README file for Extreme ultraviolet Spectro-Photometer (ESP) Level 1 version 6 release (6/15/17)

Files in this directory 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. ESP Level 1 data products are generated using software and algorithms created at the Univ. of Southern California Space Sciences Center in Los Angeles, CA.

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, (Don.Woodraska at lasp.colorado.edu). For science issues please contact Leonid Didkovsky (leonid at usc.edu).

ESP Overview:

The Extreme ultraviolet Spectro-Photometer uses a transmission grating, thin film filters and multiple silicon photodiodes to measure solar irradiance in 5 discrete wavelength bands. These bands include first order diffraction measurements of 33.3 – 40.04 nm, 27.16 – 33.8 nm, 22.28 – 28.78 nm, 16.64 – 21.5 nm as well as zero-order measurements, obtained by 4 photodiodes in a quad configuration, of 0.1-7 nm. Additionally a fully-obscured "dark" photodiode is used as part of a correction for background signal related to high energy particles. Under normal operation, ESP provides these measurements with 0.25 sec time resolution.

ESP channel 1 with band of 33.3 – 40.04 nm demonstrates significant noise pattern related to the increased instability of the detector's shunt resistance. We do not recommend using this band's data for short-time evaluation of solar irradiance.

Table 1. ESP Channels Names and Wavelength Ranges

ESP Channel Number	Description	Wavelength Range	Data Product Names
1	36 nm Irradiance	33.3-40.04 nm	CH_36
2	26 nm Irradiance	22.28-28.78 nm	CH_26
3	Dark Diode	N/A	CH_D
4	Quad Diode #0	0.1-7.0 nm *QD = name for sum of four quad diodes*	Q_0
5	Quad Diode #1		Q_1
6	Quad Diode #2		Q_2
7	Quad Diode #3		Q_3
8	18 nm Irradiance	16.64-21.5 nm	CH_18
9	30 nm Irradiance	27.16-33.8 nm	CH_30

More information about the ESP instrument, measurements, and calibrations can be found in:

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, p. 182, doi: 10.1007/s11207-009-9485-8, Dec. 2009. http://www-rcf.usc.edu/~leonid/papers/SolPhys2010.pdf

This paper provides an overview of the instrument design and calibrations. Equations 17 and 18 in this paper provides the calculation for the solar X-ray center intensity location using the quad diode signals (ESP channels 4-7). Because the quad diode is for the X-ray band of 0.1-7.0 nm, this intensity location is not the center of the sun but is instead the weighted location of active regions on the solar disk; this is particularly useful for identifying a flare's location.

Product Overview:

The ESP Level 1 irradiance data are fully calibrated and corrected for particle background, visible light leakage, degradation in sensitivity, and spacecraft location (corrected to 1-AU). A suborbital sounding rocket payload is flown once a year for EVE absolute calibrations. The first suborbital flight after the launch of SDO was on May 3, 2010 followed by flights on March 23, 2011, June 23, 2012, October 21, 2013, and June 1, 2016. Daily on-orbit calibrations are performed to track changes in detector dark current, filter condition, e.g. its degradation, and electrometer gain.

Each data file covers a time span of 24 hours with 4 measurement/sec cadence. Level 1 data is available with about 1 day latency.

Data Availability/Gaps:

EVE/ESP provides nearly continuous solar observations with the following exceptions:

Daily calibrations: Calibration of the entire EVE instrument lasts a total of about 30 minutes, with the ESP portion lasting approximately 2.5 minutes. Daily calibrations for the EVE science channels are staggered so at least one of the other EVE science channels remains in observation mode during the period of ESP calibration.

Eclipse outage periods: Two annual eclipse outage periods of a few weeks occur as the spacecraft orbit aligns with the earth and sun. These can last up to 72 minutes each day. 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.

Lunar transits and other infrequent activities: 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.

Naming Convention:

Level 1 products follow this naming convention: esp_L1_YYYYDOY_006.fit

Level 1 Irradiance Products:

Level 1 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.

Data are stored in one-day duration files. These products can be located and downloaded from the EVE web site. A calendar interface is available for each year.

http://lasp.colorado.edu/eve/data_access/evewebdata/misc/eve_calendars/calendar_level1_2017.html

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/

For IDL, we use mrdfits.pro.

http://idlastro.gsfc.nasa.gov/mrdfits.html

http://idlastro.gsfc.nasa.gov/fitsio.html

In addition, the EVE team has provided a FITS reader in IDL called eve_read_whole_fits.pro.

Examples of Working with Data Products:

Example #1:

An IDL example to read the first fits file from a group of files and print a mean (daily) value for Ch9 (30 nm):

```
IDL> names=file_search('esp_L1_2013*_006.fit')
IDL> D_TABLE   =  MRDFITS( names[0], 1, /unsigned, /silent, status=status )
IDL> PRINT,' Mean Irradiance [W/m^2] for Ch9 =',mean(D_TABLE.ch_30)
```

In this example D_TABLE contains all variables stored in the fits file.

Example #2:

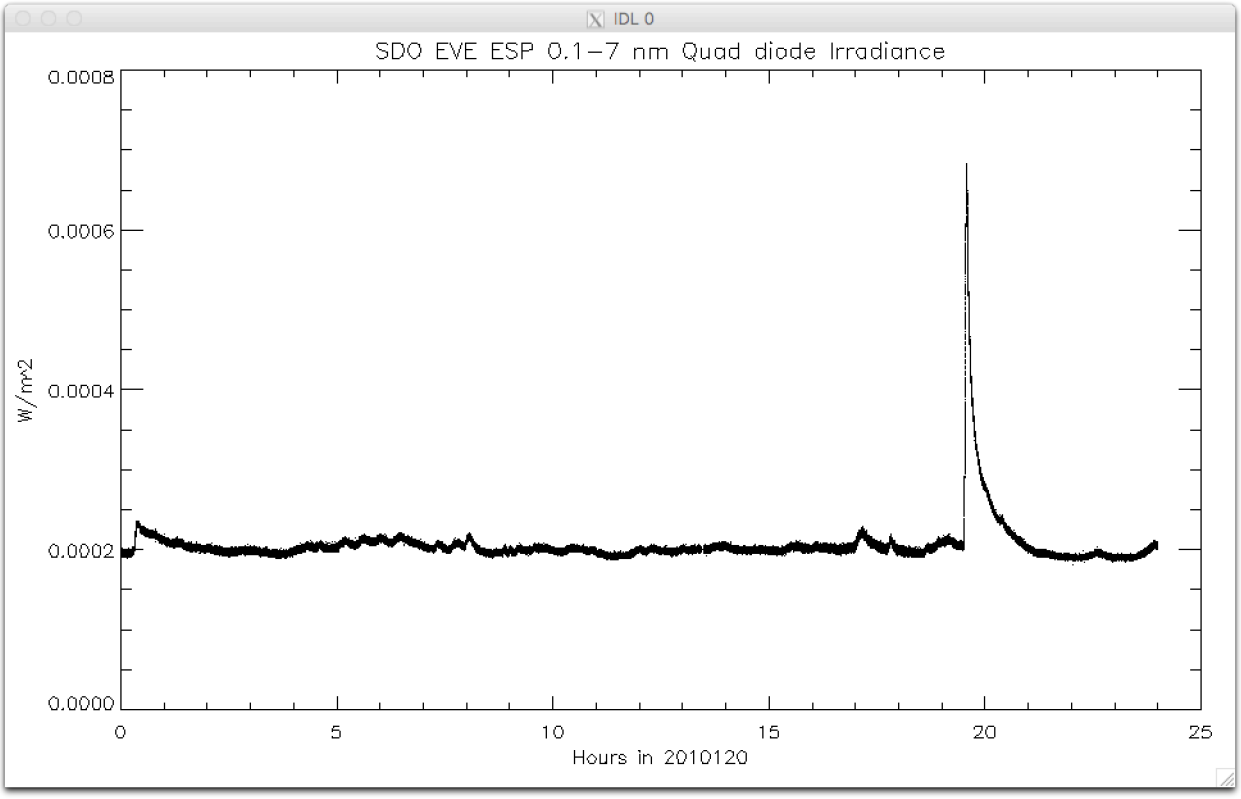
Read the file using the eve_read_whole_fits.pro function provided by LASP.

```
IDL> data = eve_read_whole_fits( 'esp_L1_2010120_006.fit' )
IDL> help,data,/structure
** Structure <103bd2c8>, 4 tags, length=38709016, data length=37326612,
refs=1:
   PRIMARY         LONG                 0
   PRIMARY_HEAD    STRING    Array[5]
   HDR001          STRUCT    -> <Anonymous> Array[345600]
   HDR001_HEADER   STRING    Array[108]
IDL> help,data.hdr001,/str
** Structure <103de0e8>, 28 tags, length=112, data length=108, refs=2:
```

Q_0	FLOAT	0.232727
Q_1	FLOAT	0.232055
Q_2	FLOAT	0.267779
Q_3	FLOAT	0.267439
QD	**FLOAT**	**0.000202255**
CH_18	**FLOAT**	**0.000529552**
CH_26	**FLOAT**	**0.000298154**
CH_30	**FLOAT**	**0.000630207**
CH_36	**FLOAT**	**0.000119363**
CH_D	FLOAT	0.00000
Q_0_PREC	FLOAT	0.000190271
Q_1_PREC	FLOAT	0.000190271
Q_2_PREC	FLOAT	0.000190271
Q_3_PREC	FLOAT	0.000190271
QD_PREC	FLOAT	0.000380541
CH_18_PREC	FLOAT	0.000214637
CH_26_PREC	FLOAT	0.000143540
CH_30_PREC	FLOAT	0.000279794
CH_36_PREC	FLOAT	0.000135331
CH_D_PREC	FLOAT	0.00000
FILTER	FLOAT	0.00000
CH_TEMP	FLOAT	0.00000
YEAR	INT	2010
DOY	INT	120
HOUR	INT	0
MINUTE	INT	0
SEC	FLOAT	0.0155208
SOD	DOUBLE	0.015520811

The bold variables above contain the irradiance in W/m^2 for each of the bandpasses.

```
IDL> plot, data.hdr001.sod/60./60., data.hdr001.qd, ps=3, charsize=1.5,
ytitle='W/m^2', xtitle='Hours in 2010120', title='SDO EVE ESP 0.1-7nm Quad
diode Irradiance'
```



A measure of uncertainty is provided in the precision variables (for example qd_prec).

The individual quadrant diode currents are provided as q_0, q_1, q_2, and q_3. These can be used to estimate the flare irradiance centroid in the quad diode coordinate system.

Similar plots can be created for other broadband diodes as follows…

```
IDL> plot,data.hdr001.sod/60./60.,
data.hdr001.ch_18,ps=3,charsize=1.5,ytitle='W/m^2',xtitle='Hours in
2010120',title='SDO EVE ESP 18nm diode Irradiance'

IDL> plot,data.hdr001.sod/60./60.,
data.hdr001.ch_30,ps=3,charsize=1.5,ytitle='W/m^2',xtitle='Hours in
2010120',title='SDO EVE ESP 30nm diode Irradiance'

IDL> for i=0,107 do print,data.hdr001_header[i]
XTENSION= 'BINTABLE'           /Binary table written by MWRFITS v1.12a
BITPIX  =                    8 /Required value
NAXIS   =                    2 /Required value
NAXIS1  =                  108 /Number of bytes per row
NAXIS2  =               345600 /Number of rows
PCOUNT  =                    0 /Normally 0 (no varying arrays)
GCOUNT  =                    1 /Required value
TFIELDS =                   28 /Number of columns in table
```

```
COMMENT
COMMENT  *** End of mandatory fields ***
COMMENT
ORIGIN  = '            SDO/EVE SPOC' // LASP, University of Colorado, Boulder
DATE    = '2017-04-14T17:54:10.000Z' // UTC file creation time
TAI_OBS =           1651276804.016 // TAI time at start of obs
DATE_OBS= '2010-04-29T23:59:30.016Z' // UTC at start of obs
T_OBS   = '2010-04-30T00:00:00.016Z' // UTC at center of obs
EXPTIME =                   60.000 // seconds exposed, or integration time
TIME    =                86370.016 // UTC seconds of day at start of obs
TELESCOP= '                 SDO/EVE'
INSTRUME= '                 EVE_ESP'
VERSION =                       006 // major code/cal version
REVISION=                       006 // reprocess number
FILENAME= 'esp_L1_2010120_006.fit'
CH1_COEF=          285602.2812//Ch1 mean Coeff
CH2_COEF=         2300010.7500//Ch2 mean Coeff
CH4_COEF=          639299.8125//Ch4 mean Coeff
CH5_COEF=          636408.8125//Ch5 mean Coeff
CH6_COEF=          725649.5000//Ch6 mean Coeff
CH7_COEF=          667953.7500//Ch7 mean Coeff
CH8_COEF=         4514812.5000//Ch8 mean Coeff
CH9_COEF=         1723012.8750//Ch9 mean Coeff
COMMENT
COMMENT  *** Column names ***
COMMENT
TTYPE1  = 'Q_0     '           /
TTYPE2  = 'Q_1     '           /
TTYPE3  = 'Q_2     '           /
TTYPE4  = 'Q_3     '           /
TTYPE5  = 'QD      '           /
TTYPE6  = 'CH_18   '           /
TTYPE7  = 'CH_26   '           /
TTYPE8  = 'CH_30   '           /
TTYPE9  = 'CH_36   '           /
TTYPE10 = 'CH_D    '           /
TTYPE11 = 'Q_0_PREC'           /
TTYPE12 = 'Q_1_PREC'           /
TTYPE13 = 'Q_2_PREC'           /
TTYPE14 = 'Q_3_PREC'           /
TTYPE15 = 'QD_PREC '           /
TTYPE16 = 'CH_18_PREC'         /
TTYPE17 = 'CH_26_PREC'         /
TTYPE18 = 'CH_30_PREC'         /
TTYPE19 = 'CH_36_PREC'         /
TTYPE20 = 'CH_D_PREC'          /
TTYPE21 = 'FILTER  '           /
TTYPE22 = 'CH_TEMP '           /
TTYPE23 = 'YEAR    '           /
```

```
TTYPE24 = 'DOY     '           /
TTYPE25 = 'HOUR    '           /
TTYPE26 = 'MINUTE  '           /
TTYPE27 = 'SEC     '           /
TTYPE28 = 'SOD     '           /
COMMENT
COMMENT  *** Column formats ***
COMMENT
TFORM1  = 'E       '           /
TFORM2  = 'E       '           /
TFORM3  = 'E       '           /
TFORM4  = 'E       '           /
TFORM5  = 'E       '           /
TFORM6  = 'E       '           /
TFORM7  = 'E       '           /
TFORM8  = 'E       '           /
TFORM9  = 'E       '           /
TFORM10 = 'E       '           /
TFORM11 = 'E       '           /
TFORM12 = 'E       '           /
TFORM13 = 'E       '           /
TFORM14 = 'E       '           /
TFORM15 = 'E       '           /
TFORM16 = 'E       '           /
TFORM17 = 'E       '           /
TFORM18 = 'E       '           /
TFORM19 = 'E       '           /
TFORM20 = 'E       '           /
TFORM21 = 'E       '           /
TFORM22 = 'E       '           /
TFORM23 = 'I       '           /
TFORM24 = 'I       '           /
TFORM25 = 'I       '           /
TFORM26 = 'I       '           /
TFORM27 = 'E       '           /
TFORM28 = 'D       '           /
COMMENT Website reference http://lasp.colorado.edu/home/eve
COMMENT EVE Principal Investigator T. N. Woods
COMMENT Laboratory for Atmospheric and Space Physics
COMMENT 1234 Innovation Drive, Boulder, CO 80303
COMMENT SDO Mission scientific and model results are open to all.
COMMENT Users should contact the PI or designated EVE team member early in an
COMMENT analysis project to discuss appropriate use of instrument data
results.
COMMENT Appropriate acknowledgement to institutions, personnel, and funding
COMMENT agencies should be given. Version numbers should also be specified.
COMMENT Pre-prints of publications and conference abstracts should be widely
COMMENT distributed to interested parties within the mission.
COMMENT Quad-Diode (QD) data (0.1 - 7.0 nm) are stored in 5 channels:
```

```
COMMENT the whole solar disk irradiance and ratios of each diode irradiance
COMMENT to the whole disk solar irradiance. These ratios are about 0.25.
END
```