Recent Space Weather Event

【Space disasters by this space weather event】

2012/03/07	Dellinger phenomenon(communication failure) with the X class flare
2012/03/07	Venus Express satellite trouble
2012/03/07	SkyTerra1 satellite trouble
2012/03/08-09	Some aircrafts changed the route from via polar region to via lower region
2012/03/12	HughesNet Spaceway 3 satellite trouble

Based on http://www2.nict.go.jp/aeri/swe/swx/swcenter/hazards.html

Recent Space Weather Event

Background
- About us
- Profile: The Right Stuff

SSA programme
- Space Situational Awareness

Multimedia (click)...

Ground Systems Engineering
- Ground Systems team at ESOC

Mission families
- Solar & planetary
- Astronomy & Fundamental Physics
- Earth Observation
- Human Spaceflight
- Technology Demonstration
- Past missions
- ESA mission history
- - Find a mission: A...Z

Mission control centres
- ATV Control Centre (ATV-CC)
- Columbus Control Centre (Col-CC)

Worldwide ground station network
- ESTRACK tracking stations

News

Venus Express

Solar flares over, Venus Express restarts science investigations

16 March 2012

ESA's Venus Express spacecraft has returned to routine operation after its startracker cameras were temporarily blinded last week by radiation from a pair of large solar flares.

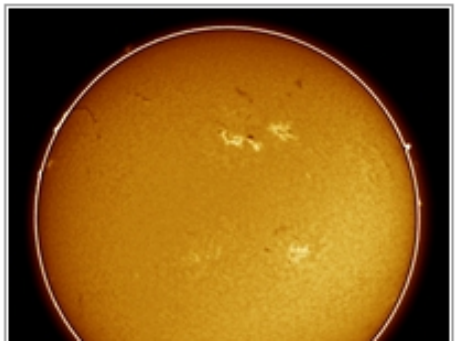
Science observations by ESA's Venus Express were temporarily suspended on 7 March after the two startrackers – used to help navigate and orient the spacecraft – were overwhelmed by excessive proton radiation.

The proton storm stemmed from the Coronal Mass Ejections (CMEs) emitted by the Sun, which were associated with a pair of massive solar flares that occurred early in the morning on 7 March.

With the startrackers unable to function properly, mission controllers at ESOC, ESA's European Space Operations Centre, Darmstadt, had to place the spacecraft into a special mode to ride out the storm.

This meant that all instruments were switched off and routine scientific observations and data gathering were stopped.

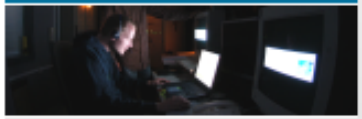
"As the radiation faded, the startrackers began functioning normally again on 9 March," said Octavio Camino, ESA's Spacecraft Operations Manager.



Venus Express operations

The Sun now

Space Situational Awareness



- ESA/NASA SOHO homepage

More news
- Large solar flares generate geomagnetic storm
- Venus Express finds planetary atmospheres such a drag

http://www.esa.int/SPECIALS/Operations/SEM402BYLZG_0.html

Recent Space Weather Event

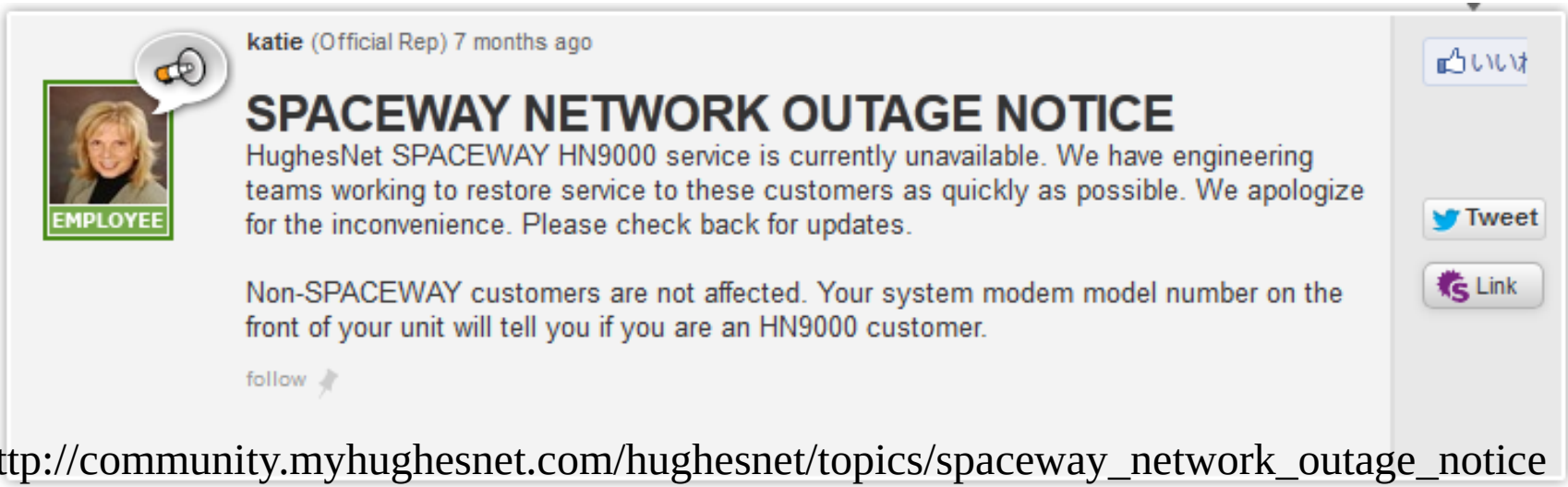
Solar Flares Knock Out LightSquared Satellite
As Run of Bad Fortune Continues

by Karl Bode Friday 16-Mar-2012 tags: satellite · business · wireless · alternatives · bandwidth · trouble · wireless

Tipped by **viperadamr**

Earlier this week we noted that recent solar flares managed to knock HughesNet's Spaceway 3 satellite offline for a significant part of Tuesday. User viperadamr writes in to note that the flares also took out LightSquared's Skyterra 1 satellite, which has been out of service since the original solar flare on March 7. The last update from the company was on March 9 insisting they'd have the satellite operational again by last Sunday -- something that didn't happen. The outage arrives as LightSquared slowly stumbles toward death after being rejected a necessary waiver to operate their interference-prone hybrid LTE network.

http://www.broadbandreports.com/shownews/Solar-Flares-Knock-Out-LightSquared-Satellite-118847



http://community.myhughesnet.com/hughesnet/topics/spaceway_network_outage_notice

Recent Space Weather Event

First GLE（Ground Level Event/Ground Level Enhancement）of Solar cycle 24(2012/05/17)

Because of the energy emission from the Sun, the radiation levels on Earth's surface rises to the degree that they are readily detected by neutron monitors.

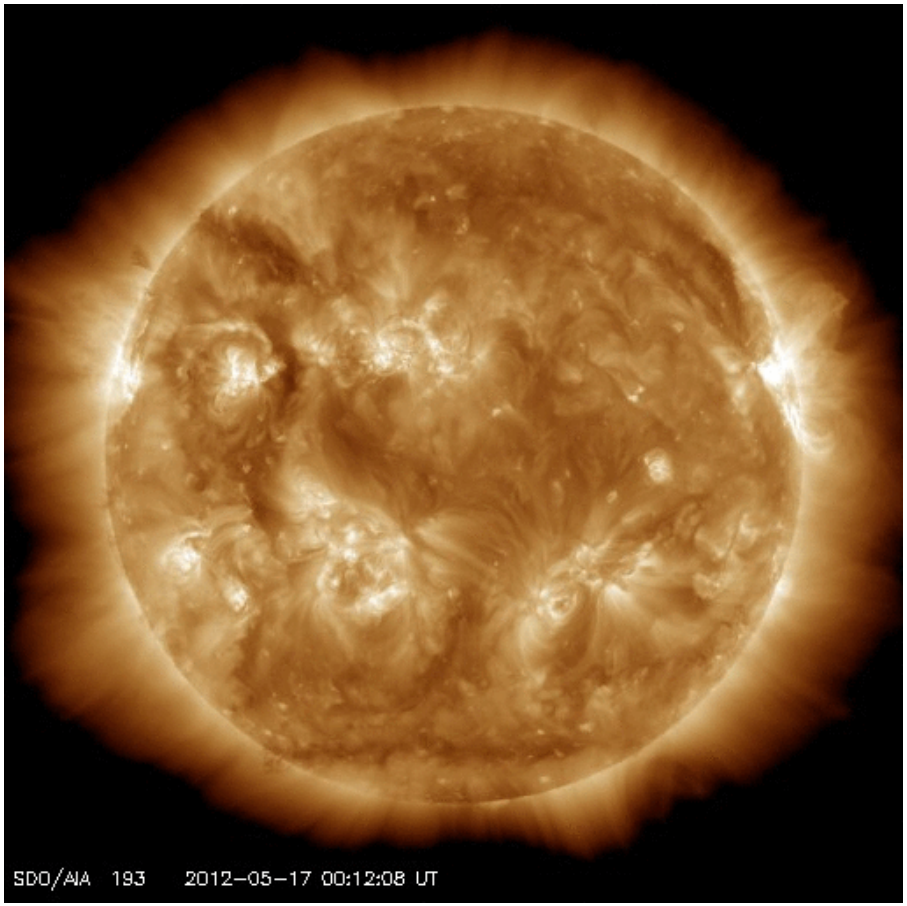
Table 1List of the 16 GLE events of solar cycle 23

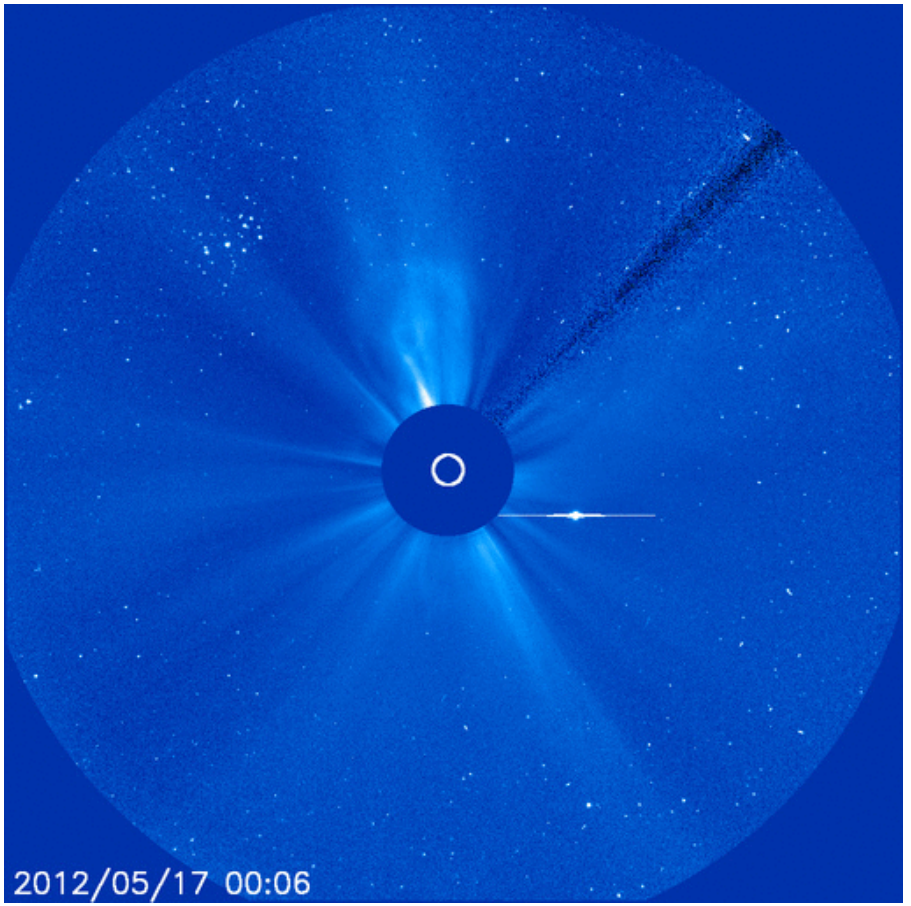
Event #	GLE event Date	GLE Onset (Obs)	GLE Onset (Inf)	Peak time (UT)	GLE Int. (%)	Type II Onset	Type III Onset	Flare onset	Flare Class /Location	CME Onset	CME ht (Rs)	Sky Speed (km/s)	Space Speed (km/s)
1	1997Nov06	12:10	12:07	14:00	11.3	11:53	11:52	11:49	X9.4/S18W63	11:39	5.2	1556	1726
2	1998May02	13:55	13:52	14:05	6.8	13:41	13:35	13:31	X1.1S15W15	13:32	3.3	938	1332
3	1998May06	08:25	08:22	09:30	4.2	08:03	08:01	07:58	X2.7/S11W65	07:55	3.8	1099	1208
4	1998Aug24	22:50	22:47	02:05	3.3	22:02	22:04	21:50	X1.0/N35E09	DG	DG	DG	DG
5	2000Jul14	10:30	10:27	11:00	29.3	10:28	10:18	10:03	X5.7/N22W07	10:25	1.4	1674	1741
6	2001Apr15	14:00	13:57	14:35	56.7	13:47	13:49	13:19	X14/S20W85	13:35	3.3	1199	1203
7	2001Apr18	02:35	02:32	03:10	13.8	02:17	02:15	02:11	?/S23W117	02:11	5.9	2465	2712
8	2001Nov04	17:00	16:57	17:20	3.3	16:10	16:13	16:03	X1.0/N06W18	16:13	8.0	1810	1846
9	2001Dec26	05:30	05:27	06:10	7.2	05:12	05:13	04:32	M7.1/N08W54	05:06	4.2	1446	1779
10	2002Aug24	01:18	01:15	01:35	5.1	01:01	01:01	00:49	X3.1/S02W81	00:59	3.6	1913	1937
11	2003Oct28	11:22	11:19	11:51	12.4	11:02	11:03	11:00	X17/S20E02	11:07	3.9	2459	2754
12	2003Oct29	21:30	21:27	00:42	8.1	20:42	20:41	20:37	X10/S19W09	20:43	8.7	2029	2049
13	2003Nov02	17:30	17:27	17:55	7.0	17:14	17:16	17:03	X8.3/S18W59	17:19	3.0	2598	2981
14	2005Jan17	09:55	09:52	09:59	3.0	09:43	09:41	09:42	X3.8/N14W25	09:43	3.2	2547	2802
15	2005Jan20	06:51	06:48	07:00	277.3	06:44	06:45	06:39	X7.1/N14W61	06:33	4.0	3242	3675
16	2006Dec13	02:45	02:42	03:05	92.3	02:26	02:24	02:17	X3.4/S06W23	02:25	4.2	1774	2164

Gopalswamy et al., 2008

Recent Space Weather Event

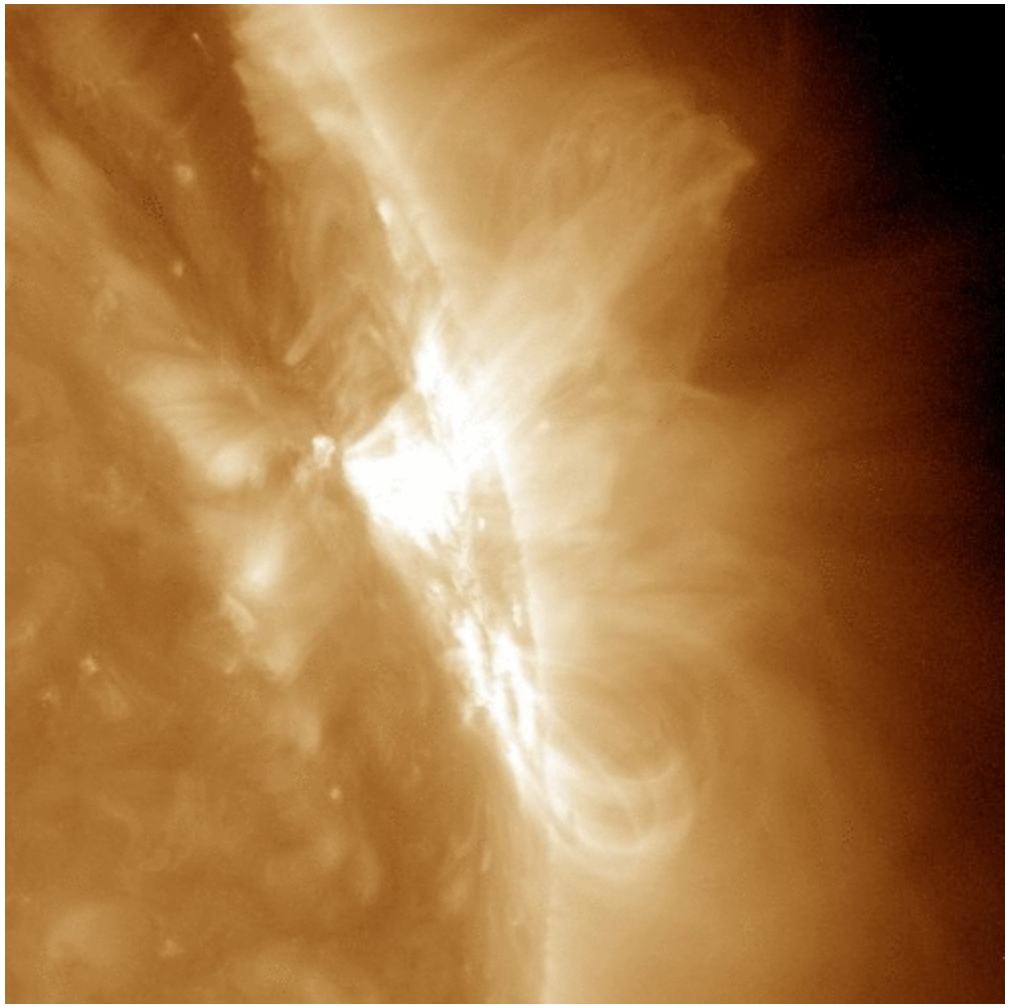
First GLE（Ground Level Event/Ground Level Enhancement）Solar cycle 24(2012/05/17)



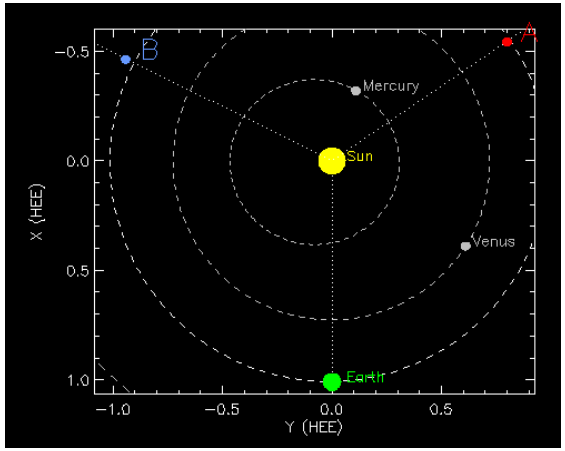


Recent Space Weather Event

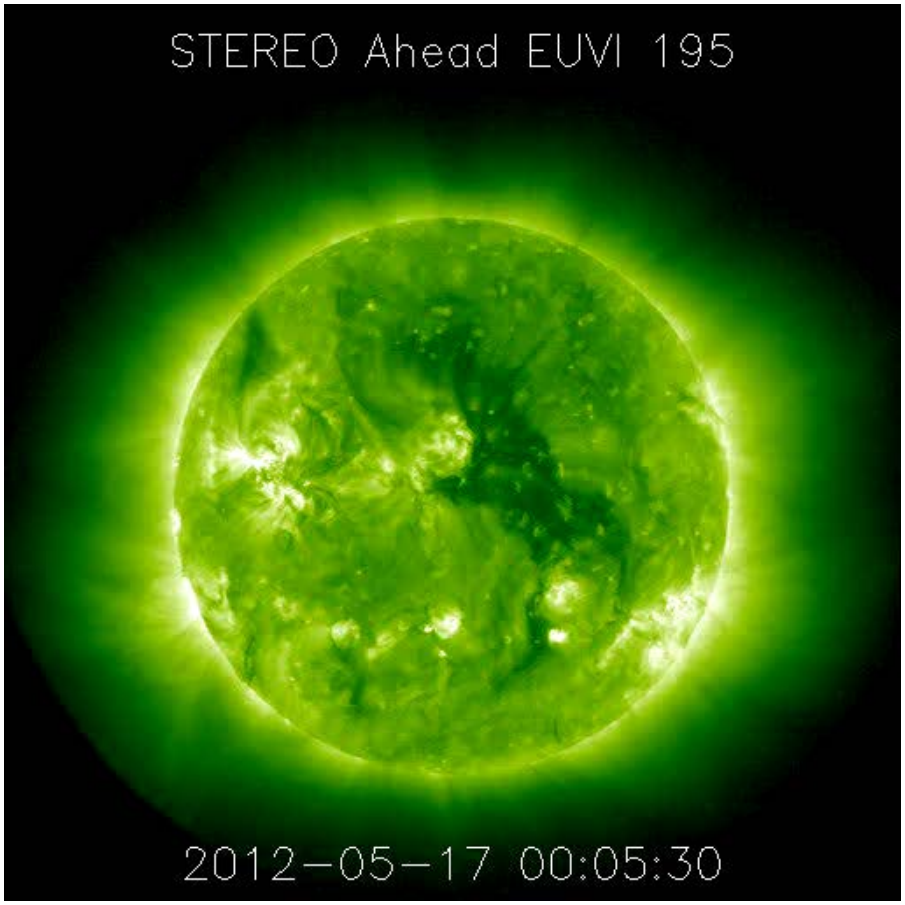
First GLE（Ground Level Event/Ground Level Enhancement）Solar cycle 24(2012/05/17)

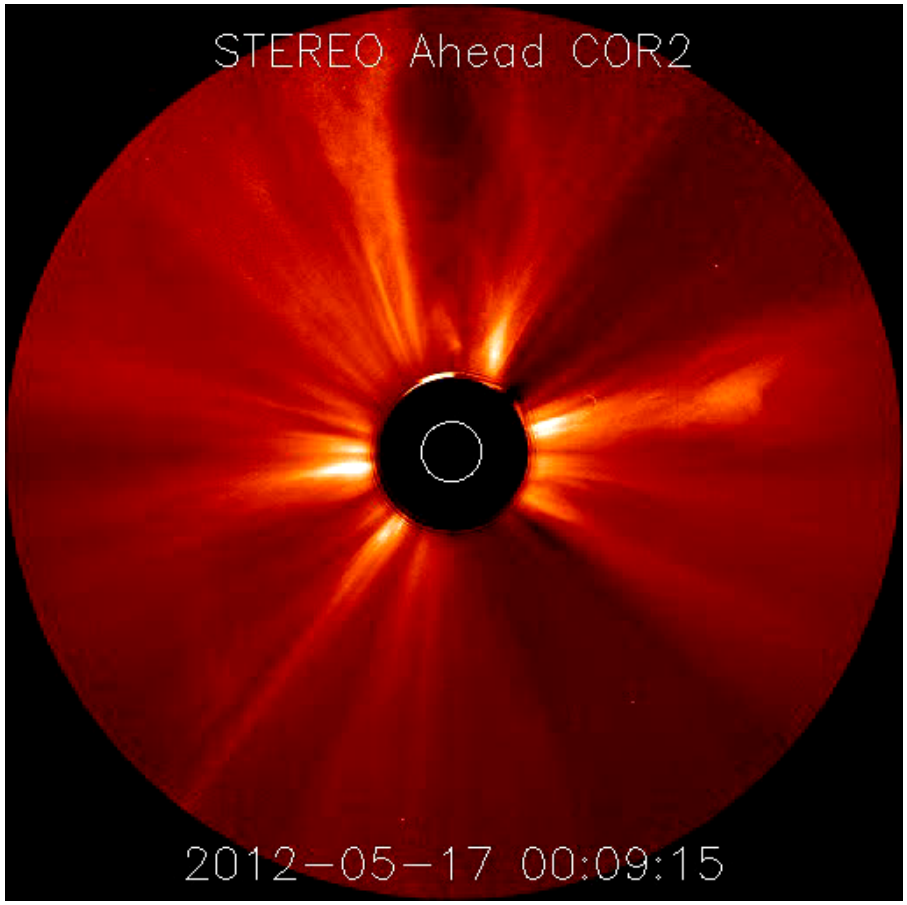


Recent Space Weather Event



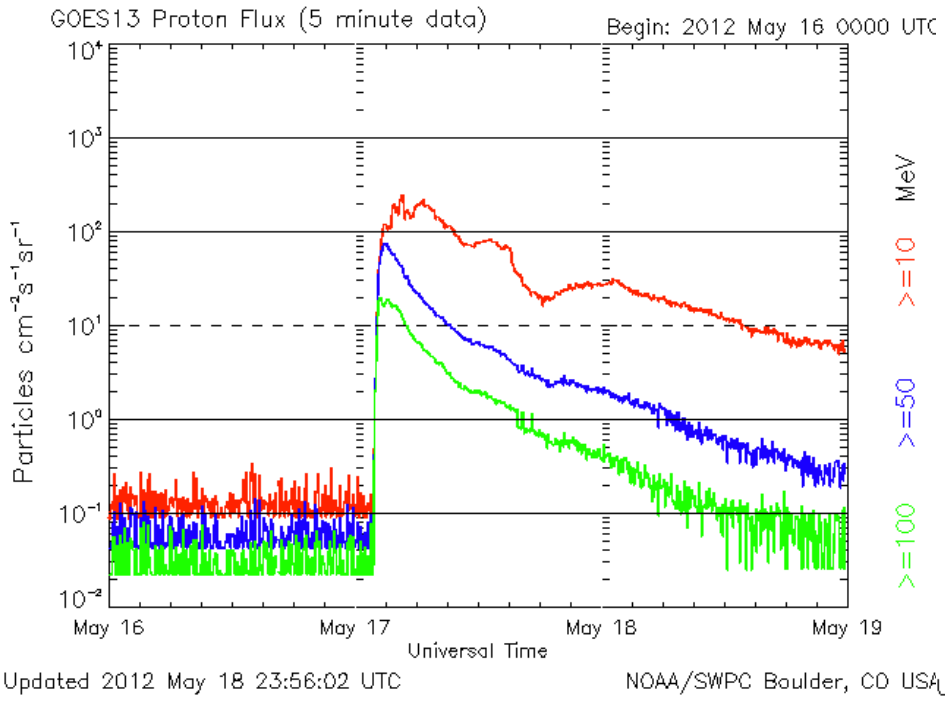
First GLE（Ground Level Event/Ground Level Enhancement）
Solar cycle 24(2012/05/17)

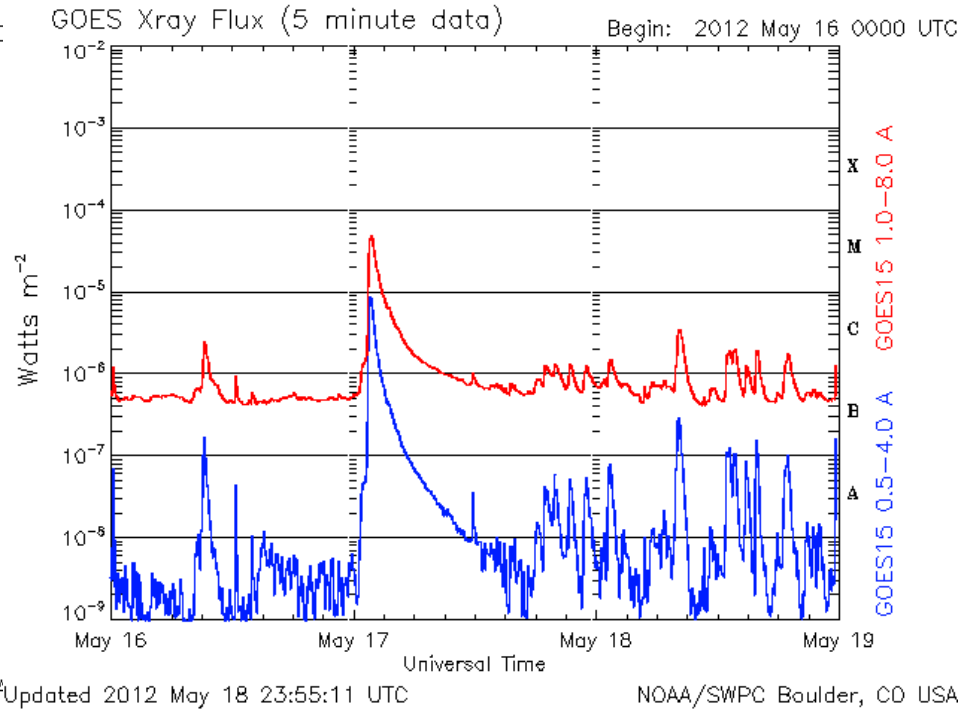




Recent Space Weather Event

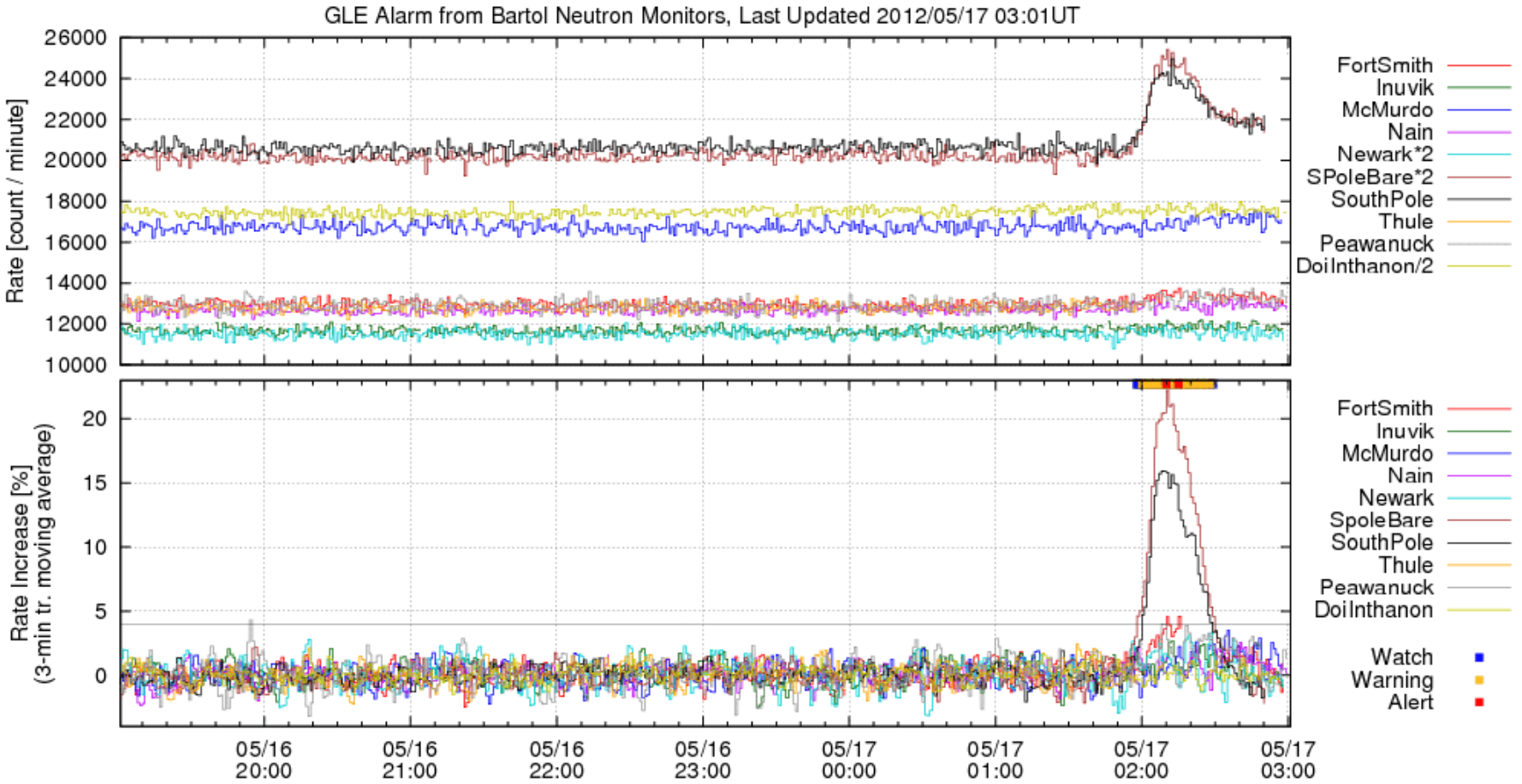
First GLE（Ground Level Event/Ground Level Enhancement）Solar cycle 24(2012/05/17)





Recent Space Weather Event

4) First GLE（Ground Level Event/Ground Level Enhancement）Solar cycle 24(2012/05/17)



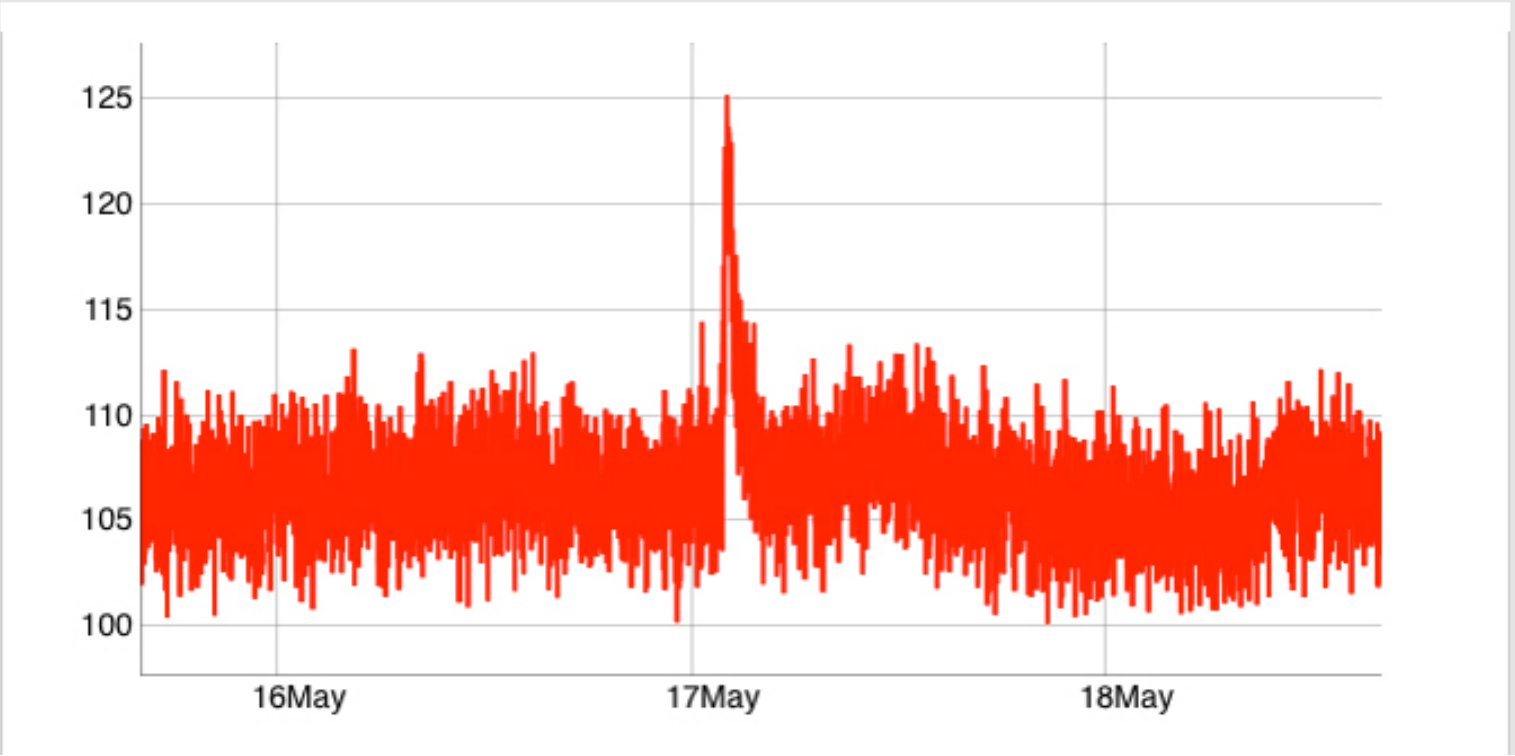
http://www.bartol.udel.edu/~takao/neutronm/glealarm/index.html

Recent Space Weather Event

Science Nugget: Catching Solar Particles Infiltrating Earth's Atmosphere **05.31.12**

Science nuggets are a collection of early science results, new research techniques, and instrument updates that further our attempt to understand the sun and the dynamic space weather system that surrounds Earth.

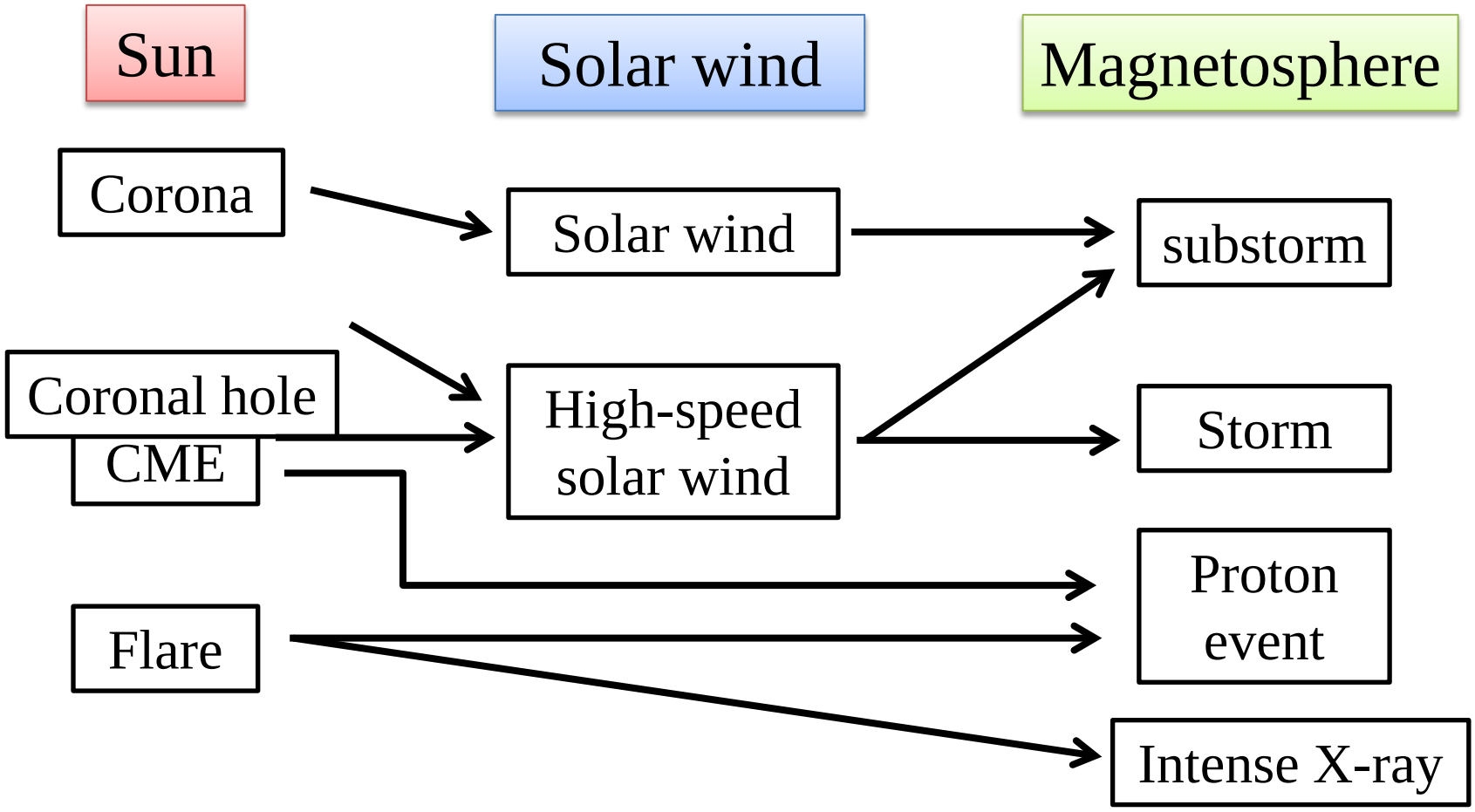
On May 17, 2012 an M-class flare exploded from the sun. The eruption also shot out a burst of solar particles traveling at nearly the speed of light that reached Earth about 20 minutes after the light from the flare. An M-class flare is considered a "moderate" flare, at least ten times less powerful than the largest X-class flares, but the particles sent out on May 17 were so fast and energetic that when they collided with atoms in Earth's atmosphere, they caused a shower of particles to cascade down toward Earth's surface. The shower created what's called a ground level enhancement (GLE).



http://www.nasa.gov/mission_pages/sunearth/news/particles-gle.html

Summary

■The Sun controls the Erath's magnetosphere. Summary of the space weather system is as follows.



■Let's check daily space weather. You can meet more interesting space weather events!