Science-Quality GOES X-Ray Measurements and Implications for Solar Flare Research
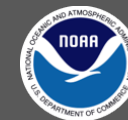
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Overview of X-ray Sensor (XRS) Measurements

- The GOES X-ray sensors (XRS) have provided continuous solar X-ray flux measurements since 1975 with little change to the instrument bandpasses
- XRS provides NOAA's Space Weather Prediction Center (SWPC) with the first notice of major space weather events such as radio blackouts and SEP events
- The XRS instrument has two channels:
  - XRS-A ($0.5 - 4$ Å) and XRS-B ($1 - 8$ Å)
- The 1-minute average XRS-B channel flux defines the widely used solar flare magnitudes:
  - A: 10^{-8} W m^{-2} nm-1, B: 10^{-7} W m^{-2} nm^{-1}, C: 10^{-6} W m^{-2} nm^{-1}, M: 10^{-5} W m^{-2} nm^{-1}, X: 10^{-4} W m^{-2} nm^{-1}
- The latest XRS instruments, part of the EXIS instrument built by LASP, onboard the GOES-R series of satellites (GOES-16 and -17) provide pre-flight radiometric calibration and improved irradiance sensitivity
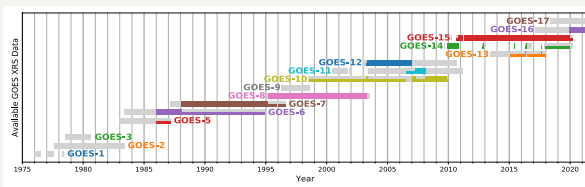

Science-Quality XRS Data Now Available for GOES 13-17

- Until recently, XRS data has only been available as operational-quality, which values speed and historical consistency over accuracy
- The science-quality data has been reprocessed to provide improved calibration methods, more accurate calibration factors, and better data quality flagging over the operational data (see figure for example)
- **Importantly, the science-quality XRS data removes the historical GOES 8-15 SWPC scaling factor, providing XRS measurements in true radiometric units [W m^{-2} nm^{-1}]**
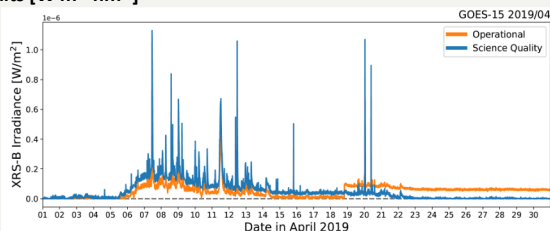
Removing the SWPC Scaling Factor and the Effect on Solar Flare Research
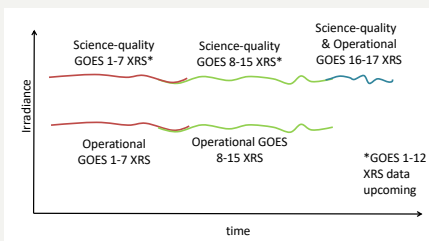
Removing the SWPC scaling factor

- X-ray rocket measurements and measurements at NIST SURF demonstrated that the SWPC scaling factor for GOES 8-15 is not needed and should be removed
- The science-quality GOES 13-17 XRS data removes this scaling factor, but operational data does not
  - Note that no scaling factor is needed for operational GOES 16-17 XRS data
  - Future science-quality GOES 1-12 XRS data will be properly scaled
- Users should take care to ensure that their data is appropriately scaled as some routines in SolarSoft and SunPy may remove the scaling factor (e.g., goes_chianti_tem.pro)
- Operational GOES 1-7 XRS data should be scaled upward to match the GOES 16-17 and the unscaled GOES 8-15 X-ray irradiances
- GOES 16-17 XRS irradiances agree well with the science-quality (unscaled) GOES 15 XRS irradiances

Impact on Research

- Removing the scaling factors implies that all flares measured operationally by GOES 8-15 are 40% larger than reported
  - I.e., the X9.3 class flare measured by GOES-15 on September 6, 2017 flare is actually a X13.3 class flare
- The updated flare irradiances (and therefore classifications) will impact:
  - Analysis based on the A,B,C,M,X classifications for pre GOES-16 data (the flare distributions will be shifted to larger classes)
  - Analysis using the temperature estimates derived from the XRS channel ratios if the pre GOES-16 data was left unscaled

Data Products and Access

https://www.ngdc.noaa.gov/stp/satellite/goes-r.html

XRS L1b Products:
- Detailed irradiance and flagging data at 1-second cadence

XRS L2 Products:
- 1-second irradiances (2-second irradiances for GOES 13-15)
- 1-minute average irradiances (with electron contamination removal for GOES 16-17)
- Flare location (for GOES 16-17 only, based on XRS quadrant photodiode measurements)
- Flare summary (list of solar flares with times, flare classes and integrated fluxes)
- Daily background X-ray flux

- ReadMes, User Guides, quicklook plots, and example code are also available on the website

- **The science-quality GOES 13-17 XRS data provides the most accurate solar X-ray flux in true radiometric units and users are strongly advised to use this data over the operational data**

Outstanding Questions/Future Work

- We are working to reprocess and produce science-quality XRS data for GOES 1-12 which will:
  - Remove the SWPC scaling factor from the GOES 8-12 data
  - Apply the proper scaling factor to the GOES 1-7 data
  - Improve the calibration methods and factors
  - Provide more accurate data quality flagging
- Using the full GOES 1-17+ science-quality XRS data, we will also release an updated solar flare list (time, flare class, satellite, and location where applicable) in multiple formats (csv, netcdf, ascii, etc.)
- **At this time, many data sources (including the operational data) still include the scaling factor in GOES 8-15 XRS data, and users should take care to ensure that their data is appropriately scaled**