GOES Flare Report ReadMe

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1 Summary

The GOES Flare Report is a composite data set of flare events based on available GOES satellite data, currently spanning GOES-08 through GOES-19 (1995 - 2025). For each flare, the flare report provides flare timing, irradiances, flare magnitude, flare locations, and other useful information. Supplemental flare location is provided from ground-based solar observatories via the NOAA Space Weather Prediction Center (SWPC). This data is intended for use by scientists and the general public. It is provided in both a metadata-rich NetCDF format and a CSV format for those wanting a more easily human-readable list of flare events. Flares from GOES-01 through GOES-07 are planned to be added later this year. The flare report is updated daily with the latest data. The GOES Flare Report is available at `thttps://data.ngdc.noaa.gov/platforms/solar-space-observing-satellites/goes/multi/l2/data/xrsf-l2-flrpt_science/`.

Measurements from GOES satellites are the primary source of flare information. Generally, since 1975, there have been at least two GOES satellites operating at all times, with one satellite designated as primary and one as secondary. Each GOES satellite carries an X-Ray Sensor (XRS) with detectors that measure solar soft X-ray irradiance in two integrated passbands: 0.05-0.4 nm (XRS-A) and 0.1-0.8 nm (XRS-B). Reported irradiances in the flare report are derived from the XRS-B 1-minute average irradiances.

The data in the flare report is primarily derived from the GOES XRS Level 2 (L2) science-quality flare summary data. This data has been consolidated into an event-based table, with one entry per flare and indexed by the flare peak time. The flare information is for the designated primary satellite if that data is available, or is otherwise taken from the secondary (or tertiary) satellite. The primary and secondary flare designations are provided in Appendix A. The flare report gathers flare location data from two sources: GOES satellites and ground-based observatories. More information about GOES XRS measurements can be found in the XRS User Guides and ReadMes.

The flare report is a science-quality product produced by the NOAA National Center for Environmental Information (NCEI). The flare report is provided in two formats, NetCDF (*.nc) and CSV (*.csv), and in 2 aggregation lengths, yearly and mission-length. The NetCDF files have full global and variable metadata, and are intended for software development purposes. The CSV files are human-readable, and have most metadata available in a separate JSON file.

Users of the GOES-R XRS L2 Flare Report 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 Flare Report Input Data

A summary of the input data products used in the creation of the flare report is listed in Table 1.

Table 1: Data Sources for Flare Report

Product	Abbreviation	Primary Variables Used
XRS Flare Summary	`flsum`	Irradiances and flare timing
XRS Flare Location	`flloc`	X-ray solar flare location
SWPC Solar Event Report	`swpc`	Visible wavelength[1] flare location

[1] GOES-12 Solar X-ray Imager (SXI) locations are also used from 2004 to 2006.

2.1 XRS Flare Summary

The science-quality L2 GOES XRS flare summary data product is the basis for the flare report. It provides information on flare timing, irradiance, and flare class, as well as other relevant information such as background irradiance, saturation, and flare sequence number. This data has a 1 minute resolution, as it is derived from the 1-min XRS-B averages. Each record of the flare summary includes a time, a 'flare state' (START, PEAK, END, or POST_END), and associated irradiance. In contrast, the output flare report has one record per flare event, which provides the times of the start, peak, and end of each flare. More information about GOES XRS data products can be found in the XRS L2 ReadMe and User's Guides.

2.2 XRS Flare Location

GOES XRS flare locations are only available for GOES-R series satellites (from 2017 onward) and are taken from the science-quality L2 XRS flare location product. The files provide flare locations for two coordinate systems: heliographic Stonyhurst and helioprojective Cartesian. The uncertainty for flares of C-class and larger is about 1 arcmin (6 degrees HGS); more details on the XRS flare locations and their uncertainties are provided in the GOES-R L2 XRS User's Guide.

2.3 SWPC Solar Event Reports

SWPC produces daily Solar Event Reports (edited_events_YYYYMMDD.txt), which include flare irradiance, flare class, flare location where applicable, associated satellite or ground stations, and active region number. These solar event reports cover the period from 1997 to present. Prior to 1997, NCEI produced historical reports compiled from SWPC data. The two types of files are formatted differently; the NCEI historical reports have less flare information than later reports. We used both types of files to populate SWPC flare locations in the flare report. From here onward in this guide, both of these files will be referred to as SWPC solar event reports.

Most of the flare locations in the SWPC solar event reports are from the optical ground-based network known as the Solar Observing Optical Network (SOON). SWPC provides the SOON-reported flare locations, measured at visible wavelengths, in their daily solar event reports, with occasional corrections or recentering of flares. The data is provided with a resolution of 1 degree (HGS), and there is no estimate of error on these locations from SOON.

While most flare locations from SWPC are optical ground-based observations, for a period between 2004-2006, the majority of SWPC flare locations were provided by the GOES-12 Solar X-Ray Imager (SXI). Because SXI flare locations are obtained from the SWPC reports, they are included with the SWPC flare locations in the Flare Report, rather than the GOES XRS flare locations. The XRS team has made six corrections to SWPC flare locations based on SOON, SXI, and/or AIA 193 nm data.

Because SWPC only provides flare coordinates in the heliographic Stonyhurst coordinate system, there is no representation of off-disk flares until 2017, when the GOES-R satellite series data is included.

3 Flare Report Files

To create the flare report, for each flare, the values for just one GOES satellite are used. The flare report gives priority to the satellite designated as 'primary' at any given time. If two satellites see the same flare

within a tolerance of 4 minutes, and within a flare irradiance window of ±15%, the primary satellite's data will be used as the source for that flare event. If one or both of those conditions are not met, two separate flare events will be reported. Appendix A defines the primary and secondary satellite designations in Table 5.

Data from the input files described in Section 2 is parsed, cleaned, and combined, and then logic is applied to match SWPC events to XRS events within specified tolerances. Then, events are deduplicated and written out to both mission and yearly files.

As shown in Table 2, the Flare Report is available in both NetCDF and CSV (text) file formats. The JSON metadata file pairs with the CSV files, which do not include detailed metadata. The data in the CSV and JSON metadata files are derived from the NetCDF files.

Examples of how to use both the NetCDF and CSV flare report files are provided at the GOES-R Space Weather Examples website.

Table 2: XRS L2 Flare Report Files

Product	Example Filename(s)
Mission Flare Report	`sci_xrsf-l2-flrpt_geo_s19950103_e20251215_v1-0-0.nc`
	`sci_xrsf-l2-flrpt_geo_s19950103_e20251215_v1-0-0.csv`
Yearly Flare Report	`sci_xrsf-l2-flrpt_geo_y2025_v1-0-0.nc`
	`sci_xrsf-l2-flrpt_geo_y2025_v1-0-0.csv`
Metadata JSON	`sci_xrsf-l2-flrpt_geo_metadata.json`

4 XRS L2 Flare Report Variables Overview

The flare report indices are based on the flare peak time obtained from the science flare summary, and the rest of the event variables are obtained from other variables in the science flare summary, the science flare location, and the SWPC solar event reports. Table 3 below describes the variables included in the flare report. Any nonexistent data has a fill value in the NetCDF files, and is left blank in the CSV files. For further information on product variables, refer to the NetCDF file metadata or the JSON metadata file.

Table 3: Flare Report Variables

Variable	Units	Description	Source
time	time[1]	Flare peak time	flsum
start_time	time[1]	Flare start time	flsum
end_time	time[1]	Flare end time	flsum
flare_id		Flare ID (flare start time)	flsum
xrsb_irrad	W/m^2	1-minute averaged peak irradiance for XRS-B	flsum
flare_class		Flare class	flsum
xrsb_irrad_source		XRS-B irradiance	flsum
background_irrad	W/m^2	Background irradiance	flsum
integrated_irrad_peak	J/m^2	Integrated irradiance (start to peak)	flsum
integrated_irrad_end	J/m^2	Integrated irradiance (start to end)	flsum
flare_loc_swpc_hgs[2]	deg, deg	SWPC flare location (heliographic Stonyhurst)	swpc
flare_loc_swpc_source		Source observatory for SWPC flare location	swpc
flare_loc_xrs_hgs[2]	deg, deg	XRS flare location (heliographic Stonyhurst)	flloc
flare_loc_xrs_hpc[2]	arcsec, arcsec	XRS flare location (helioprojective Cartesian)	flloc
flare_loc_xrs_source		Source instrument for XRS flare location	flloc
sequential_flare_num		Flare number within sequence of flares	flsum
event_id_swpc		Flare event ID 'bin' number assigned by SWPC	swpc
peak_saturated		Flare peak saturation	flsum
active_region		Active Region	swpc

[1] See Section 4.1.
[2] The flare location variables have separate latitude and longitude columns in the CSV files.

4.1 Flare Times

The flare report is indexed by the variable `time`, which is the flare peak time. The variables `start_time` and `end_time` correspond to `EVENT_START` and `EVENT_END`, respectively. These times in the NetCDF files are formatted as seconds since 1970-01-01 00:00:00 UTC, neglecting leap seconds. Times in the CSV files are provided in datetime format (YYYY-MM-DD HH:MM:SS). The files have a 1-minute cadence, because they are based on 1-minute average products.

4.2 Flare Magnitudes

The GOES Flare Report provides flare irradiances and flare classes. The `flare_class` is denoted by a letter and a number based on the $\log_{10}$(peak irradiance) of the flare, and minimum thresholds of:

- X: 10^{-4} W/m^2
- M: 10^{-5} W/m^2
- C: 10^{-6} W/m^2
- B: 10^{-7} W/m^2

Earlier flare lists have different flare irradiances (and corresponding flare classes) for satellites before GOES-16. The current science-quality XRS data and the GOES Flare Report have consistent flare magnitudes between all GOES satellites. More information about flare classes and the scaling of the XRS irradiances is provided in the GOES-R L2 User Guide.

4.3 Flare Locations

X-Ray and optical flare locations are provided in the variables `flare_loc_xrs_hgs`, `flare_loc_xrs_hpc`, and `flare_loc_swpc_hgs`. The XRS flare locations are included only for C-class and larger flares because of XRS' decreasing flare location accuracy with decreasing flare magnitude.

4.4 Additional Flare Information

`peak_saturated` is a boolean flag that is set to indicate that the irradiance measurement near the flare peak is saturated ("cut off"). Saturation occurs rarely and will never happen for GOES-R (GOES-16 through GOES-18). Between GOES-8 and GOES-19, saturation has only occurred four times:

- 2001-04-02 (GOES-8, GOES-10)
- 2003-10-28 (GOES-10, GOES-12)
- 2003-11-04 (GOES-10, GOES-12)
- 2005-09-07 (GOES-10, GOES-12)

The time stamp for a saturated flare peak is the `EVENT_PEAK_SATURATED` time from the science-quality XRS flare summary file.

5 Data Caveats

The following is a list of caveats for the Flare Report data.

1. Flare classifications and magnitudes for science-quality GOES-8 through GOES-15 match those of GOES-R. These are different than the original operational data. For more information on these prior changes, see the GOES-R L2 XRS User Guide.
2. Some flare events do not have corresponding SWPC flare locations and active region numbers. This is due to difference between the XRS and SWPC solar event where there is difference either in event peak times of more than 4 minutes, or in the flare peak irradiances of more than 15%.
3. There are some non-negligible differences in flare locations between the original SOON values and the flare locations in the SWPC Solar Event Reports. SWPC has stated that they occasionally correct SOON flare locations based on the geometric center of the flare, or when there are obvious errors.
4. The flare report CSV files have more data variable names than the NetCDF files, because the three multi-dimensional NetCDF coordinate variables have been split into a total of six coordinate variables for the CSV, as noted in Table 3.
5. Differences between XRS flare locations and the SOON flare locations may be due to errors in either measurement, because they are measured at different wavelengths, or due to different spatial resolutions.
6. SWPC flare locations on the following dates have been corrected with SOON, SXI, and/or AIA 193 nm data: 2003-01-07 23:33, 2005-08-23 14:44, 2011-02-14 17:26, 2013-11-19 10:26, 2020-11-05 00:22, 2022-07-05 12:38. Active regions on the following dates have been manually added: 2026-02-02, 2026-02-04.

6 Future Improvements

After reprocessing and validation of GOES-1 through GOES-7 XRS data is complete, the flare report will be extended to cover those satellites. Additional flare location measurement information will also be added in the future.

7 Flare Report Versions

Version numbers for the flare report are listed in Table 4.

Table 4: XRS Flare Report Versions

Version	Release date	Revisions
1-0-1	2026-06-24	More active regions and SWPC flare locations Added sequential flares > 2
1-0-0	2026-01-23	Initial public data release

8 Data Acknowledgements

The GOES data is available from the following sites:

`https://www.ncei.noaa.gov/products/goes-r-extreme-ultraviolet-xray-irradiance`

`https://www.ncei.noaa.gov/products/goes-1-15/space-weather-instruments`

The SWPC Solar Event Reports and the NCEI SWPC Historical Event Reports are available from:

`https://www.ngdc.noaa.gov/stp/space-weather/swpc-products/daily_reports/solar_event_reports/`

`https://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-flares/x-rays/goes/xrs/`

9 Acknowledgements

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10 References

GOES irradiance documentation, plots and data products can be found on the following webpages. The primary document is the XRS L2 User's Guide which covers data products from GOES-8 through GOES-19.

GOES-R XRS L2 User's Guide:

`https://data.ngdc.noaa.gov/platforms/solar-space-observing-satellites/goes/goes16/l2/docs/GOES-R_XRS_L2_Data_Users_Guide.pdf`

GOES-R webpage (Select "Documentation" or "Data Access" tab):

`https://www.ncei.noaa.gov/products/goes-r-extreme-ultraviolet-xray-irradiance`

GOES-1 through -15 webpage (Select "Documentation" or "Solar Irradiance" tab):

`https://www.ncei.noaa.gov/products/goes-1-15/space-weather-instruments`

GOES-R Space Weather Examples:

https://cires-stp.github.io/goesr-spwx-examples/examples/index.html#exis

Journal article about XRS measurements:

Machol, J. L., Codrescu, S. M., Peck, C. L., Lucas, E. S., Mothersbaugh, J. F., III, Woods, T. N., A.M. Mahon, J. Negus, D.L. Woodraska, T. D. Eden Jr., F. G. Eparvier, A.R. Jones, B. Kotten, L.A. Rachmeler, A.C. Wilson, B.T. Kress, J.V. Rodriguez, R.A. Viereck (2026). GOES-R series X-Ray Sensor (XRS): 2. On-orbit measurements and calibrations. Journal of Geophysical Research: Space Physics, 131, e2026JA035181. https://doi.org/10.1029/2026JA035181

Appendix A GOES Primary and Secondary Satellite Designations

Table 5: Dates for Satellite Designations

Date	Time	Primary	Secondary
2025-04-07	00:00	18	19
2023-01-04	00:00	16	18
2021-08-24	00:00	16	17
2019-12-09	17:30	16	15
2017-12-12	16:30	15	14
2017-08-23	21:20	15	13
2017-08-16	19:15	13	14
2016-06-09	17:30	15	13
2016-05-16	17:00	14	15
2016-05-12	17:30	14	13
2016-05-03	13:00	13	14
2015-06-09	16:25	15	13
2015-05-21	18:00	14	13
2015-01-26	16:01	15	13
2012-11-19	16:31	15	14
2012-10-23	16:00	14	15
2011-09-01	00:00	15	14
2010-10-28	00:00	15	15
2010-09-01	00:00	14	15
2009-12-01	00:00	14	11
2007-01-01	00:00	10	11
2006-06-28	00:00	12	11
2003-05-15	15:00	12	10
2003-04-08	15:00	10	12
1998-07-27	00:00	8	10
1995-03-01	00:00	8	7
1995-01-05	00:00	7	7
1994-12-11	00:00	7	8
1988-01-26	00:00	7	6
1986-01-01	00:00	6	5

In the SWPC reports, each SWPC event ID usually has multiple lines for different labels related to the data source. In order to select the best values for active region and SWPC flare location for each SWPC Event ID in the SWPC report, the following prioritized order of the SWPC source labels is used: (1) GOES X-Ray Events (AR only), (2) Optical Flare or GOES X-Ray Flare Location Events, (3) Other Labels (marked with + after the SWPC Event ID), (4) Other Labels (not marked with a +).