Solar Dynamics Observatory (SDO) Extreme Ultraviolet Variability Experiment (EVE): Release notes for version 5 science data products

Level 3 Science Data Products

Table of Contents

Introduction

EVE level 3 data files were created at the Laboratory for Atmospheric and Space Physics in Boulder, Colorado for the NASA Solar Dynamics Observatory (SDO) Extreme Ultraviolet Variability Experiment (EVE). The Science Processing and Operations Center (SPOC) is responsible for creating and maintaining access to all EVE products.

This is a new release of EVE Level 3 data products. We have made every effort at verification and validation, but if you have any questions or encounter any problems with the data, please let us know about them.
For access and data product issues please contact
Don.Woodraska@lasp.colorado.edu.
For science issues please contact Frank.Eparvier@lasp.colorado.edu.

Responsible Data Usage:

SDO Mission scientific and model results are open to all, however users should contact the PI or designated EVE team member early in an analysis project to discuss appropriate use of instrument data results. Appropriate acknowledgement to institutions, personnel, and funding agencies should be given. Version numbers should also be specified. Pre-prints of publications and conference abstracts should be widely distributed to interested parties within the mission.

Reference Publications

More information about the EVE instrument measurements, and calibrations can be found in these references:

Woods, T. N., F. G. Eparvier, R. Hock, A. R. Jones, D. Woodraska, D. Judge, L. Didkovsky, J. Lean, J. Mariska, H. Warren, D. McMullin, P. Chamberlin, G. Berthiaume, S. Bailey, T. Fuller-Rowell, J. Sojka, W. K. Tobiska, and R. Viereck, "Extreme Ultraviolet Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO): Overview of Science Objectives, Instrument Design, Data Products, and Model Developments", *Solar Physics, 275*, 115-143, doi: 10.1007/s11207-009-9487-6, 2012. http://lasp.colorado.edu/home/eve/files/2011/06/EVE_Overview_SolarPhys.pdf

Hock, R. A., P. C. Chamberlin, T. N. Woods, D. Crotser, F. G. Eparvier, D. L. Woodraska, and E. C. Woods, "Extreme Ultraviolet Variability Experiment (EVE) Multiple EUV Grating Spectrographs (MEGS): Radiometric Calibrations and Results", *Solar Physics, 275*, 145-178, doi: 10.1007/s11207-010-9520-9, 2012.

http://lasp.colorado.edu/home/eve/files/2011/06/Final_Sol_Phy_Hock_1April_2010.pdf

Didkovsky, L., D. Judge, S. Wieman, T. Woods, and A. Jones, "EUV SpectroPhotometer (ESP) in Extreme Ultraviolet Variability Experiment (EVE): Algorithms and Calibrations", *Solar Physics, 275*, 179-205, doi: 10.1007/s11207-009-9485-8, 2012.

Level 3 Science Products

Level 3 spectra are the merged spectral measurements from the two spectrographs, MEGS-A and MEGS-B. The A detector is designed to measure from about 6-17 nm and 17-37 nm using two filters on two different parts of the detector. The B detector can measure fro about 33 to 105 nm using a double dispersion grating design with no filters. All level 3 irradiances are adjusted to 1 AU. The level 3 products contain daily averages of the level 2 spectrum measurements at the same wavelength sampling as level 2. The level 3 products also contain daily average measurements of the diodes, extracted bands, and selected lines reports in the level 2 products. The level 3 data products are available as one file per day, and also as merged dataset files that are updated daily with new measurements. The mission length merged datasets are provided at three sampling sizes for user convenience; specifically, native level 2 sampling, 1 Angstrom, and 1 nm. See the section "Merged Datasets" below for more details.

For an in-depth discussion of EVE instrumentation please visit http://lasp.colorado.edu/home/eve/science/instrument/.

Naming Convention

Level 3 products follow this naming convention
`EVE_L3_YYYYDDD_vvv_rr.fit` where:
`EVE` designates this as an EVE product
`L3` designates this as a level 3 product
`YYYY` is the year
`DDD` is the day of year (001-366)
`vvv` is the version number (005)
`rr` is the revision number (01-99)

The version number only increments after major software changes or after major calibration updates. These are expected to change after the incorporation of each suborbital rocket calibration flight. When referencing EVE data in scientific papers, users agree to mention this version number.

The revision increments whenever updated information are available. Generally, revision 1 is considered "preliminary". After 30 days, products become "definitive" since no new telemetry can be delivered after this period of time due to finite storage capacity of the SDO ground station. For most days, revision 1 will be the final revision, but newer revisions take precedence over older ones if they exist.

Merged File Naming Convention

Level 3 merged products have the following naming convention that has similar date and version elements as described above.

`EVE_L3_merged_YYYYDDD_vvv.fit`
Contains the full resolution (0.02 nm) sampling.

`EVE_L3_merged_1nm_YYYYDDD_vvv.fit`
Contains the spectrum resampled to a 1 nm grid with 0.5-nm bin centers.

`EVE_L3_merged_1a_YYYYDDD_vvv.fit`
Contains the spectrum resampled to 1 angstrom with 0.5-angstrom bin centers.

Note that all merged files are also available in NetCDF 3 format, and can also be downloaded as IDL sav files. The NetCDF and IDL sav files are generated from the FITS files, since FITS is the officially supported data format.

Level 3 Daily Averaged Data

Each daily file spans one UT day centered at noon UTC. Regardless of data collection time, all good data within the 24-hour window is averaged together.

The EVE level 3 files contain 6 FITS header data units, containing data and corresponding metadata information pertaining to daily averaged spectra, diode measurements, lines, and bands.

The SpectrumMeta data unit contains one array representing the center wavelengths of each spectral bin. The previous version had accuracy as a second array in this HDU, but that was moved into the data HDU in version 5 data products.

SpectrumMeta:

Column Name	Type	Description
Wavelengths	Float (array)	Center wavelength for each bin

The LinesMeta data unit contains information about lines derived from the EVE level 2 full resolution spectrum. It contains wavelength information describing the line, line temperature, the line name, line type, and other lines included within the wavelength band of the line as described in the following table.

LinesMeta:

Column Name	Type	Description
wave_center	Float	Center wavelength of line
wave_min	Float	Minimum wavelength of line
wave_max	Float	Maximum wavelength of line
LogT	Float	Log (base 10) temperature of line (K)
Name	String	Line name example (Fe XVIII)
Type	String	Type of line example (F)
Blend	String	Other lines included in this line

The BandsMeta data unit describes the extracted bands from the EVE spectrum that correspond to the 7 AIA spectral bands, two GOES-14 bands, 4 extracted MEGS spectral bands corresponding to the ESP diodes, two very broadbands used for creating the Q_{EUV} proxy, two MEGS-A broadbands representing each slit, and 3 MEGS-B bands. The BandsMeta data unit is described in the following table.

BandsMeta:

Column Name	Type	Description
Name	String	Name of the band example (AIA_304)
Type	String	SDO instrument example (AIA)

The DiodeMeta data unit contains information about spectral bands derived from EVE level 2 spectra that corresponds to measurements made by EVE diodes from ESP and MEGS P. The DiodeMeta data unit is described in the following table.

DiodeMeta:

Column Name	Type	Description
Name	String	Name of the band example (171)
Type	String	SDO instrument example (ESP)

The ESP central quad diode contains information about the center of brightness for the 0.1-7 nm bandpass. These are normalized to provide a relative measure of the distribution of irradiance.

QuadMeta:

Column Name	Type	Description
Name	String	Name of the band example (Q0)
Type	String	SDO instrument example (ESP)

The last Data HDU contains the actual data. It holds the irradiance spectrum as well as other values as described in the following table.

Data:

Column Name	Type	Description
YYYYDOY	Long	4-digit year and 3-digit day of year of the observation
Capture	ULong	Seconds in the day where the spectrum is measured.
MEGSA_Valid	ULong	Number of valid spectral measurements from MEGS-A (primary science filter)
MEGSB_Valid	ULong	Number of valid spectral measurements from MEGS-B (filter wheel open)
SP_Irradiance	Float (array)	Power per unit area at 1-AU in W/m^2/nm. 5200 element array containing the irradiance for each wavelength bin
SP_StDev	Float (array)	Relative one-sigma spread, the standard deviation for each bin (fractional)
SP_Precision	Float (array)	Relative Precision information for each bin. This represents the uncertainty based only on counting statistics. (fractional)
SP_Accuracy	Float (array)	Relative uncertainty representing the NIST combined standard uncertainty. This includes all known contributing factors including the absolute calibration. (fractional)
SP_Flags	UInt (array)	5200 element array containing quality information for each bin (refer to level 2 data product documentation for descriptions)
Line_Irradiance	Double (array)	Power per unit area at 1-AU over the integrated line with no background subtraction.

Line_StDev	Float (array)	Relative one-sigma spread, the standard deviation for each line (fractional)
Line_Precision	Float (array)	Relative Precision information for each line. This represents the uncertainty based only on counting statistics. (fractional)
Line_Accuracy	Float (array)	Relative uncertainty representing the NIST combined standard uncertainty (fractional)
Band_Irradiance	Float (array)	Power per unit area at 1-AU over the integrated band from the combined MEGS-A and B spectrum. Note that the AIA bands are in counts per second per pixel, not irradiance.
Band_StDev	Float (array)	Relative one-sigma spread, the standard deviation for each band (fractional)
Band_Precision	Float (array)	Relative Precision information for each band. This represents the uncertainty based only on counting statistics. (fractional)
Band_Accuracy	Float (array)	Relative uncertainty representing the NIST combined standard uncertainty (fractional)
Diode_Irradiance	Float (array)	Power per unit area at 1-AU measured by the diodes.
Diode_StDev	Float (array)	Relative one-sigma spread, the standard deviation for each diode (fractional)
Diode_Precision	Float (array)	Relative Precision information for each diode. This represents the uncertainty based only on counting statistics. (fractional)
Diode_Accuracy	Float (array)	Relative uncertainty representing the NIST combined standard uncertainty (fractional)
Quad_Fraction	Float (array)	The fraction of the total signal on each quadrant diode comprising the 0.1-7 nm measurement.
Quad_StDev	Float (array)	Relative one-sigma spread, the standard deviation for each of the ESP central order quadrant diodes (fractional)
Quad_Precision	Float (array)	Relative Precision information for each bin. This represents the uncertainty based only on counting statistics. (fractional)

Data Processing

All data products are generated at LASP, and the Level 3 products described in this document are all publicly available at the EVE website. We caution users to carefully consider their data needs. The level 3 products are free for responsible public use; however, downloading the entire dataset from one of the merged files is probably the best solution for most users.

FITS Definition and Software

The EVE Level 3 products are stored in the scientific format called FITS as binary tables. FITS was first introduced in 1979. As one of the oldest scientific data formats, it continues to be widely used and expanded.

FITS reference: FITS: A Flexible Image Transport System, Wells, D. C., Greisen, E. W., and Harten, R. H., Astronomy & Astrophysics Supplement Series, 44, 363-370, 1981.
http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1981A%26AS...44..363W&db_key=AST&high=3db47576cf05627

FITS Binary Table reference: Binary Table Extension to FITS, Cotton, W. D., Tody, D. B., and Pence, W. D., Astronomy & Astrophysics Supplement Series, 113, 159-166, 1995.
http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1995A%26AS..113..159C&db_key=AST&high=3db47576cf06210

Additional detailed documentation is available on-line.
http://fits.gsfc.nasa.gov/fits_documentation.html

Standard reader software is available from GSFC for many different languages. A graphical program called "fv" is useful for browsing the contents without writing any programs.
http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/

LASP provides an IDL function called eve_read_whole_fits.pro which allows easy reading of any EVE data product that is in FITS format. read_whole_fits.pro may be downloaded here http://lasp.colorado.edu/eve/data_access/software/eve_read_whole_fits.pro.

For IDL, you may also use mrdfits.pro available at:
http://idlastro.gsfc.nasa.gov/mrdfits.html
http://idlastro.gsfc.nasa.gov/fitsio.html

Explanation and Examples in IDL

Level 3 data products are stored in FITS format and may be read by a variety of software, see the documentation section at http://lasp.colorado.edu/home/eve/data/data-access/ for more details. LASP provides an IDL function called eve_read_whole_fits.pro which allows easy reading of any EVE data product that is in FITS format. The software eve_read_whole_fits.pro may be downloaded here http://lasp.colorado.edu/eve/data_access/software/eve_read_whole_fits.pro.

We will use the function in the following examples.

To read in a level 3 data product, simply provide the function with the desired filename.

```
IDL> data = eve_read_whole_fits( 'EVE_L3_2013300_005_01.fit' )
```

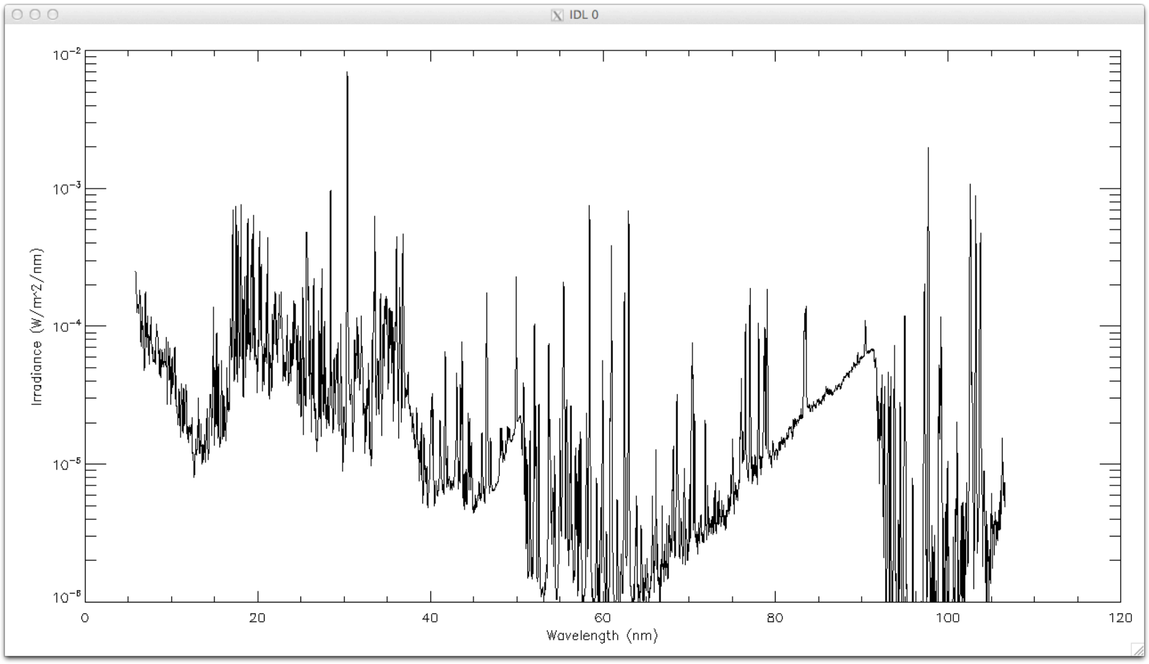
To see a listing of what is in the retrieved structure, perform the following command:

```
IDL> help,data,/struct
** Structure <17ea5928>, 14 tags, length=123496, data length=123486, refs=1:
   PRIMARY         LONG                 0
   PRIMARY_HEAD    STRING    Array[5]
   SPECTRUMMETA    STRUCT    -> <Anonymous> Array[5200]
   SPECTRUMMETA_HEADER
                   STRING    Array[28]
   LINESMETA       STRUCT    -> <Anonymous> Array[39]
   LINESMETA_HEADER
                   STRING    Array[48]
   BANDSMETA       STRUCT    -> <Anonymous> Array[20]
   BANDSMETA_HEADER
                   STRING    Array[28]
   LINESMETA       STRUCT    -> <Anonymous> Array[39]
   LINESMETA_HEADER
                   STRING    Array[48]
   BANDSMETA       STRUCT    -> <Anonymous> Array[20]
   BANDSMETA_HEADER
                   STRING    Array[28]
   DIODEMETA       STRUCT    -> <Anonymous> Array[6]
   DIODEMETA_HEADER
                   STRING    Array[27]
   QUADMETA        STRUCT    -> <Anonymous> Array[4]
   QUADMETA_HEADER STRING    Array[27]
   DATA            STRUCT    -> <Anonymous> Array[1]
   DATA_HEADER     STRING    Array[105]
```

As described above, the wavelength information is stored in the data.spectrummeta structure. To plot the daily averaged spectrum, issue the following command:

```
IDL> plot,data.spectrummeta.wavelength, data.data.sp_irradiance,yrange=[1e-
6,1e-2],/ylog,charsize=1.5,xtitle='Wavelength (nm)',ytitle='Irradiance
(W/m^2/nm)'
```

This command will produce a plot similar to the following:



Processing the lines, bands and diode file is similar to processing the spectrum files as show below. To read in the lines file issue the following commands:

```
IDL> data = eve_read_whole_fits( 'EVE_L3_2013300_00_005_01.fit' )
```

The metadata regarding the line name, wavelength ranges, temperature, and other useful information are contained in the linesmeta HDU. These are stored the same way as the level 2 data files, and can be accessed to generate a table as follows:

```
IDL> for i=0,n_elements(data.linesmeta)-1 do print,data.linesmeta[i].name,
data.linesmeta[i].wave_center, data.linesmeta[i].logt, i
```

Fe XVIII	9.39260	6.81000	0
Fe VIII	13.1240	5.57000	1
Fe XX	13.2850	6.97000	2
Fe IX	17.1070	5.81000	3
Fe X	17.7243	5.99000	4
Fe XI	18.0407	6.07000	5
Fe XII	19.5120	6.13000	6
Fe XIII	20.2044	6.19000	7
Fe XIV	21.1331	6.27000	8
He II	25.6317	4.75000	9
Fe XV	28.4150	6.30000	10
He II	30.3783	4.70000	11
Fe XVI	33.5410	6.43000	12
Fe XVI	36.0758	6.43000	13
Mg IX	36.8076	5.99000	14
S XIV	**44.5700**	**6.44000**	**15**
Ne VII	46.5221	5.71000	16
Si XII	49.9406	6.29000	17
Si XII	**52.1000**	**6.28000**	**18**
O III	52.5795	4.92000	19
He I	**53.7000**	**3.84000**	**20**
O IV	55.4370	5.19000	21
Fe XX	**56.7870**	**6.96000**	**22**
He I	58.4334	4.16000	23
Fe XIX	**59.2240**	**6.89000**	**24**

O III	59.9598	4.92000	25
Mg X	**60.9800**	**6.10000**	**26**
Mg X	62.4943	6.05000	27
O V	62.9730	5.37000	28
O II	71.8535	4.48000	29
Fe XX	**72.1560**	**6.96000**	**30**
Ne VIII	77.0409	5.81000	31
O IV	79.0199	5.19000	32
O II	**83.5500**	**4.52000**	**33**
H I	**94.9700**	**3.84000**	**34**
H I	97.2537	3.84000	35
C III	97.7030	4.84000	36
H I	102.572	3.84000	37
O VI	103.190	5.47000	38

Note that this line list differs from the version 4 line list. Nine new lines are shown in bold with blue color. These additional MEGS-B lines were added to replace the ones that were lost after the MEGS-A anomaly. Most of the new lines are coronal but there are a few cooler lines as well. The lines between 33.5410 nm and 36.8076 nm are now measured by MEGS-B after the MEGS-A anomaly. We believe there is uncorrected degradation in MEGS-A for at least the 36.8076 nm emission line and the time series shows a step.

During MEGS-B observations 27 lines are now extracted (33.541-103.190 nm).

SolarSoft

SolarSoft and IDL users may wish to download the EVE SolarSoft software package. It is available at our web site by browsing the Data Access page.
http://lasp.colorado.edu/home/eve/data/data-access/

Additional information about SolarSoft can be found through the LMSAL website, http://www.lmsal.com/solarsoft.
Note that the EVE SolarSoft package can be run in IDL without SolarSoft.

Data Availability and Data Gaps

Daily calibrations are performed that last a total of about 30 minutes; however, the channel calibrations are staggered so that one of the science channels is always observing the Sun during the daily calibration. These daily calibrations allow for EVE to directly measure dark signals on the detectors to track changes. For the CCDs, the flatfield LEDs are also used. On Sundays, a slightly longer calibration is performed to increase statistics.

Two annual eclipse outage periods of about 3 weeks occur as the spacecraft orbit aligns with the Earth and Sun. These can last up to 72 minutes each day. After longer eclipses (10+ minutes), some thermal settling causes a wavelength shift on MEGS-A that is not yet corrected. Around the 2 eclipse seasons, additional off-pointing maneuvers are performed including EVE cruciform scans (9 hours), EVE FOV maps (~2 hours), plus maneuvers for the other instruments and the guide telescopes.

The spacecraft is also subject to being blocked by the moon, but this is infrequent. Other infrequent activities include momentum management, and station-keeping thruster firings.

CCD bakeouts have occurred as needed to maintain instrument sensitivity. The first bakeout started on June 16 (day 167), 2010 and continued through June 18 (day 169), 2010. The second CCD bakeout was much longer lasting from September 23 (day 266) through September 28 (day 271), 2010. After each bakeout, there is a period of several days where the detectors change rapidly, and this is not corrected in version 3. No future bakeouts will be scheduled.

To minimize the degradation on the MEGS B detector, MEGS B only observes the sun 2 to 3 hours per day and the timing of the observation has changed throughout the mission. When not observing the Sun, the MEGS B portion of the spectra is filled with -1.0 when MEGS-A data is available. After the MEGS-A anomaly when no MEGS-B data are available, the spectra file is no longer generated. The lines/bands file is generated because the ESP data remains continuously available.

Detailed daily information is provided in the Science Operations Mission Log and is available at this location:
http://lasp.colorado.edu/eve/data_access/evewebdata/EVE_sciopslog.html

Version Release Notes

The ESP 30.4nm diode data is now used to correct the trend for the MEGS-A 30.4 nm line, currently the only highly degraded line on the MEGS-A detector. Data from calibration rocket 36.258 is used to pin the calibration on 2010 day123.

We have applied the rocket calibration to MEGS-B in an attempt to recover some of the information that seems to be getting lost in the application of the pre-flight SURF responsivity. This process involved creating a modified responsivity that differs from the ground measurements for wavelengths shorter than 40 nm and longer than 60 nm. This compensates for unexpected sensitivity losses witnessed in early operations at long wavelengths prior to observing the sun for the first time. It also compensates for wavelength uncertainties and lower count rates during the calibration that affect the shorter wavelengths. Degradation trends in MEGS-B are estimated by comparing count rates measured to multiple linear regression proxy models using ESP, MEGS-P, and the 10.7 cm radio flux. The ratio provides a dimensionless degradation trend that is pinned to the first rocket.

In the version 5 EVE products MEGS-P was increased by a factor of 1.015 (1.5%) to agree with the SORCE SOLSTICE version 13 calibration.

The extracted bands used to produce an effective AIA count rate have not been updated to use newer AIA response functions that would spill over onto the MEGS-B wavelength region. Since MEGS-B is not available all day for most days, including the contribution would cause significant steps up and down in a time series (resulting from the availability of MEGS-B data.)

Other Notes

The spectra bins should not be used individually for analysis due to the possibility of small-scale wavelength shifts. Rather, users should integrate over the features of interest. MEGS-A (5-37 nm) is the most sensitive to these small wavelength shifts.

Since the MEGS-A 30.4 line has suffered detector burn-in and filter degradation, the line shape itself is being adjusted. This is likely to affect attempts to observe Doppler shifts. We recommend using the count rate spectrum to investigate the incredibly small line shifts.

The MEGS-P Lyman-alpha diode measurement is susceptible to low energy particles. Our initial attempt to remove the low energy particle noise using the dark diode needs refinement. Rather than exclude this measurement, we filter it based on those periods of increased particle noise. Therefore, the MEGS-P Lyman-alpha measurement is sometimes very complete, and sometimes only available from about 6-12 UT each day. The Lyman-alpha measurement uses the same filter mechanism as MEGS-B, so it is also operating with the same reduced-exposure scenario.

Also, due to random large particle hits, the Lyman-alpha measurement is filtered using a 10-second Kalman smoothing technique. Additional filtering was implemented for version 3 where data are pre-filtered using a median technique. Unfortunately, the Lyman-alpha measurement is very noisy, and therefore most useful after averaging to a daily value.