Peer Stakeholder-Product Validation Review (PS-PVR)

GOES-17 EXIS XRS:
User Perspective

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GOES-R Calibration Working Group (CWG)

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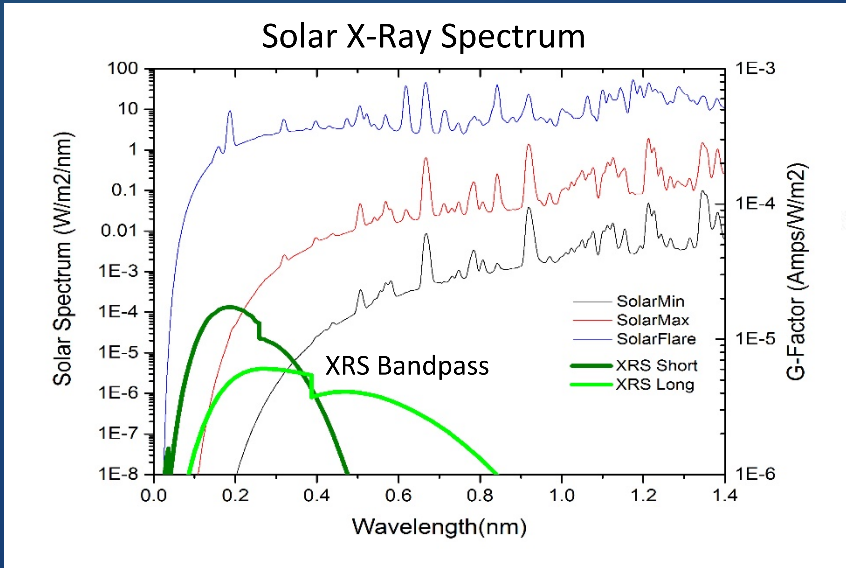
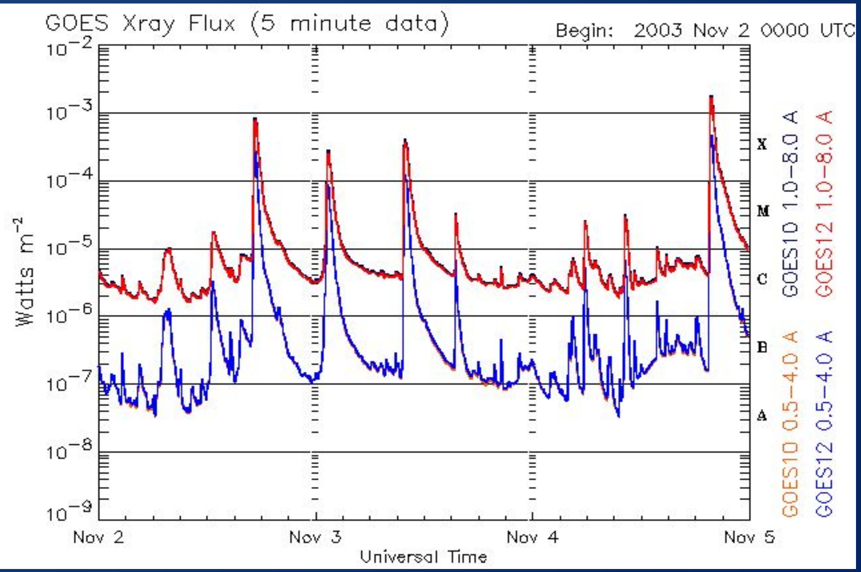
Solar X-Ray Sensor (XRS)

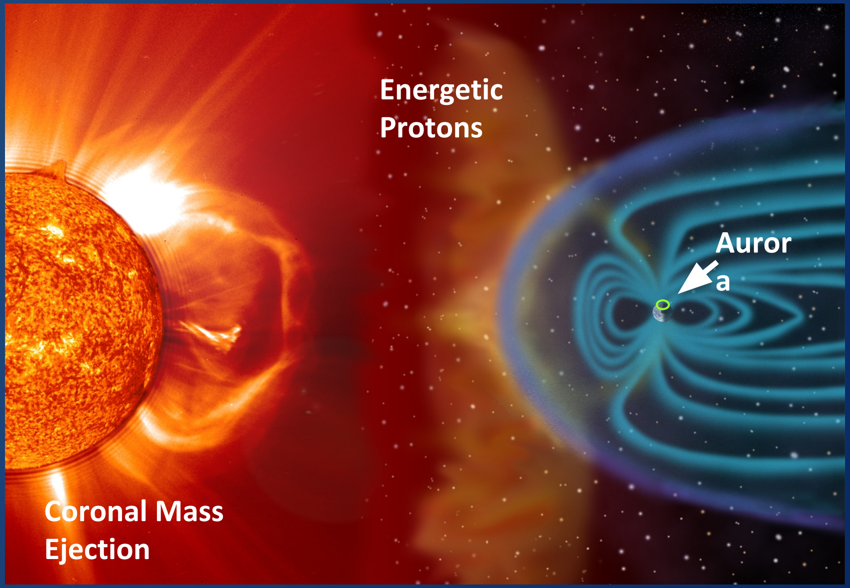
- Purpose:
  - Monitor the disk-integrated solar flux in two x-ray wavelengths
    - XRSA 0.05 nm – 0.4 nm
    - XRSB 0.1 nm – 0.8 nm
  - Define the magnitude of solar x-ray flares
- History:
  - Solar X-Ray Sensors have flown on every GOES and the NASA SMS satellite (1974) before them





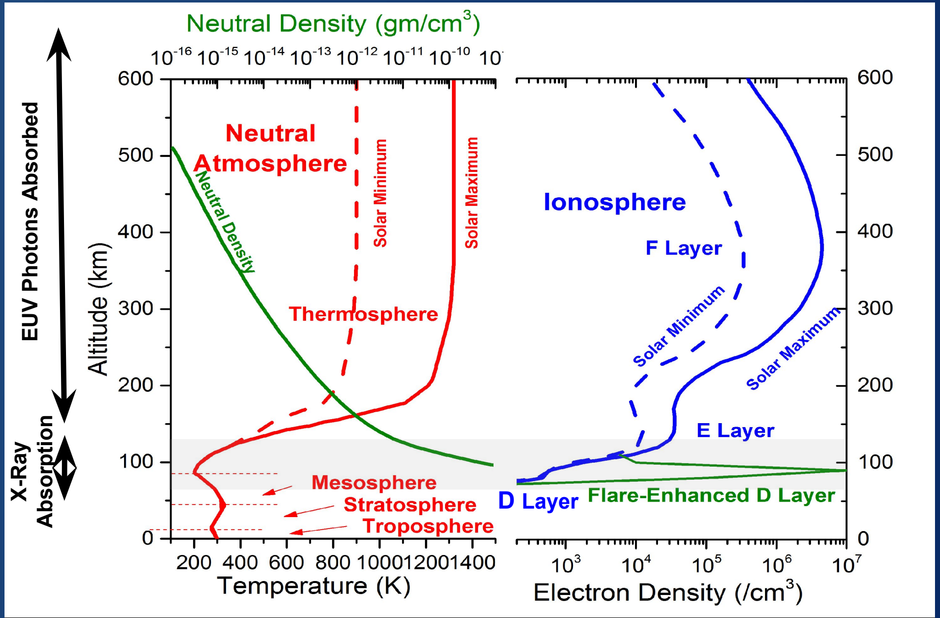
X-Ray Flares

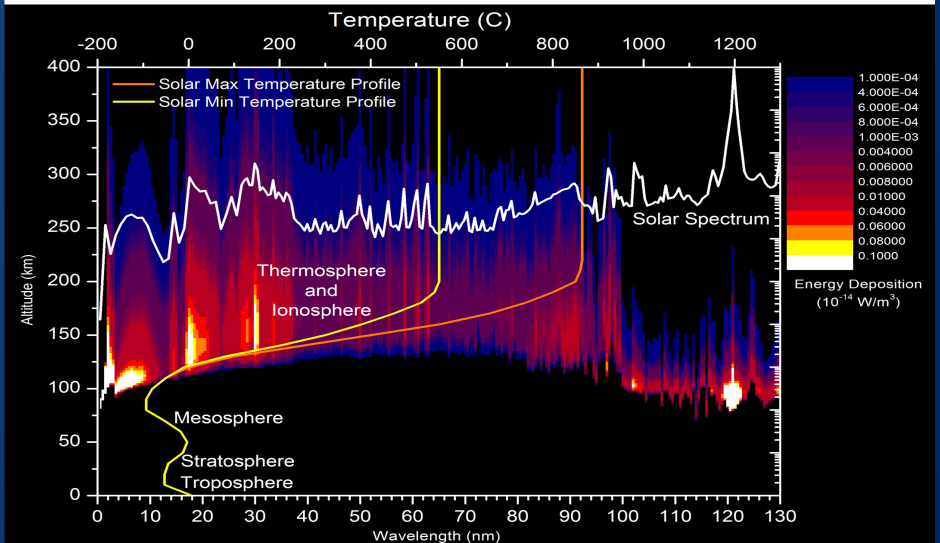
- Every major space weather storm starts with a solar flare.
  - X-ray flares are often associated with energetic solar protons.
    - Protons accelerated to ¼ the speed of light
    - Arrive at Earth in 30 minutes
  - X-ray flares often correlate with Coronal Mass Ejections (CMEs)
    - Billion tons of plasma
    - Traveling a million miles per hour
    - Arrive at Earth in a day
    - Create geomagnetic storms
- Forecasters receive audio alerts based on GOES XRS data reaching threshold values.
  - Contact critical customers (airlines, DOD)
  - Initiate procedures for other space weather
    - Proton (radiation storms)
    - CME (geomagnetic storms)



Solar X-Ray Flare Impacts on HF Radio

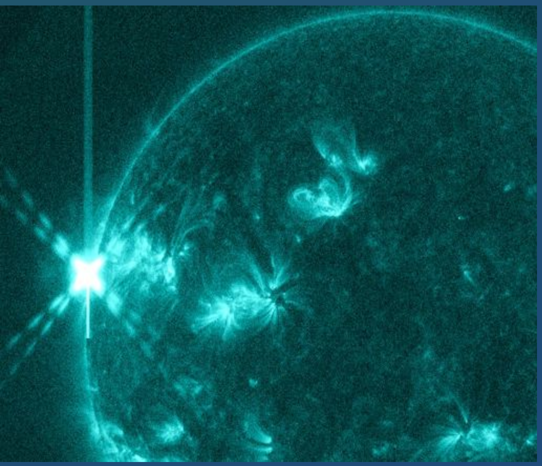
- Solar EUV and X-rays penetrate the upper atmosphere to about 100 km altitude where they collide with atmospheric atoms and molecules.
- Photo-ionization
  - e.g. $O_2 + \lambda_{x\text{-}ray} = O^+ + e$
  - This creates a layer of electrons in the ionosphere (D Layer)
  - The Ionosphere refracts and bends radio waves
  - An enhanced D Layer is too low in the atmosphere to refract waves. It absorbs radio waves

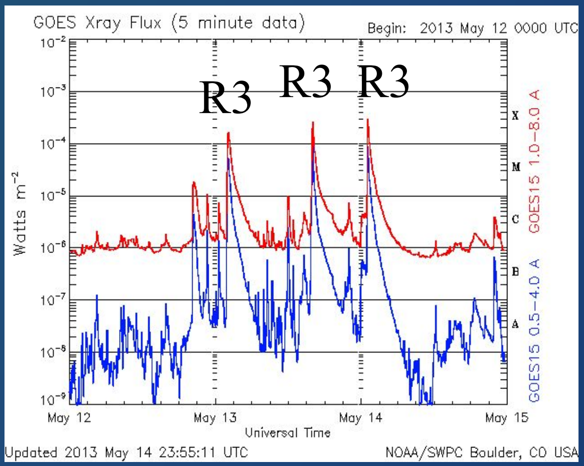


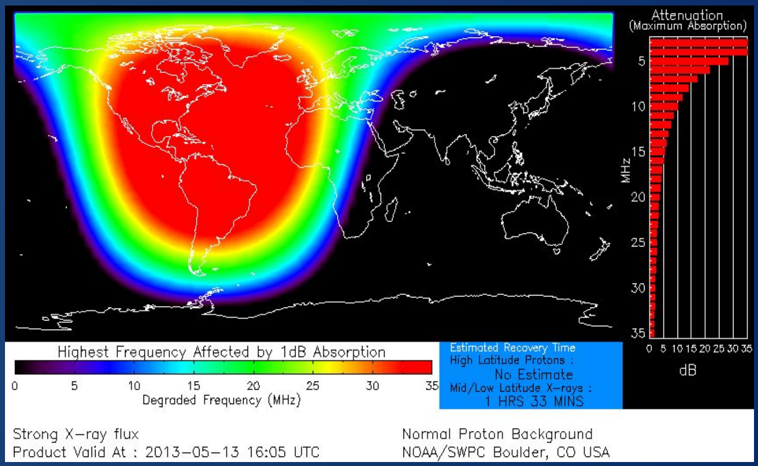


Solar spectrum (white) and where it is absorbed in the atmosphere (colors)

Space weather impact on High Frequency communications







SFO Center - 13May13: 0150Z to 0300Z "Severe solar impact to Central West Pacific, SFO read flights weak but flights could not hear SFO. Delivery of ATC [Air Traffic Control] traffic delayed. Tokyo & Manila Radio requested SFO comms assistance with their flights."

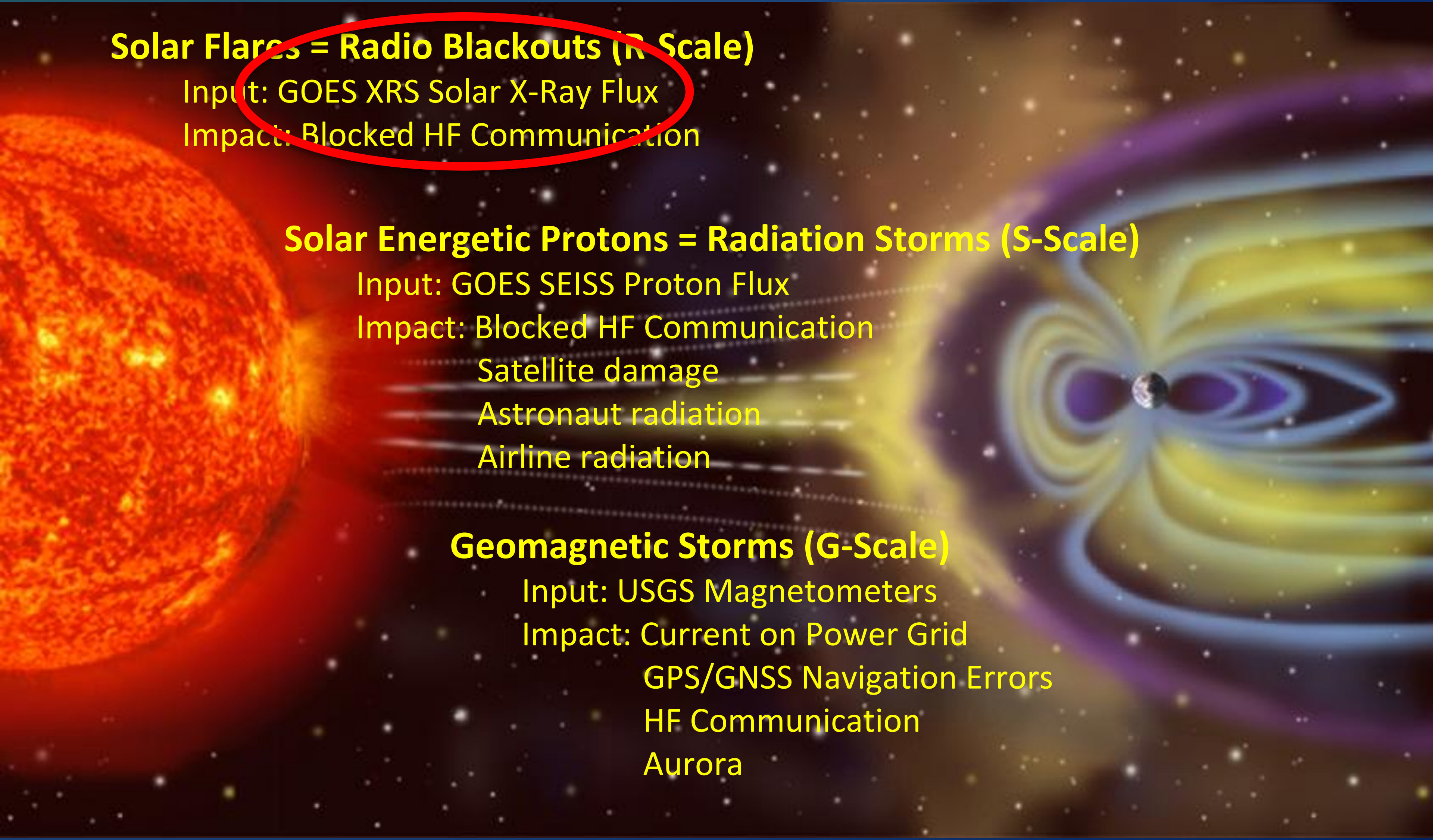
NY Center - 13May13: From 1548Z thru 1715Z "Solar activity causing severe impact to HF Comms resulting in several ATC clearances being cancelled and/or delayed."

New Development: NOAA Space Weather Prediction Center has been chosen as a primary space weather center for the International Civil Aviation Organization (ICAO).

- **New requirements**
- **New products**
- **Formalized procedures**

Three Space Weather Scales

(Scales from 1 to 5)



Solar Flares = Radio Blackouts (R-Scale)

Input: GOES XRS Solar X-Ray Flux

Impact: Blocked HF Communication

Solar Energetic Protons = Radiation Storms (S-Scale)

Input: GOES SEISS Proton Flux

Impact: Blocked HF Communication

Satellite damage

Astronaut radiation

Airline radiation

Geomagnetic Storms (G-Scale)

Input: USGS Magnetometers

Impact: Current on Power Grid

GPS/GNSS Navigation Errors

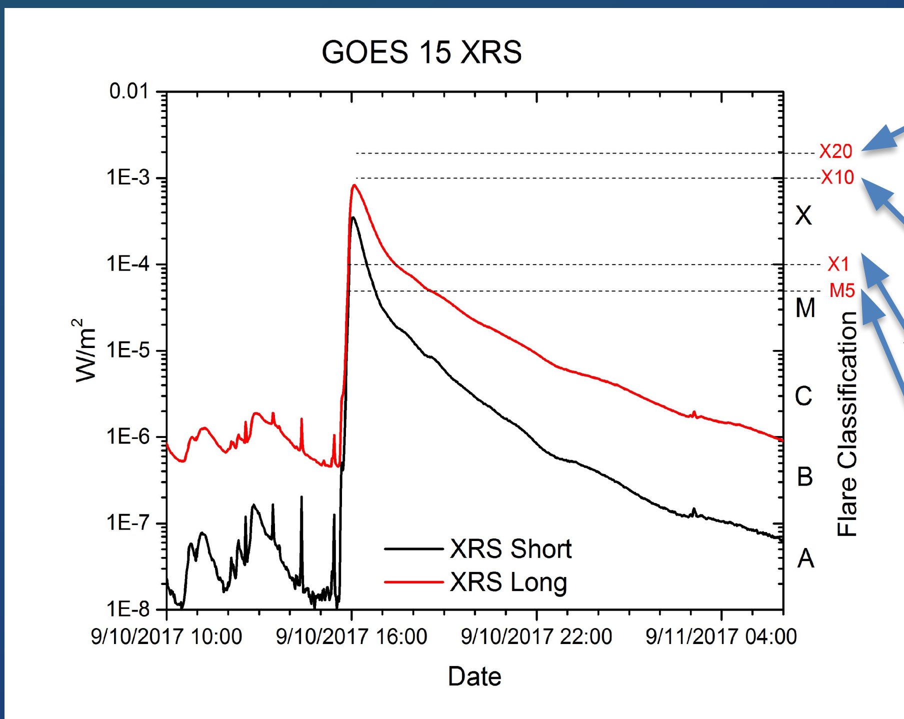
HF Communication

Aurora

XRS Alert Levels

Alert Levels: M5, X1, X10, X20

- Based on customer impacts



NOAA R-Scale

Radio Blackouts

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
R 5	Extreme	**HF Radio:** Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Less than 1 per cycle
R 4	Severe	**HF Radio:** HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	350 per cycle (300 days per cycle)
R 1	Minor	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

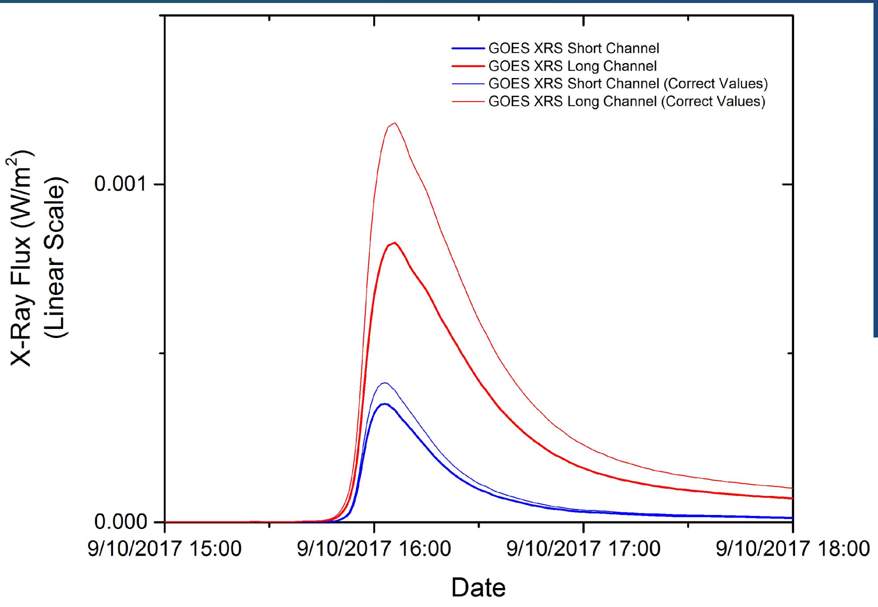
Issue: Significant Difference Between GOES 16/17 XRS and earlier GOES XRS

- The current GOES 15 XRS flux values (in W/m^2) are not correct.
  - GOES 8 XRS data did not agree with GOES 7 XRS data. No obvious reason for this discrepancy was found so the GOES 8 XRS data were “adjusted” to maintain continuity with GOES 7 XRS data
    - More recent comparisons with other solar x-ray observations (e.g. MinXSS) indicate that the current “published” GOES XRS flux values are too low by 15% (XRS Short) and 30% (XRS Long).
  - The latest in the series, GOES 16/17 XRS, was calibrated at NIST and confirms that the current “adjusted” GOES 13-14-15 XRS values are incorrect.

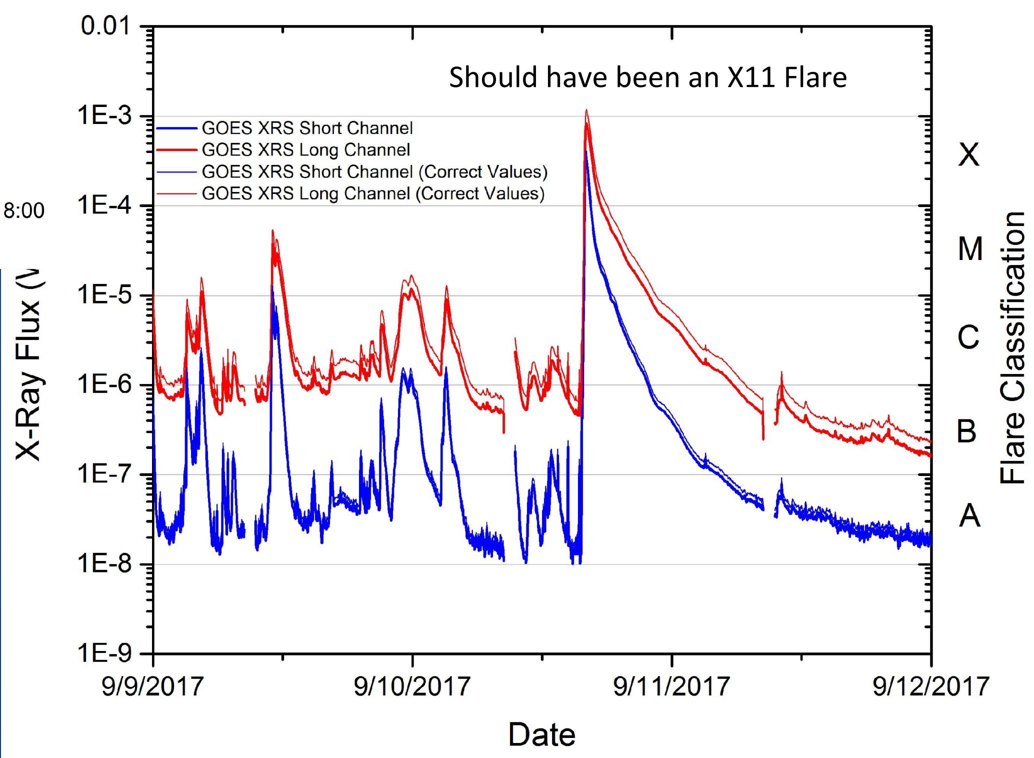
- How will we present the new GOES 16/17 XRS values?
  - We could continue to adjust the data maintain continuity.
  - We could present new values that are more accurate.

GOES XRS With and Without "Correction"

Linear scale highlights the differences

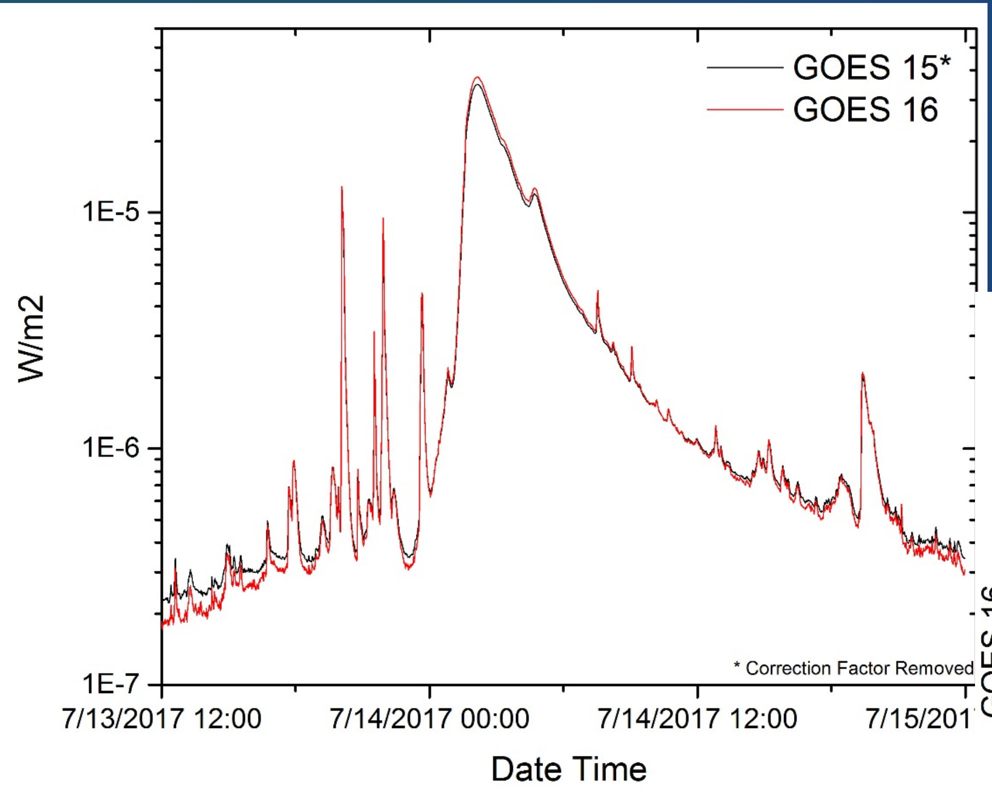


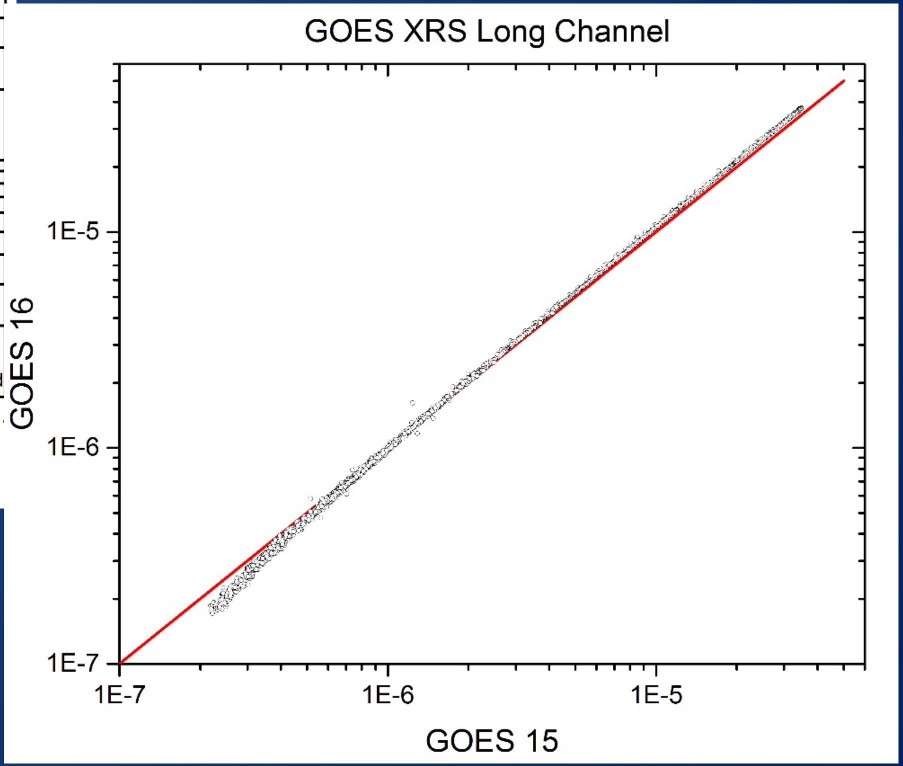
Doesn't look so bad on a log scale



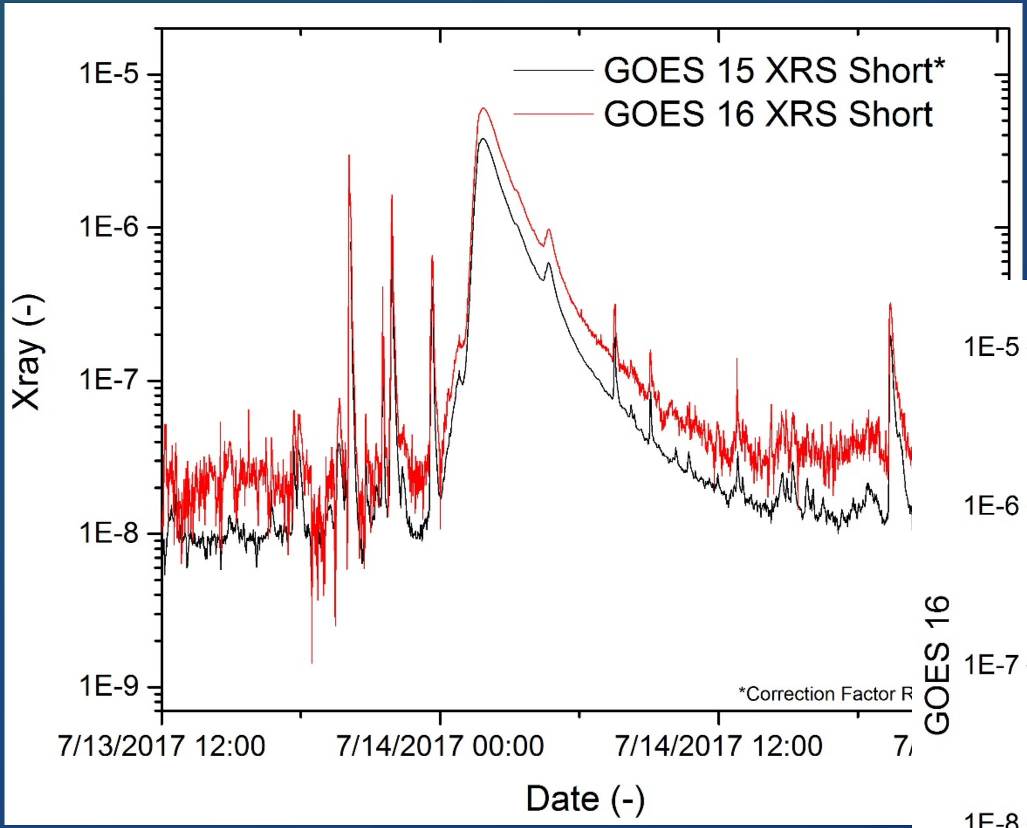
GOES 16 Performance

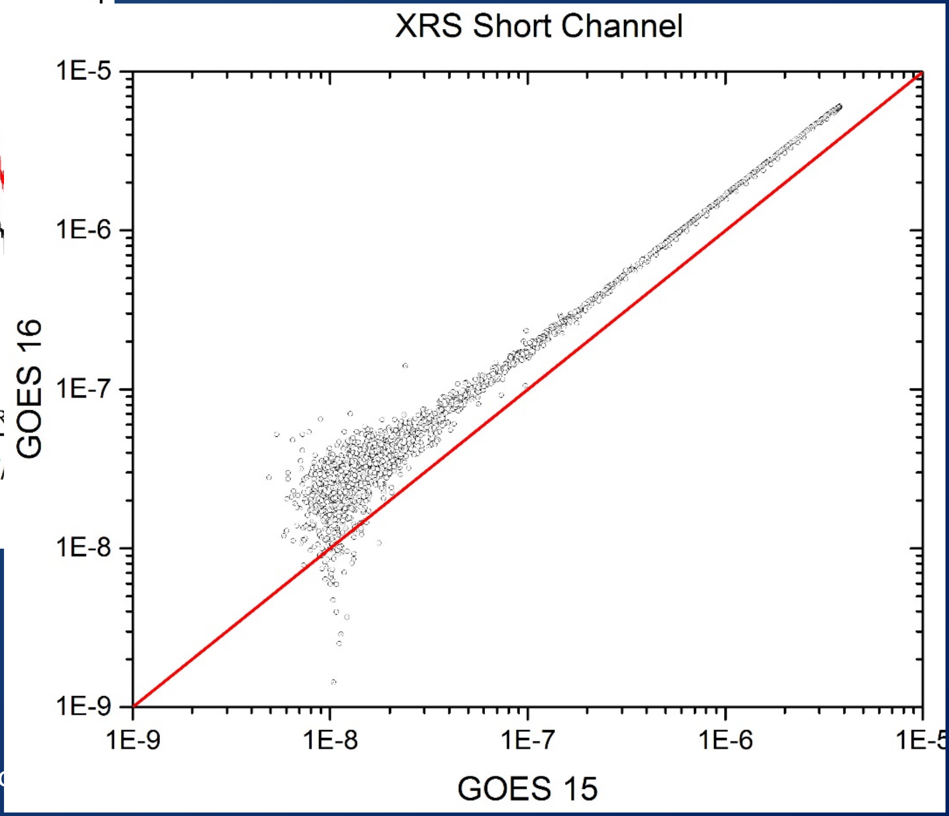
XRS B (Long)





GOES 16 Performance XRSA (Short)





Moving Forward

We considered several options:

1. Forecaster Perspective: Scale to the older data to keep everything **consistent**.
2. Scientist Perspective: Adjust everything to the new calibrated data be more **accurate**
3. Compromise: Keep the flare classification (A, B, C, M, X) the same for **continuity** but adjust the flux values (W/m^2) to be more **accurate**.
4. Develop a new XRS product that more accurately represents the actual solar flux values .
   - Modeled Solar Spectra (not flat spectra)
   - Variable Band-passes with flare magnitude
5. Redefine the Watt or the meter?

Current Plan: Introduce GOES 16/17 XRS data in its most accurate form.

- Customers will be informed
- Adjustments will need to be made
- Older (archived) data will need to be reprocessed

Summary

- GOES Solar X-Ray Sensor is one of the most important space weather instruments.
  - Monitors and measures the magnitude of solar flares.
  - Measures a critical space weather alert parameter
    - The Radio Blackout or R Scale
  - Input to models of radio propagation and ionosphere models
  - Provides a precursor to other types of space weather
    - Energetic protons
    - CMEs and Geomagnetic Storms

- GOES 16/17+ data will be presented in its most accurate form.
  - There will be a discontinuity in the data when the XRS data comes on line.
  - There will be more flares that reach and exceed critical thresholds.
  - Customers will need to adjust their models and procedures.