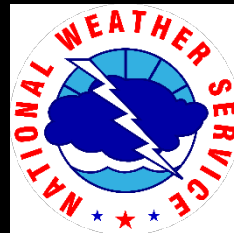
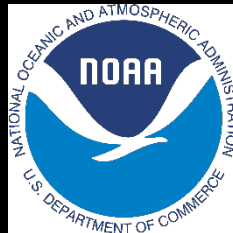


# Space Weather Update

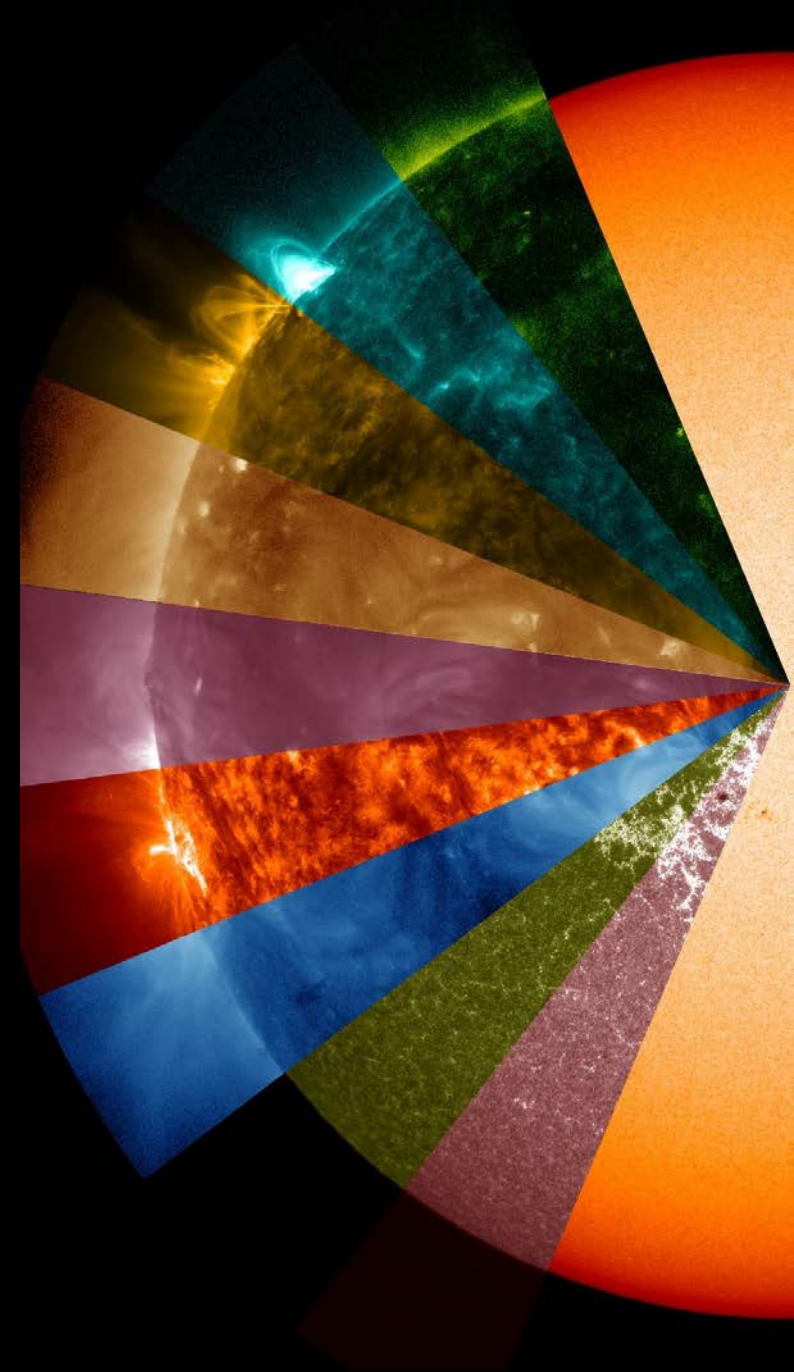
Bob Rutledge

NOAA Space Weather Prediction Center, Boulder, CO



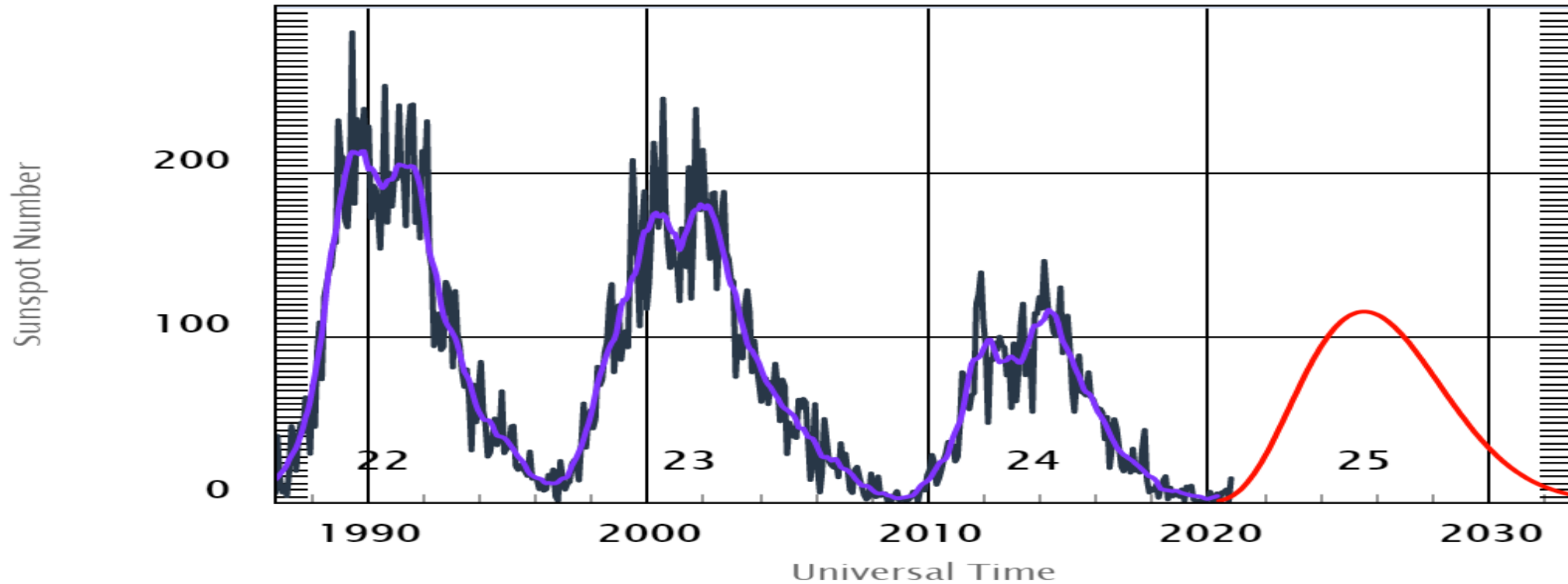
# Outline

- Solar cycle update
- Brief space weather primer/refresh
- ICAO space weather advisory service/updates



# Solar Cycle Update

ISES Solar Cycle Sunspot Number Progression



◆ Monthly Values      — Smoothed Monthly Values      — Predicted Values

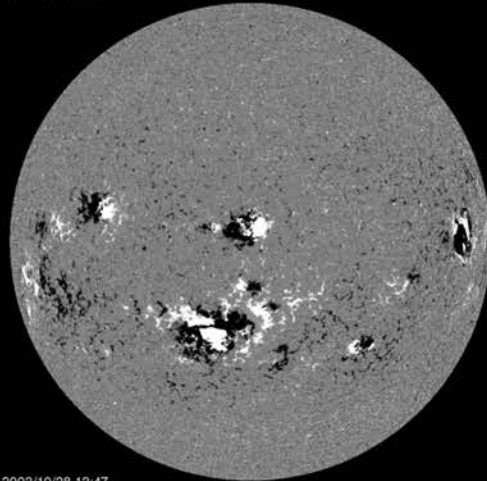
Space Weather Prediction Center



# Space Weather Primer

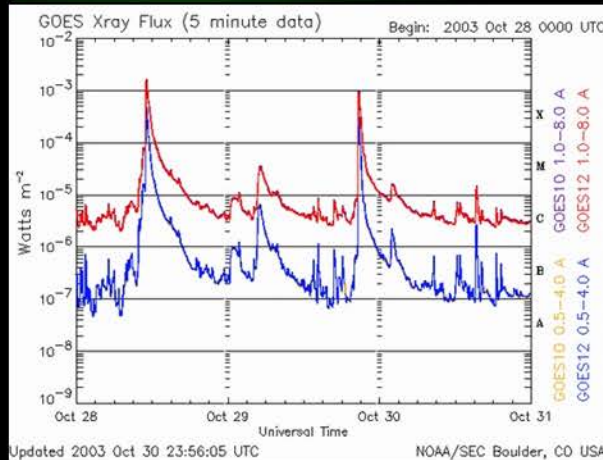
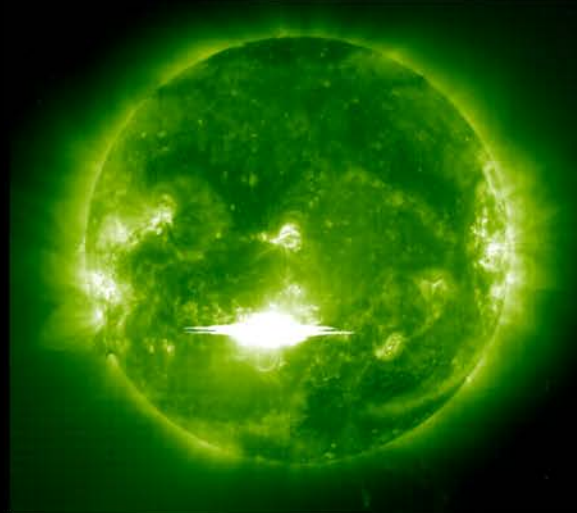


2003/10/28 17:36

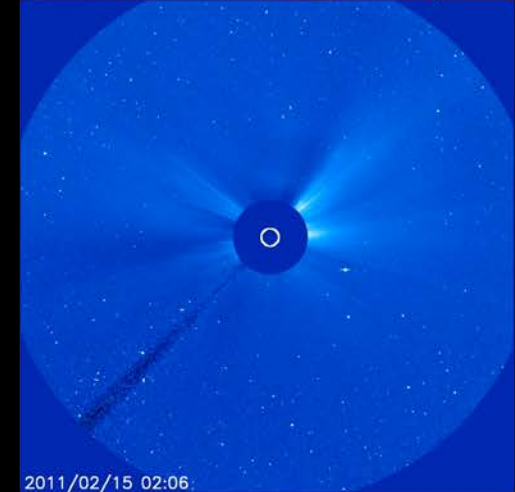


2003/10/28 12:47

Conditions are Favorable for  
Activity



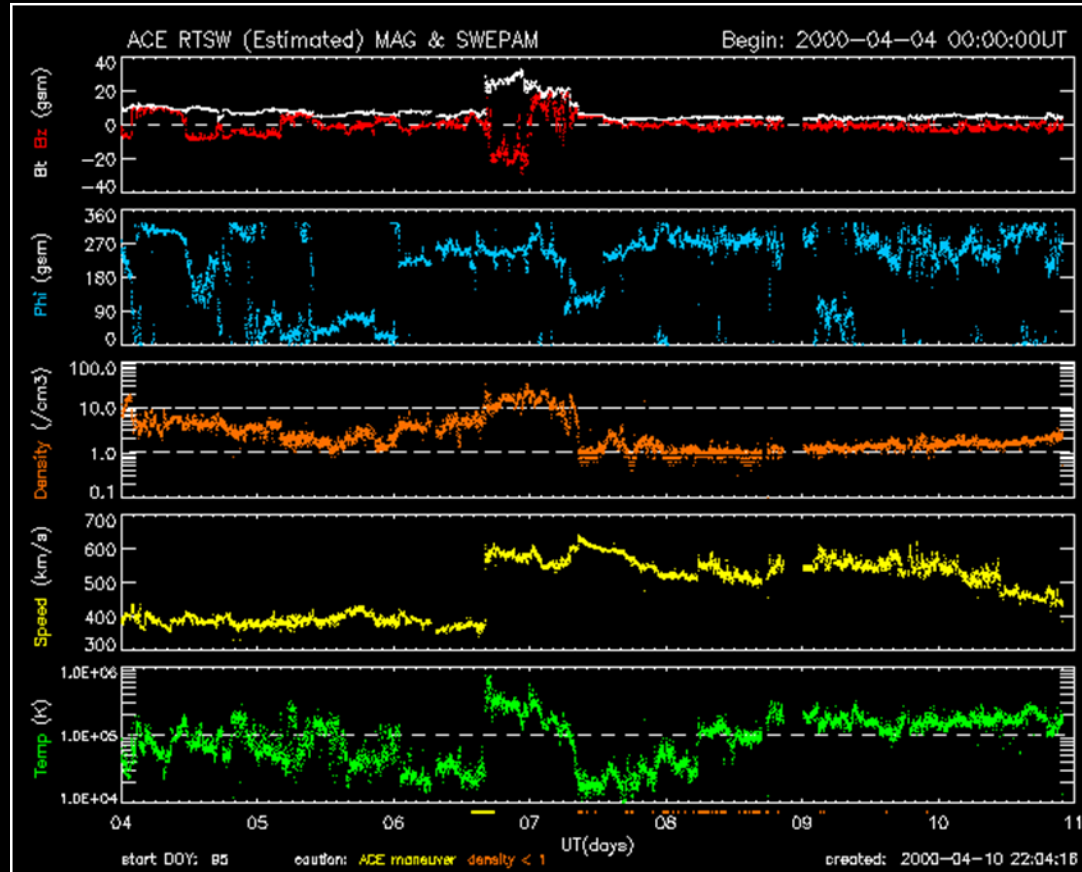
Event  
Occurs



2011/02/15 02:06

Coronal  
Observations

# Space Weather Primer



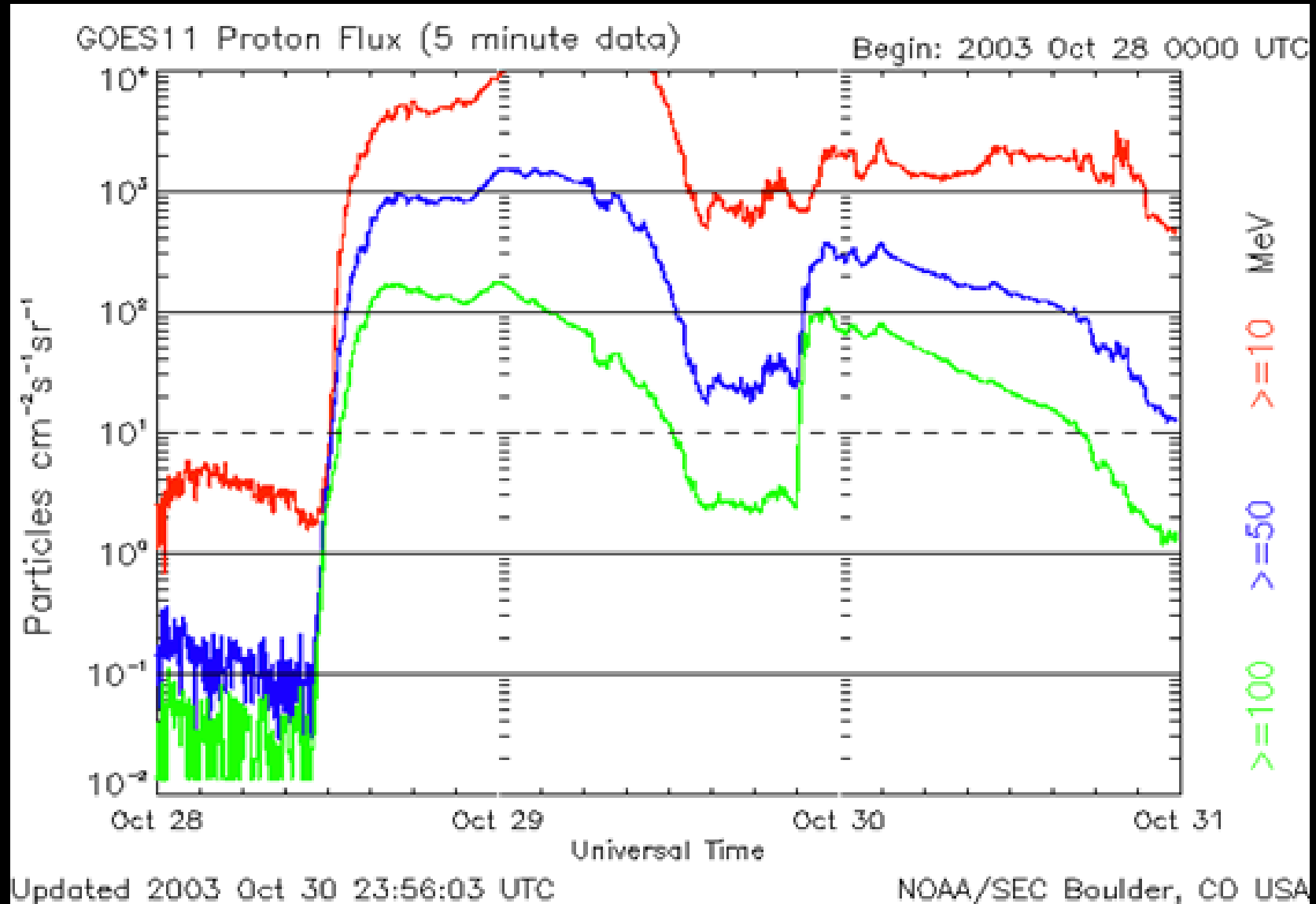
In situ Solar Wind  
Observations



Geomagnetic Storm  
Occurs



# Space Weather Primer



# Space Weather Primer

## Solar Flare Radio Blackout (R Scale):

- No advance warning
- Effects lasts for 10's of minutes to several hours
- Impacts High Frequency (HF) communication on the sunlit side of the Earth
- First indication significant S and G scale activity may be possible

## Solar Radiation Storm (S Scale):

- Warnings possible on the minutes to hours time scale
- Elevated levels can persist for several days
- Impacts to the health and operation of satellites and International Space Station operations and crew
- Impacts High Frequency communication in the polar regions, affecting commercial airline operations

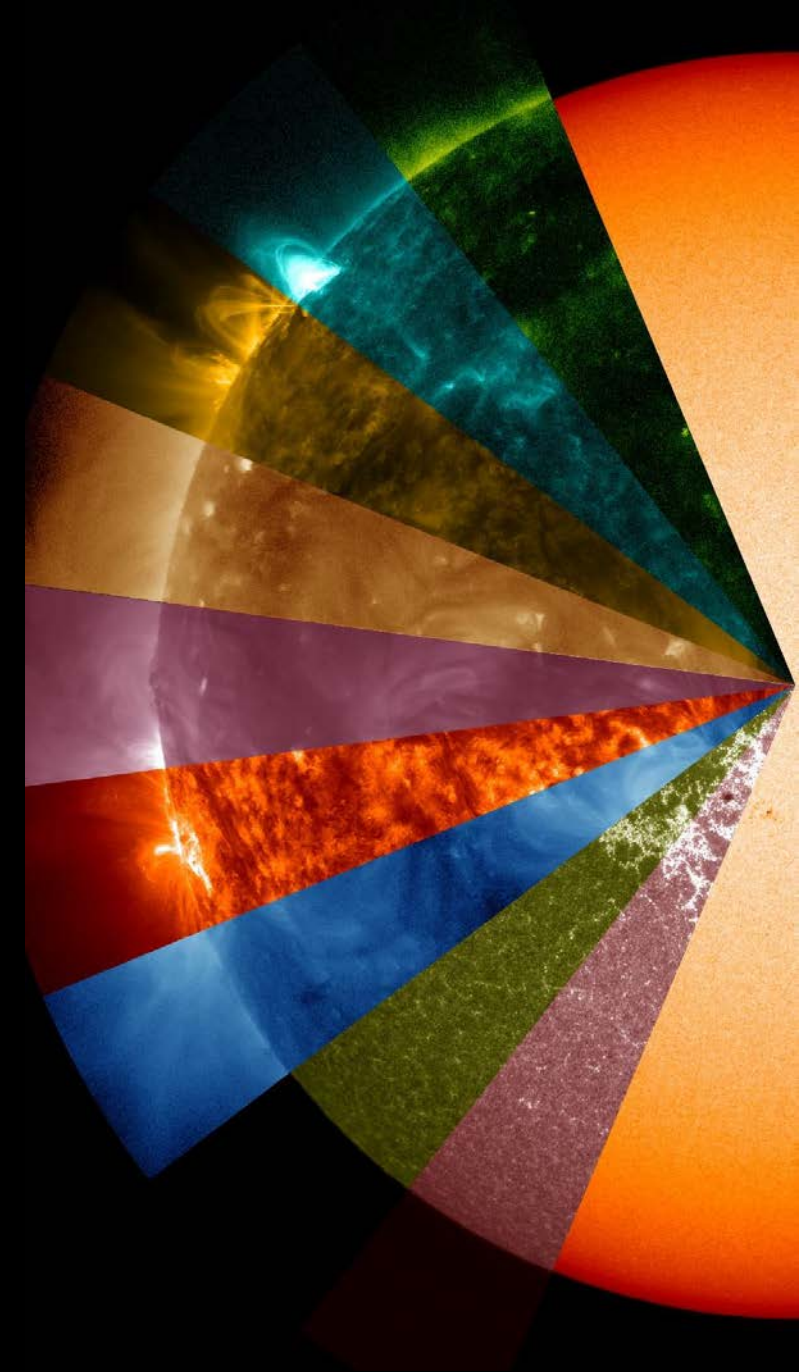
## Geomagnetic Storm (G Scale):

- Advance notice possible given coronal mass ejection (CME) transit times from Sun to Earth range from just under a day to several days (CMEs being the main driver of significant storms)
- In extreme storms, impacts to power grid operations and stability
- Impacts to Global Positioning System (GPS) accuracy and availability
- Driver of aurora; severe to extreme storms may cause aurora to be visible over most of the lower 48



# Services Within ICAO

- Services proposed for inclusion in Amendment 78 to Annex 3
  - HF Communications (propagation, absorption)
  - Communications via satellite (propagation, absorption) (**NOT REALIZED**)
  - GNSS-based navigation and surveillance (degradation)
  - Radiation at flight levels (increased exposure)
- Event-driven advisories for Moderate or Severe effects
- Applicability in November 2018 (actual services commence in November 2019)
- Global service model with ~~three~~ **four** providers





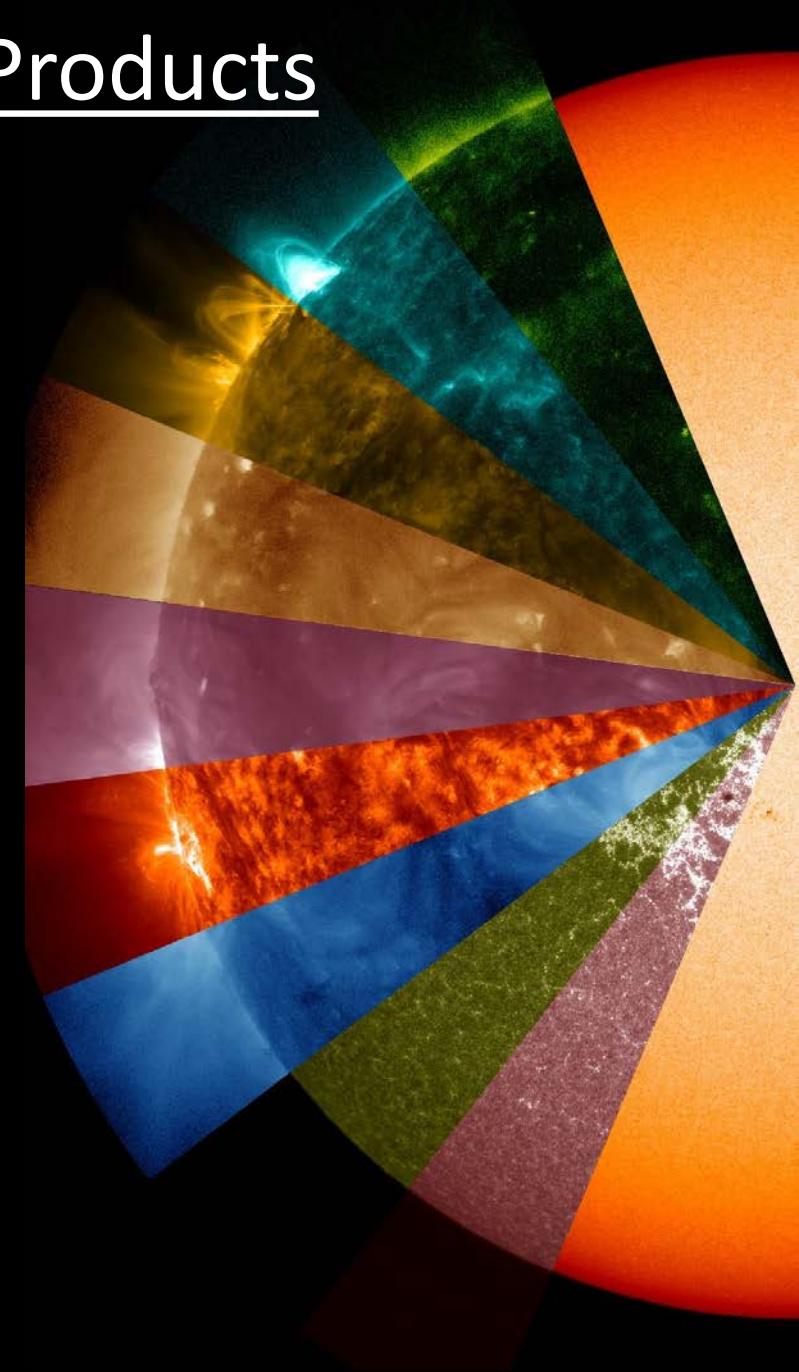
# Services Within ICAO – Example Products

Example A2-4: Space weather advisory message (RADIATION effects)

(communication header)	
SWX ADVISORY	
DTG:	20161108/0000Z
SWXC:	(to be determined)
SWX EFFECT:	RADIATION MOD
ADVISORY NR:	2016/2
FCST SWX:	20161108/0100Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +6 HR:	20121108/0700Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +12 HR:	20161108/1300Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +18 HR:	20161108/1900Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +24 HR:	20161109/0100Z NO SWX EXP
RMK:	RADIATION LEVELS HAVE EXCEEDED 100 PERCENT OF BACKGROUND LEVELS AT FL350 AND ABOVE. THE CURRENT EVENT HAS PEAKED AND LEVELS ARE SLOWLY RETURNING TO BACKGROUND LEVELS. SEE <a href="http://WWW.SPACEWEATHERPROVIDER.WEB">WWW.SPACEWEATHERPROVIDER.WEB</a>
NXT ADVISORY:	NO FURTHER ADVISORIES

Example A2-3: Space weather advisory message (GNSS and HF COM effects)

(communication header)	
SWX ADVISORY	
DTG:	20161108/0100Z
SWXC:	(to be determined)
SWX EFFECT:	GNSS MOD AND HF COM MOD
ADVISORY NR:	2016/1
OBS SWX:	20161108/0100Z HNH HSH E18000 – W18000
FCST SWX +6 HR:	20121108/0700Z HNH HSH E18000 – W18000
FCST SWX +12 HR:	20161108/1300Z HNH HSH E18000 – W18000
FCST SWX +18 HR:	20161108/1900Z HNH HSH E18000 – W18000
FCST SWX +24 HR:	20161109/0100Z NO SWX EXP
RMK:	LOW-LEVEL GEOMAGNETIC STORMING IS CAUSING INCREASED AURORAL ACTIVITY AND SUBSEQUENT MOD DEGRADATION OF GNSS AND HF COM AVAILABILITY IN THE AURORAL ZONE. THIS STORMING IS EXPECTED TO SUBSIDE



# ICAO Space Weather Region Designations





# How Can These be Used?

## → Radiation

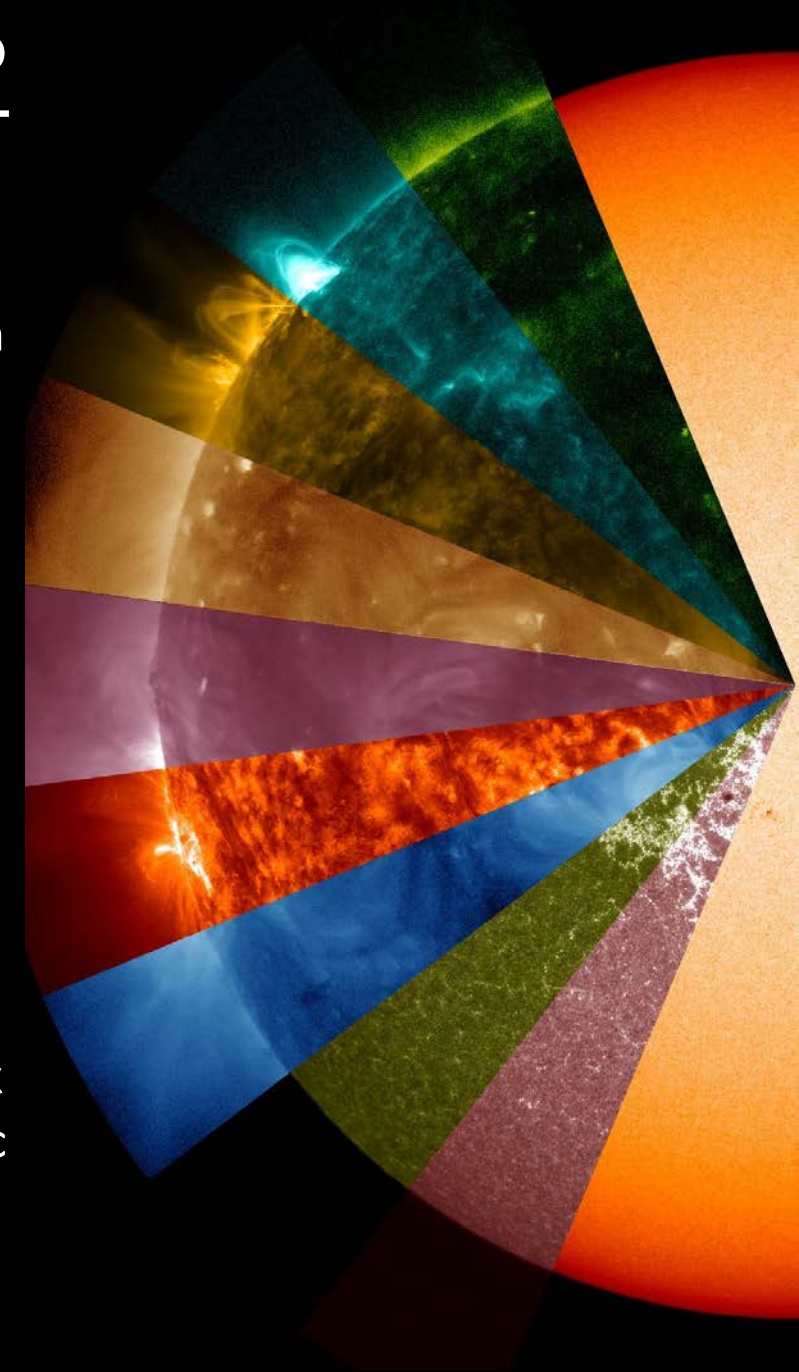
- In September, 2017 - “The solar storm we saw on September 10<sup>th</sup> was very strong... In a storm of this magnitude we will encounter increased radiation levels domestically (US)”
- Operations were affected, but to what degree should they have been? Peak of the event on the order of the ICAO Moderate event threshold

## → GNSS

- Augmentation systems generally monitor performance and shut down accordingly, but knowing that ahead of time may lead to different flight planning

## → Communications

- For the same September event, reports of loss of communication with a US cargo aircraft for ~90 minutes between ATC in French Guyana and New York
- ATC in Miami had issues with lost communications for aircraft flying oceanic routes around Hurricane Irma



# Updates and Items for Discussion

## → Continued service development under the ICAO Met Panel

- China-Russian Federation Consortium inclusion in work
- Ongoing advisory consistency work
- Nowcast phase emphasis/needed dev for the forecast phase

## → IWXXM advisories applicable as of Nov 2020

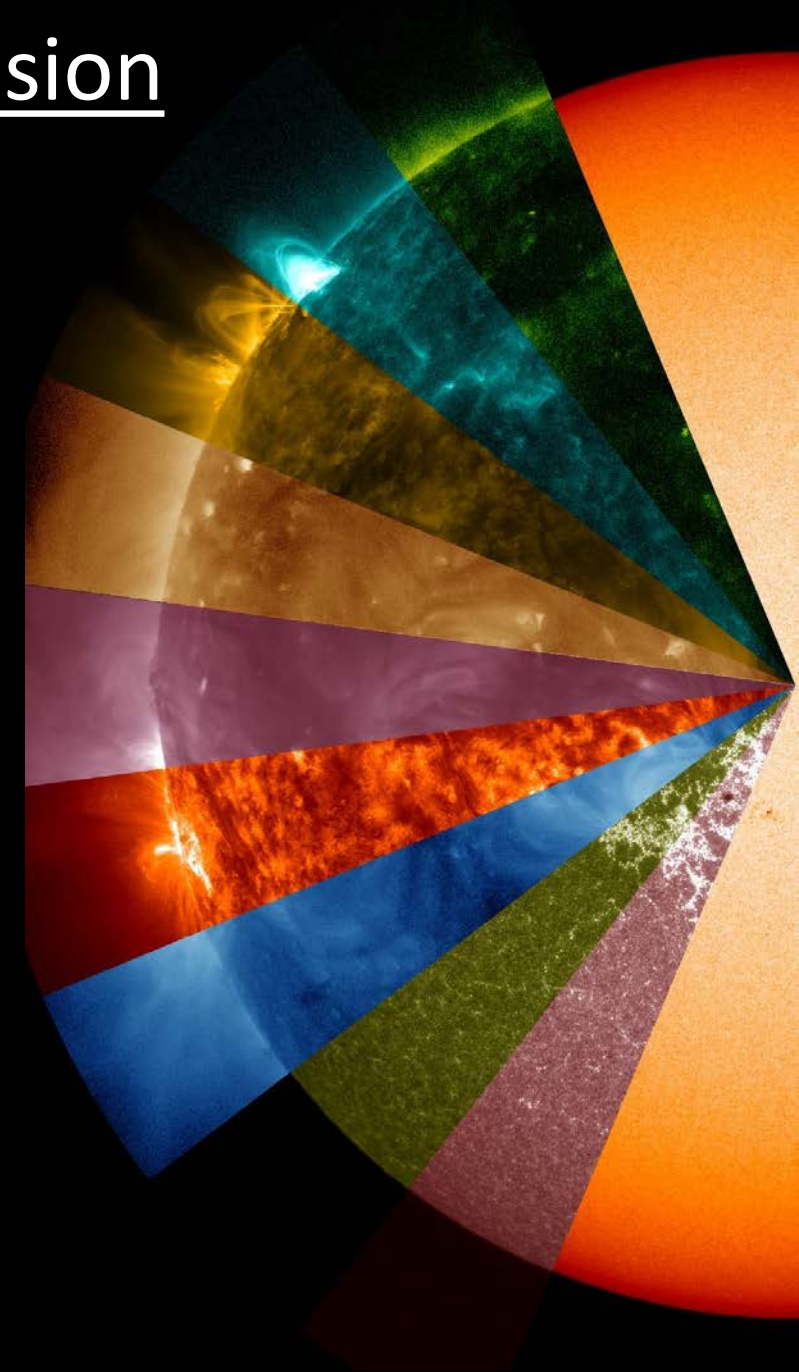
- Current implementation challenges
- Consistency with TAC/transition to polygons

## → Product access discussion

- Redistribution discussion
- Webpage, [public access](#), and visualization

## → Tabletop exercise and training

- Comparison with NOAA Scales and event re-reruns
- Additional training and education





# NOAA Space Weather Prediction Center

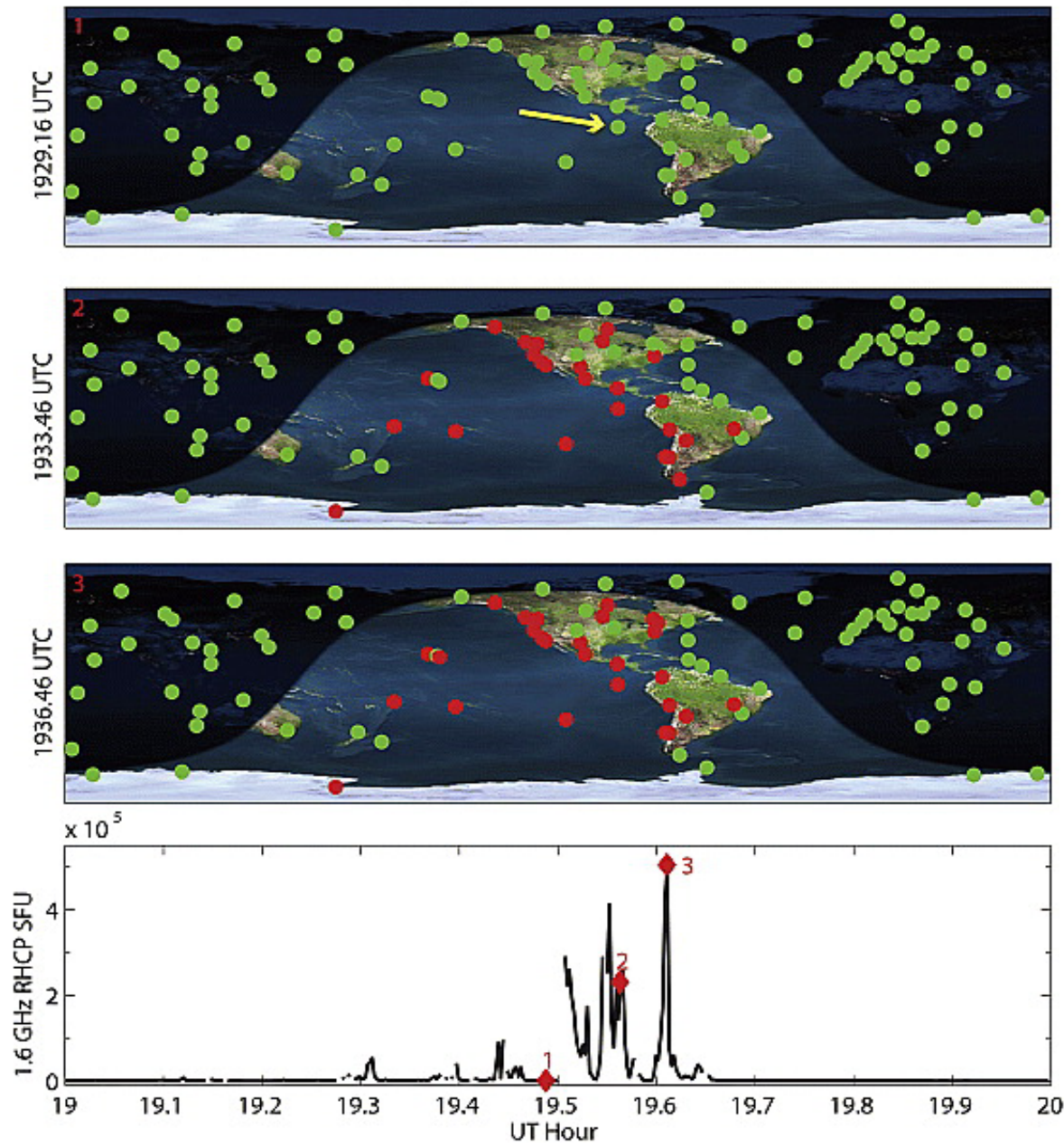
## Boulder, Colorado



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

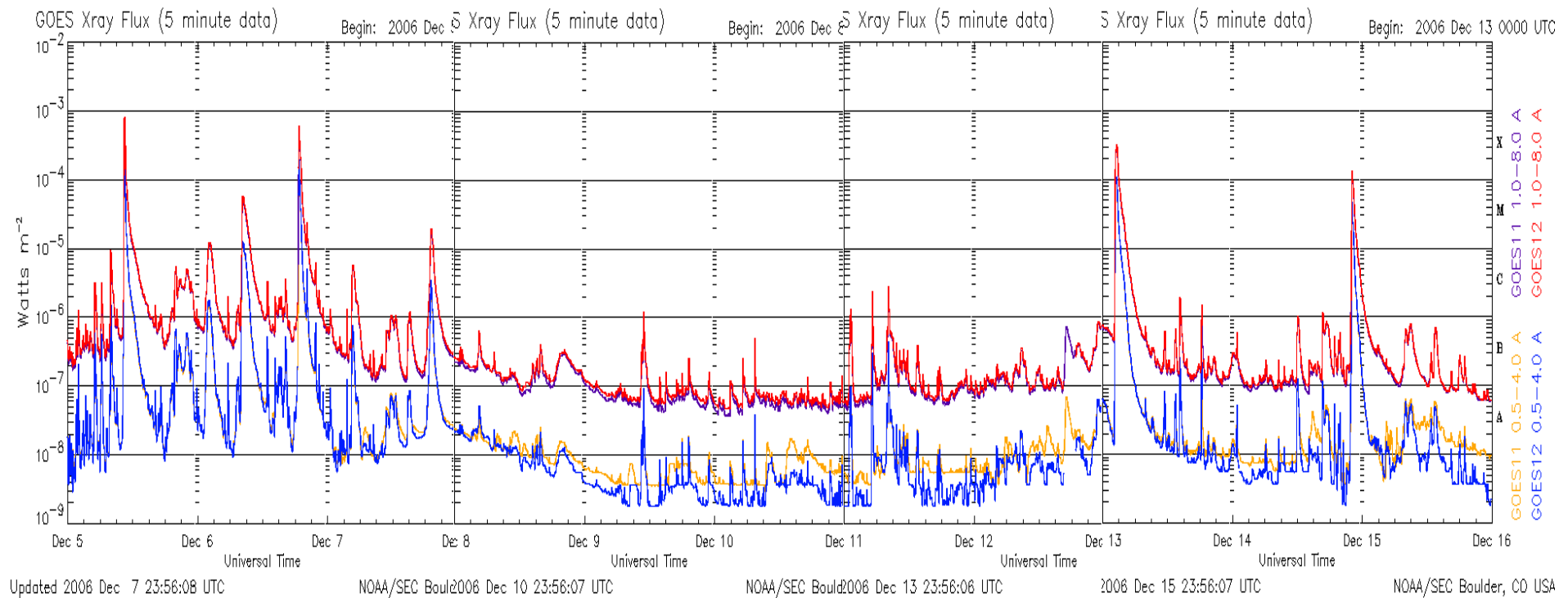


# IGS Network Dual Frequency Code Observations, 6 December 2006



Cerruti, A. P., P. M. Kintner Jr., D. E. Gary, A. J. Mannucci, R. F. Meyer, P. Doherty, and A. J. Coster (2008), Effect of intense December 2006 solar radio bursts on GPS receivers, *Space Weather*, 6, S10D07, doi:[10.1029/2007SW000375](https://doi.org/10.1029/2007SW000375).

# December 2006 – 1415MHz Radio Bursts



# December 2006 – 1415MHz Radio Bursts

