The Simultaneous Eruption of Strongest Flares and Geomagnetic Storms During Solar Cycle 24

[1]Zahid Ahmad Kumar [2] Dr. Sanjay Rathore

Department of Physics;[1,2]Sri Satya Sai University of Technology & Medical Sciences Sehore, MP.

ABSTRACT: It is important to understand the complicated effects of strongest solar flares and geomagnetic storms on ionosphere during the storm. The direct effects of solar flares are mainly related to communications and radio transmissions. Solar flares are often associated with coronal mass ejections, the ejections of electrons, protons and ions from the Sun. These charged particles have some other effects on Earth. One of the most spectacular (and extremely beautiful) consequences of this are auroras. When charged particles (especially electrons) find their way at the poles, they get accelerated along the lines of the magnetic field and collide with the particles in the atmosphere which makes them glow. That glow is what we see as an aurora.

Geomagnetic storm effects at heights of about 0–100 km are briefly (not comprehensively) reviewed, with emphasis being paid to middle latitudes, particularly to Europe. Effects of galactic cosmic rays, solar particle events, relativistic and highly relativistic electrons, and IMF sector boundary crossings are briefly mentioned as well. Geomagnetic storms disturb the lower ionosphere heavily at high latitudes and very significantly also at middle latitudes. The effect is almost simultaneous at high latitudes, while an after-effect dominates at middle latitudes. The lower thermosphere is disturbed significantly. In the mesosphere and stratosphere, the effects become weaker and eventually non-detectable. There is an effect in total ozone but only under special conditions. Surprisingly enough, correlations with geomagnetic storms seem to reappear in the troposphere, particularly in the Northern Hemisphere. Atmospheric electricity is affected by geomagnetic storms, as well. We essentially understand the effects of geomagnetic storms in the lower ionosphere, but there is a lack of mechanisms to explain correlations found deeper in the atmosphere, particularly in the troposphere.

Keywords. Coronal mass ejection, Geomagnetic storm, IMF, auroras, ionosphere, solar flares.

1 Introduction

A solar flare is an intense burst of radiation coming from the release of magnetic energy associated with sunspots. Flares are our solar system's largest explosive events. They are seen as bright areas on the sun and they can last from minutes to hours. We typically see a solar flare by the photons (or light) it releases, at most every wavelength of the spectrum. The primary ways we monitor flares are in x-rays and optical light. Flares are also sites where aparticles (electrons, protons, and heavier particles) are accelerated. The Earth's magnetosphere is created by our magnetic field and protects us from most of the particles the sun emits. When a CME or high-speed stream arrives at Earth it buffets the magnetosphere. If the arriving solar magnetic field is directed southward it interacts strongly with the oppositely oriented magnetic field of the Earth. The Earth's magnetic field is then peeled open like an onion allowing energetic solar wind particles to stream down the field lines to hit the atmosphere over the poles. At the Earth's surface a magnetic storm is seen as a rapid drop in the Earth's magnetic field strength. This decrease lasts about 6 to 12 hours, after which the magnetic field gradually recovers over a period of several days.

Solar Flares and Geomagnetic storms Struck in the year 2011

February

'Valentine's Day' 2011 flare

The solar flare peaked at 01:56 UT on February 15, 2011. The sunspot region 1158 produced an X2.2-class solar flare. Dubbed the Valentine's Day solar event by the scientific community, it was the first Solar Cycle 24 flare reaching X class level. In fact, it was the first of its class since December 2006. NOAA issued a R3 (strong) radio blackout alert pertaining to this prominent x-ray flux event. In addition to flashing Earth with X and UV radiation, the explosion also hurled a CME in Earth's direction. The magnetosphere was impacted on February 18. The CME struck a minor G1-level geomagnetic storm.

On March 9, 2011 the Sunspot region 1166 again produced an X1.5 class solar flare and on September 7 the sunspot region1283 caused an X1.8 class solar flare. CME ejected struck G2 and G1-level geomagnetic storms respectively.

G4 and G3-level geomagnetic storms struck due to the ejection of CME produced by the sunspot region1302 and 1283 with solar flares X1.9 and X2.1 respectively on 24 and 7 September 2011.

March

A CME exploded from the vicinity of sunspot 1164 during the late hours of March 7, 2011. It leapt away from the Sun traveling ~2200 km/s, making it the fastest CME since September 2005.

On March 8, the sunspot 1165 region disrupted an M5.3 class flare followed by CME caused Minor G1 geomagnetic storm. On March 9, active region 1166 erupted in an X1.5 flare. A R3-level radio blackout was reported. The related CME caused a moderate G2 geomagnetic storm two days later.

August

Sunspot 1263 produced an M9.3-class solar flare on August 3, 2011. The eruption of CME due to it caused severe G4-level geomagnetic storms. On the next day the sunspot reached 1402 and produced M6.0 class solar flare, the CME produced due to the eruption caused again the sever G4 level geomagnetic storm.

The geomagnetic storm reached a G4 (severe) level, enough to make power outages. It was one of the strongest geomagnetic storms in years. In the southern hemisphere, auroras could have been seen as far north as South Africa, Southern Chile and Southern Australia.

The CME associated with this burst. Although the flare was not Earth-directed, radiation created waves of ionization in Earth's upper atmosphere, briefly disrupting communications at some VLF and HF radio frequencies. A R3-level (strong) radio blackout alert was issued. A proton event greater than 10 MeV (=million electron volts) ions and exceeding 10 pfu (=proton flux units) was also reported, so a S1-level solar radiation storm was also issued.

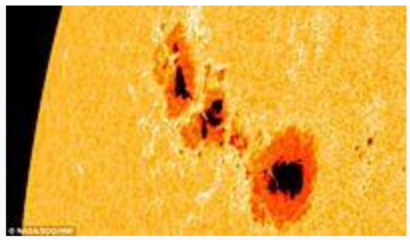
September

The X2.1-class flare – some four times stronger than the earlier flare – erupted from the same sunspot region. NOAA detected a R3 (strong) radio blackout and a S1 (minor) solar radiation storm. The combined CMEs of these bursts arrived the Earth on September 9, provoking a G3 (strong) geomagnetic storm.

The next day, September 7, an X1.8-class solar flare erupted from sunspot 1283, the eruption of solar flare produced CME which in turn caused Minor G1-level geomagnetic storm. This sequence of flares produced waves of ionization in Earth's upper atmosphere, briefly altering the propagation of low-frequency radio signals around our planet. Moreover, the eruptions hurled clouds of plasma in our direction. CME impacts, strong geomagnetic storms and auroras were registered from September 9 onwards.

On September 8, M6.7 class flare occurred from sunspot 1283 hurled CME caused minor G1-level geomagnetic storm.

The severe G4-level geomagnetic storms were recorded on September 24, by the eruption of solar flare 1.9 class and was followed by M7.1 class solar flare produced by sunspot region 1302 hurled CME which caused severe G4-level geomagnetic storms. M7.4 class solar flare struck on September 25, by the eruption of CME from the sunspot region 1302.

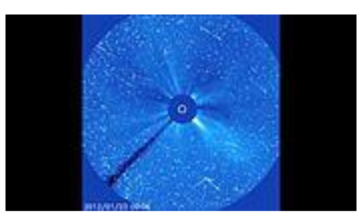


The active region 1302, responsible for two X-class flares in Sep 22 and 24, 2011. Image taken that month by NASA's SDO.

Solar Flares and Geomagnetic storms Struck in the year 2012

January

Sunspot 1402 erupted a long-duration M8.7-class flare, followed by a CME, on January 23, 2012 at 03:59 UTC. According to NOAA, the flare's radiation storm was ranked as S3 (strong level), the strongest since May 2005. The very fast-moving CME arrived at the Earth on January 24 at approximately 15:00 UTC. Geomagnetic storm reached a G1 level (minor) hurled from the production of CME.

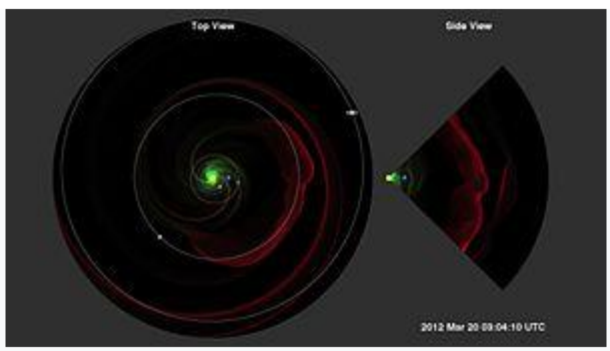


SOHO view of the Jan 23, 2012 M8.7 flare.

SDO shot of the Jan 23, 2012 M8.7 flare.

SDO shot of the Jan 23, 2012 M8.7 flare.

March



Enlil model for the March 2012 coronal mass ejection, plotted out to ten astronomical units (beyond the orbit of Saturn). The top view slices the data in the plane of the Earth's orbit and projects the planetary orbits onto that. The side view is a cross-section through the Sun-Earth line. The wedge-shape of the side view is because the Enlil model only extends above and below the solar equator by 60 degrees.

Active region 1429 erupted an X1.1-class flare on March 5 at 0413 GMT. The wave of high energy electromagnetic rays, reaching Earth in minutes, caused an R3 (strong) radio blackout over China, India and Australia, according to NOAA. Sunspot region 1429, whose size was half of that of Jupiter and was rotating toward Earth, was being particularly active since it materialized on March 2. The CME -the wave of plasma- that followed arrived at the Earth on March 7 and caused a G2 (moderate) geomagnetic storm. Just hours after ejecting the X1.1-class flare, AR1429 produced several minor C and M-class flares in chain.

X5.4-class flare

After releasing up to nine M-class flares in only one day, the active region 1429 erupted a powerful X5.4-class flare at 00:24 UTC the March 7. The related CME impacted the Earth on March 8, causing a G3 (strong) geomagnetic storm. This event marked the second strongest solar flare of Cycle 24 in terms of X-ray flux. NOAA launched a R3 (strong) radio blackout and a S3 (strong) solar radiation storm alerts. Months later, in June, NASA reported that its Fermi Gamma-ray Space Telescope detected in this powerful flare the highest flux of gamma rays—greater than 100 MeV—ever associated with an eruption on the Sun.

AR1429, rotating toward the other side of the Sun, still generated a M6.3-class flare on March 9 and a M7.9 flare on March 13. These eruptions hurled CMEs, all Earth-oriented. The first wave of plasma impacted the magnetosphere on March 12, causing a G2 (moderate) geomagnetic storm. The second CME was not geo-effective. The third wave of ionized gas reached our planet on March 15, causing another G2 storm.

In late March, the US Air Force Space Command reported that the solar storms of March 7–10 could have temporarily knocked American military satellites offline. NASA also reported that these powerful flares heated the Earth's upper atmosphere with the biggest dose of infrared radiation since 2005. From March 8 to March 10, the thermosphere absorbed 26 billion kWh of energy. Infrared radiation from carbon dioxide and nitric oxide, the two most efficient coolants in the thermosphere, re-radiated 95% of that total back into space.

March 2012, one of the most active months of Solar Cycle 24, ended up with 19 M-class and three X-class flares.

July

An X1.1-class flare erupted from sunspot 1515 on July 6, generating a R3 (strong) radio blackout and a S1 (minor) solar storm; its related CME caused a G1 (minor) geomagnetic storm. Six days after, sunspot 1520, the largest active region of Solar Cycle 24 to the moment, unleashed an X1.4-class flare, peaking at 12:52 PM EDT. This huge group of sunspots, which rotated into view on July 6, was located in the center of the Sun at the time of this event. The related CME caused a G2 (moderate) geomagnetic storm, following a R3 radio blackout and a S1 solar storm.

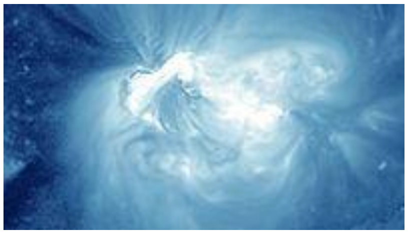
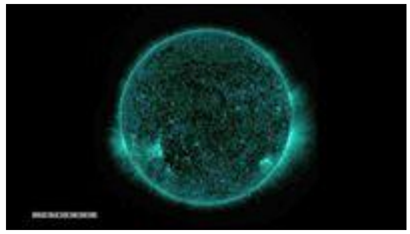


Photo of the July 12, 2012 X1.4 flare using SDO AIA footage in 131(teal), 171(gold) and 335 (blue) angstrom wavelengths.



Solar Flares and Geomagnetic storms Struck in the year 2013

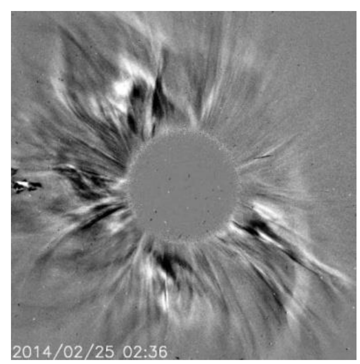
String of X-class flares

Solar activity increased rapidly in mid-May 2013 with four consecutive strong flares in two days. These powerful bursts all surged from the just-numbered sunspot AR1748, located in the eastern limb of Sun and barely rotating around the front of the solar disk. AR1748 emitted the first flare, an X1.7-class, on May 13, peaking at 02:17 UTC. This event was quickly followed the same day at 16:09 UTC by a X2.8-class flare. On May 14 at 01:17 UTC the same sunspot emitted a X3.2-class flare, the third strongest of current solar cycle so far. This was followed by an X1.2-class flare at 01:52 UTC on May 15. The four X-ray bursts generated a R3 (strong) radio blackout in upper atmosphere.

Every X-rays event was followed by a massive coronal mass ejection (CME). The first three CMEs were not geoeffective at all as they were not directed toward Earth; the fourth CME was partially geoeffective, so a G1 (minor) geomagnetic storm was expected to occur on May 18. A S1 (minor) proton storm event was also detected in connection with the May 15 X1.2 flare.

Solar Flares and Geomagnetic storms Struck in the year 2014

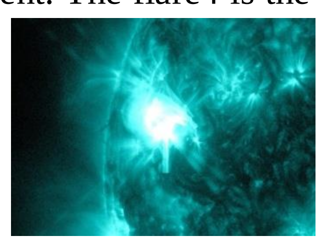
February



On February 25, 2014 the sun erupted with a X4.9-class solar flare, the strongest of that year. The solar flare caused disturbances in the horizontal component of the Earth's magnetic field. The planetary Kp-index reached level 6, so a G2 (moderate) geomagnetic storm was reported hurled due the production of CME.

The active sunspot region remained magnetically potent. This just proves that you cannot judge a book by its cover. A 10cm radio bust measuring 3700 sfu and lasting 85 minutes was associated with the event. The flare4 is the 3rd largest X-Ray event of the solar cycle 24.

MAY



NASA reports that the sun emitted a mid-level solar flare on Thursday (May 8, 2014), peaking at 10:07 UTC (6:07 a.m. EDT). NASA's Solar Dynamics Observatory, or SDO, captured the image. This flare is classified as an M5.2-class flare. M-flares are about one-tenth as strong as the most intense flares, called X-flares. The sunspot region 2056 produced the M5.3 Class solar flare and due to this eruption the CME hurled a G1-level geomagnetic storm.

September

The sun erupts with an X-flare from the sunspot region 2158 of intensity X1.6 in the center of the solar disk. The event also launches a coronal mass ejection earthward and caused strong G3 level geomagnetic storms. Starting around 23:00 CEST on 10 September, a gradual increase in the solar proton flux was observed by particle spectrometers on board GOES satellites. The flux is currently above the event threshold near 30 pfu. This is only a minor radiation event with limited consequences for high-frequency radio communication in the polar regions.

Solar Flares and Geomagnetic storms Struck in the year 2015

June

A serious solar storm has been battering Earth's magnetosphere, in the wake of a series of solar flares that erupted from a highly active sunspot 2371, the solar flare was M6.6 class. The flashes of electromagnetic waves from the flares reach Earth in just a few minutes, but enormous bursts of charged particles — known as coronal mass ejections, or CMEs — take longer to get here. The CME from the latest flare, on Sunday, was particularly fast and arrived on the coattails of earlier outbursts. As if that weren't enough, another strong flare occurred Monday.

The result is an extended and severe geomagnetic storm that reached G4 on the National Oceanic and Atmospheric.

The sunspot 2371 emitted a mid-level solar flare, an M7.9-class, peaking at 4:16 a.m. EDT on June 25, 2015 and a lopisided CME which caused moderate G2 level geomagnetic storms observed at higher latitudes. Associated with this event was a Type II radio emission with an estimated velocity of 2056 km/s.

The SDO captured an image of the June 25, 2015 event.

Solar Flares and Geomagnetic storms Struck in the year 2017

September

Sunspot region 2673 was one of the most active regions during the entire cycle, creating both of the largest flares in the cycle, and 4 total X-class flares. As of April 2018, no flares stronger than M1 have occurred since. The sunspot region 2673 generated X1.3 class solar flare but there was no ejection of CME but a severe G4 level geomagnetic storm erupted from the event. This strong flare occurred after a gap of about two years. This event generated strong R3 blackout and moderate S2 solar radiations.

Conclusion:

Solar flares strongly influence the local space weather in the vicinity of the Earth. They can produce streams of highly energetic particles in the solar wind or stellar wind, known as a solar proton event. These particles can impact the Earth's magnetosphere (see main article at geomagnetic storm), and present radiation hazards to spacecraft and astronauts. Additionally, massive solar flares are sometimes accompanied by coronal mass ejections (CMEs) which triggers geomagnetic storms that have been known to disable satellites and knocks out terrestrial electric power grids for extended periods of time.

The soft X-ray flux of X class flares increases the ionization of the upper atmosphere, which can interfere with short-wave radio communication and can heat the outer atmosphere and thus increase the drag on low orbiting satellites, leading to orbital decay. Energetic particles in the magnetosphere contribute to the aurora borealis and aurora australis. Energy in the form of hard x-rays can be damaging to spacecraft electronics and are generally the result of large plasma ejection in the upper chromosphere.

Geomagnetic storm strongly influence the Earth-orbiting satellites, especially those in high, **geosynchronous orbits**. Communications satellites are generally in these high orbits. Either the satellite becomes highly charged during the storm and a component is damaged by the high current that discharges into the satellite, or a component is damaged by high-energy particles that penetrate the satellite. We are not able to predict when and where a satellite in a high orbit may be damaged during a geomagnetic storm. The energetic particles from a flare or CME would be dangerous to an astronaut on a mission to the Moon or Mars, however.

Another effect which can occur during geomagnetic storms is the temporary loss of electrical power over a large region. This is most likely to happen at high latitudes, where the induced currents are greatest, and in regions having long power lines and where the ground is poorly conducting.

A positive aspect of geomagnetic storms, from an aesthetic point of view, is that the Earth's **auroras** are enhanced.

The damage to satellites and power grids can be very expensive and disruptive. Fortunately, this kind of damage is not frequent. Geomagnetic storms are more disruptive now than in the past because of our greater dependence on technical systems that can be affected by electric currents and energetic particles high in the Earth's magnetosphere.

Result:

Solar flares produce high energy particles and radiation that are dangerous to living organisms. However, at the surface of the Earth we are well protected from the effects of solar flares and other solar activity by the Earth's **magnetic field** and atmosphere. The most dangerous emissions from flares are energetic charged particles (primarily high-energy **protons**) and **electromagnetic radiation** (primarily **x-rays**).

The x-rays from flares are stopped by our atmosphere well above the Earth's surface. They do disturb the Earth's **ionosphere**, however, which in turn disturbs some radio communications. Along with energetic **ultraviolet radiation**, they heat the Earth's outer atmosphere, causing it to expand. This increases the drag on Earth-orbiting satellites, reducing their lifetime in orbit. Also, both intense radio emission from flares and these changes in the atmosphere can degrade the precision of Global Positioning System (GPS) measurements.

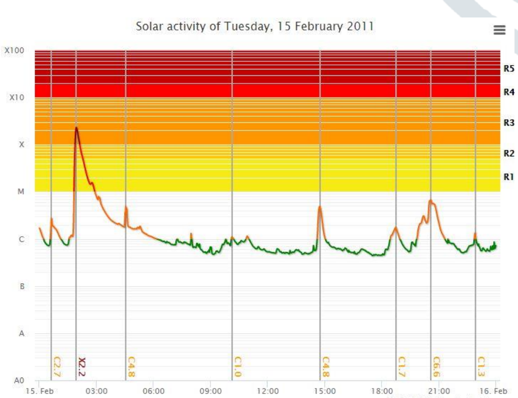
The energetic particles produced at the Sun in flares seldom reach the Earth. When they do, the Earth's magnetic field prevents almost all of them from reaching the Earth's surface. The small number of very high energy particles that does reach the surface does not significantly increase the level of radiation that we experience every day.

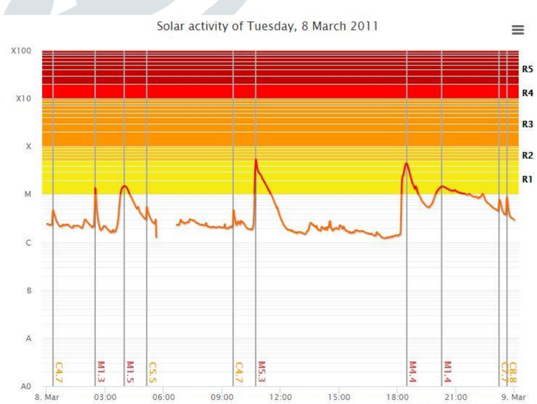
A **geomagnetic storm** (commonly referred to as a **solar storm**) is a temporary disturbance of the Earth's magnetospherecaused by a solar wind shock wave and/or cloud of magnetic field that interacts with the Earth's magnetic field. The increase in the solar wind pressure initially compresses the magnetosphere. The solar wind's magnetic field interacts with the Earth's magnetic field and transfers an increased energy into the magnetosphere. Both interactions cause an increase in plasma movement through the magnetosphere (driven by increased electric fields inside the magnetosphere) and an increase in electric current in the magnetosphere and ionosphere.

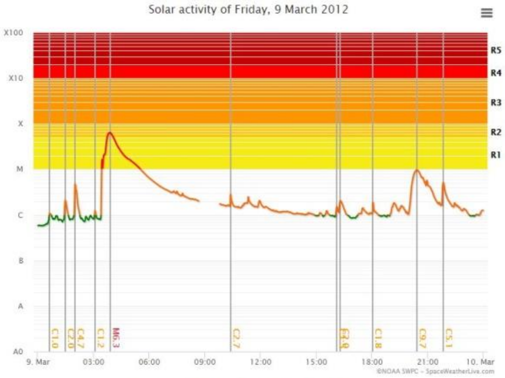
During the main phase of a geomagnetic storm, electric current in the magnetosphere creates a magnetic force that pushes out the boundary between the magnetosphere and the solar wind. The disturbance in the interplanetary medium that drives the storm may be due to a solar coronal mass ejection (CME) or a high speed stream (co-rotating interaction region or CIR)[1] of the solar wind originating from a region of weak magnetic field on the Sun's surface. The frequency of geomagnetic storms increases and decreases with the sunspot cycle. CME driven storms are more common during the maximum of the solar cycle, while CIR driven storms are more common during the minimum of the solar cycle.

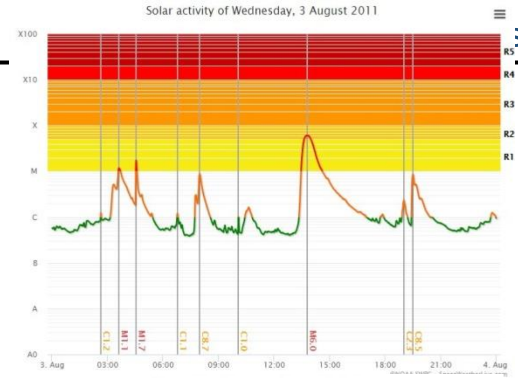
As per the data from NOAA SWPC

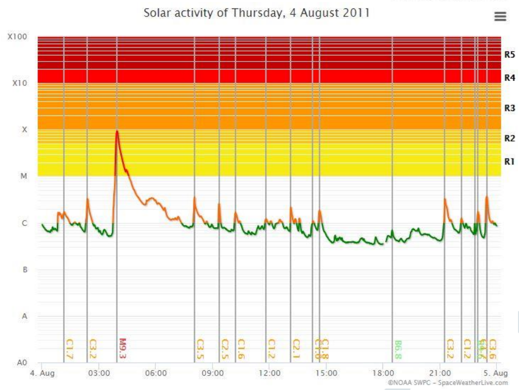
Flare Class	Year	Date	Sunspot Region	CME	GM Storm
X2.2	2011	Feb 15	1158	Yes	G1
M5.3	2011	March 8	1165	Yes	G1
X1.5	2011	March 9	1166	Yes	G2
M6.0	2011	Aug 3	1261	Yes	G4
M9.3	2011	Aug 4	1402	Yes	G4
X2.1	2011	Sep 6	1283	Yes	G3
X1.8	2011	Sep 7	1283	Yes	G1
M6.7	2011	Sep 8	1283	Yes	G1
X1.9	2011	Sep 24	1302	Yes	G4
M7.1	2011	Sep 24	1302	Yes	G4
M7.4	2011	Sep 25	1302	Yes	G1
M8.7	2012	Jan 23	1402	Yes	G1
X1.1	2012	Mar 5	1429	Yes	G2
X5.4	2012	Mar 7	1429	Yes	G3
M6.3	2012	Mar 9	1429	Yes	G2
M7.9	2012	Mar 13	1429	Yes	G2
X1.1	2012	July 6	1515	Yes	G1
X1.4	2012	July 12	1520	Yes	G2
X1.2	2013	May 15	1748	Yes	G1
X4.9	2014	Feb 25	1990	Yes	G2
M5.3	2014	May 8	2056	?	G1
X1.66	2014	Sep 10	2158	Yes	G3
M6.6	2015	Jun 22	2371	Yes	G4
M7.9	2015	Jun 25	2371	Yes	G2
X1.3	2017	Sep 7	2673	No	G4

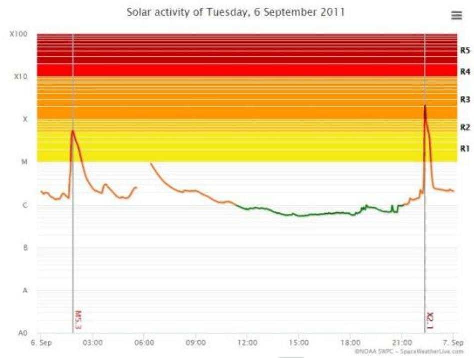


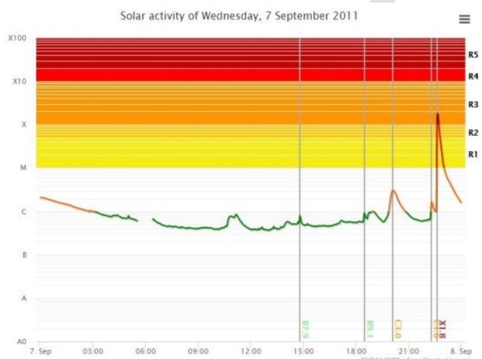


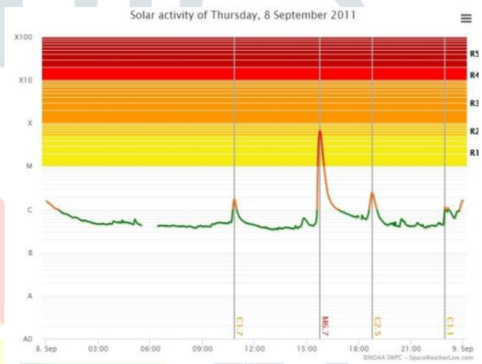

Solar activity of Friday, 9 March 2012

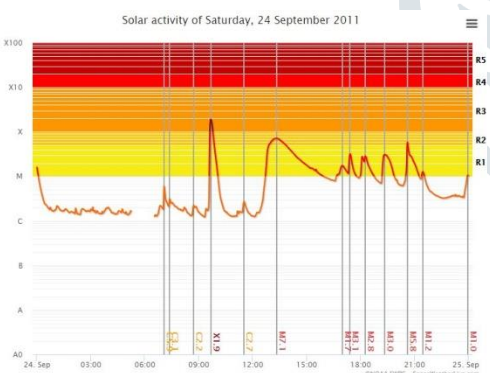

Solar activity of Wednesday, 3 August 2011

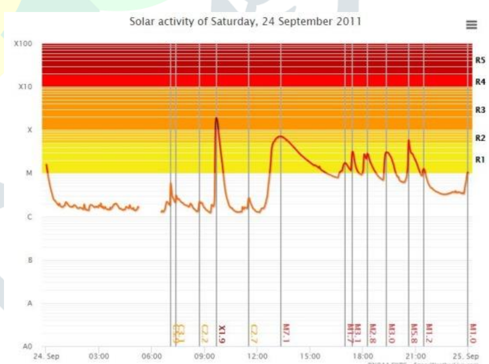

Solar activity of Thursday, 4 August 2011

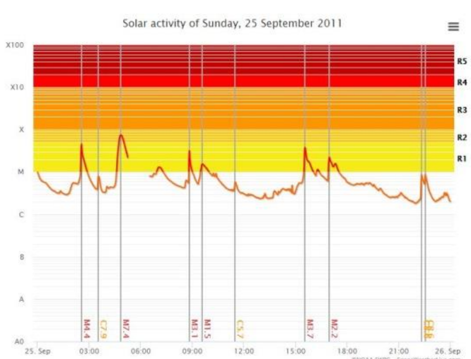

Solar activity of Tuesday, 6 September 2011

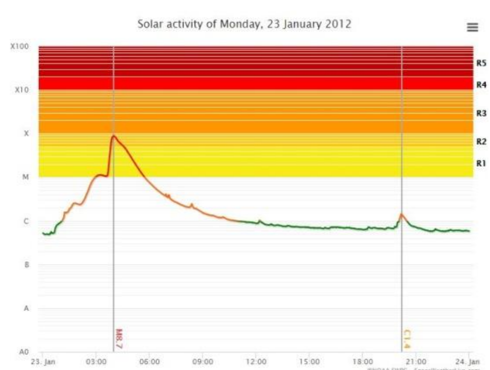

Solar activity of Wednesday, 7 September 2011

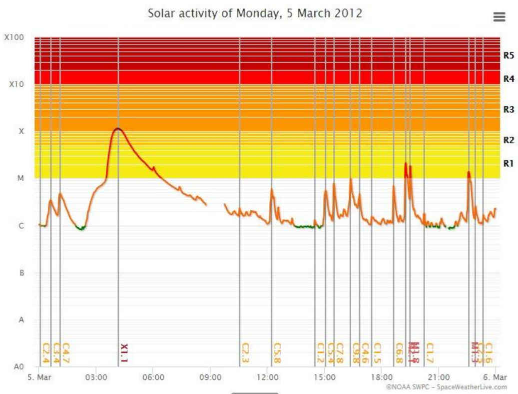

Solar activity of Thursday, 8 September 2011

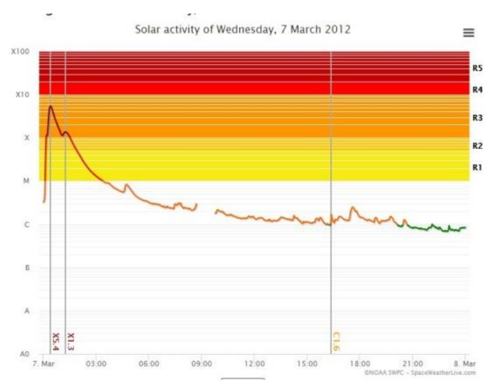

Solar activity of Saturday, 24 September 2011

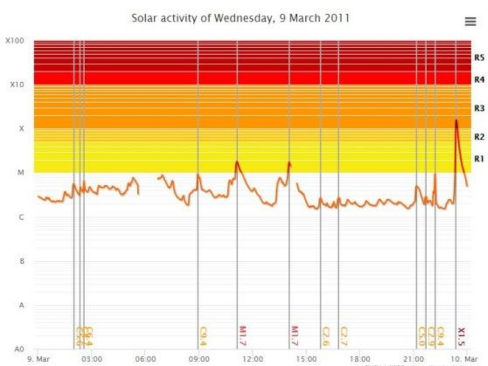

Solar activity of Saturday, 24 September 2011

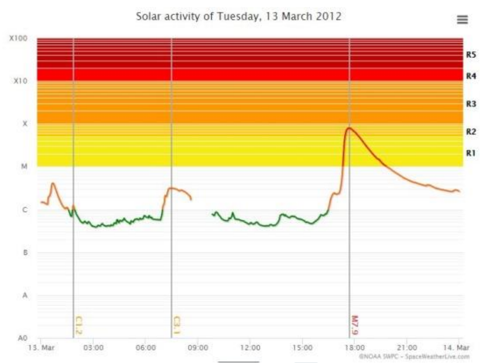

Solar activity of Sunday, 25 September 2011

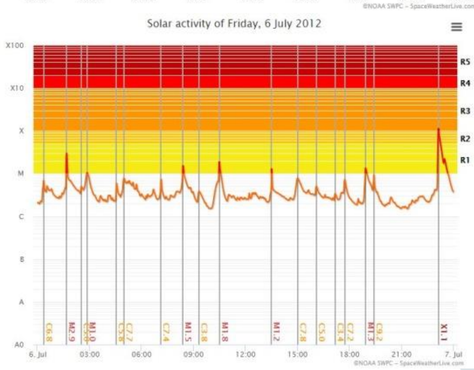

Solar activity of Monday, 23 January 2012

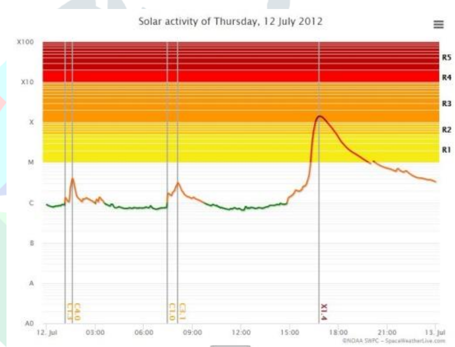

Solar activity of Monday, 5 March 2012

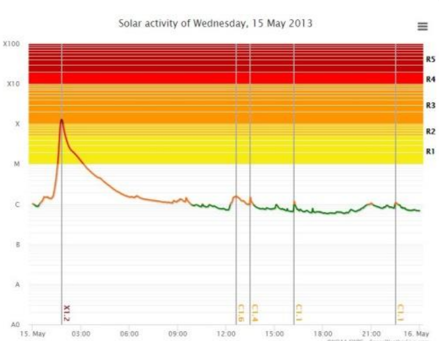

Solar activity of Wednesday, 7 March 2012

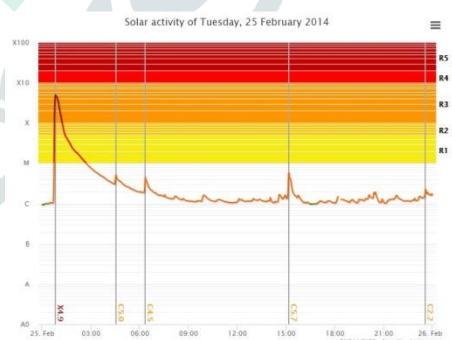

Solar activity of Wednesday, 9 March 2011

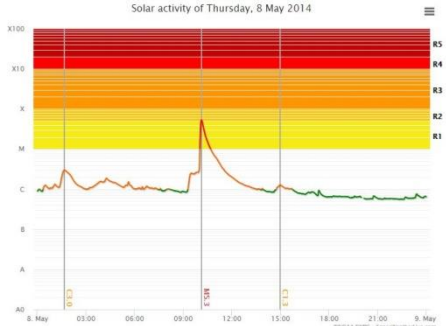

Solar activity of Tuesday, 13 March 2012

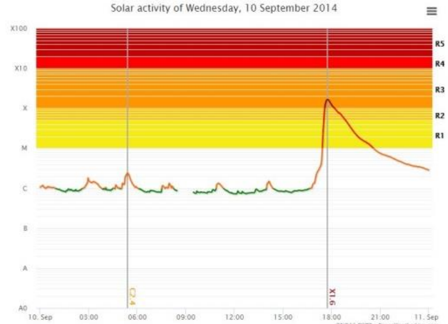

Solar activity of Friday, 6 July 2012

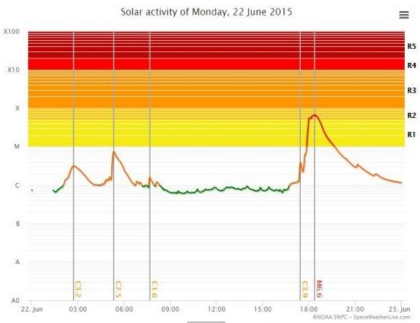

Solar activity of Thursday, 12 July 2012

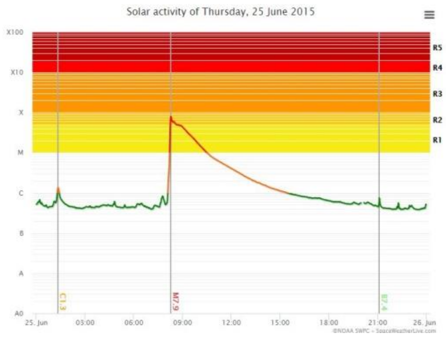

Solar activity of Wednesday, 15 May 2013

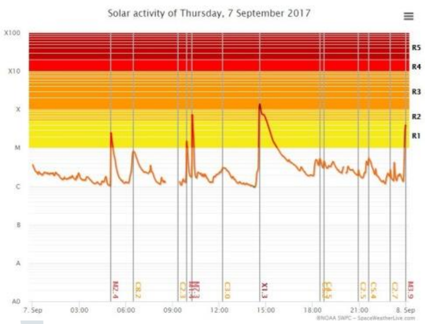

Solar activity of Tuesday, 25 February 2014


Solar activity of Thursday, 8 May 2014


Solar activity of Wednesday, 10 September 2014







References:

1. *Kopp, G.; Lawrence, G.; Rottman, G. (2005). "The Total Irradiance Monitor (TIM): Science Results". Solar Physics. **20**(1–2): 129–139. Bibcode:2005SoPh..230..129K. doi:10.1007/s11207-005-7433-9.*
2. *"What is a Solar Flare?". NASA. Retrieved May 12, 2016.*
3. Menzel, Whipple, and de Vaucouleurs, "Survey of the Universe", 1970
4. Jump up to:[a] [b] *Phillips, Dr. Tony (July 23, 2014). "Near Miss: The Solar Superstorm of July 2012". NASA. Retrieved July 26, 2014.*
5. *Staff (April 28, 2014). "Video (04:03) – Carrington-class coronal mass ejection narrowly misses Earth". NASA. Retrieved July 26, 2014.*
6. "Description of a Singular Appearance seen in the Sun on September 1, 1859", *Monthly Notices of the Royal Astronomical Society*, v20, pp13+, 1859
7. Zhu et al., ApJ, 2016, 821, L29
8. "The Mysterious Origins of Solar Flares", *Scientific American*, April 2006
9. *"Great Ball of Fire". NASA. Retrieved May 21, 2012.*
10. https://www.nasa.gov/feature/goddard/2017/active-region-on-sun-continues-to-emit-solar-flares
11. *"Solar Storm and Space Weather—Frequently Asked Questions". NASA Mission Pages: Sun-Earth. Retrieved November 12, 2018.*
12. *"SOHO Hotshots". Sohowww.nascom.nasa.gov. Retrieved May 21, 2012.*
13. *"Biggest ever solar flare was even bigger than thought | SpaceRef – Your Space Reference". SpaceRef. 2004-03-15. Retrieved May 21, 2012.*
14. *"Geomagnetic Storms Can Threaten Electric Power Grid". Earth in Space. **9** (7): 9–11. March 1997. Archived from the original on 2008-06-11.*
15. High-voltage power grid disturbances during geomagnetic storms Stauning, P., Proceedings of the Second Solar Cycle and Space Weather Euroconference, 24–29 September 2001, Vico Equense, Italy. Editor: Huguette Sawaya-Lacoste. ESA SP-477, Noordwijk: ESA Publications Division, ISBN 92-9092-749-6, 2002, p. 521–524
16. World Data Center for Geomagnetism, Kyoto
17. *McGrath, Matt (5 September 2017). "Northern lights link to whale strandings" – via www.bbc.com.*

18. https://www.usnews.com/news/national-news/articles/2017-09-06/solar-storms-may-ignite-south-reaching-auroras-wednesday
19. *"Homepage - NOAA / NWS Space Weather Prediction Center". noaa.gov.*
20. *"Aurora Update". Harvard-Smithsonian Center for Astrophysics. 2010-08-03.*
21. Jump up to:[a] [b] *"Solar Tsunami to Strike Earth Tonight". FoxNews.com. 2010-08-03.*
22. *"Alerte aux aurores boréales pour le 3 et le 4 août ! | Ciel et Espace" (in French). Cieletespace.fr. Retrieved 2010-08-03.*
23. *"News and information about meteor showers, solar flares, auroras, and near-Earth asteroids". SpaceWeather.com. Retrieved 2010-08-03.*
24. *"Northern lights could illuminate the sky late Tuesday night". CNN.com. 2010-08-03.*
25. *"Time Machine". Spaceweather.com. Retrieved 2012-01-24.*
26. *Jones, Meg. "Northern lights produce great show Tuesday night; encore expected Wednesday". Milwaukee-Wisconsin Journal Sentinel. Retrieved 2010-08-04.*
27. *Kaplan, Jeremy (2010-08-04). "Solar Storm Causes Fantastic Light Show". Foxnews.com. Retrieved 2010-08-04.*
28. *"M5 solar flare". SpaceWeather.com.*
29. Valentine's Day Solar Flare, NASA, February 17, 2011.
30. *"Time Machine". Spaceweather.com. Retrieved 2012-01-24.*
31. *"Time Machine". Spaceweather.com. Retrieved 2012-01-24.*
32. *"Spaceweather.com Time Machine". spaceweather.com.*
33. *"Spaceweather.com Time Machine". spaceweather.com.*
34. Sun packs a double punch, NASA website, August 4, 2011.
35. Strong geomagnetic storm in progress now as solar storm nails earth, WeatherSpace.com, August 5, 2011.