User's Guide for GOES-R EUVS L2 Products

Janet Machol, Stefan Codrescu, and Courtney Peck

15 December 2023

Contents

1 Summary

The GOES-R Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS) Extreme Ultraviolet Sensor (EUVS) Level 2 (L2) data is based on the high-cadence extreme ultraviolet irradiance measurements in the EUVS Level 1b (L1b) data. EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder. The data is produced by NOAA's National Center for Environmental Information (NCEI) in netCDF data format and is similar to the operational product used at the NOAA Space Weather Prediction Center (SWPC).

This User's Guide provides descriptions of the L2 algorithms (Machol et al., 2020). Caveats for the operational EUVS L2 data are given in the Readme at `https://www.ngdc.noaa.gov/stp/satellite/goes-r.html`.Users of the GOES-R EUVS data are responsible for inspecting the data and understanding the known caveats prior to use. Technical questions about this data can be sent to *janet.machol@noaa.gov*, while data access questions should be sent to *pamela.wyatt@noaa.gov* or *josh.riley@noaa.gov*.

2 EUVS L2 Products Overview

GOES-R EUVS (Eparvier et al., 2009; Snow et al., 2009) makes extreme ultraviolet (EUV) and far ultraviolet (FUV) high-spectral-resolution measurements of distinct solar emission lines representative of different layers of the solar atmosphere. EUVS measurements are made for seven solar lines and the Mg II core-to-wing ratio (Mg II index) as shown in Table 1. An EUV spectrum from 5 to 127 nm is constructed from the EUVS measurements using an empirical proxy model (Thiemann et al., 2019). The model outputs solar spectral irradiance (SSI), i.e., the solar irradiance as a function of wavelength, which is used in conjunction with absorption cross sections that are a function of wavelength and altitude as inputs to atmospheric models (e.g., Solomon and Qian, 2005). Irradiance values are as measured at that satellite; conversion factors are provided in the files for users who wish to convert to irradiance at 1 AU.

Table 1: Main Solar Lines Measured by EUVS

Wavelength (nm)	Lines(s)	Source Region
25.632	He II	Transition region
28.415	Fe XV	Corona
30.378	He II	Transition region
117.5	C III	Chromosphere
121.567	H I	Transition region
133.57	C II	Chromosphere
140.5	Si IV, O IV	Transition region
279.5528, 280.2704	Mg II h, k	Chromosphere

* The Mg II index is derived from measurements near 280 nm.

The EUVS L2 products are listed in Table 2. Figure 1 shows measurement time periods for the three GOES satellites.

Table 2: EUVS L2 Products

Product	Name	Description	Available Now
high resolution	hires	irradiances, currents at highest resolution	
1-min averages	avg1m	irradiances, MgII index, spectral model at 1-min cadence	x
daily averages	avg1d	daily averages of irradiances, MgII index, spectral model	x

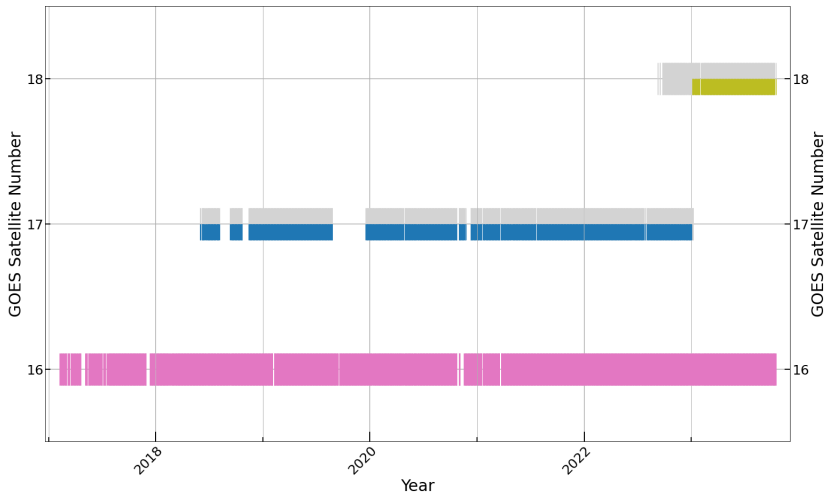

Figure 1: EUVS measurements for GOES-16 through -18 as of December 2023. Coloring indicates primary (full-thickness lines) and secondary (half-thickness lines) satellites.

2.1 Science-Quality versus Operational EUVS 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. Operational data has a latency of one day.

2.2 Time

The time variable, $time[secs] = Time[UTC] - base\_time[UTC]$, is an elapsed time in units of "secs since *base_time*" where $base\_time = 2000\text{-}01\text{-}01\ 12{:}00{:}00[UTC]$ and was calculated without including leap seconds that occurred since 1 Jan 2000. Time stamps can be calculated by the user in Coordinated Universal Time (UTC) as

$$Time[UTC] = base\_time[UTC] + time[secs] + n[secs] \tag{1}$$

where $n = 0$ for a time conversion function which ignores leap seconds (e.g., Python cftime.num2date or netCDF4.num2date) and $n = number\ of\ leap\ seconds\ since\ base\_time$ if the function includes leap seconds. It should be noted that the reference epoch of "2000-01-01 12:00:00 UTC" is not the same as the J2000 epoch, because the latter is given in terrestrial time (TT) units which differ by more than a minute from UTC. For a table of leap seconds, see `https://www.nist.gov/pml/time-and-frequency-division/time-realization/leap-seconds`.

3 1-minute Averages Product

This product contains the 1-minute averages of the L1b data. The wavelengths of the associated low and high bandpass cutoffs as well as the line center are provided. Irradiance values scaled to a 1-nm bandpass

are also provided for the 28.4, 30.4 and 121.6 nm lines.

Flags are provided which state the status of the averaged irradiances. There are only four flag meanings as shown in Table 3. Additionally, the unions of flags set for data excluded from the averages are provided. There is also a flag which is set for 8 hours around local midnight when the Lyman-alpha (121.6 nm) measurements will be impacted by geocoronal absorption.

The spectral model provides 1-minute time averages of the EUVS solar spectral irradiance model. There are 22 model bands with a 5-nm bandpass from 5 to 115 nm, and a 23rd bin from 117 to 127 nm. The spectrum is created based on the available EXIS data which is flagged by the model_case_flag which ranges from 1 to 8.

Table 3: Status flag states for 1-min irradiance averages.

Flag	Description
good_quality	none of eclipse, lunar_transit or bad_or_no_data flags are set
eclipse	Earth eclipse
lunar_transit	lunar transit
bad_or_no_data	pointing error, missing data, or otherwise bad data

4 Daily Average Product

This product consists of daily averages of the 1-minute averages. The daily average only includes 1-minute data where the good_quality flag is set. For the 121.6-nm line, the daily average excludes 6 hours around local midnight in order to exclude impacts of geocoronal absorption.

5 High Resolution Product

This product is under development and will provide higher time and spectral resolution diode currents and irradiances.

6 Acknowledgements

We thank J. Marcus Hughes for development of the L1b science-quality processing code. We also acknowledge Tom Eden, Frank Eparvier, Andrew Jones, Ann Marie Mahon, Bill McClintock, Jamie Mothersbaugh, Josh Riley, Marty Snow, Rodney Viereck, Don Woodraska, and Pamela Wyatt.

7 References

Eparvier, F. G., D. Crotser, A. R. Jones, W. E. McClintock, M. Snow, and T. N. Woods, The Extreme Ultraviolet Sensor (EUVS) for GOES-R, Proc. SPIE 7438, Solar Physics and Space Weather Instrumentation III, 743804 (September 23, 2009). doi:10.1117/12.826445.

Machol, J., F. Eparvier, R. Viereck, D. Woodraska, M. Snow, E. Thiemann, T. Woods, W. McClintock, S. Mueller, T. Eden, R. Meisner, S. Codrescu,S. Bouwer, and A. Reinard (2020), GOES-R Series Solar X-ray and Ultraviolet Irradiance. In S. Goodman, T. Schmit, J. Daniels, R. J. Redmon) (Eds.), The GOES-R Series: A New Generation of Geostationary Environmental Satellites (pp. 233-242), Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-814327-8.00019-6.

Snow, M., W. E. McClintock, D.Crotser and F. G. Eparvier, "EUVS-C: the measurement of the magnesium II index for GOES-R EXIS", Proc. SPIE 7438, Solar Physics and Space Weather Instrumentation III, 743803 (August 26, 2009). doi:10.1117/12.828566.

Solomon, S. C., and Qian, L. (2005), Solar extreme-ultraviolet irradiance for general circulation models. J. Geophys. Res. 110. doi:10.1029/2005JA011160.

Thiemann, E.M.B., F.G. Eparvier, D. Woodraska, P.C. Chamberlin, J. Machol, T. Eden, A.R. Jones, R. Meisner, S. Mueller, M. Snow, R. Viereck, and T. N. Jones (2019). The GOES-R EUVS Model for EUV Irradiance Variability, J. Space Weather and Space Clim., 9, A43, https://doi.org/10.1051/swsc/2019041