SDO Data JSOC Export and Cutout Service Example and Documentation

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In this document, we walk through the process of using Stanford University's JSOC export service[1] to download data from SDO's HMI and AIA instruments. In particular, we show how to make use of the JSOC's cutout service. This option allows users to avoid downloading the full-resolution, full-disk images, which take up a sizable amount of storage space and can be computationally expensive to work with. We also provide some tips and tricks on some of the more subtle intricacies of using the JSOC and cutout services.

In actuality, there are multiple other ways to access the archived data besides through the JSOC export system, including via the Virtual Solar Observatory (VSO)[2] and Lockheed's Heliophysics Coverage Registry (HCR)[3]. However, there are benefits and restrictions with using any retrieval method. From experience, the authors prefer using the JSOC service, even though the user interface might initially seem more formidable to a new user (precisely the reason we created this document!).

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[1] http://jsoc.stanford.edu/ajax/exportdata.html
[2] http://sdac.virtualsolar.org/cgi/search
[3] http://www.lmsal.com/hek/hcr?cmd=search-events

Both HMI and AIA data are available for download from the JSOC, but following example uses an AIA data series. However, many of the tips and tricks are applicable to both data sets. We note that there may be other intricacies for downloading HMI data that are not covered here.

We note that first-time users must register for the JSOC service upon initial use. The JSOC checks your e-mail address (given in the **Notify** box at the bottom of the page) to determine if it is already registered. If not, an e-mail is sent to the account and you must respond within a few minutes in order to register the new e-mail address.

There are multiple AIA product series available for download. The main archived data set is the AIA level-1 series (*AIA.lev1*). As opposed to the raw level-0 data, the level-1 data have been processed for pixel-level calibrations including bad-pixel removal, despiking, and flat-fielding. The processing of level-1.5 data further corrects for geometric calibrations, such as plate-scaling, rotation to solar north, and shifting the image centers to match the HMI data. Further details on the differences between data processing products can be found in the SDO documentation website[4], run by the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL). In particular, the PDF link to N. Hurlburt's "*AIA plan for producing and distributing data*" (last updated June 29, 2010, as of writing this documentation) describes the various AIA level differences in detail. Another useful resource is M. DeRosa's "*Guide to SDO Data Analysis*"[5] (last update February 10, 2015, as of writing this documentation), which is also available via LMSAL's SDODocs website above.

The only fully-archived AIA data series is the level-1 processed data. Other series include, but are not limited to, those listed in Table 1. There are several options for how to convert a level-1 download to level-1.5, such as using the IDL SolarSoftware (SSW) routine *aia_prep.pro*. There is also a processing option embedded into the JSOC export system that performs the same conversion, which will be discussed later.

Figure 1 shows a screenshot of the JSOC export website with parameter specifications for the SDO-AIA data set used in our example. We will move our discussion through the export page, starting at the top.

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[4] https://www.lmsal.com/sdodocs/
[5] https://www.lmsal.com/sdodocs/doc/dcur/SDOD0060.zip/zip/entry/

Table 1: A small selection of series names available through the JSOC, along with a brief description of the series data.

SERIES NAME	DESCRIPTION
aia.lev1	AIA Level 1, all data
aia.lev1_euv_12s	AIA Level 1, Extreme Ultraviolet Subset - 12 second cadence
aia.lev1_uv_24s	AIA Level 1, Ultraviolet Subset - 24 second cadence
aia.lev1_vis_1h	AIA Level 1, Visible Subset - 1 hour cadence

The **RecordSet** specifies the desired data series, date and time range, and any other keyword options for the export query. It can either be entered manually, if the user knows the query syntax and desired data set, or it can be built using the JSOC Lookdata service.[6] Our **RecordSet** query is for the *aia.lev1* data series on February 5th, 2014, between 8:00 (8AM) and 16:00 (4PM). The wavelength keyword in Figure 1 is set to 304 Å; however, we made the same query for three other wavelengths as well: 171 Å, 193 Å, and 211 Å. There is a **Record Count** of about 2400 AIA images that meet the **RecordSet** specifications for each wavelength, one image every ∼12 seconds. (The **WAVELNTH**=171 query actually has a count of 2401 because the first image per minute for that wavelength is taken on the 00-second, which includes the 16:00:00 time step.)

For some series, such as the *aia.lev1_euv_12s*, there are query shortcuts for specifying the the series time range. Instead of specifying an ending date and time, users can append a forward-slash / to the start date and time, followed by a length of time consisting of a number and units of time (e.g. /1h, /30m, or /45s). Similarly, the "at" symbol @ can be used to specify the cadence of the returned data (e.g. @1h, @30m, or @45s). Unfortunately, these shortcuts do not work with the main *aia.lev1* time series. However, in the context of our example, the date/time would be specified as [2014.02.05_8:00/8hr]. If we wanted a cadence of only one image per minute, we would use [2014.02.05_8:00/8hr@1m].

Another minor but time-saving note pertains to the retrieval format. If you do not change the delivery **Method** from url to url-tar, you will have to download each of the 2400 .fits files individually. It is much more convenient to download a single tar file containing all the data files.

The **Filename Format** is the filename template for the returned data files. Each data

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[6]http://jsoc.stanford.edu/ajax/lookdata.html

RecordSet from file ☐ Check box to allow upload of RecordSet list file, file will be requested after Submit button click.

RecordSet aia.lev1[2014.02.05_8:00-2014.02.05_16:00][][? WAVELNTH=304 ?] Lookdata

Record Limit none Optional manual limit to number of records to export.

Record Count 2400 Recount Limit for AIA to about 15,000 and for HMI about 30,000 in each request.

Method url-tar ▼ Choose method, url_quick or url for now. url_quick implies protocol of "as-is"

Filename Format aia.lev1.{T_OBS:A}.{WAVELNTH}.noproj File name template.

Processing
☐ no_op - none ☐ hide
☑ aia_scale - Scale AIA lev1 to 0.6 arcsec/pixel
☐ resize - Resize and rotate if needed, use sub-pixel registration
☑ im_patch - Extract sub-frame
☐ maproj - Extract a sub-frame and remap to a chosen projection.
☐ rebin - Rebin with boxcar or gaussian smoothing

AIA_Scale Normalize image scale to AIA standard 0.6 arc-sec per pixel is enabled **Only for aia.lev1 for now.**

IM_Patch
Image Patch Extract - used to export rectangular sub-frames from a sequence of images. The patch may be stationary or tracked at the Carrington rate.
If only the seriesname is given, the query will be made for the last record only, [$], unless tracking a from the east limb is requested.
If the limb checkboxes are checked, tracking will begin or end at the indicated limb(s). If the "register" checkbox is checked, the patch will be interpolated to the desired location. If "register" is not-checked the patch will be exact pixel cutout from the input image.
RecordSet: aia.lev1[2014.02.05_8:00-2014.02.05_16:00][][? WAVELNTH=304 ?] Reset params Update RecordSet Times

Options ☑ Tracking, ☑ Register, ☐ Crop, NOAA AR number: NotSpecified
T_START 2014-02-05T08:00:00Z ☐ Check for start at east limb.
T_STOP 2014-02-05T16:00:00Z ☐ Check for stop at west limb.
CADENCE 1.000000s
LocUnits Carrington LatLon ▼ Units for X and Y to select center of extracted patch
CAR_ROT 2146 Carrington rotation number for X and Y, latitude and longitude.
X 82 East-West location of patch center.
Y 24 North-South location of patch center.
BoxUnits pixels ▼ Width of extracted patch, Units determined be BoxUnits.
Width 512 Width of extracted patch, Units determined be BoxUnits.
Height 512 Height of extracted patch, Units determined be BoxUnits.
Verify Check params OK to submit

Protocol FITS ▼ Choose protocol, "FITS", "JPEG", "MPG", "MP4", or "as-is". Note uncompressed FITS not an option.
Notify OK Provide your email address for notification. If Requestor is your SolarMail name you may use "solarmail" here.
Requestor shessweb Provide an identifier for you. Optional if not using SolarMail.
Check Params for Export OK to proceed
Submit Export Request Please only click once for export request.

Figure 1: A snapshot of the JSOC Data Export Request Generation webpage with parameter specifications for this example.

series has its own default template. Changing the template is optional. Any acceptable keyword of the current data series can be used in the template, surrounded by braces. In our example, we adjust the **Filename Format** to differentiate between data by adding the **{WAVELNTH}** keyword. Added text without braces is included as-typed, e.g. our appended ".noproj" text. Our returned filenames look something like *aia.lev1.2014-02-05T080009Z.304.noproj*. (Users who choose to change the filename template should read an important side note at the end of this document.)

The AIA_SCALE **Processing** option essentially converts the level-1 data to level-1.5 data. It applies the appropriate plate scaling, and shifts and rotates the images according to

the metadata information so that they match the center and solar north of the HMI data.[7] Selecting this option removes the need to later use *aia_prep.pro*.

The IM_PATCH **Processing** option tracks rectangular subframes from images. This is how the cutout service is applied to the data. As mentioned, we may not need (or want) to download the full-Sun 4Kx4K resolution images, since even the compressed tar files would be enormous for an 8 hour data set. The user can define the desired coordinates of the image center as well as the dimensions of the domain. If the tracking option is set, the image patch is tracked at the Carrington rate. The register option performs an interpolation on sequences of cutouts so that a movie derived from the cutouts will transition smoothly in time. If the register option is not set the movie will show occasional 1-pixel jumps as the field-of-view center moves. One drawback of the register option is that the *aia_respike.pro* routine in Solarsoft will no longer be able to accurately re-spike the AIA images, which can be important for flare data for example. The crop option sets all off-limb pixels to NAN values. We have no need for the cropping option because our example data is near disk center. More details can be found in the IM_PATCH documentation.[8]

Our example data is not associated with an active region. However, pre-defined active region locations can be used automatically by including the NOAA active region number. The authors have not used this feature at this point in time, so cannot include possible information of the subtleties of using this option. We welcome input from other users who have experience with this feature.

The desired location and dimension parameters all have brief descriptions on the page, but we review them here. The **X** and **Y** parameters are the central locations of the desired image patch. The **LocUnits** option dictates the units of **X** and **Y**. In our example, we use Carrington latitude and longitude coordinates to specify the patch center. The size of the bounding box for the patch is given by **Width** and **Height**, the units of which are specified by the **BoxUnits** parameter. Our example uses pixels for the bounding box units. Note, when using **LocUnits** of Carringtion LatLon, the tracking option MUST be selected or the returned data will be complete nonsense![9]

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[7]Personal Communication with P. Scherrer
[8]http://jsoc.stanford.edu/doxygen_html/group__im__patch.html
[9]Personal Communication with A. Amezcua

Before you can submit an export request, you must first verify the IM_PATCH parameters by clicking the "Check params" button. If all the necessary parameters are specified, it will display the message "OK to submit". Similarly, you must click the "Check Params for Export" button. It will display "OK to proceed" if everything is in order for the export. Clicking "Submit Export Request" sends the query to the JSOC server. After successful submission, the **RequestID** for the current **RecordSet** will appear on the page below the submit button. Again, remember to write this ID down! The form is generally *JSOC_YYYYMMDD_request#*, where the date is the date that the export request was submitted and the request number resets at the beginning of each day. This **RequestID** will also be the filename of the .tar file containing the data .fits files.

The JSOC export service will **Notify** the provided email account when the export process is complete and the data is ready for download. Note, however, that even when you provide a notification email address, experience shows that notifications are not always sent/received. As a precautionary measure, record the **RequestID** for each export query so that you can manually check the status of the request on the website and, when available, download the tar file. The **RequestID** is also important information to provide to the JSOC team if you have an issue that requires debugging.

Some useful websites with documentation on how to use the JSOC and its cutout service, including those aforementioned, are listed here.

– JSOC Lookdata webpage:
  http://jsoc.stanford.edu/ajax/lookdata.html

– JSOC Export Service webpage:
  http://jsoc.stanford.edu/ajax/exportdata.html

– EIS wiki page on obtaining SDO cutouts from the JSOC:
  http://solarb.mssl.ucl.ac.uk:8080/eiswiki/Wiki.jsp?page=AIAEIS

– Online Guide to SDO Data Analysis:
  https://www.lmsal.com/sdodocs/doc/dcur/SDOD0060.zip/zip/entry/

- Lockheed's SDOdocs website:

  https://www.lmsal.com/sdodocs/

- Peter Young's SDO quick-guides webpage on downloading SDO data:

  http://pyoung.org/quick_guides/sdo_download_data.html

- Specific documentation on the JSOC IM_PATCH processing option:

  http://jsoc.stanford.edu/doxygen_html/group__im__patch.html

- Reference C-code for the JSOC IM_PATCH processing option:

  http://jsoc.stanford.edu/doxygen_html/im__patch_8c-source.html

- SDO "Ways to Access Data" (particularly the "Science Data" and "Other Useful Places" tabs):

  http://sdo.gsfc.nasa.gov/data/dataaccess.php

SIDE NOTES

- If you choose to change your **Filename Format**, be aware that changing the **RecordSet** query in any way will automatically revert the template back to its default. To ensure you have consistently named files between various export requests, check/reset your desired filename template each time you change your **RecordSet** (e.g. changing the desired wavelength).

- We note that within the JSOC code, tracking-on is equivalent to parameter $t = 0$ and tracking-off is equivalent to $t = 1$. This lead one of the authors to some confusion. We point this out to help future users avoid the same confusion!