Readme for GOES-R XRS L2 Data

Janet Machol, James Mothersbaugh III, Elysia Lucas, Ann Marie Mahon

15 December 2025

1 Summary

The GOES-R Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS) X-Ray Sensor (XRS) Level 2 (L2) data is based on 1-second cadence soft X-Ray irradiance measurements covering 0.05-0.4 nm (Channel A) and 0.1-0.8 nm (Channel B) integrated passbands. EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder. The L2 products are available in netCDF format as science-quality data produced by NOAA's National Center for Environmental Information (NCEI) and as real-time operational data used at the NOAA Space Weather Prediction Center (SWPC). The science-quality dataset differs from the operational product in that it incorporates retrospective fixes for issues in the operational product and updated calibrations, and the data have been reprocessed since the start of the mission (See Section 3).

This Readme gives brief descriptions of the L2 products and discusses the data caveats for the XRS L2 data. More details about the XRS L2 algorithms can be found in the GOES-R XRS L2 User's Guide. Links to the science-quality XRS data, Readme's, a User's Guide, plots, responsivity data, and associated documentation can be found at `https://www.ncei.noaa.gov/products/goes-r-extreme-ultraviolet-xray-irradiance`.

Users of the GOES-R XRS L2 data are responsible for inspecting the data and understanding the known caveats prior to use. Questions about this data can be sent to swx.irradiance@noaa.gov.

2 XRS L2 Products Overview

Start and end dates for the science-quality (and operational) L1b and L2 XRS data provided by NOAA NCEI are listed in Table 1. The official transitions at SWPC to use GOES-R XRS operational data occurred considerably later.

Table 1: Currently available XRS Data from NOAA/NCEI.

Satellite	Start Date	Final Date
GOES-16	2017-02-07	2025-04-07
GOES-17	2018-06-01	2023-01-10
GOES-18	2022-06-17	present
GOES-19	2024-09-20	present

The six L2 products for XRS are listed in Table 2 and briefly described below. Data is provided in daily, annual and mission aggregations. More complete product descriptions can be found in the XRS L2 User's Guide.

Table 2: Summary of XRS L2 Products

Product	Name	Description
1s fluxes	flx1s	XRS irradiances at 1-s cadence
1-min fluxes	avg1m	XRS irradiances at 1-min cadence
flare summary	flsum	flare detection flags such as start and peak
flare detection[1]	fldet	flare detection status for every minute
flare location	flloc	flare location on solar disk
daily background	bkd1d	daily background and daily averages
flare report[2]	flrpt	XRS and SWPC composite flare report

[1] The flare summary product should be used, instead of the flare detection product, as noted in Section 2.4.

[2] The new flare report for GOES-1 through -19 will be released in Summer 2025. Contains flare irradiances, timing, and locations.

Both XRS Channels, A and B, each have two irradiance sensors to capture the full dynamic range of the solar X-ray irradiance, where "1" and "2" denote the low- and high-irradiance sensors, respectively. The variable names refer to the channel and the sensor; for example, "xrsa2_flux" corresponds to the irradiance in Channel A on the high irradiance sensor "2". The flag "xrsa_primary_chan" indicates whether XRS-A1 or XRS-A2 provides the primary irradiance values. It is generally most useful to use the time series for the primary detectors, designated "xrsa" and "xrsb", which consist of low- and high-irradiance sensor values merged into a single time series based on the primary_chan flags.

A notable change between the GOES-R and previous GOES data is that the GOES-R XRS irradiances are provided in true physical units of $\mathrm{W\,m^{-2}}$ without a 'SWPC scaling factor'; this is further described in the XRS L2 User Guide.

A related note is that reprocessed science-quality GOES 8-15 XRS L1b and L2 data are now available. In this reprocessed data, the irradiances are provided in the same units as the GOES-R data, and with similar file format and products. This earlier data is available from the GOES 1-15 tab at `https://www.ncei.noaa.gov/products/goes-1-15/space-weather-instruments`. The GOES 1-7 data will be available later this year.

2.1 1-second Fluxes Product

This product provides the highest resolution XRS irradiances for the A and B channels along with a condensed set of quality flags. Time series of irradiance values are provided for each detector (XRS-A1, XRS-A2, XRS-B1 and XRS-B2) and for the primary detectors (XRS-A and XRS-B). Additional variables include corrected currents for XRS-A2 and -B2, the roll angle, and flags.

2.2 1-minute Averages Product

This product contains the 1-minute averages of the 1-s cadence data. Flags are provided which state the status of the averaged irradiances. Additionally, the number of 1-s data points included in the average and the union of flags set for data points that were excluded from the averages are provided.

Electron contamination to the irradiance is approximated and removed in the L2 1-min averaged data. Three values are reported for each channel: the uncorrected flux (e.g., xrsb_flux_observed), the estimated electron contamination (e.g., xrsb_flux_electrons), and the flux corrected for the electron contamination (e.g., xrsb_flux). The corrected flux has a minimum threshold of $10^{-9}\,\mathrm{W\,m^{-2}}$.

2.3 Flare Summary Product

This product provides information on the flares, including flare class, flare timing, integrated flux, and background flux. The flare summary product uses 1-minute averaged data. Status flags are listed in Table 3.

Table 3: Status Flags for Flare Summary Product

Flag	Description
EVENT_START	start of flare
EVENT_PEAK	peak of flare
EVENT_END	flare declined by 1/2
POST_EVENT	flare declined to background

2.4 Flare Detection Product

This product has a status flags every minute. The time stamps represent the time that the algorithm detected an event such as the peak of the flare, rather than when the actual peak occurred. For some types of events (flare start, flare peak, and flare end), this may be later than the actual event time. *Therefore, for most users, the flare summary product should be used* because it (1) has the correct event times and (2) consists of shorter files which exclude unnecessary monitoring status flags. The flare detection product is provided for users who wish to examine the algorithm behavior.

2.5 Flare Location Product

Flare location on the solar disk is determined based on the measurements from the high flux XRS-B2 quad diode detector. This product is the result of a center-of-mass calculation of the flare intensity on the quad diode. Flare location is provided in four coordinate systems: Stonyhurst/heliographic (lon, lat), Carrington (lon, lat), heliocentric-radial (R, θ) and helioprojective Cartesian (x,y) coordinates. The solar P-angle and apparent solar angular radius are also provided.

2.6 Daily Background Product

This product provides daily averages of irradiances and backgrounds for XRS-A and -B. The daily background algorithm uses hourly and 8-hour minima of the 1-minute averages.

2.7 Flare Report Product

This product is a composite data set of flare events. For each flare, the flare report provides flare timing, irradiance, flare magnitude, flare location, and other related information. Supplemental flare location is provided from largely ground-based solar observatories via NOAA's Space Weather Prediction Center (SWPC). This data is intended for both the general public and scientists alike, and is provided in both a metadata-rich NetCDF format, as well as a CSV format aimed at those wanting a more easily human-readable list of flare events. The flare report currently covers GOES-08 through -18, spanning 1995 to 2025. GOES-01 through -07 are planned to be added in 2026.

3 Science-Quality Versus Operational Data

The science-quality L2 data products differ from the operational L2 products used in operations at SWPC in completeness and quality. The science-quality data incorporate the most up-to-date calibrations and algorithm fixes and they are reprocessed since the start of the mission. The science-quality L2 data products are created from the science-quality L1b data. Both the science-quality and the operational data include some recovered data that was missing in the real-time operational products. The operational L1b and L2 data, especially from the earlier dates, contain significant issues that are not retroactively corrected, and therefore should be used with great caution and not for scientific analysis.

The science-quality data directories have names which end in "_science" and the file names have prefixes of "sci_". The science-quality data has a latency of three days.

The operational data are in directories without the "_science" suffixes, and the operational filenames have prefixes of "ops_" for L1b data and 'dn-' for L2 data. The operational data can be accessed from the parent directories of the science-quality data. This data has a latency of one day.

4 Data Caveats

The following is a list of caveats for the GOES-R XRS L2 data.

1. The XRS-A irradiance is approximately 41% larger for GOES-R than GOES-15; i.e., XRS-$A_{\text{GOES-R}}$ / XRS-$A_{\text{GOES-15}} \approx 1.41$ (for GOES-15 data without SWPC scaling factors). The GOES-R XRS instrument was carefully calibrated at NIST and the source of this discrepancy is currently unknown and under investigation. the error is likely to be in the GOES-8 through -15 data. There is no such discrepancy for the XRS-B irradiance.
2. Because of rescaling, the flare classifications have changed somewhat from the original GOES 1-15 classifications, as discussed in the XRS L2 User Guide.
3. The XRS irradiances are noticeably contaminated by electrons during periods where X-ray fluxes are low and electron fluxes are high. The impact is negligible in other conditions. In the L2 1-min cadence data, a correction is applied which removes much of the electron contamination. The method for removing electron contamination is currently being improved and revised data will be provided at a later date.
4. The dark radiation coefficient is not applied to the XRS irradiances. This coefficient corrects the irradiances for proton contamination during SEP events. Until this is applied, signals will be artificially high during strong SEP events, especially in the A2 and B2 channels. Analysis to determine this term is in progress.
5. The spacecraft eclipse flag and the roll angle values are incorrect early in the mission. Future versions of the science-quality data will correctly derive these values from the telemetry data.
6. GOES-17 has done twice-yearly yaw flips since 2019 and several before that. The yaw_flip_flag variable is briefly set incorrectly to 0 (instead of 2) on 2018-10-24 in ops, but not sci. GOES-16 has had no yaw flips prior to the date of this document and the yaw_flip_flag variable is set properly for all times.
7. Users of the XRS L2 operational data are advised to read the Readme for the GOES-R XRS L1b Operational Data for additional caveats.
8. GOES-17 L2 data is not provided for the period where it was disrupted by the SUVI Extended Coronal Imaging experiment from 2019-08-28 through 2019-12-17.
9. The science-quality data uses a time-dependent dark count, while the operational data uses a static dark count, and so in general, this data will not be identical.

5 Science-Quality Data Versions

Version numbers for the science-quality L2 XRS data are listed in Table 4. For each new version, the version numbers are updated for all of the L2 products. The products impacted by the specific changes are listed parenthetically in the table.

Table 4: Science-quality L2 data versions

Version	Release date	Revisions
2-2-1	15 December 2025	Uses v0.0.2 science-quality L1b data with revised responsivities. (all) First GOES-19 release. (all) Sets start date for GOES-18 data earlier to 17 June 2022. (all) Reduces number of data gaps. (all) Updates calibrations for spike flagging, electron contamination, and flare location. (flx1s, avg1m, flloc) Fixes code for spike threshold equation error. (flx1s) Adds interpolation over 1- and 2-minute data gaps. (avg1m) Adds interpolation flag. (avg1m) Creates separate electron_correction_flag. (avg1m, GOES-R only) Fixes error in flare classes near C1, M1, and X1. (fldet, flsum) Allows for flare_end and next flare_start at same time. (fldet, flsum) Adds new variable: sequential_flare_num. (fldet, flsum, flloc) Improves method of background selection. (flloc) Slightly revises definition of EVENT_END. (flsum)
2-2-0	14 April 2022	Improves flare location method. (flloc) Uses flux thresholds to select e- contamination coefficients. (avg1m) Updates parameters. (flloc, avg1m) First release of GOES-18. (all) Improves monthly plots. (avg1m)
2-1-0	6 April 2021	Uses v0.0.1 science L1b data. (all) Adds spike detection on all data, not just good quality. (flx1s) New flare location product. (flloc) Removes flare_counter variable.(fldet, flsum, flloc) New flare_id variable. (fldet, flsum, flloc) New flag meaning marks times of significant electron contam. (avg1m) New electron correction coefficients and account for yaw flip. (avg1m) pointing_degraded flag meaning removed. (all) Fixes incorrect au_factor averages. (avg1m)
2-0-1	15 June 2020	Corrects timestamp in 1-sec fluxes by 0.516 s. (all) Integrated fluxes set to fill value in monitor state. (fldet)
$\leq$ 2-0-0	21 May 2020	Initial public data release.

6 Acknowledgements

We acknowledge contributions from R. Allsopp, S. Codrescu, K. Hallock, J. Negus, C. Peck, J. Riley, W. Rowland, A. Wilson, and P. Wyatt.