Readme for GOES-R EXIS EUVS Level 1b Science-Quality Data

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1. Summary

This Readme is for the Level 1b (L1b) science-quality product for the GOES-R Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS) Extreme Ultraviolet Sensor (EUVS). EUVS measures solar spectral irradiance at discrete wavelengths between 25 and 141 nm and in the vicinity of 280 nm. The L1b data products derived from EUVS observations are irradiances for seven solar lines, the Magnesium core-to-wing ratio (i.e., the Mg II index), and EUV proxy spectra from 5 to 127 nm. The nominal data cadence is 30-s. EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder. The science-quality dataset is produced by the NOAA National Centers 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. The science-quality data have been reprocessed from the start of the mission to the present date. Both the science-quality and the operational data sets contain recovered data due to spurious dropouts. This ReadMe discusses the science-quality L1b data products, as well as current and future improvements to the dataset. Further details on the EUVS instrument can be found in the articles by Eparvier et al. (2009), Snow et al. (2009), and Thiemann et al. (2019), and at https://www.goes-r.gov/spacesegment/exis.html.

Science-quality L2 data, are produced from these science-quality L1b data. In general, science users are advised to use the science-quality L2 data rather than the science-quality L1b data. Links to the science-quality EUVS L1b and L2 data, Readmes, a User's Guide, plots and otherdocumentation can be found at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html.

Science-quality and operational EUVS data has been released from NCEI for GOES-16. GOES-17 science-quality and operational data will be released from NCEI after corrections have been completed for the science-quality data. On GOES-17, in the fall of 2019 and during other shorter periods, extended coronal imaging (ECI) tests were performed for Solar Ultraviolet Imager (SUVI). To do this, the platform shared by SUVI and EXIS was repeatedly slewed at a high cadence across a wide field-of-view. For EUVS, this resulted in a high fraction of data gaps as well as new spatial and temporal degradation trends during this period which require further analysis and long-term trending measurements to correct.

Users of the GOES-R EUVS L1b science-quality data are responsible for inspecting the data and understanding the known caveats described in Section 3 prior to use. Questions about this data set can be sent to courtney.peck@noaa.gov or janet.machol@noaa.gov, while questions about data access should be sent to pamela.wyatt@noaa.gov.

2. Data 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 core-to-wing ratio (Mg II index) as shown in Table 1. An empirical proxy model (Thiemann et al. 2019) uses the EUVS measurements to reconstruct an EUV spectrum from 5 to 127 nm. The model outputs solar spectral irradiance (SSI), i.e., the solar irradiance as a function of wavelength, which can be used in conjunction with wavelength- and altitude-dependent absorption cross-sections as inputs to atmospheric models (e.g., Solomon and Qian, 2005). The L1b data is stored in netCDF format, and can be readily accessed via pre-packaged routines in many programming languages, including IDL and Python. A full list of variables, data type, long name, and units is provided in Appendix 1.

Table 1. Solar lines measured by GOES-R EUVS. The Mg II index is derived from measurements near 280 nm.

Wavelength [nm]	Line(s)	Source region
25.632	He II	transition region
28.415	Fe XV	corona
30.378	He II	transition region
117.5	CIII	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

Flags are provided to indicate data outages and reliability. The EUVS model spectrum data quality is indicated in the variable “qualityFlags” 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 “qualityFlags” variable indicates these events.

3. Data Caveats

The following is a list of caveats for the GOES-R EUVS L1b science-quality data as of the date of this document. Some of these issues will be corrected in future versions of the data.

1. The spacecraft eclipse flag is incorrect early in the mission. The flag "degraded_due_to_eclipse_state_received_from_ground_qf" in the "qualityFlags" variable should be used to identify Earth eclipses.
2. The solar array currents variable is bad for all GOES-17 data.
3. There are small discrepancies in some of the line irradiances after eclipses due to uncorrected temperature impacts.
4. The dark correction as a function of temperature has small errors for all dates prior to March 2020. The impact of this error to the line irradiances is estimated to be less than 1%. This also impacts the spectral model. This will be corrected in future data versions.
5. Some bands in the spectral model have jumps when entering and exiting the geocoronal period. The model will be revised with improvements in a future data version.
6. The Mg II index may have small improvements in the future to account for non-linear behavior in the wings and lines and to remove spikes in the data.
7. The eclipse flag was set too narrowly around eclipses for the line irradiances in February and March 2017. This also impacts the spectral model.
8. There are some days of data that are missing, but will be included in future data versions. The missing time periods include the following:

2017/02/16 - 2017/02/23	2017/12/30 - 2018/01/04	2018/09/16 - 2018/09/22
2017/04/13 - 2017/04/18	2018/02/21 - 2018/02/24	2018/10/14 - 2018/10/17
2017/04/21 -2017/05/04	2018/04/07 - 2018/04/13	2018/11/27 - 2018/12/01
2017/07/19 - 2017/07/23	2018/06/19 - 2018/06/24	2019/12/17 - 2019/12/20
2017/10/02 - 2017/10/05	2018/07/25 - 2018/07/28	2020/06/10 - 2020/06/12
2017/12/17 - 2017/12/20	2018/09/09 - 2018/09/13	2021/02/22 - 2021/02/25

9. An annual cycle oscillation artifact impacts four of the EUVS line irradiances with a maximum peak near the winter solstice. For GOES-16, the approximate magnitudes of the artifact are ±1.5% (117 nm), ±1.3% (121 nm), ±1% (133 nm) and ±0.9% (140 nm). These oscillations will also impact the spectral model. Similar oscillations occur in the GOES-17 irradiances. This artifact will be removed in a future version of the data.
10. There are multi-hour post eclipse thermal dips in the spectral lines and some model bins. The effect is most pronounced in the 25.6, 117.5, 133.5 and 140.5 nm lines. Due to the overlying geocoronal dip, it is unclear if this artifact occurs for the 121.6 nm line.
11. There is a small (<1%) offset between the science-quality and operational data line irradiances. This is under investigation.

12. 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 irradiance.
13. EUVSA and B have a nominal cadence of 1-second to within a few microseconds. If the cadence is slightly less than 1-second, one second's worth of data at the start or end of the day is discarded to maintain the standard array sizes of data reported at 1-second cadence. This should have a negligible effect on the data quality.
14. EUVS data is not good during periods of extended coronal imaging (ECI) for SUVI. These dates are G16: 2018-02-12, 2011802-13; and G17: 2018-04-30, 2018-06-04 through 2018-06-07, 2018-08-06 through 2018-09-13, 2019-08-28 through 2019-12-16, 2021-04-27 through 2021-04-30.
15. The ECEF variables are bad for most of 2017.
16. Eclipse penumbra events occurring without a full eclipse are not flagged.
17. Approximately 10 minutes of irradiance data immediately preceding and following eclipses is currently flagged as bad_data despite having good pointing. This data will be flagged as good_data in future data versions.
18. Solar array current decreases by 1-3% during arc jet firing, which occurs for roughly one hour per day.
19. There are small discrepancies in the cross_dispersion_angle of about 0.003° (1 arcsec) for about an hour after eclipses.
20. Time is defined as seconds since 2000-01-01 12:00:00 UTC epoch, neglecting leap seconds. To convert the time variables to UTC time (which does include leap seconds), the user must add the leap seconds that have passed since the epoch. See https://www.nist.gov/pml/time-and-frequency-division/time-realization/leap-seconds.

4. Document Versions

Table 2. Document versions.

Release date	Updates
25 April 2021	N/A
20 May 2021	Added caveats regarding ECEF, eclipses, time, cross_dispersion_angle, ECI, and irradiance discrepancies.

Table 3. Science-quality L1b data versions.

Version	Release date	Updates
v0.0.0	25 April 2021	N/A

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.

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.

Appendix 1. Variables

Tables 4 and 5 list the variables in the XRS L1b data. Further attributes such as valid ranges and flag names are provided in the netCDF files.

Table 4: EUVS variable dimensions.

Dimension	Value
report_number	2880
max_num_XRS_obs_spectrum_interval	30
max_num_EUVS_A_obs_spectrum_interval	30
max_num_EUVS_B_obs_spectrum_interval	30
max_num_EUVS_C_obs_spectrum_interval	10

wavelength_bin	23
solar_array_current_channel_index	4
num_currents_EUVSA	24
num_currents_EUVSB	24
max_num_diodes_EUVSC_h_line	10
max_num_diodes_EUVSC_k_line	10
number_of_time_bounds	2
wavelength_bin_str_len	20
solar_array_mnemonic_str_len	25
line_number	7

Table 4: EUVS variables.

Variable	Dimension	long_name	Units
irradianceSpectrum	report_number, wavelength_bin	irradiance spectrum for wavelengths between 5 and 127 nm calculated using a proxy model based on inputs from XRS A and B channels, and EUVS A, B. and C channels	W m^{-2} nm^{-1}
time	report_number	EUV spectrum observation center time, neglecting leap seconds	seconds since 2000-01-01 12:00:00
lowWavelength	wavelength_bin	lower limit of each of wavelength bin, all 5nm in width except for the last 10 nm bin, used in EUV spectrum proxy model	nm
highWavelength	wavelength_bin	upper limit of each of wavelength bin, all 5nm in width except for the last 10 nm bin, used in EUV spectrum proxy model	nm
EUV_CaseNumber	report_number	EUV spectrum product quality case number	1
qualityFlags	report_number	EUVS L1b processing and data quality flags	1

quaternion_Q0	report_number	spacecraft ACRF to J2000 ECI attitude quaternion Q0	1
quaternion_Q1	report_number	spacecraft ACRF to J2000 ECI attitude quaternion Q1	1
quaternion_Q2	report_number	spacecraft ACRF to J2000 ECI attitude quaternion Q2	1
quaternion_Q3	report_number	spacecraft ACRF to J2000 ECI attitude quaternion Q3	1
ECEF_X	report_number	spacecraft ECEF X coordinate	m
ECEF_Y	report_number	spacecraft ECEF Y coordinate	m
ECEF_Z	report_number	spacecraft ECEF Z coordinate	m
au_factor	report_number	earth to sun distance multiplicative correction factor to normalize to 1-AU at time of observation. not applied in EUVS L1b processing	1
SC_yaw_flip_flag	report_number	flags indicating whether spacecraft is operating in yaw flip configuration	1
nXRS	report_number	number of XRS L1b reports generated during time interval associated with EUV proxy spectrum model	count
nGoodXRSA	report_number	number of calculated good quality XRS-A 0.05 to 0.4 nm irradiance values used in generation of EUV proxy spectrum model	count
nGoodXRSB	report_number	number of calculated good quality XRS-B 0.1 to 0.8 nm irradiance values used in generation of EUV proxy spectrum model	count
nEUVSA	report_number	number of EUVS-A observations (L0) processed during time interval associated with EUV proxy spectrum model	count
nGood256	report_number	number of calculated good quality EUVS-A 25.6 nm irradiance values used in generation of EUV proxy spectrum model	count
nGood284	report_number	number of calculated good quality EUVS-A 28.4 nm irradiance values used in generation of EUV proxy spectrum model	count
nGood304	report_number	number of calculated good quality EUVS-A 30.4 nm irradiance values used in generation of EUV proxy spectrum model	count
nEUVSB	report_number	number of EUVS-B observations (L0)	count

		processed during time interval associated with EUV proxy spectrum model	
nGood1175	report_number	number of calculated good quality EUVS-B 117.5 nm irradiance values used in generation of EUV proxy spectrum model	count
nGood1216	report_number	number of calculated good quality EUVS-B 121.6 nm irradiance values used in generation of EUV proxy spectrum model	count
nGood1335	report_number	number of calculated good quality EUVS-B 133.5 nm irradiance values used in generation of EUV proxy spectrum model	count
nGood1405	report_number	number of calculated good quality EUVS-B 140.5 nm irradiance values used in generation of EUV proxy spectrum model	count
nEUVSC	report_number	number of EUVS-C observations (L0) processed during time interval associated with EUV proxy spectrum model	count
nGoodMg	report_number	number of calculated good quality Mg II core-to-wing ratio values used in generation of EUV proxy spectrum model	count
xrsQualityFlags	report_number, max_num_XRS_obs_spectrum_interval	XRS L1b processing and data quality flags	1
euvsaQualityFlags	report_number, max_num_EUVS_A_obs_spectrum_interval	EUVS-A L1b processing and data quality flags	1
euvsbQualityFlags	report_number, max_num_EUVS_B_obs_spectrum_interval	EUVS-B L1b processing and data quality flags	1
euvscQualityFlags	report_number, max_num_EUVS_C_obs_spectrum_interval	EUVS-C L1b processing and data quality flags	1
euvsaAvgTemp	report_number	average temperature of EUVS-A detector during time interval associated with EUV proxy spectrum model	degrees_C
euvsbAvgTemp	report_number	average temperature of EUVS-B detector during time interval associated with EUV proxy spectrum model	degrees_C

euvsc1AvgTemp	report_number	average temperature of EUVS-C detector #1 during time interval associated with EUV proxy spectrum model	degrees_C
euvsc2AvgTemp	report_number	average temperature of EUVS-C detector #2 during time interval associated with EUV proxy spectrum model	degrees_C
avgIrradianceXRSA	report_number	average primary irradiance at wavelengths between 0.05 and 0.4 nm (XRS-A) during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradianceXRSB	report_number	average primary irradiance at wavelengths between 0.1 and 0.8 nm (XRS-B) during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance256	report_number	EUVS-A 25.6 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance284	report_number	EUVS-A 28.4 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance304	report_number	EUVS-A 30.4 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance1175	report_number	EUVS-B 117.5 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance1216	report_number	EUVS-B 121.6 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance1335	report_number	EUVS-B 133.5 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgIrradiance1405	report_number	EUVS-B 140.5 nm average irradiance during time interval associated with EUV proxy spectrum model	W m^{-2}
avgRatioMgExis	report_number	EUVS-C average EXIS Mg II core-to-wing ratio during time interval associated with EUV proxy spectrum model	1
avgRatioMgNoaa	report_number	EUVS-C average NOAA historical Mg II core-to-wing ratio during time interval associated with EUV proxy spectrum model	1

ObservationTimesEUVSAB	report_number, max_num_EUVS_A_obs_spectrum_interval	spectrum observation center time for 1 second high time resolution EUVS-A and EUVS-B measurements, neglecting leap seconds	seconds since 2000-01-01 12:00:00
ObservationTimesEUVSC	report_number, max_num_EUVS_C_obs_spectrum_interval	spectrum observation center time for 3 second high time resolution EUVS-C measurement, neglecting leap seconds	seconds since 2000-01-01 12:00:00
CurrentsEUVSA	report_number, max_num_EUVS_A_obs_spectrum_interval, diode_num	currents at observation time for each EUVS-A diode in telemetry order	ampere
CurrentsEUVSB	report_number, max_num_EUVS_B_obs_spectrum_interval, diode_num	currents at observation time for each EUVS-B diode in telemetry order	ampere
SignalsEUVSC_hLine	report_number, max_num_EUVS_C_obs_spectrum_interval, diode_num	signals at observation time for the first 10 EUVSC diodes masked by the MgII h line mask in telemetry order	count
SignalsEUVSC_kLine	report_number, max_num_EUVS_C_obs_spectrum_interval, diode_num	signals at observation time for the first 10 EUVSC diodes masked by the MgII k line mask in telemetry order	count
IntegratedSignalsEUVSC_BlueWing	report_number, max_num_EUVS_C_obs_spectrum_interval	blue wing signal at observation time	count
IntegratedSignalsEUVSC_RedWing	report_number, max_num_EUVS_C_obs_spectrum_interval	red wing signal at observation time	count
IntegratedSignalsEUVSC_DarkMask	report_number, max_num_EUVS_C_obs_spectrum_interval	dark signal at observation time	count
Average_SPS_dispersion_angle	report_number	average dispersion direction pointing angle from SPS during time interval associated with EUV proxy spectrum model	degree
Average_SPS_cross_dispersion_angle	report_number	average cross-dispersion direction pointing angle from SPS during time interval associated with EUV proxy spectrum model	degree

solar_array_current	report_number, solar_array_current_channel_index	solar array current in DN for 4 channel groups (1-4, 5-8, 9-12, 13-16)	count
euvscIntegrationTime	report_number	The EUVSC packet Integration Time in seconds	seconds
SC_eclipse_flag	report_number	flags indicating whether sun is obscured by earth as provided by spacecraft	1
Total_SPS_angles	report_number	number of SPS measurements used to determine the Average_SPS_dispersion_angle and Average_SPS_cross_dispersion_angle values	count
Total_valid_SPS_angle_pairs	report_number	number of valid SPS measurements used during XRS L1b processing	count
euvscActiveChannel	report_number	indicates which EUVSC channel is active	1
product_time	input_file, number_of_time_bounds	start and end time of observations associated with product, neglecting leap seconds	seconds since 2000-01-01 12:00:00
wavelength_bin_label	wavelength_bin, wavelength_bin_str_len	labels for 23 wavelength bins associated with the EUV proxy spectrum model. labels are ordered the same as applicable data variables	-
solar_array_current_channel_index_label	solar_array_current_channel_index, solar_array_mnemonic_str_len	labels for four solar array current telemetry mnemonics. labels are ordered the same as applicable data variable	-
lowWavelengthLines	line_number	lower edge of bandpass for line irradiances	nm
highWavelengthLines	line_number	upper edge of bandpass for line irradiances	nm
percent_uncorrectable_L0_errors	report_number	percent data lost due to uncorrectable L0 errors	percent