Readme for GOES-R EXIS XRS Level 1b Operational Data
version 1.0

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WARNING - THE USE OF SCIENCE-QUALITY DATA INSTEAD OF OPERATIONAL DATA IS STRONGLY RECOMMENDED.

Science users are advised to use the science-quality L2 data rather than the operational L1b data. The operational data is intended for archiving and for analyses that require "SWPC operational-like" data. Persons desiring to use the XRS Operational L1b products are advised to involve the responsible NOAA scientists before proceeding.

Links to the science-quality XRS data, Readmes, a User's Guide, plots, responsivity functions and other the associated documentation can be found at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html.

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1. Summary

The GOES-R Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS) X-Ray Sensor (XRS) Level 1b (L1b) science-quality data contains 1-second cadence soft X-Ray irradiance measurements covering 0.05-0.4 nm and 0.1-0.8 nm integrated passbands. EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder. This Readme is for the XRS L1b product used in operations at SWPC. This Readme discusses the data and data caveats. Further details on the XRS instrument can be found in the article by Chamberlin et al. (2009) and at https://www.goes-r.gov/spacesegment/exis.html.

Users of the GOES-R XRS L1b operational data are responsible for inspecting the data and understanding the known caveats prior to use. Questions about this data set can be sent to janet.machol@noaa.gov or courtney.peck@noaa.gov, while questions about data access should be sent to pamela.wyatt@noaa.gov.

2. Use of Science-Quality Data instead of Operational Data

The operational L1b data, especially from the earlier dates, contain significant issues that are not retroactively corrected, and therefore this data should be used with great caution and not for

scientific analysis. While major issues in the operational processing code have been resolved, minor issues remain to be fixed.

In general, users are advised to use the reprocessed science-quality XRS L1b and L2 data instead of the operational data. The science-quality dataset is produced by NOAA's National Center for Environmental Information (NCEI), and differs from the L1b operational product used at the NOAA Space Weather Prediction Center (SWPC) in that it incorporates retrospective fixes for issues in the operational product, and uses the most recent calibrations. Both operational and science-quality data contain recovered data due to spurious dropouts. The science-quality data have been reprocessed from the start of the mission to the present date.

Links to the science-quality XRS data, Readmes, a User's Guide, plots, responsivity data, and associated documentation can be found at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html. The science-quality data directories have names which end in "_science" and the file names have prefixes of "sci_". 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.

3. Data Overview

This section briefly describes the main L1b variables from the XRS instrument. The data is stored in netcdf format, and can be readily accessed via pre-packaged routines in many programming languages, including IDL and Python.

XRS measures soft X-ray fluxes at 1-second cadence in the historical bandpasses 0.05 to 0.4 nm (Channel A) and 0.1 to 0.8 nm (Channel B). Each channel has two irradiance sensors to capture the full dynamic range of the solar X-Ray irradiance, where "1" denotes the low-irradiance sensor and "2" is for the high-irradiance sensor, which is a quad photodiode. This numbering is utilized in the variable naming convention where, for example, "irradiance_xrsa2" corresponds to the irradiance in channel A on the high irradiance sensor. The flags "primary_xrsa" and "primary_xrsb" indicate whether the low or high irradiance sensors for Channel A and B provide the primary irradiance value. The current thresholds for switching the primary channels are 10^{-5} W m^{-2} for Channel A and 10^{-4} W m^{-2} for Channel B.

Flags are provided to indicate data outages and reliability. XRS data quality is indicated in the variable "quality_flags" which have individual bits regarding the reliability of pointing, temperature, irradiance, and other issues. An overall flag value of 0 indicates good quality data. Since the GOES instruments operate in geostationary orbit, they experience two eclipse seasons per year around the equinox. The flags "fov_eclipse" and "SC_eclipse_flag" indicate these events. There are three L1b pointing error flags (Table 1); the flag names will simplified in autumn of 2020.

The Sun Pointing Sensor (SPS) on EXIS utilizes a quadrant photodiode to provide pointing information. SPS operates at 4 Hz, and the average pointing is provided by the variables "dispersion_angle" and "crossdispersion_angle" and the time is provided by "sps_obs_time".

Table 2. L1b pointing error flags for operational XRS data

Pointing error range	Original flag name	Revised flag name (after autumn 2020)
(7 arcmin) 0.11° to 0.4° degrees	degraded_due_to_calibrated_but_exceeds_requirements _XRS_pointing_qf	XRS_pointing_warning_qf
0.4 to 0.8°	degraded_due_to_uncalibrated_range_XRS_pointing_qf	degraded_XRS_pointing_qf
>0.8°	invalid_due_to_out_of_range_XRS_pointing_qf	invalid_XRS_pointing_qf

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 W m^{-2}. The operational data prior to GOES-16 had scaling factors applied by SWPC so as to adjust the GOES 8-15 irradiances to match fluxes from GOES-7. The flare index was based on the operational irradiances, but to get true irradiances, the scaling factors of 0.85 (for the XRS-A channel) and 0.7 (for the XRS-B channel) applied to GOES 8-15 had to be removed. There are no such scaling factors in the GOES-R XRS data; the provided irradiances are in true physical units.

The magnitude of a flare is defined by SWPC with a flare index that is based on the 1-minute average of the GOES operational irradiance in the XRS-B channel at the peak of the flare. Flare indices are denoted by a letter and a number based on the log 10 peak irradiance of the flare (X: 10^{-4} W m^{-2}, M: 10^{-5} W m^{-2}, C: 10^{-6} W m^{-2}, B: 10^{-7} W m^{-2}, and A: 10^{-8} W m^{-2}). For instance, an M5 index is defined for a 5x10^{-5} W m^{-2} peak irradiance, and an X2.5 index is defined as an irradiance level of 2.5x10^{-4} W m^{-2} peak irradiance. Because of the SWPC scaling factors in the pre-GOES-R data, flare indices for the earlier satellites were based on irradiances that were reported as 42% (1.0/0.7) smaller than for GOES-R (e.g., an X2.5 class flare reported operationally for GOES-15 will be an X3.6 class flare for GOES-R). Two XRS Level 2 (L2) products useful for flare detection are the event detection and event summary which provide flare peak irradiances, indices, and times.

A related note is that reprocessed science-quality GOES 13-15 XRS data are now available. In this GOES 13-15 science-quality data, the irradiances are provided in physical units (i.e., without the SWPC scaling factors) to match the GOES-R data. This earlier data is available from the GOES 8-15 tab at https://ngdc.noaa.gov/stp/satellite/goes-r.html.

3. Data Caveats

The following is a list of caveats for the GOES-R XRS L1b operational data at this time.Earlier operational data has more significant errors which are not described here.

1. The XRS-A irradiance is approximately 41% larger for GOES-R than GOES-15; i.e., $XRS\text{-}A_{GOES\text{-}R}/XRS\text{-}A_{GOES\text{-}15} \approx 1.41$ (for GOES-15 data without the SWPC scaling factors). The GOES-R XRS instrument was carefully calibrated at NIST, and the source of this discrepancy is unknown and under investigation. There is no such discrepancy for the XRS-B irradiance.
2. The XRS irradiances are noticeably contaminated by electrons during periods where X-ray fluxes are low and electron irradiances are high. The impact is negligible in other conditions. The electron contamination is removed in the L2 data.
3. The irradiances contain spikes probably due to galactic cosmic rays. These spikes are flagged and removed in the L2 data.
4. The dark radiation coefficient is not applied. This coefficient corrects the irradiances for proton contamination during SEP events. Until this is applied, signals will be artificially high during SEP events, especially in the A2 and B2 channels. Analysis to determine this term is in progress.
5. The dark count values will be updated. Until this is done, fluxes will be slightly elevated, but this will only be noticeable for the lowest XRS-A fluxes.
6. The spacecraft eclipse flag and the roll angle values are incorrect early in the mission.
7. The solar array current for all GOES 17 data is incorrect.
8. The yaw_flip_flag variable is not set properly and should not be used. GOES-16 has had no yaw flips prior to the date of this document.
9. Mercury transits are not flagged. There are only two Mercury transits in the GOES mission lifetimes (11 November 2019 and 13 November 2032) and they cause no noticeable decrease in XRS irradiance.
10. In the early part of the mission, the alg_container and packet_count variables were incorrect and should not be used.
11. The lunar_transit_flag variable is not set properly.
12. During lunar transits, the sps variables, angles and fov_planet_transit are set incorrectly.
13. The SPS observation times have a small error of 0.125 s.
14. The pointing error flags are not set properly during eclipses and lunar transits.

4. Document Versions

Table 2. Document versions.

Version number	Release date	Updates
v1.0	15 April 2020	N/A

References

Chamberlin, P. C., F. G. Eparvier, A. R. Jones, and T. N. Woods (2009). Next Generation X-Ray Sensors (XRS) for the NOAA GOES-R Satellite Series, SPIE Proc., 7438-23. https://doi.org/10.1117/12.826807