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# Space Weather Activity – A Year in Review

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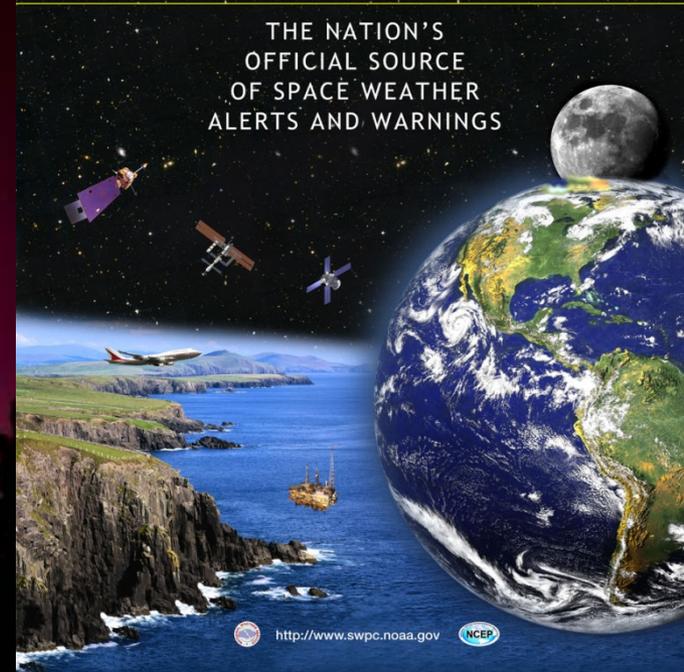
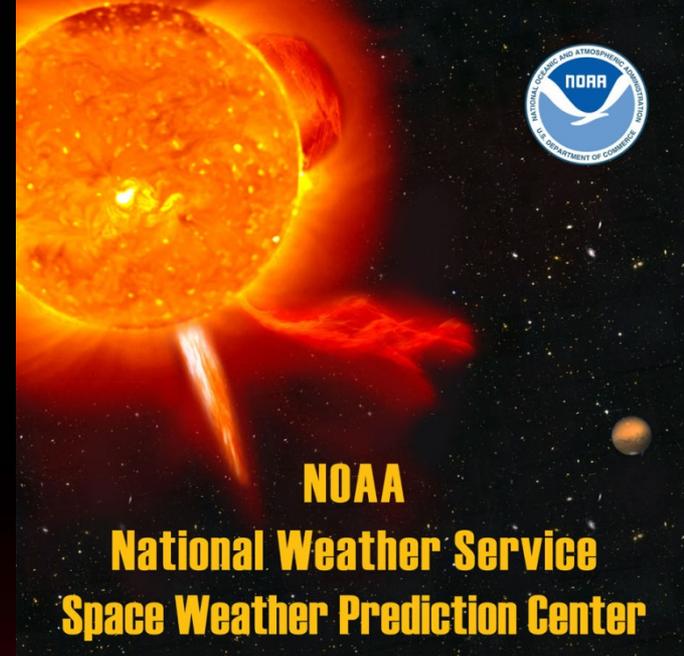
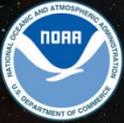
*Bob Rutledge*

*NOAA Space Weather Prediction Center*

*Boulder, Colorado*

*April 26<sup>th</sup>, 2016*

2016 Space Weather Week – Broomfield, CO



<http://www.swpc.noaa.gov> NCEP

# Outline

- Activity Trends
- June 2015 Geomagnetic Storm
- November 2015 Radio Burst



**NOAA**  
**National Weather Service**  
**Space Weather Prediction Center**

THE NATION'S  
OFFICIAL SOURCE  
OF SPACE WEATHER  
ALERTS AND WARNINGS

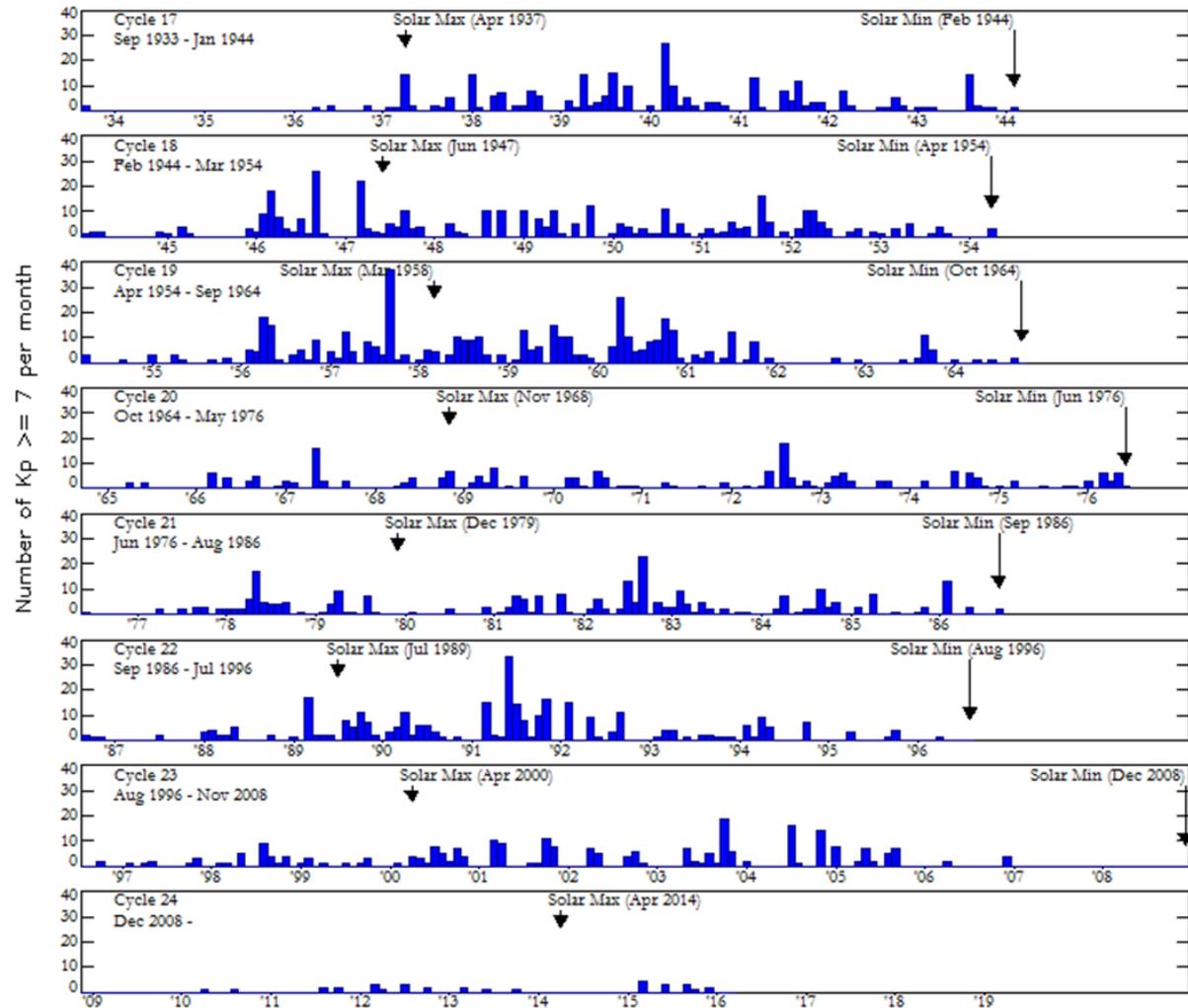
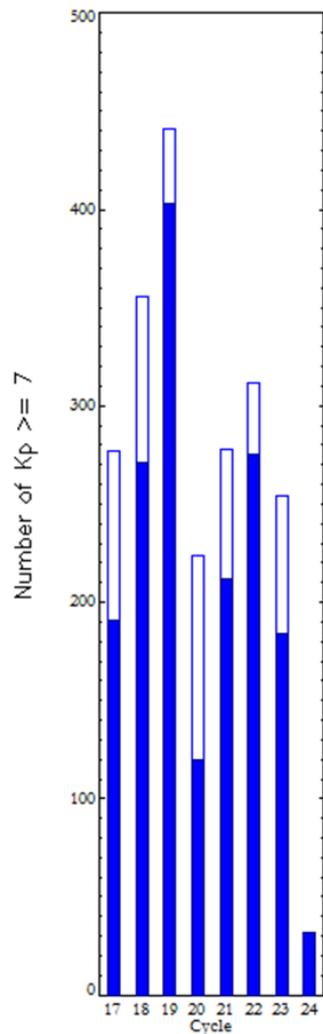


# Periods with $K_p \geq 7$

March 2016

(Month 88)

Comparison of Cycles  
at current month in cycle

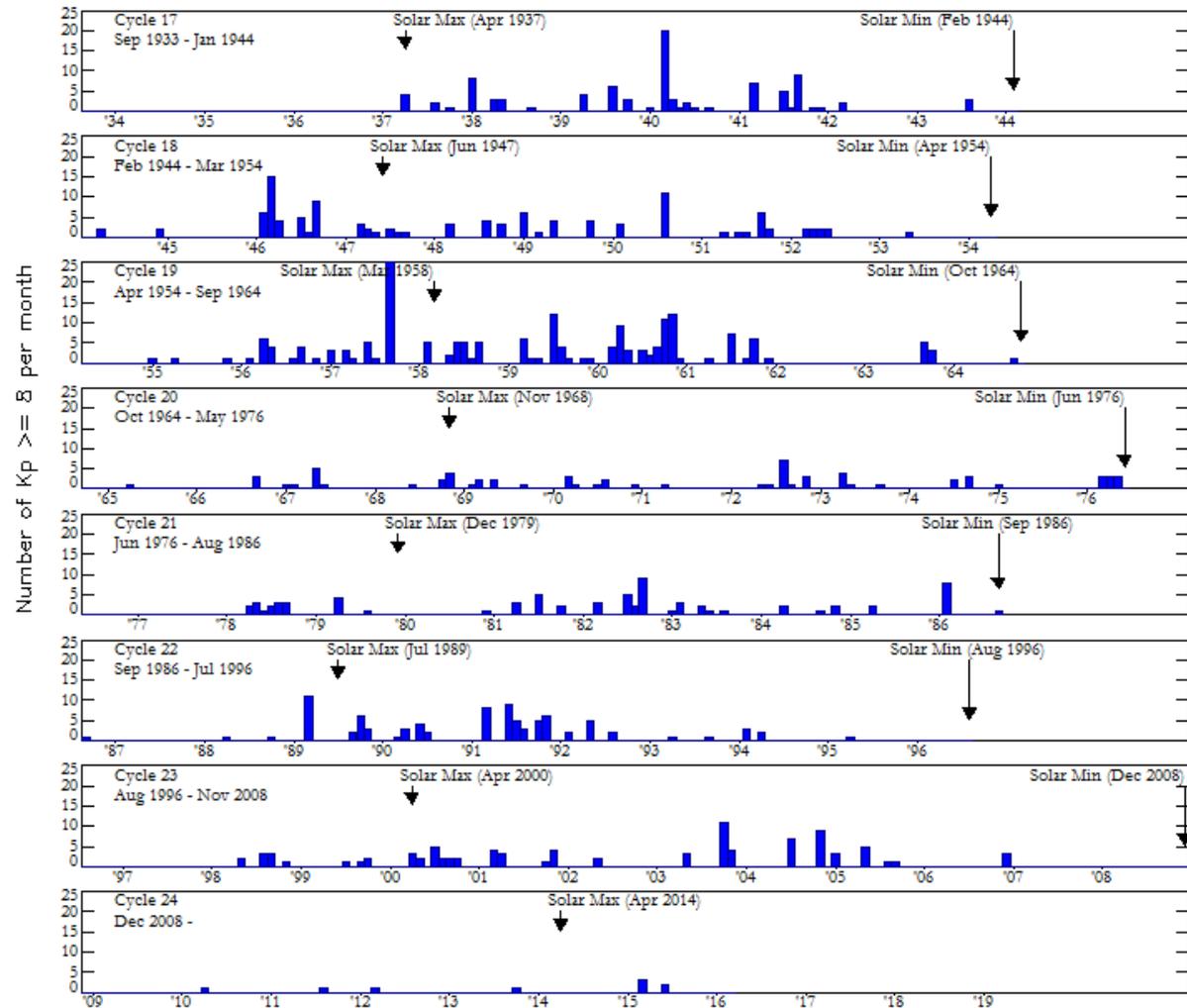
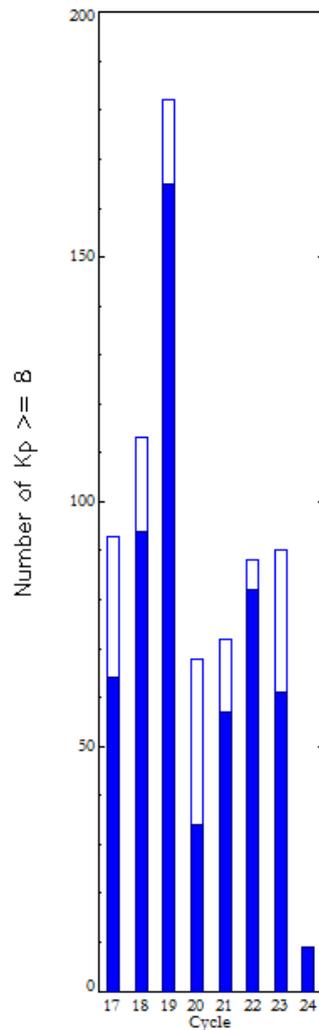


# Periods with $K_p \geq 8$

March 2016

(Month 88)

Comparison of Cycles  
at current month in cycle

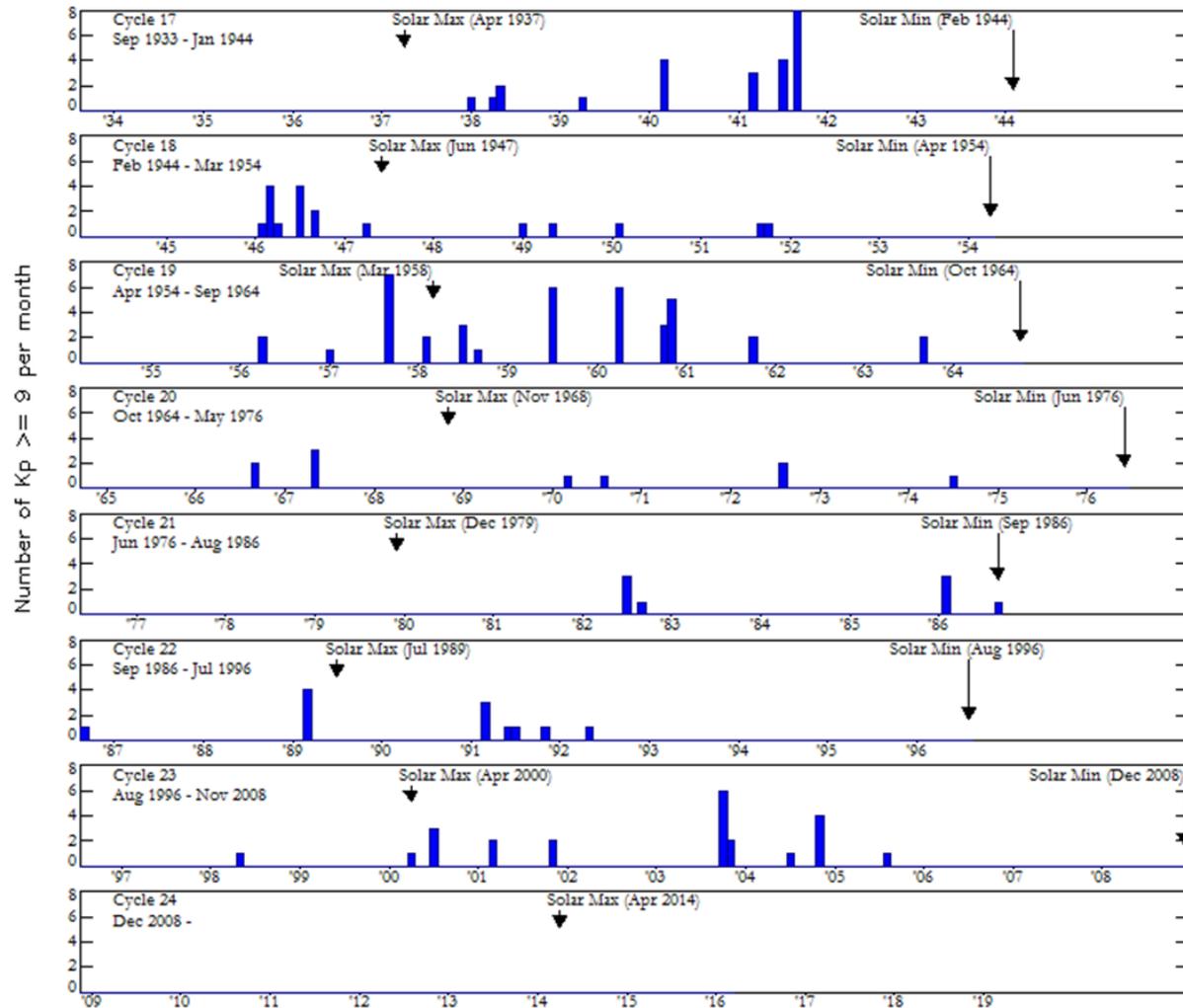
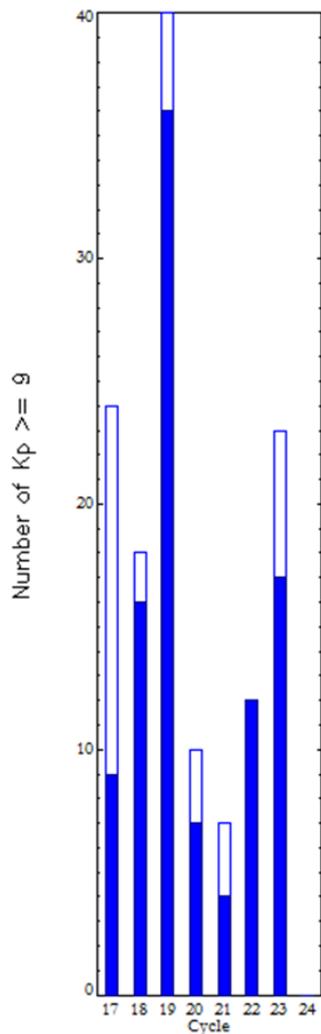


# Periods with $K_p \geq 9$

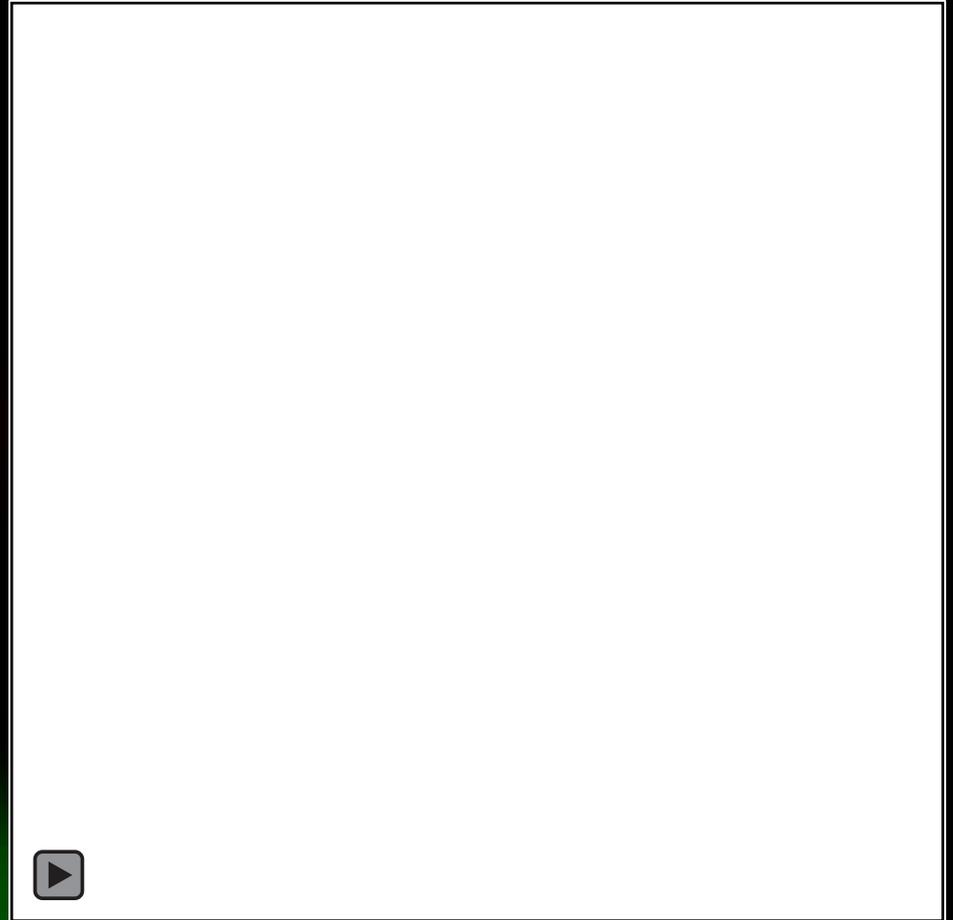
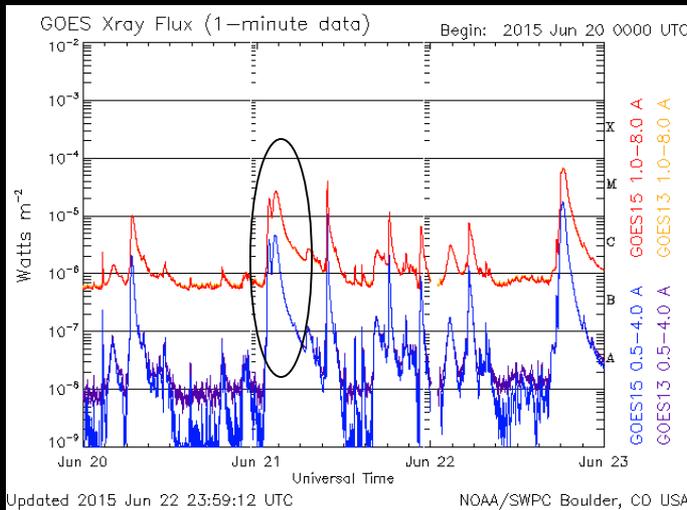
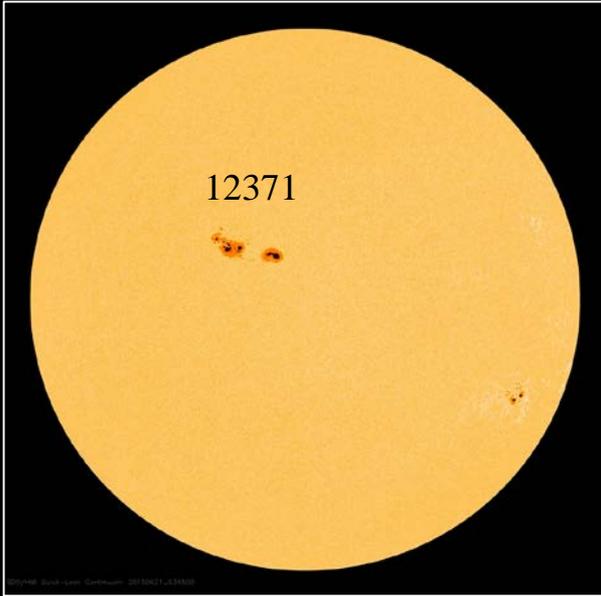
March 2016

(Month 88)

Comparison of Cycles  
at current month in cycle



# June 2015 Geomagnetic Storm



# June 2015 Geomagnetic Storm

Product: 3-Day Forecast  
 Issued: 2015 Jun 22 0030 UTC  
 Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center

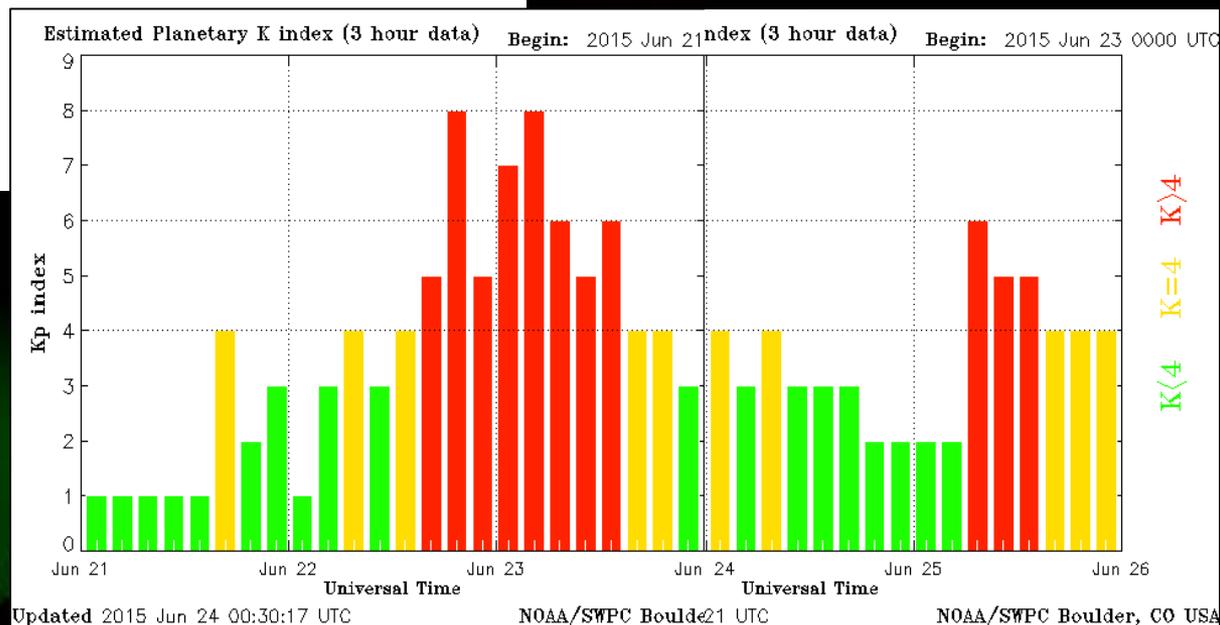
## A. NOAA Geomagnetic Activity Observation and Forecast

The greatest observed 3 hr Kp over the past 24 hours was 4 (below NOAA Scale levels).

The greatest expected 3 hr Kp for Jun 22-Jun 24 2015 is 7 (NOAA Scale G3).

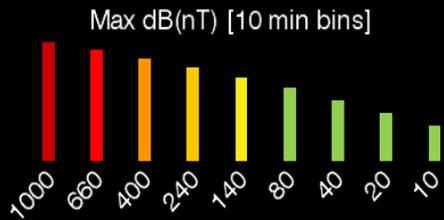
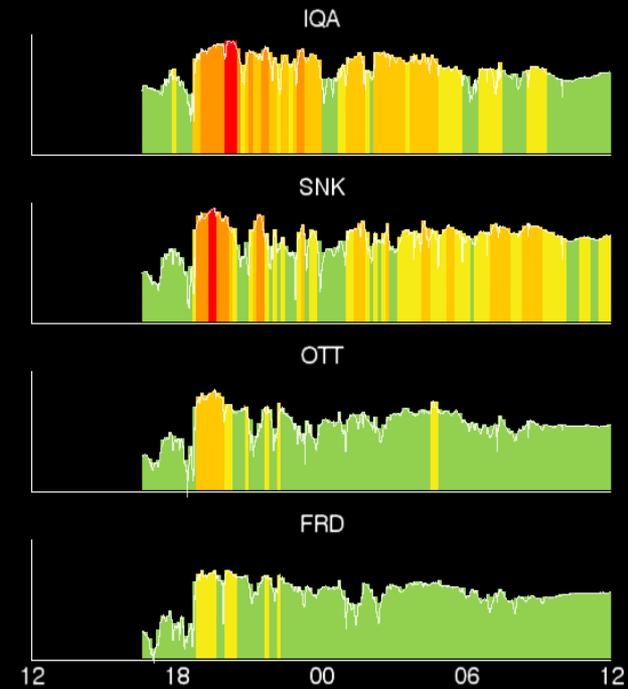
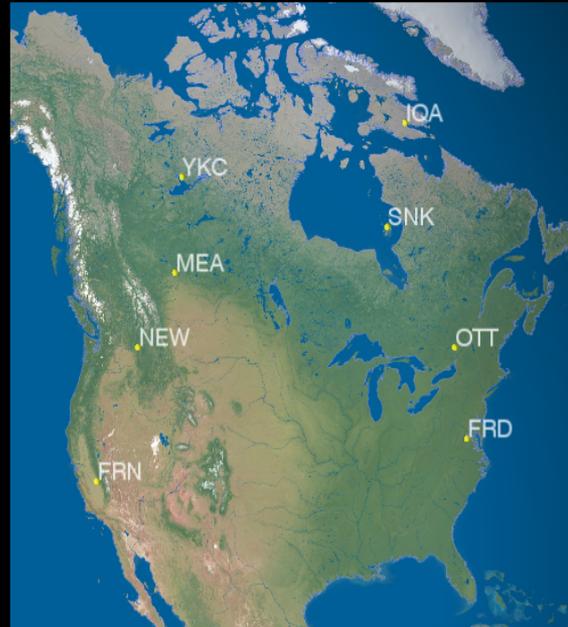
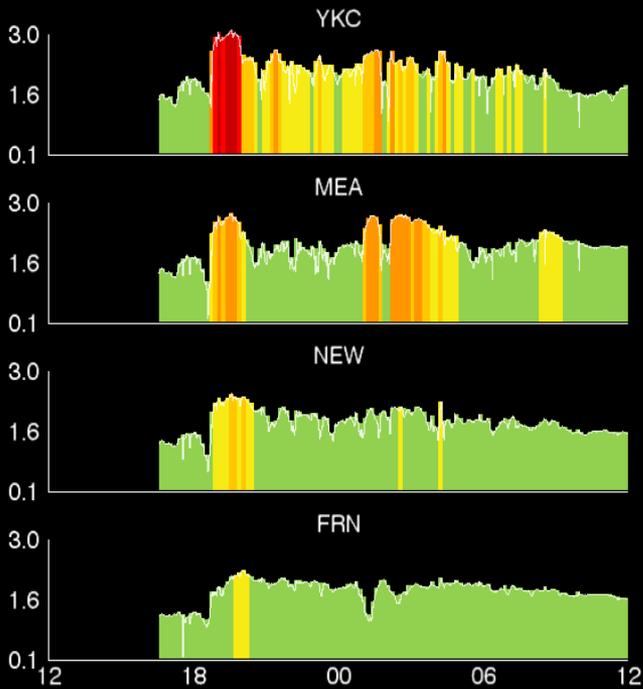
### NOAA Kp index breakdown Jun 22-Jun 24 2015

	Jun 22	Jun 23	Jun 24
00-03UT	3	6 (G2)	4
03-06UT	3	6 (G2)	4
06-09UT	3	5 (G1)	3
09-12UT	3	4	2
12-15UT	6 (G2)	4	2
15-18UT	7 (G3)	4	2
18-21UT	7 (G3)	3	2
21-00UT	6 (G2)	3	3

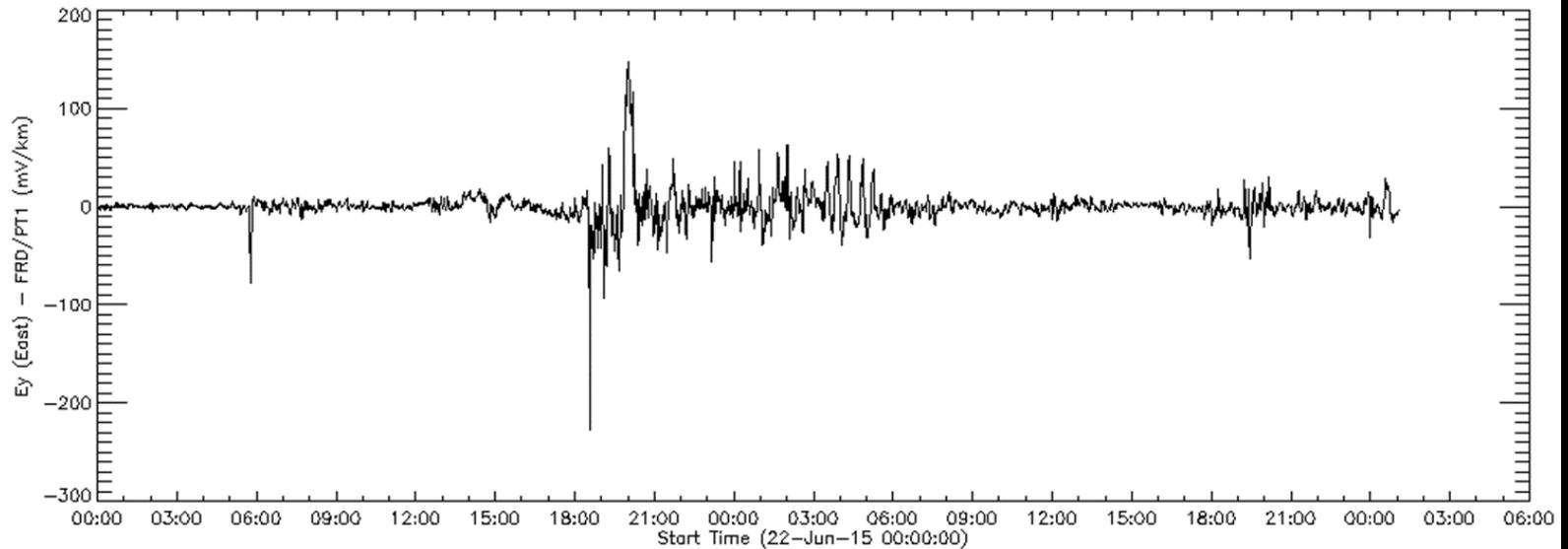
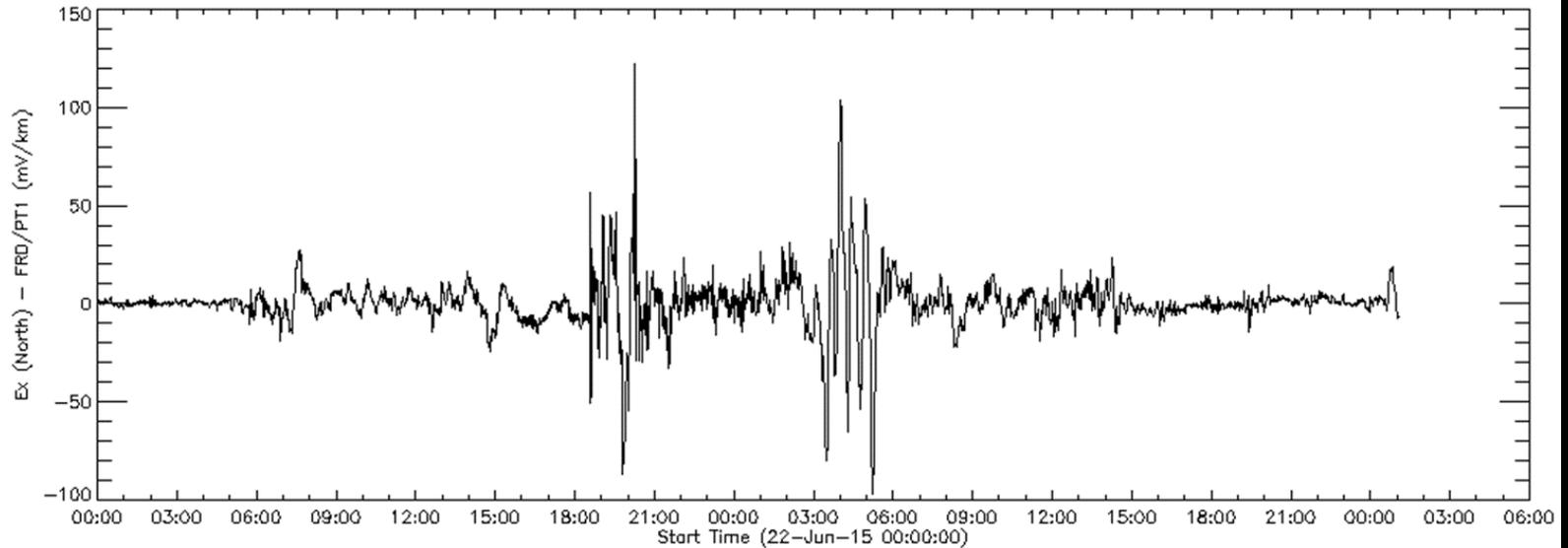


# Example Geospace Model Output

SWMF Geospace : Regional dB 22nd-23rd June 2015  
North American Sector



# Induced-E Prototype Model Output





NASA Astronaut Scott Kelly captured this photo of an aurora from the International Space Station on June 23, 2015. – Image Credit NASA

# November 2015 Radio Burst

The screenshot shows the CBC News website interface. At the top, there are navigation links for TV, RADIO, NEWS, SPORTS, MUSIC, ARTS, LOCAL, and MORE. Below these are buttons for WATCH, LISTEN, and LOG IN, along with a search bar. The main header features the 'CBCnews' logo and the section title 'Technology & Science'. A secondary navigation bar includes links for Home, World, Canada, Politics, Business, Health, Arts & Entertainment, Technology & Science (highlighted), Trending, and Video. Below this, there are more specific links for Technology & Science, Quirks & Quarks Blog, Spark, and Photo Galleries. The main article headline is 'Solar storm knocks out flight control systems in Sweden, grounds planes'.

## Solar storm knocks out flight control systems in Sweden, grounds planes

Flights disappeared from radar screens

The Associated Press | Posted: Nov 04, 2015 3:38 PM ET | Last Updated: Nov 04, 2015 3:40 PM ET

2160 shares

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Aviation officials say a solar storm knocked out the air traffic control systems in Sweden on Wednesday, prompting them to close the country's airspace for more than an hour.

The civil aviation authority said the solar storm created disturbances in the Earth's magnetic field, which affected radar installations in southern Sweden. No such problems were reported in neighbouring countries.

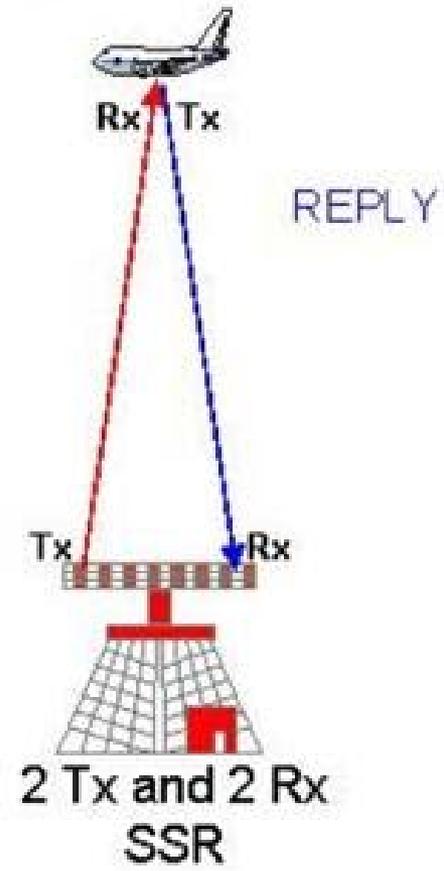
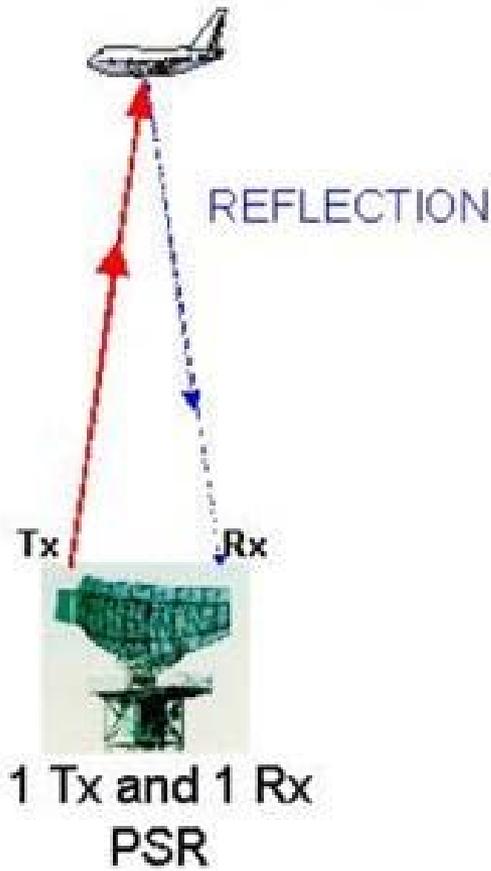


Parked aircraft are seen at Stockholm Arlanda Airport photo from March 2015. Swedish airspace was closed for an hour Wednesday after a solar storm knocked out air control systems. (Johan Nilsson/Associated Press)

What we could see was how it appeared **rows of unfamiliar echoes on the screens, these echoes were incorrect identification numbers and incorrect heights and they came and went all the time**, says Anders Andersson, Systems for monitoring infrastructure LfV. - The problems meant that our older stations were overloaded, while the newer ones are not affected in the same way. According to Anders Andersson, two things that indicate that solstörmen is one of the causes of the accident: • **All the stations affected are located in the part of Sweden where the sun was above the horizon when the problems occurred.** • **All false echoes appeared over a nine degree narrow sector on the radar in the direction that was facing the sun.** -- <http://www.dn.se/nyheter/sverige/solstorm-bara-en-del-av-forklaringen-till-radarstopp/>

# Primary and Secondary Surveillance Radar

## PSR versus SSR



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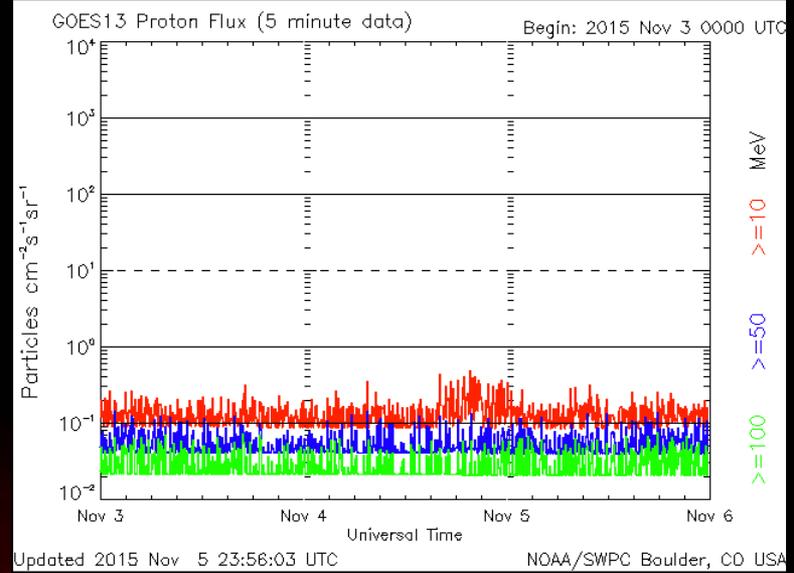
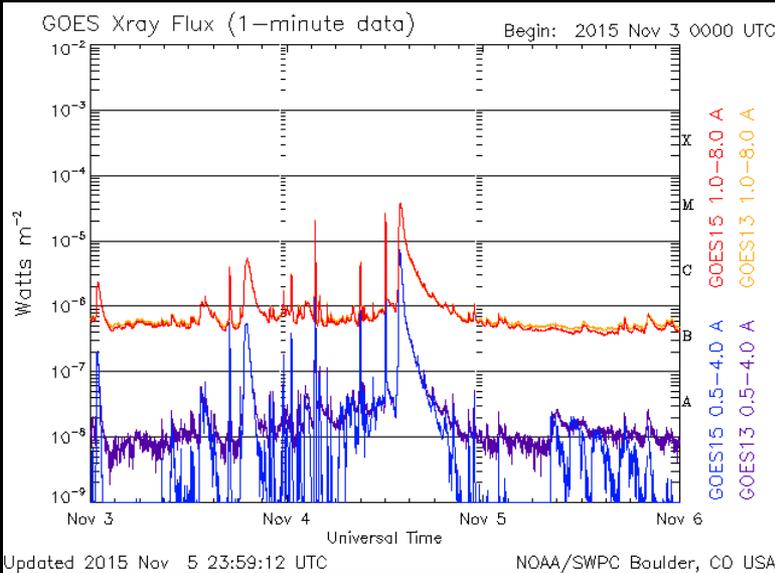
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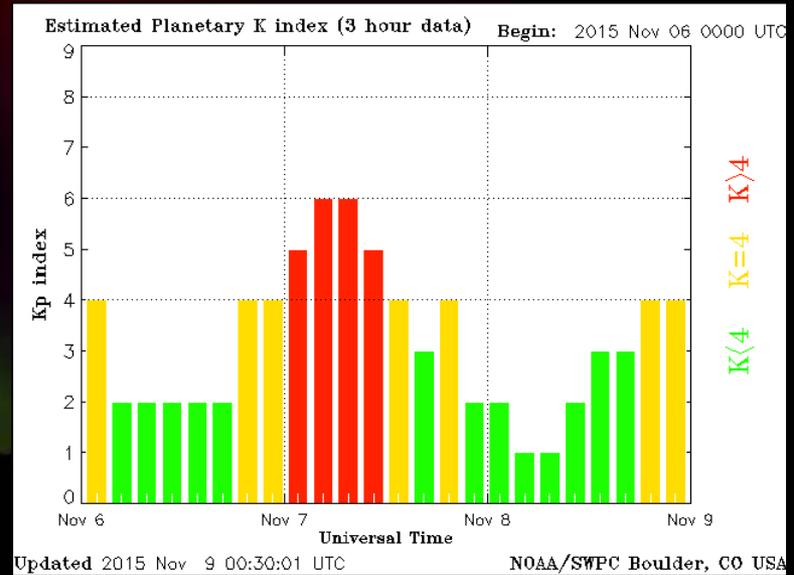
Parked aircraft are seen at Stockholm Arlanda Airport in Sweden, March 2015. Swedish airspace was closed for an hour Wednesday after a solar storm knocked out air control systems. (Johan Nilsson/Associated Press)

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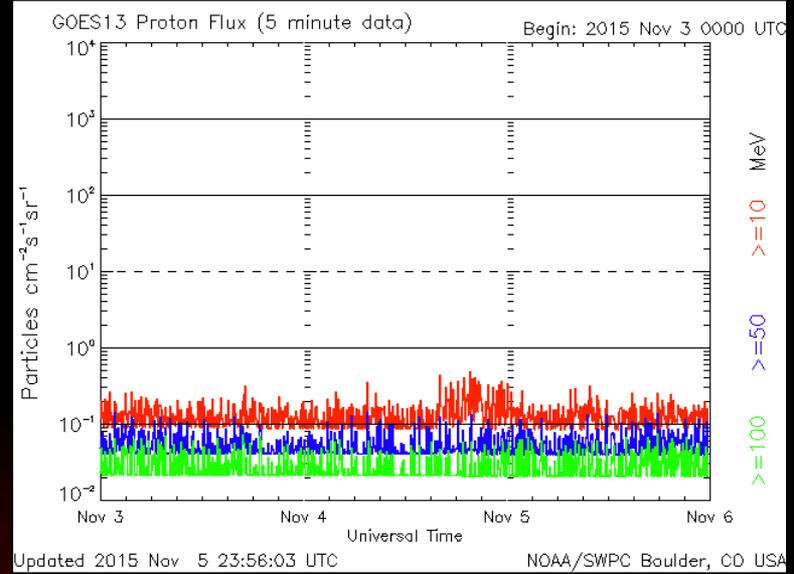
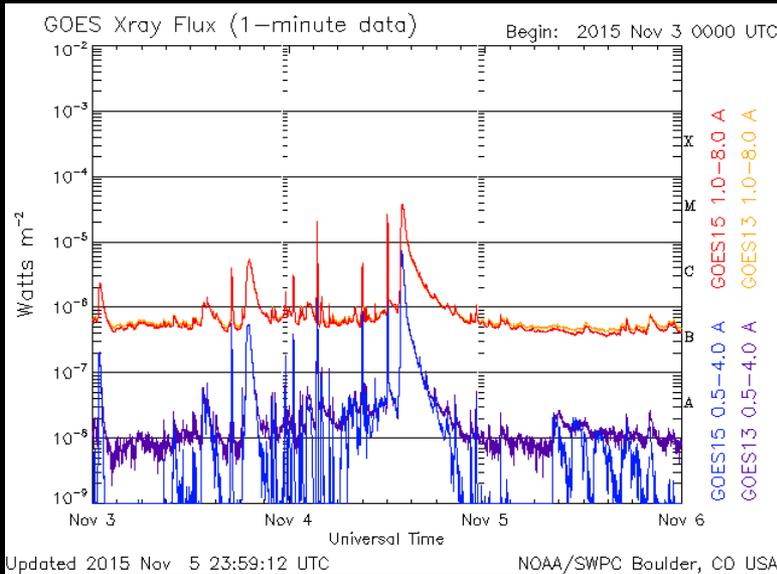
# November 2015 Radio Burst



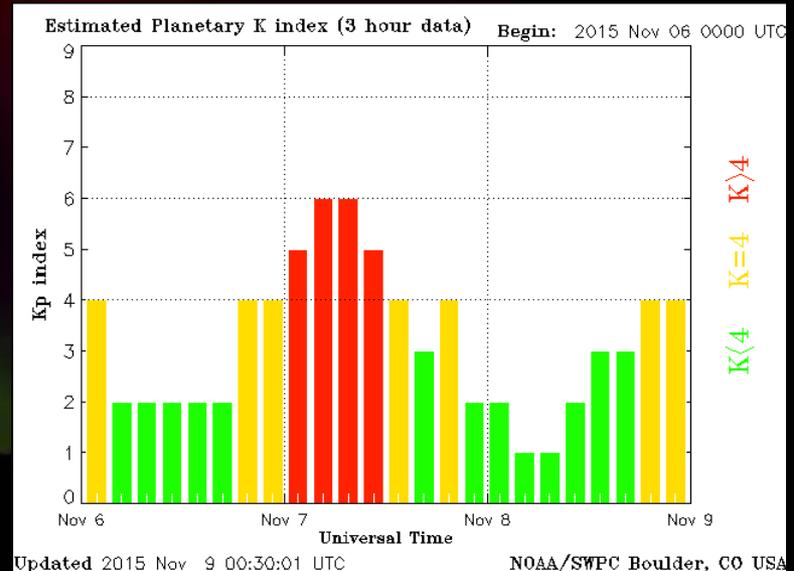
Peak SFU 1415 MHz	Event Date/Time
5800	2015-11-04 14:27:24.24



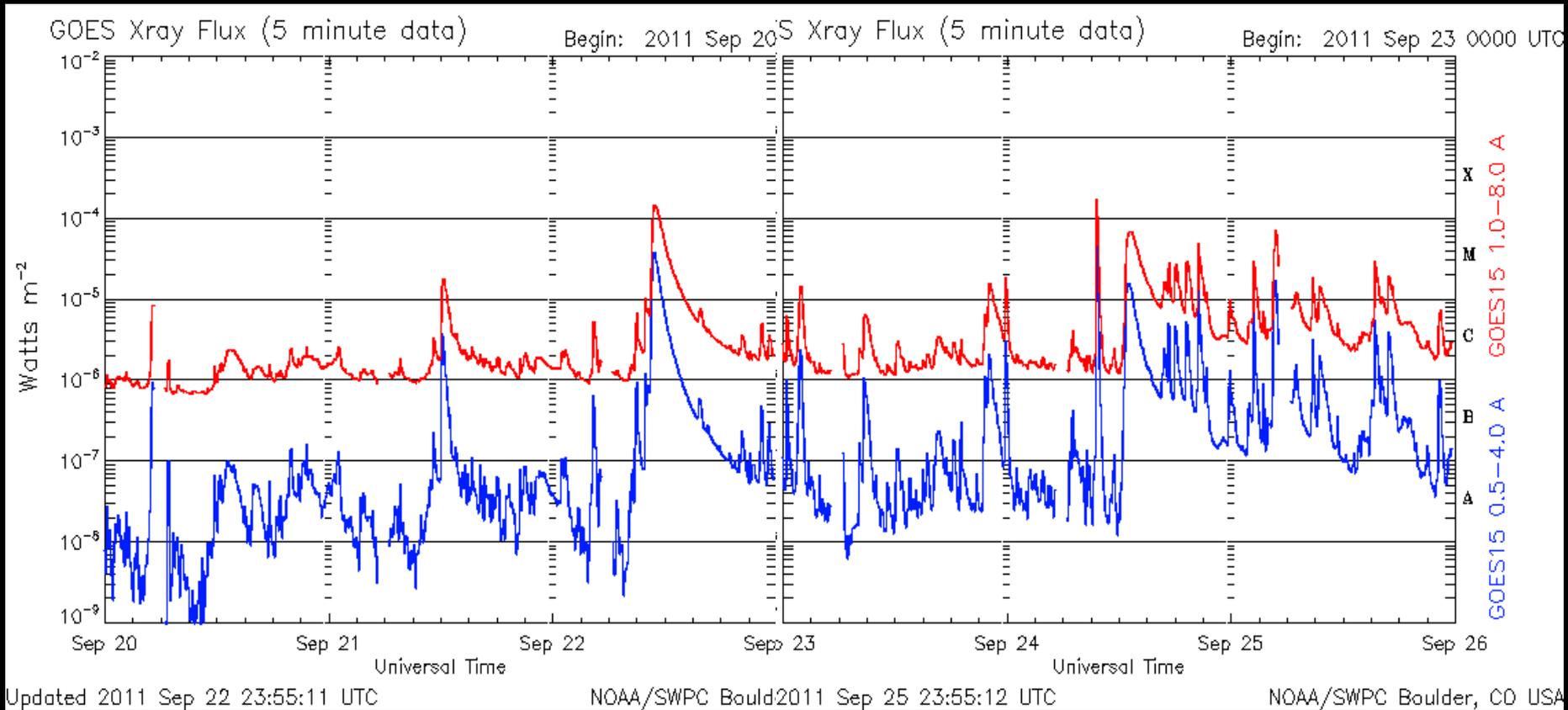
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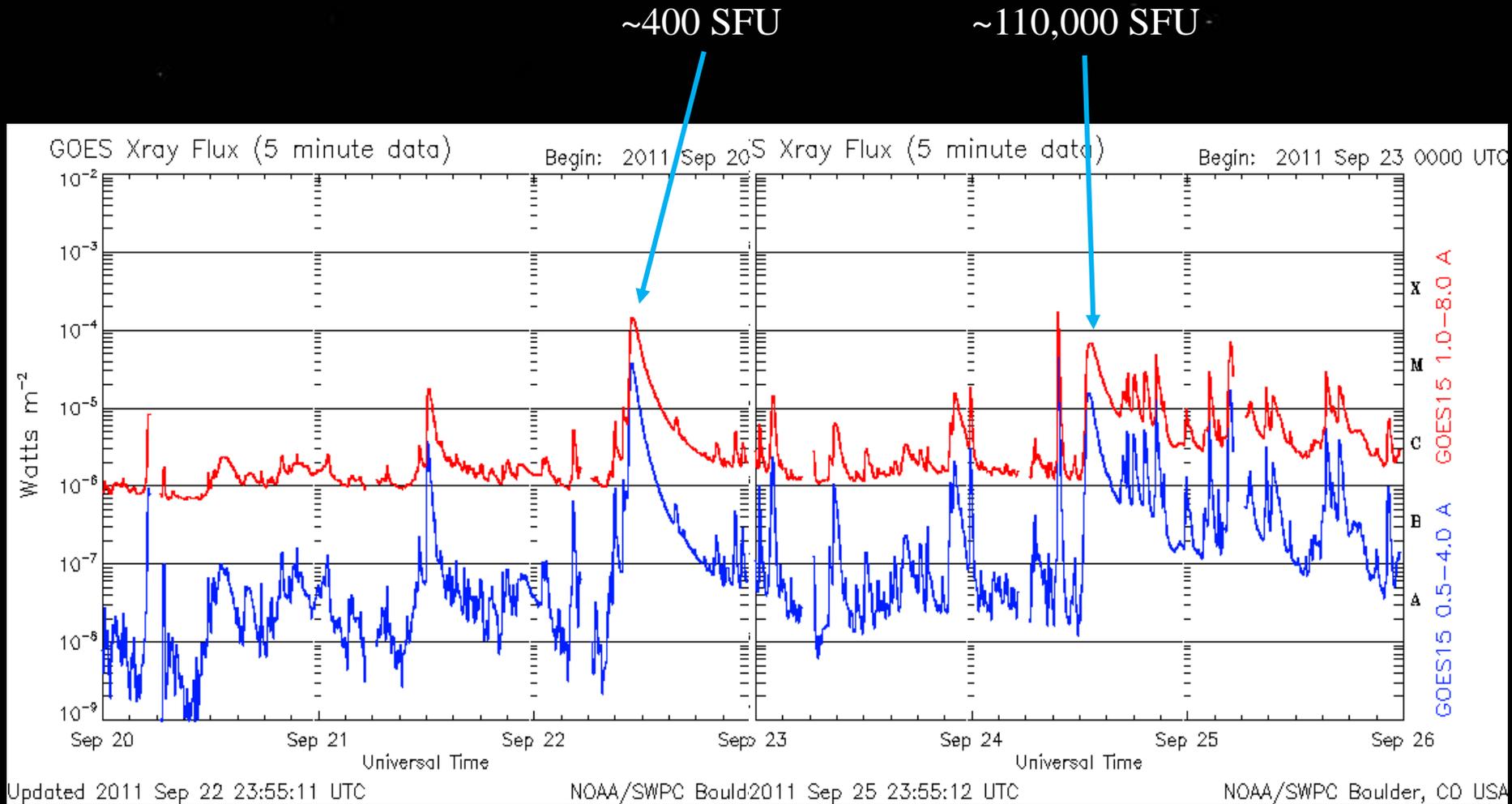
Peak SFU 1415 MHz	Event Date/Time
5800	2015-11-04 14:27:24.24
17000	2015-06-25 09:19:36.36
7700	2014-01-04 19:30:54.54
26000	2012-03-05 04:27:06.06
8900	2012-03-05 04:21:42.42
34000	2012-03-04 11:16:54.54
67000	2011-09-24 13:04:42.42
110000	2011-09-24 13:04:42.42



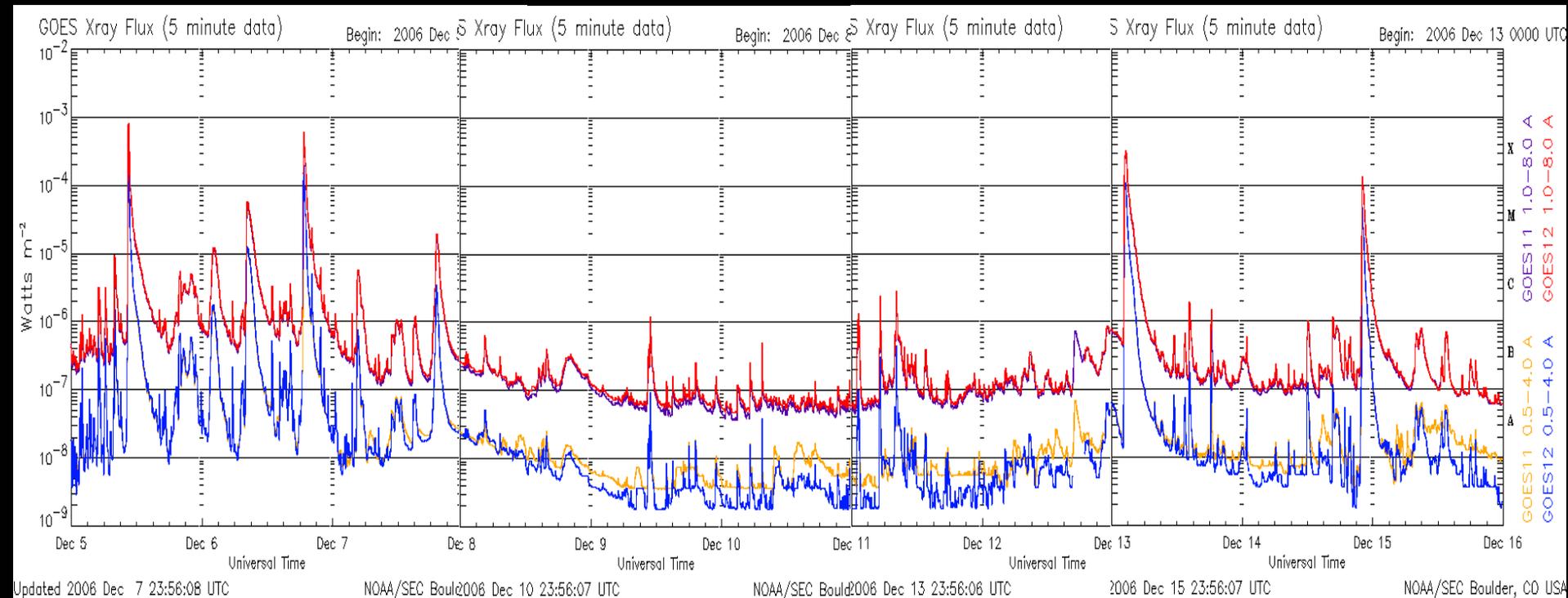
# September 2011 – 1415MHz Radio Bursts



# September 2011 – 1415MHz Radio Bursts



# December 2006 – 1415MHz Radio Bursts



# December 2006 – 1415MHz Radio Bursts

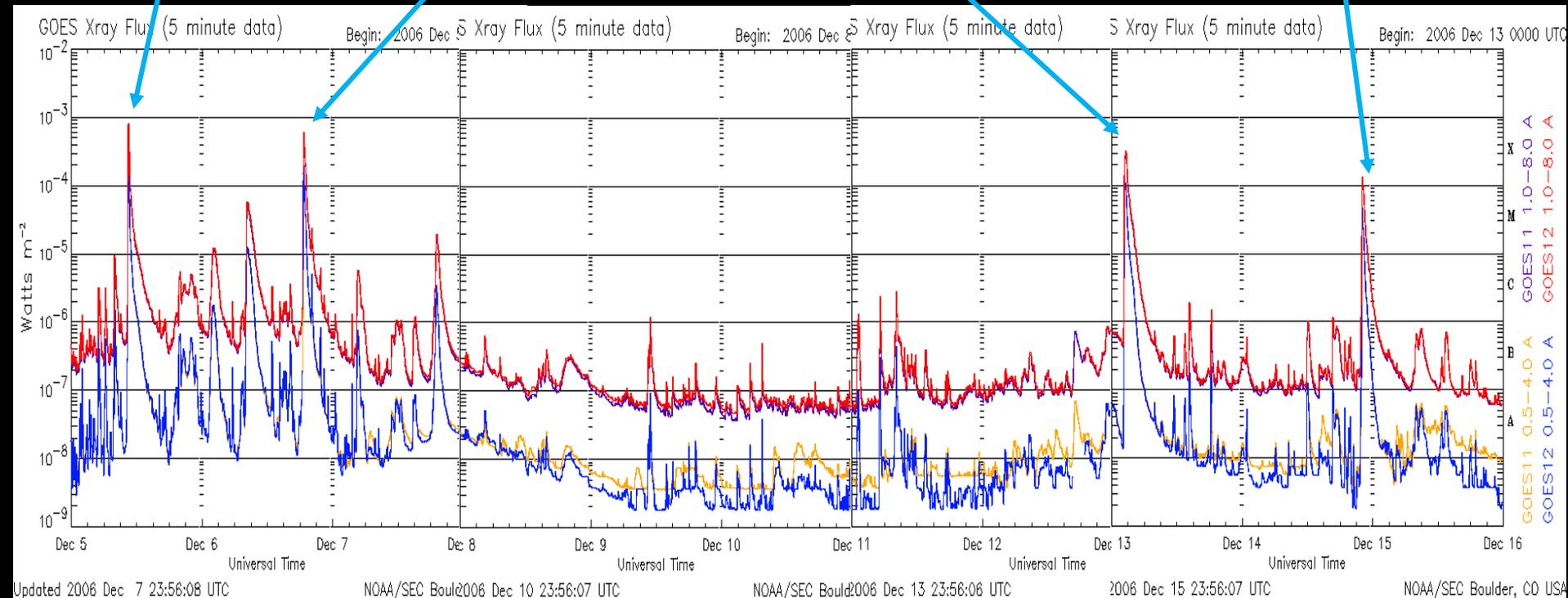
Cerruti et al. (2008)

~4,000 SFU

1,000,000+ SFU

~440,000 SFU (1GHz)

~150,000 SFU (1.6 GHz)



# *NOAA Space Weather Prediction Center Boulder, Colorado*



[www.spaceweather.gov](http://www.spaceweather.gov)