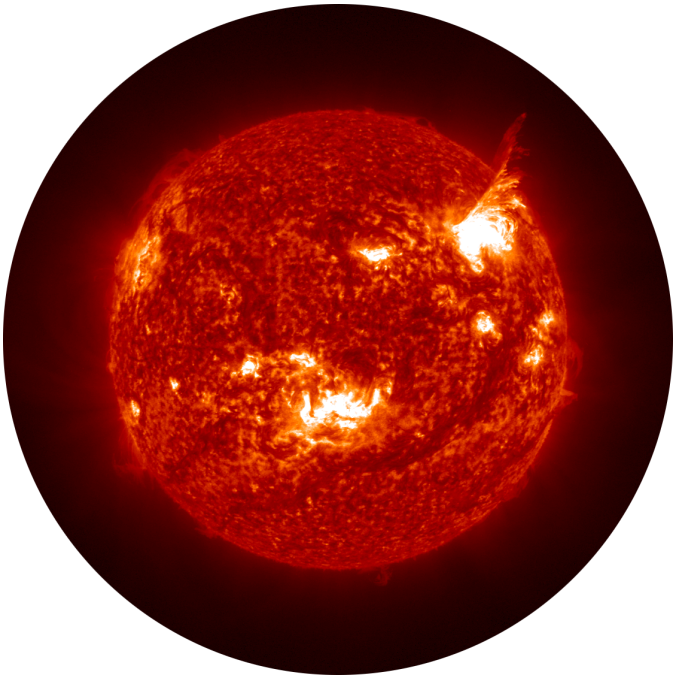
SUVI data guide for SDO/AIA users



National Centers for Environmental Information (NCEI)

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Why this guide?

On November 26, 2024, the Joint Science Operations Center (JSOC) for SDO data had to shut down operations due to a broken pipe in the server room. It is currently unclear when JSOC can return to normal operations. Until then, accessing AIA data will be more difficult (see here), particularly for real-time data. This guide is intended for scientists who are looking for an AIA EUV data alternative in SUVI.

Operational Users should contact NOAA's Space Weather Prediction Center (SWPC). *Scientific Users* should get data through NCEI here, where you can find links to the data and documentation. The shortest latency data files can be found here (AWS S3 buckets). More information in "Resource Links" at the end.

AIA vs SUVI: key instrument characteristics

AIA and SUVI share heritage and are similar instruments. There are some key differences though, which are outlined in Table 1 below. The SUVIs are operational instruments, so the data and handling might be a bit unexpected for AIA users.

A SUVI instrument is installed on 4 satellites of the GOES-R series (GOES-16 through GOES-19). Only two are delivering data at any time, currently GOES-16 and GOES-18. GOES-16 data flow is expected to be replaced with GOES-19 in February 2025.

	AIA	SUVI
Image size	4096x4096 pixels	1280x1280 pixels
Resolution	0.6 arcsec/pixel	2.5 arcsec/pixel
EUV channels	94 Å, 131 Å, 171 Å, 193 Å, 211 Å, 304 Å, 335 Å	94 Å, 131 Å, 171 Å, 195 Å, 284 Å, 304 Å
Cadence	12 s	L1b data: 50-240 s*, L2 data: 4 min
Field of view (N-S, E-W)	41 arcmin	53 arcmin
Date range	2012-05-11 to now	2018-05-05 to now

Table 1: Comparison of key characteristics for AIA and SUVI

*The L1b data cadence differs from channel to channel and is irregular for 195 Å and 304 Å. See the next page for a more detailed explanation of SUVI image sequencing.

SUVI observational sequence and product cadence explained

One full observational sequence is repeated every 4 minutes with both short and long exposures for each channel, and a 4 minute calibration sequence (which still takes most of the regular data) is executed every hour:

Regular operational imaging sequence

Minute	1						2						3						4					
Time	00:10	00:20	00:30	00:40	00:50	01:00	01:10	01:20	01:30	01:40	01:50	02:00	02:10	02:20	02:30	02:40	02:50	03:00	03:10	03:20	03:30	03:40	03:50	04:00
Exp. time	1 s	5 ms	5 ms	1 s	5 ms	1 s	5 ms	1 s	5 ms	5 ms	1 s	5 ms	1 s	5 ms	5 ms	1 s	5 ms	1 s	1 s	5 ms	1 s	5 ms	1 s	5 ms
Exp. type	long	short	short flare	long	short flare	long	short flare	long	short	short flare	long	short flare	long	short	short flare	long	short flare	long	long	short flare	long	short flare	long	short flare
Channel	94 Å	94 Å	94 Å	195 Å	195 Å	304 Å	304 Å	131 Å	131 Å	131 Å	195 Å	195Å	94 Å	94 Å	94 Å	171 Å	171 Å	195Å	284 Å	284 Å	304 Å	304 Å	195 Å	195Å

Operational imaging sequence when calibration is necessary

Minute	1						2						3						4					
Time	00:10	00:20	00:30	00:40	00:50	01:00	01:10	01:20	01:30	01:40	01:50	02:00	02:10	02:20	02:30	02:40	02:50	03:00	03:10	03:20	03:30	03:40	03:50	04:00
Exp. time	1 s	5 ms	5 ms	1 s	5 ms	N/A	N/A	1 s	5 ms	5 ms	1 s	5 ms	1 s	5 ms	5 ms	1 s	5 ms	1 s	1 s	5 ms	1 s	5 ms	1 s	5 ms
Exp. Type	long	short	short flare	long	short flare	N/A	N/A	long	short	short flare	long	short flare	long	short	short flare	long	short flare	long	long	short flare	long	short flare	long	short flare
Channel	94 Å	94 Å	94 Å	195 Å	195 Å	Cal	Cal	131 Å	131 Å	131 Å	195 Å	195Å	94 Å	94 Å	94 Å	171 Å	171 Å	195Å	284 Å	284 Å	304 Å	304 Å	195 Å	195Å

Table 2: SUVI operational observing sequences

This operational imaging sequence is based on forecasting needs. The primary needs as stated by the forecasting office are flare identification and coronal hole tracking. SUVI also has a requirement to be able to image all solar conditions without saturating the detector. This leads to a complicated imaging sequence as can be seen from Table 2. Thus, the user should understand that the product cadence for any given channel is irregular when compared to AIA.

SUVI data products

Level 1b (L1b)

The SUVI L1b products contain the data taken in all EUV channels at the full cadence. The L1b data are science-ready and are available in FITS and netCDF format. They have been calibrated with standard CCD image corrections (dark/bias/flatfield) and the response functions have been applied, so the data are reported in physical units (W m^{-2} sr^{-1}). Many scientists are used to working with AIA data in DNs instead of physical units.

Note that the L1b data are still in the CCD frame, i.e. the images have to be rotated manually using CROTA or the PC-matrix in the metadata in order to have Solar North pointing upwards.

There are 3 different exposure types for L1b data:

1. *Long exposures*: Standard exposure with 1 s exposure time (1.5 s for more recent 94 Å data on GOES-16). This is probably the data you are interested in if you are used to AIA data.
2. *Short exposures*: Standard exposure with 5 ms exposure time to reduce the signal in bright or flaring regions.
3. *Short flare exposures*: Another 5 ms exposure, but with an additional filter in the optical path to attenuate the signal even more in flaring regions.

All channels take long and short flare exposures, short exposures are only taken in 94 Å and 131 Å. Unfortunately, the different types of exposures are not indicated in the filenames, but it is listed in the SCI_OBJ keyword in the FITS header.

The FITS files contain the data in the Primary HDU. They also contain an extension called the *DQF* (data quality flag) specifying pixels with potential issues such as missing data and cosmic ray hits.

Level 2 (L2)

The SUVI L2 products encompass the data taken in all EUV channels, plus the *Thematic Map* (see Fig. 1), a product which identifies different features on the sun such as flares, bright regions, and coronal holes based on a machine learning classifier using the data in all 6 EUV channels. Using the pixel classification from the Thematic Maps, we create report products for specific themes. See Table 3 below for an overview of each of the L2 products.

You can think of the L2 EUV *Composites* as HDR images (High Dynamic Range). For each channel, all L1b exposures (long, short, short flare) within a 4 minute observing window are co-aligned and assembled into pixel-by-pixel composite images: as the long exposures are starting to reach saturation, the signal from the shorter exposures is used instead. This is done using a weighting scheme to avoid image artifacts. In short, the L2 Composites avoid saturation even for the brightest flares (up to ~X20). Like the L1b files, the L2 data are reported in physical units ($W\ m^{-2}\ sr^{-1}$).

The L2 Composites are centered, corrected for cosmic ray hits, and rotated such that Solar North is pointing upwards. The Thematic Maps are based on these L2 composites and are therefore also centered and rotated.

L2 product	Description	Data format
Composites	High Dynamic Range images for all 6 EUV channels.	FITS
Thematic Maps	Pixels are sorted into themes based on a random forest classifier.	FITS
Bright Region Report	Contains locations and other information about the bright regions identified in the Thematic Maps.	netCDF
Coronal Hole Boundaries	Contains locations and other information about the coronal holes identified in the Thematic Maps.	netCDF
Flare Locations	Contains locations and other information about flares identified in the Thematic Maps.	netCDF

Table 3: SUVI L2 products

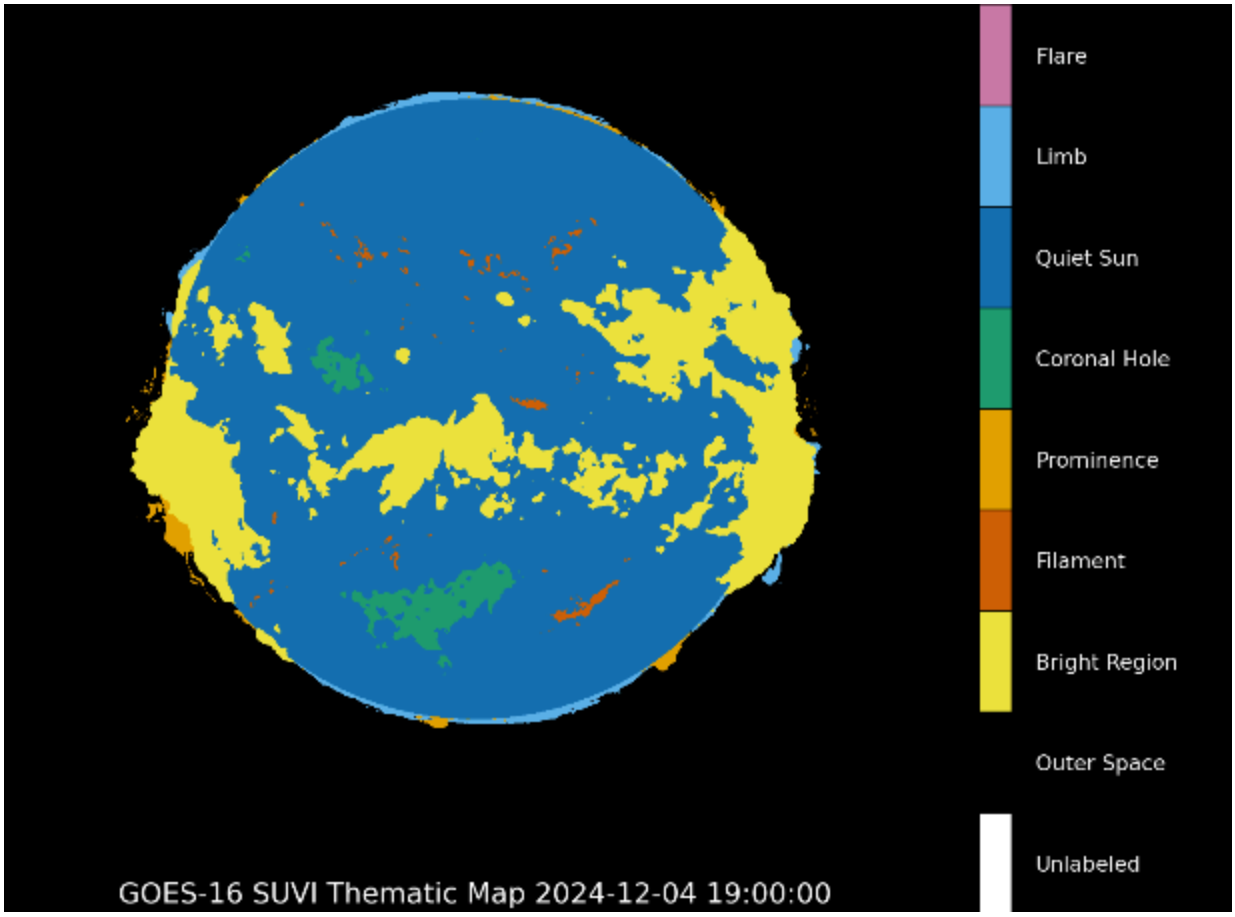

Figure 1: Example SUVI Thematic Map

Things to be aware of

Operational vs scientific data

Currently available L1b data is always operational, i.e. those are the files being used in operations and directly made available to the public. Efforts are underway to reprocess that data and release improved L1b data products that are more suitable for scientific purposes (such as correcting for the roll angle error, see below). We do not have a timeline for when those improved L1b files are going to be released, but you will be able to recognize them through their filenames (starting with “sci_”).

The L2 data available here are operational data products and are created by the algorithm that is currently used in operations. The L2 data available through here are produced using the latest algorithms and are considered more suitable for scientific purposes.

Roll angle error

All of the SUVI instruments have an unresolved roll angle error on the order of +/- 0.25 degrees compared to AIA data. The periodicity of the amplitude of this error is 24 hours due to SUVI's orbit. If your daily SUVI movies "wobble" a bit - that's why.

Intercalibration

Intercalibration efforts between the different SUVI instruments (degradation, differences in response functions) are underway, but not finalized. Images taken at the same time by different SUVIs will therefore report different radiances, up to about 35% difference depending on the channel.

Image artifacts in L2 Composites

The compositing of L1b data taken at different times can lead to image artifacts in the L2 Composites for fast-moving structures like CMEs. See an example below in Fig. 2.

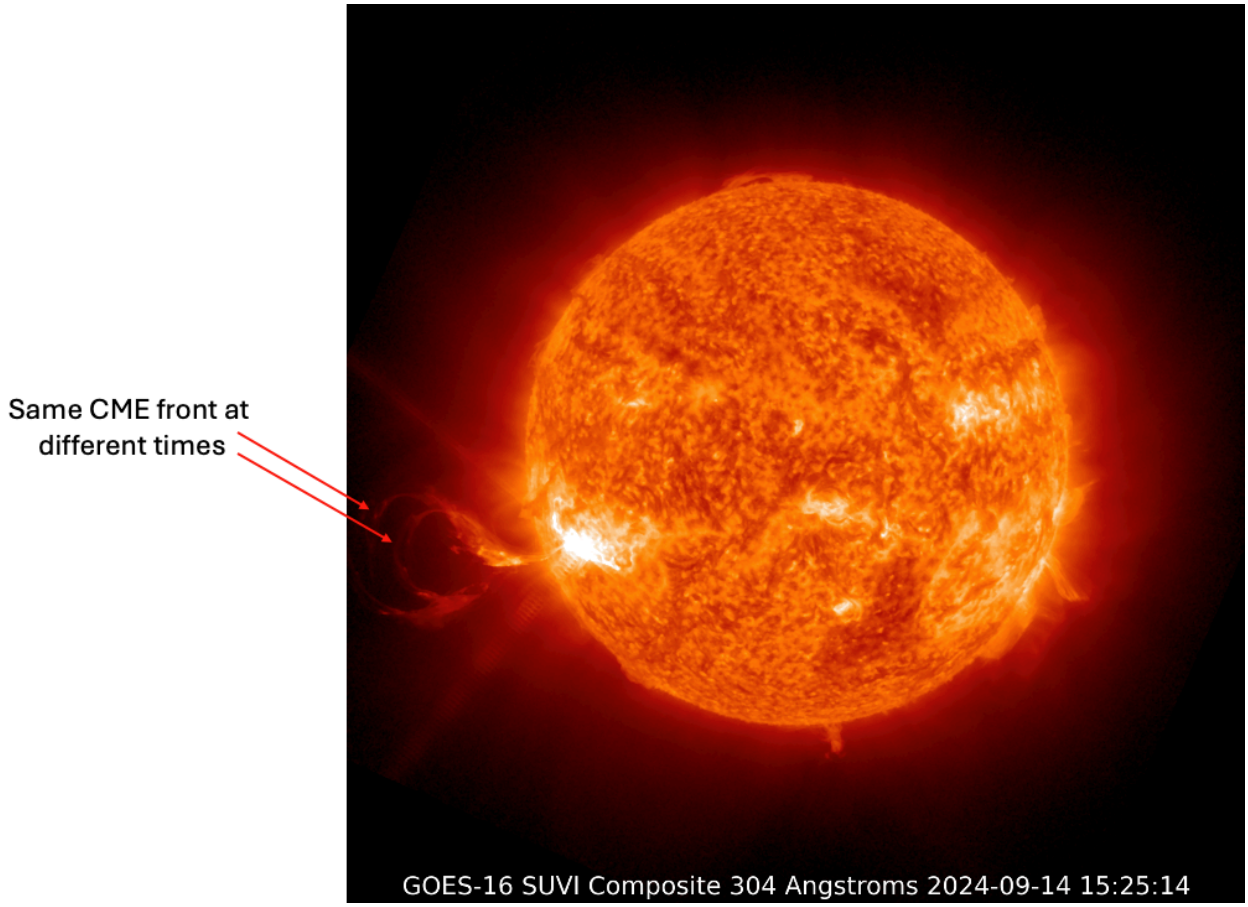

Figure 2: Image artifact in SUVI 304 Å L2 Composite

PSF deconvolution

We currently do not perform PSF deconvolution on SUVI data.

CONTINUE error in the metadata

Early GOES-16 L1b FITS files were produced with an error in the CONTINUE keyword convention, causing software such as astropy.io.fits to quit. If you run into this issue, please use the SUVI software library in sunkit-instruments (see the resource links below) to read in those data, instead of using astropy directly.

L1b vs L2 filenames

The L1b filenames contain 3 dates: start of exposure (starting with "_s"), end of exposure ("_e"), and file creation date ("_c"). The dates are formatted like this:

YYYYDOYhhmmssf with

YYYY:	year
DOY:	day of year
hh:	hour
mm:	minute
ss:	second
f:	fraction (hundredth) of second

The L2 filenames only contain start and end of the exposure, and the dates are formatted like this:

YYYYMMDDThhmmssZ with

YYYY:	year
MM:	month
DD:	day
T:	separator
hh:	hour
mm:	minute
ss:	second
Z:	time zone ("Zulu" = UTC)

Resource links

Data access

- Quicklook data:
  - SWPC website (animation of last 3 hours, latency about 15 minutes)
  - LASP space weather data portal (animation of last 24 hours, latency about 1 hour)
  - JHelioviewer (GOES-16/SUVI data starting sometime in 2022, latency about 1-2 days)
- Scientific data:
  - NESDIS data link tree (latency 30-60 min for L1b data and 1 day for L2 data)
  - Virtual Solar Observatory and/or Fido in sunpy.net (latency unknown)
  - NOAA Open Data Dissemination (NODD) (corresponding AWS S3 buckets here, latency about 1-2 min after data downlink)
  - Extended Coronal Imaging (ECI) data (look for “Special Event Data”) These are special campaigns where SUVI is offpointed from sun center to cover a larger FOV.

How to use the data

- Documentation: SUVI products README files (click the “Documentation” tab)
- Code
  - CIRES Jupyter notebook example website
  - SUVI code in sunkit-instruments

Contact

Any questions about the NCEI data? Please reach out to ncei.info [at] noaa.gov !

General feedback, comments, or suggestions about any NOAA Space Weather product can be left here.