README file for Level 2 version 1 release (06/18/10)

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.

This is the first public release of EVE Level 2 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.

EVE Overview:

EVE spectrographs measured the solar extreme ultraviolet (EUV) radiation spectrum from 6-105 nm with a resolution of approximately 0.1 nm and a cadence of 10 seconds from geosynchronous orbit. A series of photometers are used to also provide broadband measurements at a 4 Hz cadence.

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, p. 3, doi: 10.1007/s11207-009-9487-6, Jan. 2010.
http://lasp.colorado.edu/eve/docs/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, doi: 10.1007/s11207-010-9520-9, Feb. 2010.
http://lasp.colorado.edu/eve/docs/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, p. 182, doi: 10.1007/s11207-009-9485-8, Dec. 2009.

Daily activities are performed to maintain calibration; otherwise EVE has nearly continuous solar observing capability.

Data Availability/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 a few 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 may occur as needed to maintain instrument sensitivity. The first bakeout started on June 16 (day 167), 2010 at 9:15 UT and is expected to continue through June 18 (day 169), 2010.

Product Overview:

There are 2 types of EVE level 2 products: **Spectra** (EVS) and **Lines** (EVL).

Level 2 spectra are the merged spectral measurements from the two spectrographs, A and B. The A detector is designed to measure from 6-17 nm, and 16-38 nm using two filters, while the B detector is designed to measure 35-105 nm. Level 2 processing stitches these pieces to form one spectrum.

Lines are integrated from low to high bounds, and the 4 Hz photometer data are averaged down to the same time scale as the spectrum. No continuum is subtracted from the line irradiances.

Version 1 Data Notes:

Missing or corrupted data is replaced using the “fill” value of -1.0. Fill values should be discarded since these are not science measurements.

MEGS-B is not included in this product release. We have elected to release these Version 1 products early because the other channels are working well. MEGS-B is showing a larger than expected signal decrease, and the data is not yet ready to support science investigation, like the other channels. The investigation into MEGS-B is ongoing.

The spectrum 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.

The 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.

Also, due to random large particle hits, the Lyman-alpha measurement is filtered using a 10-second kalman smoothing technique.

Naming Convention:

Level 2 products follow this naming convention `EV?_L2_YYYYDDD_HH_vvv_rr.fit` where:

`EV` designates this as an EVE product
`?` is either S (spectrum) or L (lines/bands)
`L2` designates this as a level 2 product
`YYYY` is the year
`DDD` is the day of year (001-366)
`HH` is the UT hour of day (00-23)
`vvv` is the version number (001)
`rr` is the revision number (01-99)

Each Level 2 data file spans one hour.

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 2 is the final revision.

Level 2 Spectra Products:

Level 2 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/`

For IDL, we use mrdfits.pro.
`http://idlastro.gsfc.nasa.gov/mrdfits.html`
`http://idlastro.gsfc.nasa.gov/fitsio.html`

An example follows:

```
IDL> data1 = mrdfits( 'EVS_L2_2010151_20_001_01.fit.gz', 1 ,hdr, /unsigned
)
```

This reads HDU #1 and returns an array of structures called "data1". Note that HDU #0 is reserved for image data, so it is NULL.

```
IDL> help,data1
DATA1           STRUCT    = -> <Anonymous> Array[5200]
IDL> help,data1,/str
** Structure <153e688>, 2 tags, length=8, data length=8, refs=1:
   WAVELENGTH      FLOAT           3.00000
   ACCURACY        FLOAT           0.00000
```

The data1 array of structures contains 5200 elements, one of which is the wavelength.

```
IDL> data2 = mrdfits( 'EVS_L2_2010151_20_001_01.fit.gz', 2, hdr,
/unsigned)
IDL> help,data2
DATA2           STRUCT    = -> <Anonymous> Array[360]
IDL> help,data2,/str
** Structure <18ca008>, 8 tags, length=46840, data length=46832, refs=1:
   TAI             DOUBLE       1.6540272e+09
   YYYYDOY         LONG           2010151
   SOD             DOUBLE           72006.820
   FLAGS           ULONG                2
   INT_TIME        DOUBLE           10.000000
   IRRADIANCE      FLOAT     Array[5200]
   PRECISION       FLOAT     Array[5200]
   BIN_FLAGS       BYTE      Array[5200]

IDL> plot, data1.wavelength, data2[0].irradiance, /ylog, $
       yr=[1e-6,1e-2], xr=[6,37], xs=1, $
```

```
      xtitle='Wavelength (nm)', ytitle='Irradiance (W/m^2/nm)'
```

TAI is the number of seconds elapsed since the TAI epoch (Jan 1, 1958).
YYYYDOY is the year and day of year.
SOD is the seconds of day.
FLAGS contain 32-bit fields that are used to indicate validity.
INT_TIME is the integration time in seconds.
IRRADIANCE is the irradiance in Watts / meter^2 / nanometer.
PRECISION is the relative uncertainty based on counting statistics (0-1).
BIN_FLAGS is a byte flag for each spectral bin.

Additional information is in the string array hdr.

Level 2 Lines/Bands Products:

These products are read the same way as the spectra products, except there are 5 HDUs available to read.

```
IDL> data1 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 1, hdr,
/unsigned)
IDL> help,data1
DATA1           STRUCT    = -> <Anonymous> Array[30]
IDL> help,data1,/str
** Structure <1562788>, 7 tags, length=64, data length=64, refs=1:
   WAVE_CENTER     FLOAT           9.39260
   WAVE_MIN        FLOAT           9.48000
   WAVE_MAX        FLOAT           9.69000
   LOGT            FLOAT           6.81000
   NAME            STRING    'Fe XVIII'
   TYPE            STRING    'F '
   BLENDS          STRING    '             '
```

This is HDU #1. Here data1 contains the binary table of information related to the extracted solar emission lines. Currently there are 30 lines, and the first is Fe XVIII.

Examine the "hdr" variable for additional information.

```
IDL> data2 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 2, hdr, /unsigned
)
IDL> help,data2
DATA2           STRUCT    = -> <Anonymous> Array[7]
IDL> help,data2,/str
** Structure <1540438>, 2 tags, length=32, data length=32, refs=1:
   NAME            STRING    'AIA_A94 '
   TYPE            STRING    'AIA'
```

HDU #2 is another binary table of the extracted bands corresponding to the AIA spectral bands. There are 7 that overlap with the EVE spectrum. Additional information is in the hdr variable.

```
IDL> data3 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 3, hdr, /unsigned
)
IDL> help,data3
DATA3           STRUCT    = -> <Anonymous> Array[6]
IDL> help,data3,/str
** Structure <153f6e8>, 2 tags, length=32, data length=32, refs=1:
   NAME            STRING    'ESPQ     '
   TYPE            STRING    'ESP   '
```

HDU #3 is another binary table of the diode measurements that have been averaged to 10 seconds to match the spectral measurements. Additional information is available in the hdr variable.

```
IDL> data4 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 4, hdr, /unsigned
)
IDL> help,data4
DATA4           STRUCT    = -> <Anonymous> Array[4]
IDL> help,data4,/str
** Structure <1540228>, 2 tags, length=32, data length=32, refs=1:
   NAME            STRING    'Q0'
   TYPE            STRING    'ESP'
```

HDU #4 is another binary table containing the fraction of the quadrant diodes falling on each diode quadrant. This is useful for determining flare locations.

```
IDL> data5 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 5, hdr, /unsigned
)
IDL> help,data5
DATA5           STRUCT    = -> <Anonymous> Array[360]
IDL> help,data5,/str
** Structure <1914608>, 16 tags, length=648, data length=644, refs=1:
   TAI             DOUBLE       1.6540272e+09
   YYYYDOY         LONG           2010151
   SOD             DOUBLE           72006.820
   LINE_IRRADIANCE FLOAT     Array[30]
   LINE_PRECISION  FLOAT     Array[30]
   LINE_ACCURACY   FLOAT     Array[30]
   BAND_IRRADIANCE FLOAT     Array[7]
   BAND_PRECISION  FLOAT     Array[7]
   BAND_ACCURACY   FLOAT     Array[7]
   DIODE_IRRADIANCE
                   FLOAT     Array[6]
   DIODE_STDEV     FLOAT     Array[6]
   DIODE_PRECISION FLOAT     Array[6]
   QUAD_FRACTION   FLOAT     Array[4]
   QUAD_STDEV      FLOAT     Array[4]
   QUAD_PRECISION  FLOAT     Array[4]
```

```
   FLAGS            UINT      Array[30]
```

HDU #5 contains the actual data. TAI, YYYYDOY, and SOD have been described previously. The LINE_IRRADIANCE are the extracted lines irradiances described in HDU #1. The precision and accuracy of each line are also available. Further, a FLAG is available for each line.

The AIA band irradiances are listed as BAND_IRRADIANCE with corresponding precision and accuracy.

The diode iradiances are in DIODE_IRRADIANCE with a standard deviation and precision. The quadrant diode fractions are also available with standard deviation and precision.