

Data Analysis Enabled by the Space Physics Data Facility

**Lan Jian, Robert Candey, Tamara Kovalick,
and the Rest of SPDF Team**

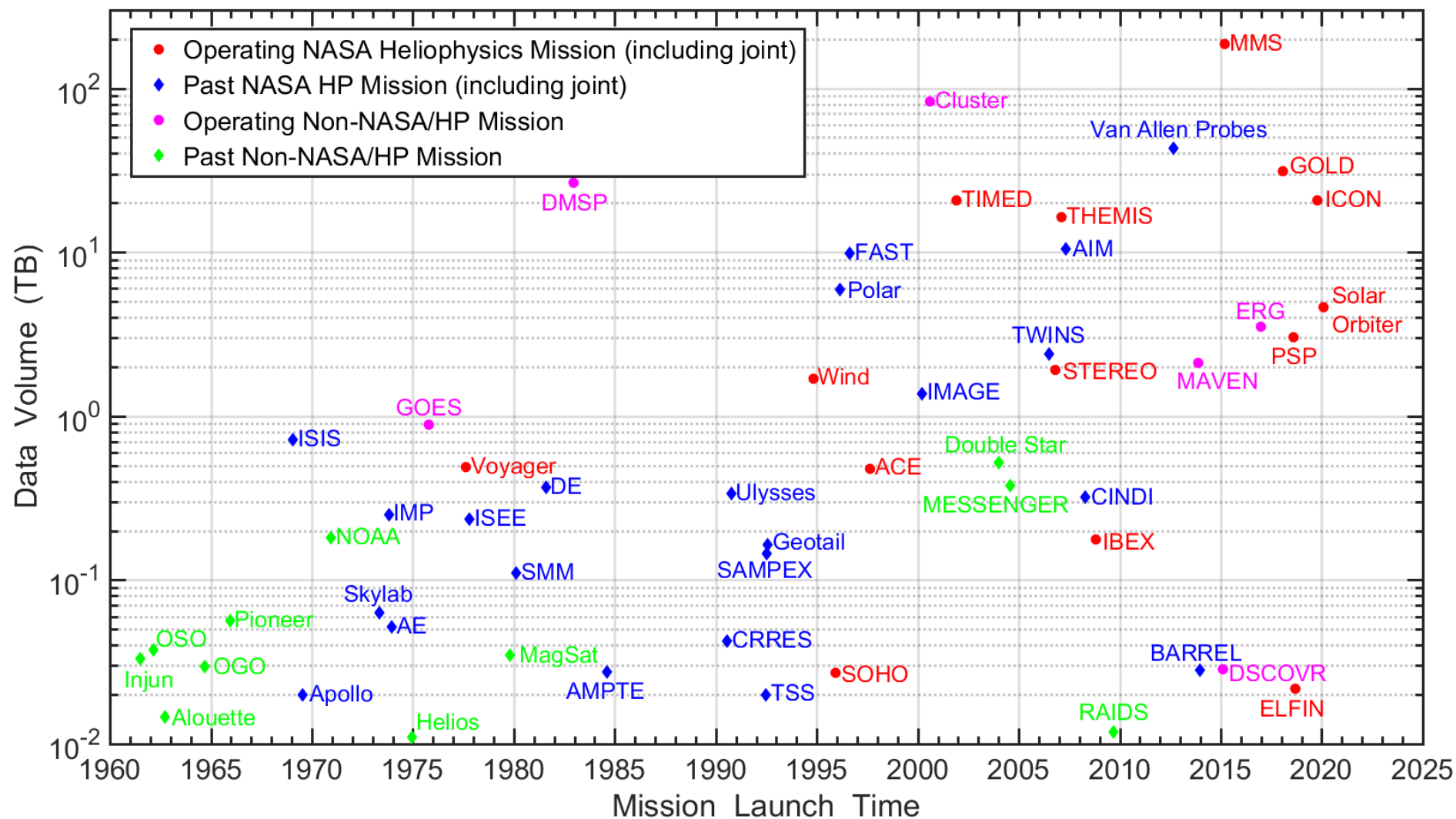
**NASA Goddard Space Flight Center,
Greenbelt, MD, USA**

<https://spdf.gsfc.nasa.gov>

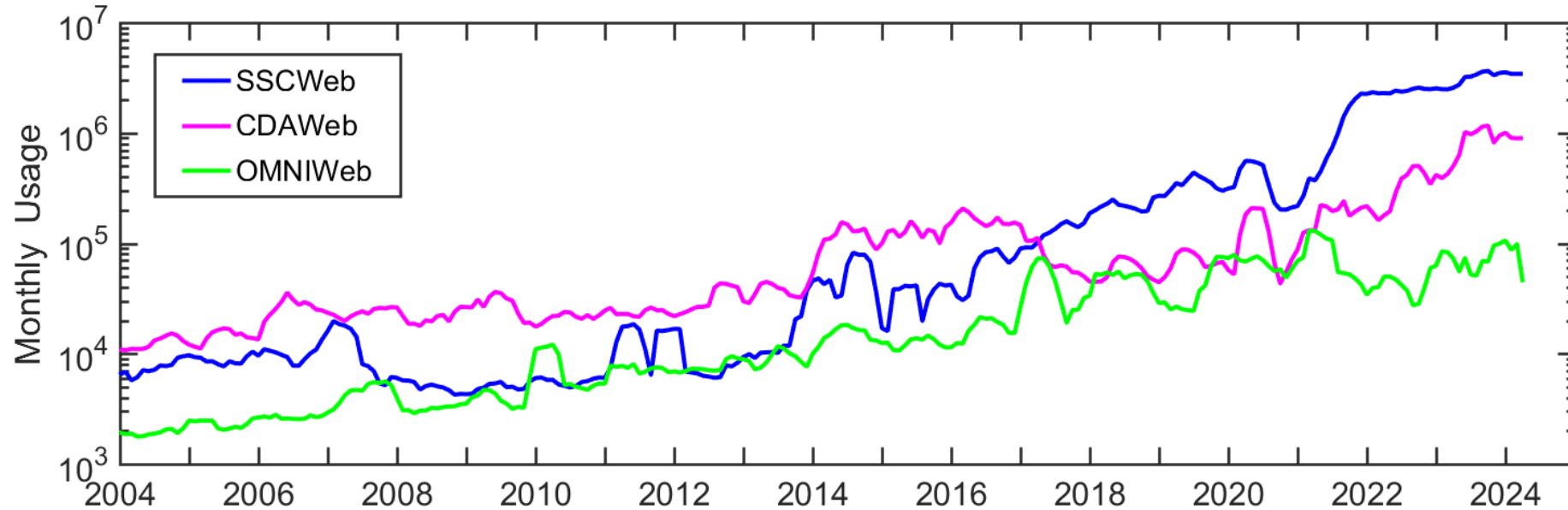
**Triennial Earth-Sun Summit (TESS)
Dallas, TX April 10, 2024**

Introduction of SPDF

SPDF is the active and permanent archive of space physics data from NASA missions and joint missions with other US and foreign agencies (~3000 CDF datasets, ~5000 non-CDF datasets, ~100M files)



Science-Enabling Services of SPDF



❑ Coordinated Data Analysis Web (CDAWeb)

- Data access through web browser, IDL, Python, API
- Interface for browsing and plotting data from 60+ missions or mission groups (audio, movie) and multiple instruments
- *Inventory plot and usage statistics* for mission data

❑ Satellite Situation Center (SSC)

- ~200 spacecraft, orbit/ground track displays and queries
- Coordinate transformation

❑ OMNIWeb (including COHOWeb)

- Solar wind plasma, magnetic field, and energetic particle data at the nose of Earth's bow shock and other locations of the heliosphere
- Interface for plotting, filtering, and simple analysis

60+ Missions/Sources (Groups) →

Coordinated Data Analysis Web (CDAWeb)

<https://cdaweb.gsfc.nasa.gov/>

- Enable multi-mission, multi-instrument science
- Present dataset view rather than individual data files

- **Select zero OR more Sources**
(default = All Sources if >=1 Instrument Type is selected)
- Balloons
- Geosynchronous Investigations
- Ground-Based Investigations
- Helio Ephemeris
- OMNI (Combined 1AU IP Data; Magnetic and Solar Indices)
- Smallsats/Cubesats
- Sounding Rockets
- ACE
- AIM
- AMPTE
- ARTEMIS
- Alouette
- Apollo
- Arase (ERG)
- CNOFS
- CRRES
- Cassini
- Cluster

- **Select zero OR more Instrument Types**
(default = All Instrument Types if >=1 Source is selected)
- Activity Indices
- Electric Fields (space)
- Electron Precipitation Bremsstrahlung
- Energetic Particle Detector
- Engineering
- Ephemeris/Attitude/Ancillary
- Gamma and X-Rays
- Ground-Based HF-Radars
- Ground-Based Imagers
- Ground-Based Magnetometers, Riometers, Sounders
- Ground-Based VLF/ELF/ULF, Photometers
- Housekeeping
- Imaging and Remote Sensing (ITM/Earth)
- Imaging and Remote Sensing (Magnetosphere/Earth)
- Imaging and Remote Sensing (Sun)
- Magnetic Fields (Balloon)

- AEROCUBE-6-B_DOSIMETER_L2:** Aerocube 6/Dosimeter Level 2 - J. B. Blake (The Aerospace Corporation) [Available Time Range: 2014/06/21 14:49:56 - 2017/06/30 15:24:08] [Info](#) [Metadata](#)
- CSSWE_REPTILE_6SEC-COUNTS-L1:** CSSWE REPTile level1 6sec Counts and Position - Xinlin Li (University of Colorado at Boulder) [Available Time Range: 2012/09/14 00:28:03 - 2014/08/20 20:27:56] [Info](#) [Metadata](#)
- CSSWE_REPTILE_6SEC-FLUX-L2:** CSSWE REPTile level2 6sec flux and Position - Xinlin Li (University of Colorado at Boulder) [Available Time Range: 2012/09/14 00:28:03 - 2014/08/20 20:27:56] [Info](#) [Metadata](#)
- ELA_L1_STATE_PRED:** ELFIN-A state file, contains predictive position, velocity, and attitude - V. Angelopoulos (UCLA, IGPP/EPSS) [Available Time Range: 2018/09/17 00:00:00 - 2022/09/17 23:59:59] [Info](#) [Metadata](#)

CDAS Web Service Client Code Examples

The following web service client code examples demonstrates how to access data from the [AEROCUBE-6-B DOSIMETER L2](#) dataset from particular programming environments.

Jupyter Notebook on Binder

The following link launches a Python Jupyter Notebook that demonstrates using the `cdasws` library to access [AEROCUBE-6-B DOSIMETER L2](#) data in a Jupyter Notebook. It is merely an example and does not show all the capabilities of the library. You should edit the code to suit your needs.

[launch binder](#)

cdasws Python Library

The following code demonstrates using the `cdasws` library to access [AEROCUBE-6-B DOSIMETER L2](#) data in Python. It is merely an example and does not show all the capabilities of the library. You should edit the code to suit your needs.

```
# Install these prerequisites once before executing the example code:
# Option 1.
#   Install CDF from https://cdf.gsfc.nasa.gov/
#   pip install -U spacepy
#   pip install -U cdasws
# Option 2.
#   pip install -U xarray
#   pip install -U cdflib
#   pip install -U cdasws

from cdasws import CdasWs
cdas = CdasWs()

# Edit the following vars, time variables, and print
environment
# (spacepy or cdflib) and needs.
vars =
['alt', 'lat', 'lon', 'XYZ_GEO', 'dos1l', 'dos1m', 'dos1rate'
```

cdasws IDL Library

The following code demonstrates using the `cdasws` library to access [AEROCUBE-6-B DOSIMETER L2](#) data in IDL. It is merely an example and does not show all the capabilities of the library. You should edit the code to suit your needs.

```
compile_opt idl2
savFilename = filepath('spdfcdas.sav', /tmp)
oUrl = obj_new('IDLnetUrl')
; For IDL installations with old root certificates
oUrl->setProperty, SSL_VERIFY_PEER=0
savFilename = oUrl->get(filename=savFilename,
url='https://cdaweb.gsfc.nasa.gov/WebServices/REST/spdfcdas.sav')
restore, savFilename

; Edit the following vars and time variables to suit your needs.
vars =
['alt', 'lat', 'lon', 'XYZ_GEO', 'dos1l', 'dos1m', 'dos1rate', 'dos2l', 'dos2m', 'dos2rate',
'dos3l', 'dos3m', 'dos3rate', 'flag', 'Sample_Rate', 'Lm_IGRF', 'Bmag_IGRF', 'MLT_IGRF',
'InvLat_IGRF', 'Lm_OPQ', 'Bmag_OPQ', 'MLT_OPQ', 'InvLat_OPQ', 'Loss_Cone_Type', 'Bxyz_GEO',
'Beq', 'I', 'K', 'K_Z', 'Lstar', 'Lstar_Z', 'Hmin', 'Hmin_Z', 'Loss_Cone_Near',
'Loss_Cone_Far', 'B100N', 'LAT100N', 'LON100N', 'B100S', 'LAT100S', 'LON100S', 'Alpha',
'Alpha_X', 'Alpha_Y', 'Alpha_Eq', 'Beta', 'Beta_X', 'Beta_Y', 'Phi_B', 'OmegaXYZ_GEO',
'B_spin', 'Spin_Sun', 'Dist_In_Track', 'Lag_In_Track', 'Dist_Cross_Track_Horiz', 'Dist_Cross_Track_Vert',
'Dist_Total', 'alt_10Hz', 'lat_10Hz', 'lon_10Hz', 'dos1l_10Hz', 'dos1m_10Hz', 'dos1rate_10Hz',
'dos2l_10Hz', 'dos2m_10Hz', 'dos2rate_10Hz', 'dos3l_10Hz', 'dos3m_10Hz', 'dos3rate_10Hz',
'flag_10Hz', 'Subcom_10Hz', 'Lm_OPQ_10Hz', 'Bmag_OPQ_10Hz', 'MLT_OPQ_10Hz', 'InvLat_OPQ_10Hz',
'Loss_Cone_Type_10Hz', 'K_Z_10Hz', 'Lstar_Z_10Hz', 'Hmin_Z_10Hz', 'Alpha_10Hz', 'Beta_10Hz',
'Dist_In_Track_10Hz', 'Lag_In_Trac
```

[Copy code to clipboard](#) [Download code](#)

More information about using this library is available from the following:

- IDL library description [cdasws](#)
- Jupyter IDL [notebook example](#)
- Application Programming Interface description [API](#)

CDAWeb Data Explorer

- Time interval is automatically set by the last available day of the selected dataset(s)
- Remove spikes or filter coarse noise
- **Plot data availability**
- Adjust X and Y lengths for plotting
- **Auto scale time axis for finding discrete bursts or events**
- Overlay vector components of selected variables, or selected variables that are identical among multiple datasets
- Output a subset or a superset of datasets in CDF, ASCII/CSV, JSON
- Create **audio** and **movie** files for selected variables

Select start and stop times from which to GET or PLOT data:

Start time (YYYY/MM/DD HH:MM:SS.mmm):

Stop time (YYYY/MM/DD HH:MM:SS.mmm):

Compute uniformly spaced binned data for scalar/vector/spectrogram data (not available with noise filtering)

Use spike removal to filter data without binning (not available with noise filtering)(Warning: Experimental !!).

Select an activity:

Data Availability Chart : Generate a chart showing when data is available for the selected data set(s) and time range (Select > 1day).

Plot Data : select one or more variables from list below and press submit.

Also create PS and PDF best quality outputs (all plot types except images and plasmagrams).
Many panels per dataset are allowed but <=4 panels optimal for standard Y-axis height and single page display.

Use coarse noise filtering to remove values outside 3 deviations from mean of all values in the plotted time interval.

Change the X-axis width for time-series and spectrogram PNG plots (NEW default=3). **NEW**

Change the Y-axis height for time-series and spectrogram plots (NEW default=2). **NEW**

Autoscale time axis (useful for finding discrete bursts/events). **NEW**

Combine all time-series and spectrogram plots, for all requested datasets, into one plot file.

Plot overlay options.

Overlay vector components of selected variables.

Overlay selected variables or variable components that are identical among the datasets chosen
(Supported constellations: MMS, Van Allen Probes (RBSP), THEMIS, Cluster, and GOES).

List Data (ASCII/CSV): select one or more variables from list below and press submit. (Works best for < 31 days)

Download original files : press submit button to retrieve list of files. (Max. 200 days - use [HTTPS site](#) for larger requests)

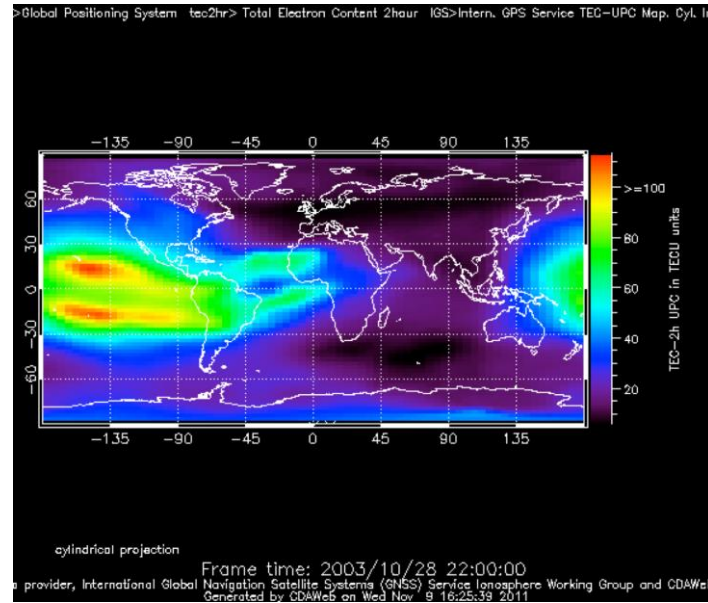
Create V3.9 CDFs for download: select one or more variables from the list below and press submit. **NEW**

Create audio files based on data from selected variables. [More information about audification.](#)

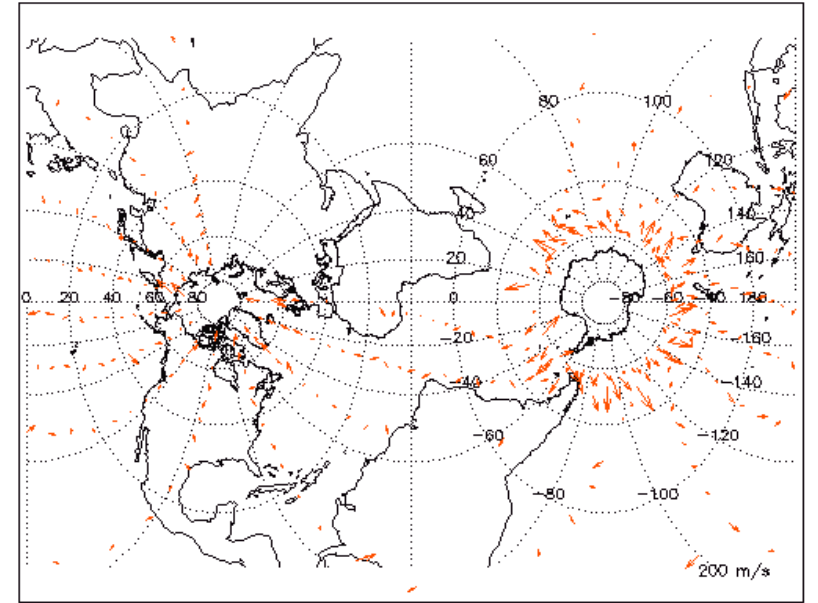
Note: [CDF patch](#) required for reading Version 3.9 CDFs in IDL or MATLAB.
Get [CDFX](#) - IDL GUI plotting/listing toolkit software. To be used with either the daily or "created" CDF files available above.

Pressing the "Submit" button will spawn a new window/tab in order to support the new "Previous" and "Next" functions.

Parameter Displays in CDAWeb

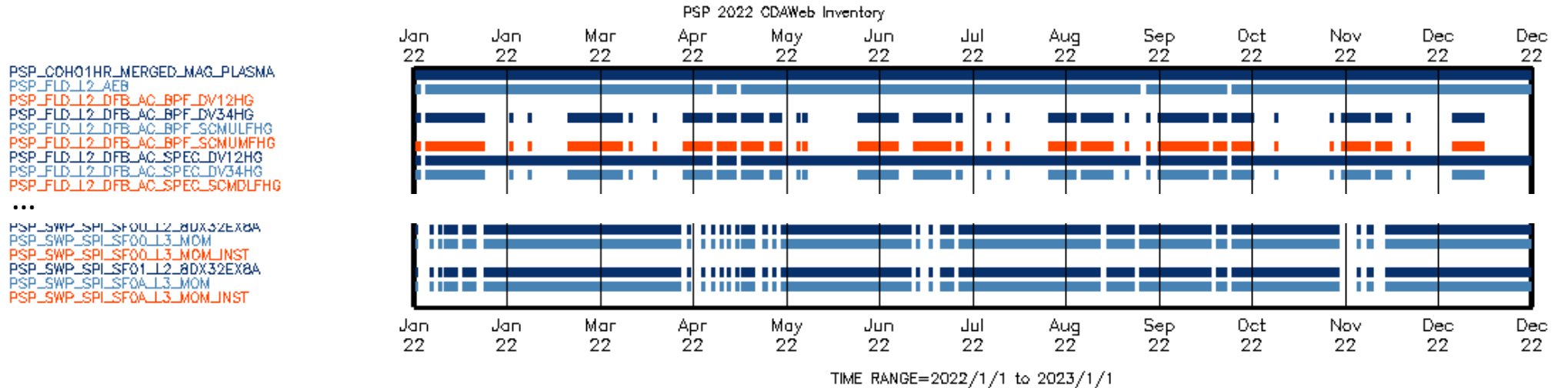


GPS International GNSS Service
Total Electron Content



TIMED/TIDI Wind Vectors Movie
Transverse Mercator Projection

Inventory Plot for Mission Datasets



Plot Walk for Pre-Generated Plots

https://spdf.gsfc.nasa.gov/plot_walk/

Summary or quick-look plots from 20+ missions (12 million plots)

Plot Walk

[User Guide](#)

Date:

2022-09-05

Time:

00:00

Mission:

AIM

Plot type:

CIPS RAA Variance (level 3a; vers

Time range:

1 day



Links:

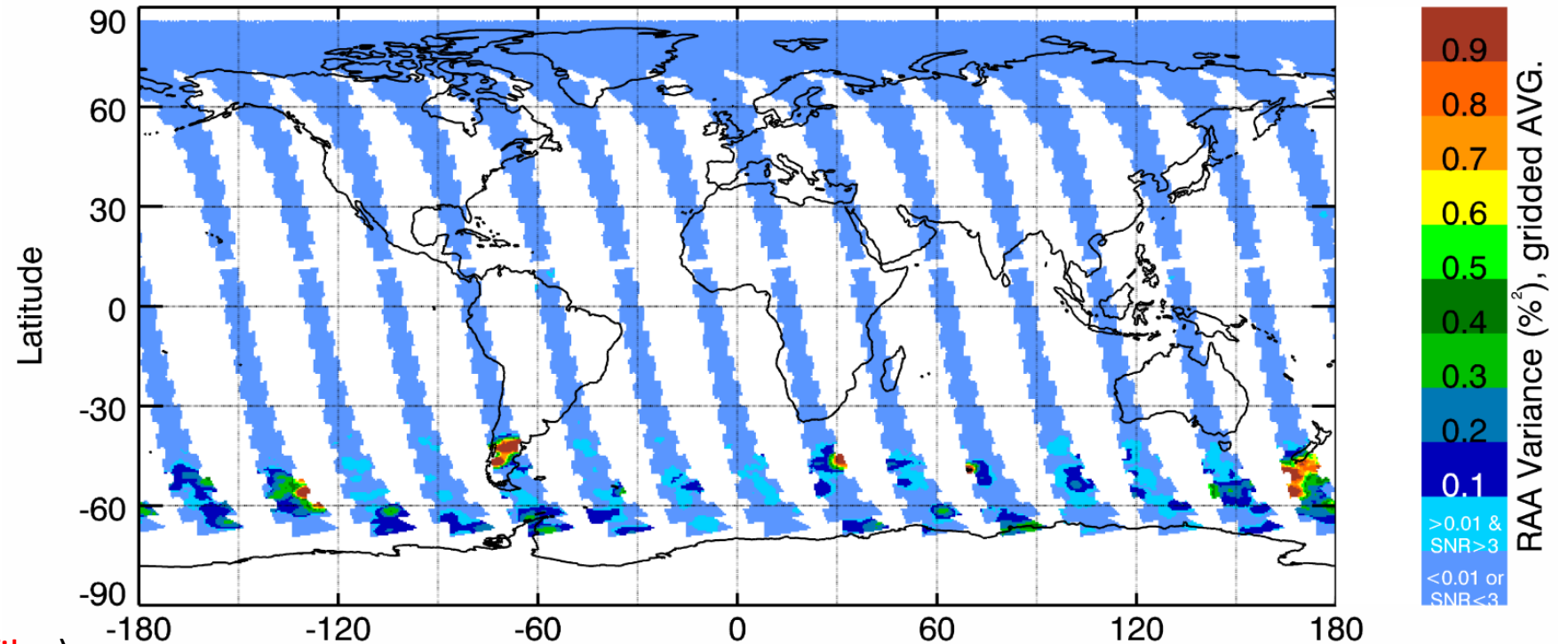
[Image](#)

(links for readme, PDF, PS files)

Powered by [URI Templates](#), [flatpickr](#) and [driver.js](#).

The catalog can be found [here](#).

20220905



Rayleigh Albedo Anomaly (RAA) variance from Cloud Imaging and Particle Size instrument (CIPS) of the Aeronomy of Ice in the Mesosphere (AIM) mission

4-D Orbit Viewer (~200 Spacecraft)

<https://sscweb.gsfc.nasa.gov/4dorbit/>

4D Orbit Viewer

Earth

Cluster-1 (FM5/Rumba)
Cluster-4 (FM8/Tango)

bow shock

magnetopause

switch to perspective camera

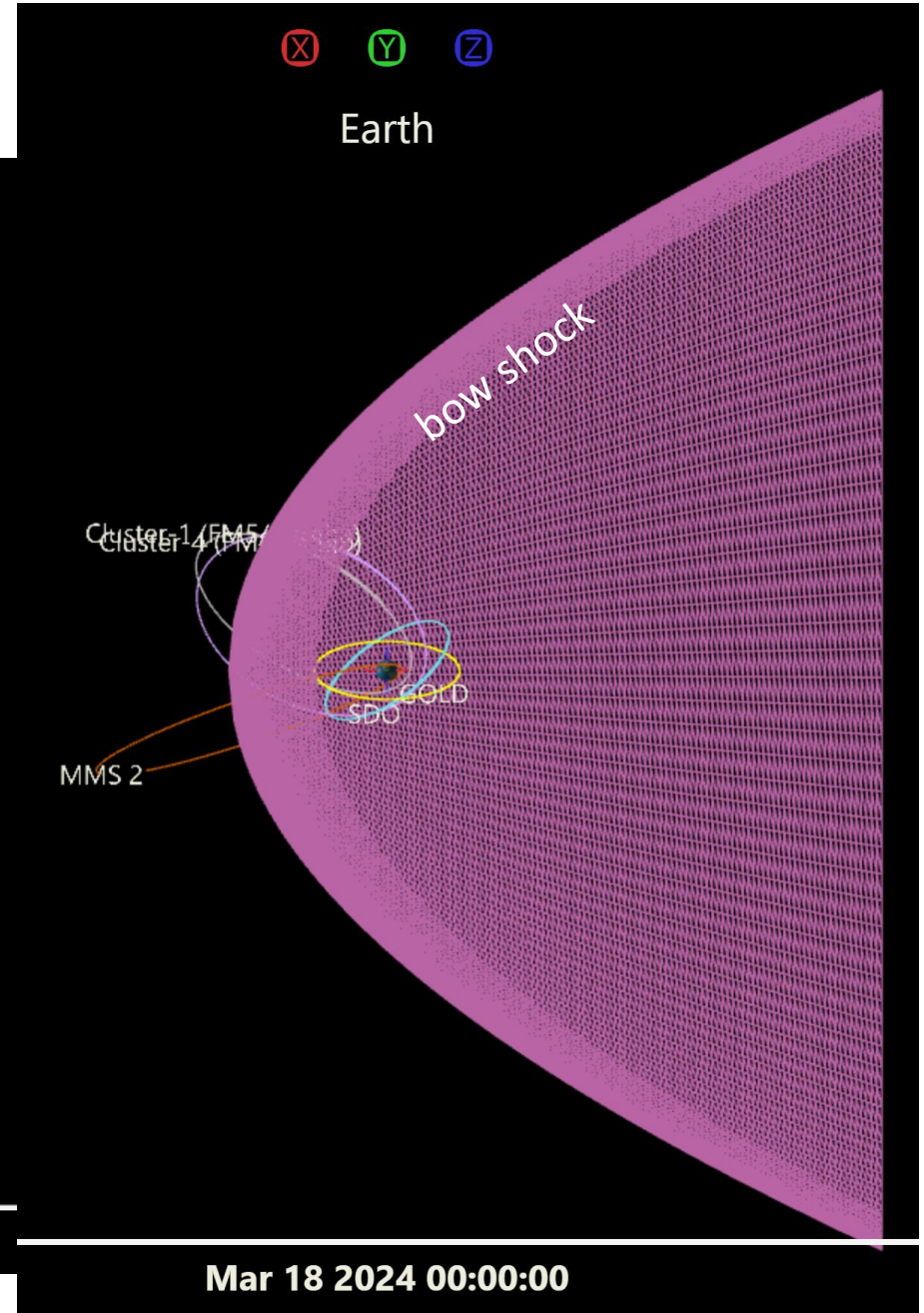
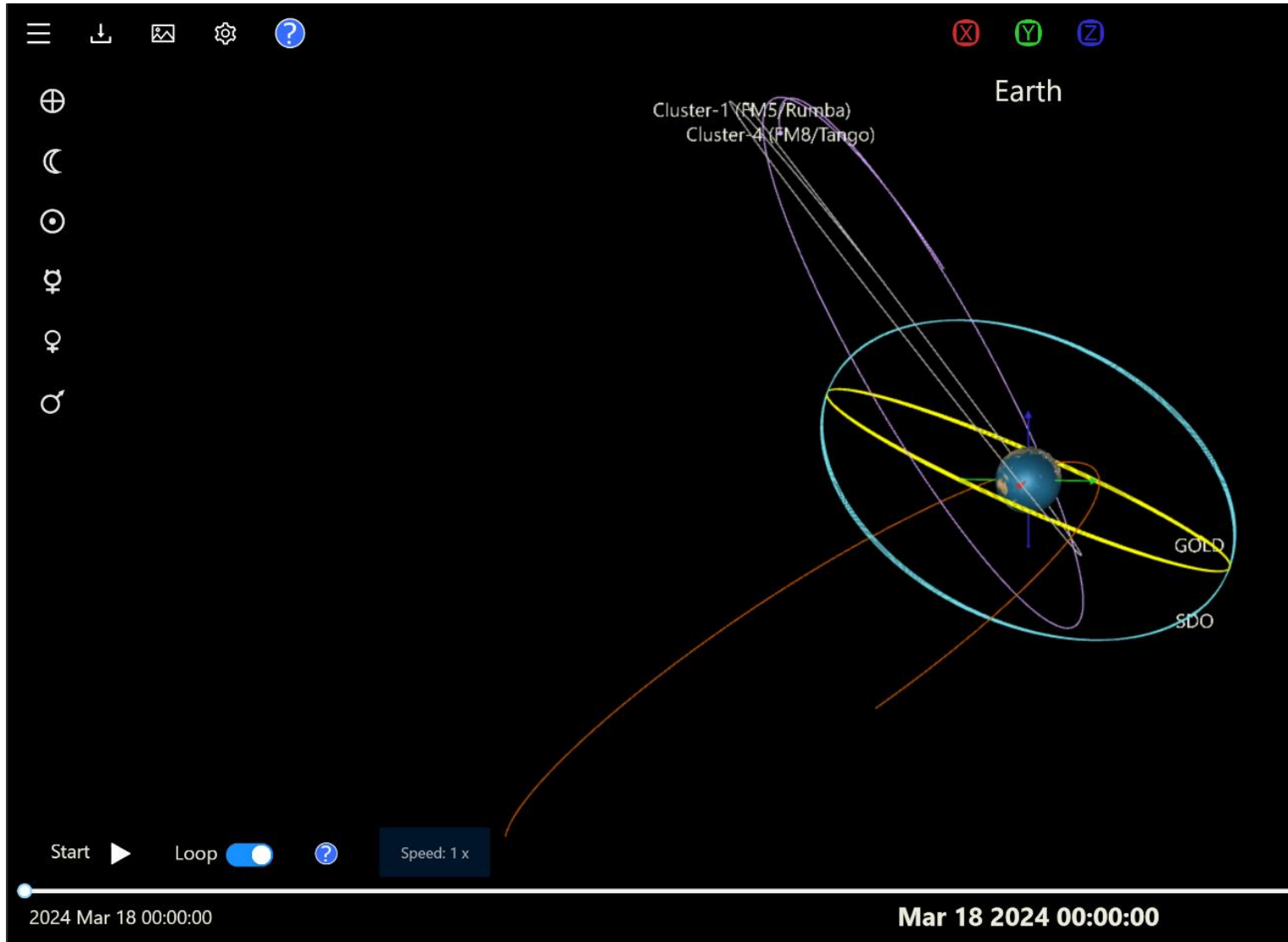
Spacecraft	X	Y	Z
Cluster-1 (FM5/Rumba)	14.7	-6.4	12.3
Cluster-4 (FM8/Tango)	14.0	-5.6	11.6
MMS 2	26.0	-9.9	-9.4
SDO	1.2	5.2	-3.9
GOLD	-4.3	4.6	-2.1

spacecraft positions in Earth Radii (Re) in GSE coordinates.

Start Loop Speed: 1 x

2024 Mar 18 00:00:00 **Mar 18 2024 00:00:00** 2024 Mar 21 00:00:00

4-D Orbit Viewer



4-D Orbit Viewer: Different Coordinates

The screenshot displays the 4-D Orbit Viewer interface. A modal dialog titled "Select A Coordinate System" is open, listing several coordinate systems. The "GSE" option is selected. The interface includes a top navigation bar with icons for menu, download, image, settings, and a highlighted coordinate system icon. A left sidebar contains various celestial body icons. The bottom of the interface features a playback control bar with "Start" and "Loop" buttons, and a timeline showing the date "2024 Apr 09 00:00:00" on the left and "2024 Apr 10 00:00:00" on the right. The right side of the interface shows the "4D Orbit Viewer" title, the NASA logo, and the "SPDF" logo. On the far right, there are several control icons for the viewer, including a "B" icon, an "M" icon, and three coordinate system axes icons (YZ, XZ, XY).

Select A Coordinate System

- GSE Geocentric Solar Ecliptic
- GEI Geocentric Equatorial Inertial
- J2000 Geocentric Equatorial Inertial for epoch J2000.0
- GSM Geocentric Solar Magnetospheric system
- SM Solar Magnetic coordinates
- GEO Geographic coordinate system

Use Earth Centered / Earth rotating reference frame

Done

4D Orbit Viewer

NASA

SPDF

Start Loop

2024 Apr 09 00:00:00

2024 Apr 10 00:00:00

Spacecraft Situation Center Conjunction Query

Spacecraft/Time Range Selection

[Spacecraft Availability & Time Ranges](#)

Satellites	Time Range
ACE Active AE-C AE-D AE-E AEROCUBE-6A AEROCUBE-6B AIM Akebono Alouette1 Alouette2 APEX-MAIN Aqua Arase (ERG) ARIEL-4 ARTEMIS_P1 ARTEMIS_P1 (6-year Predict) ARTEMIS_P2 ARTEMIS_P2 (6-year Predict) ASTRID II	<p>Valid Date/Time Formats:</p> <p>Date yyyy ddd yyyy/mm/dd yyyy-mmm-dd hh.hhhh</p> <p>Time (Optional) hh:mm:ss hh:mm</p> <p>Start Time (inclusive) <input type="text" value="2023 200"/></p> <p>Stop Time (inclusive) <input type="text" value="2023 202"/></p> <p>Query Conjunction Condition Type</p> <p><input checked="" type="radio"/> Ground Station <input type="radio"/> Lead Satellite <input type="radio"/> Region</p>

Satellite Combination
<input checked="" type="radio"/> All satellites <input type="radio"/> At least <input type="text" value="1"/> satellite(s)

Example Using THEMIS Mission

https://sscweb.gsfc.nasa.gov/examples/THEMIS_queries/

[themis_conjunction2](#) Magnetic conjunction of THEMIS-5 (lead satellite) with at least 3 other THEMIS

[themis_fast2](#) Magnetic conjunction of at least 2 THEMIS satellites with FAST (lead satellite)

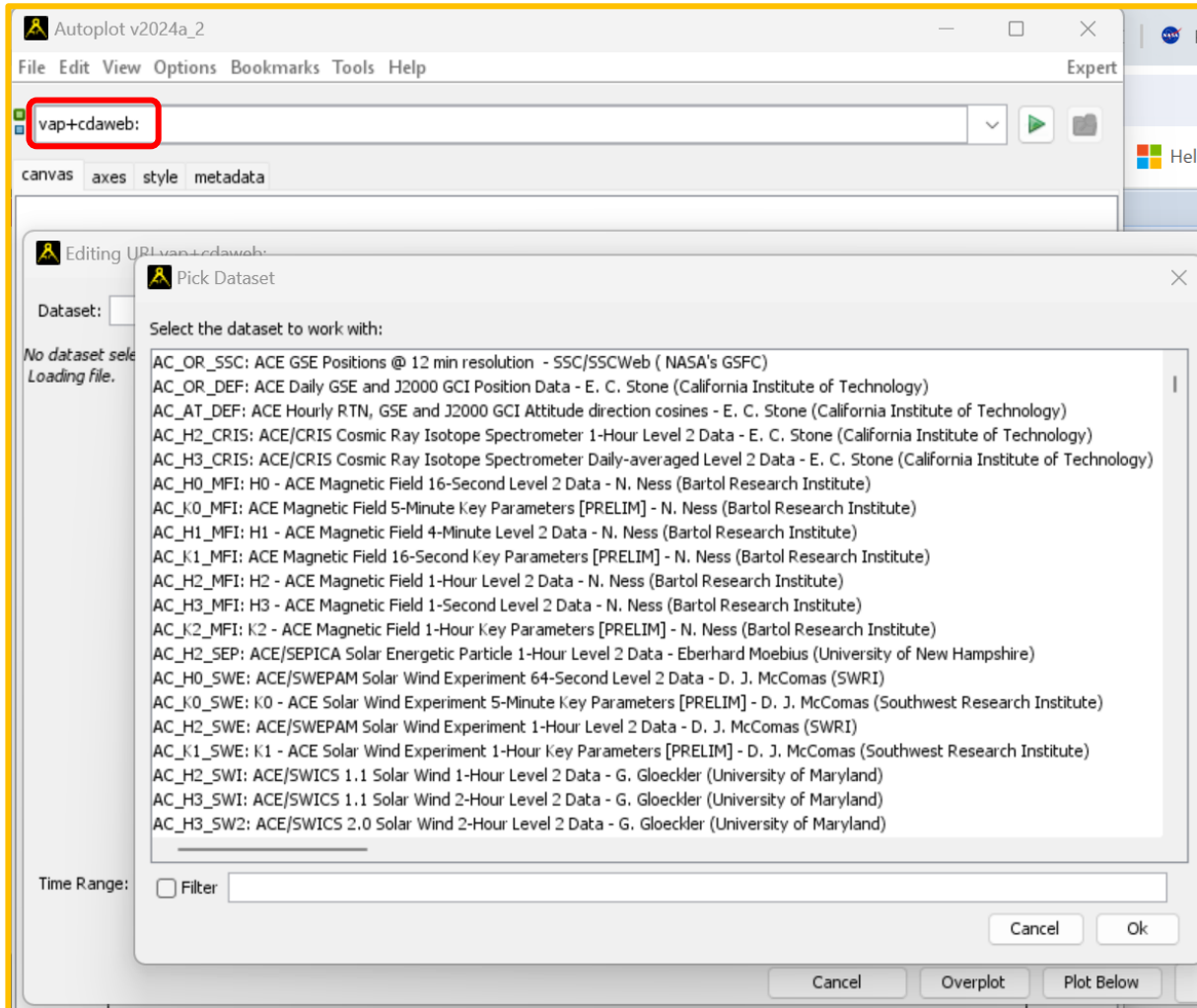
[themis_goes11a](#) Magnetic conjunction of at least two satellites (THEMIS 1-5, GOES 13) with GOES 11

[themis_goes13a](#) Magnetic conjunction of at least two satellites (THEMIS 1-5, GOES 11) with GOES 13

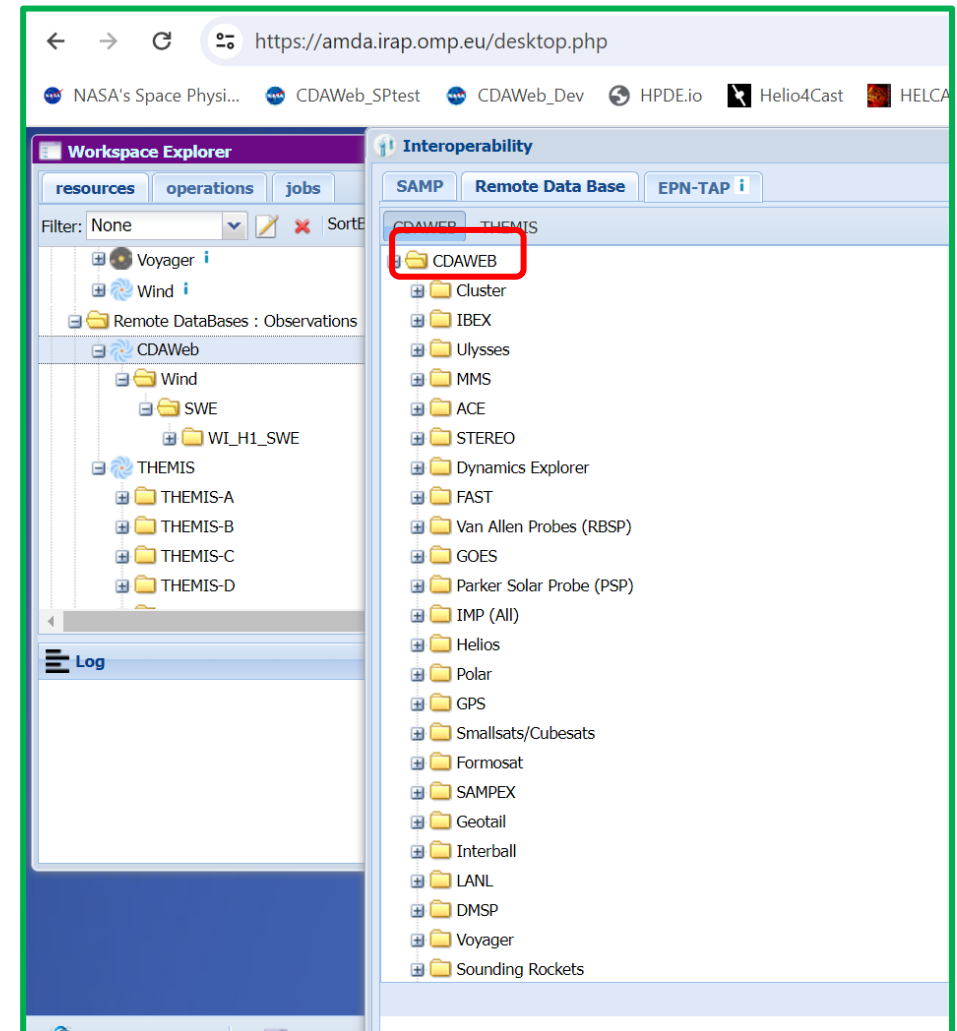
[themis_ground_stations1](#) Magnetic conjunction of at least 2 THEMIS satellites with one of 4 THEMIS ground stations during 2008 doy=1-5

CDAWeb Datasets Are Available at HelioCloud, Autoplot, AMDA, etc.

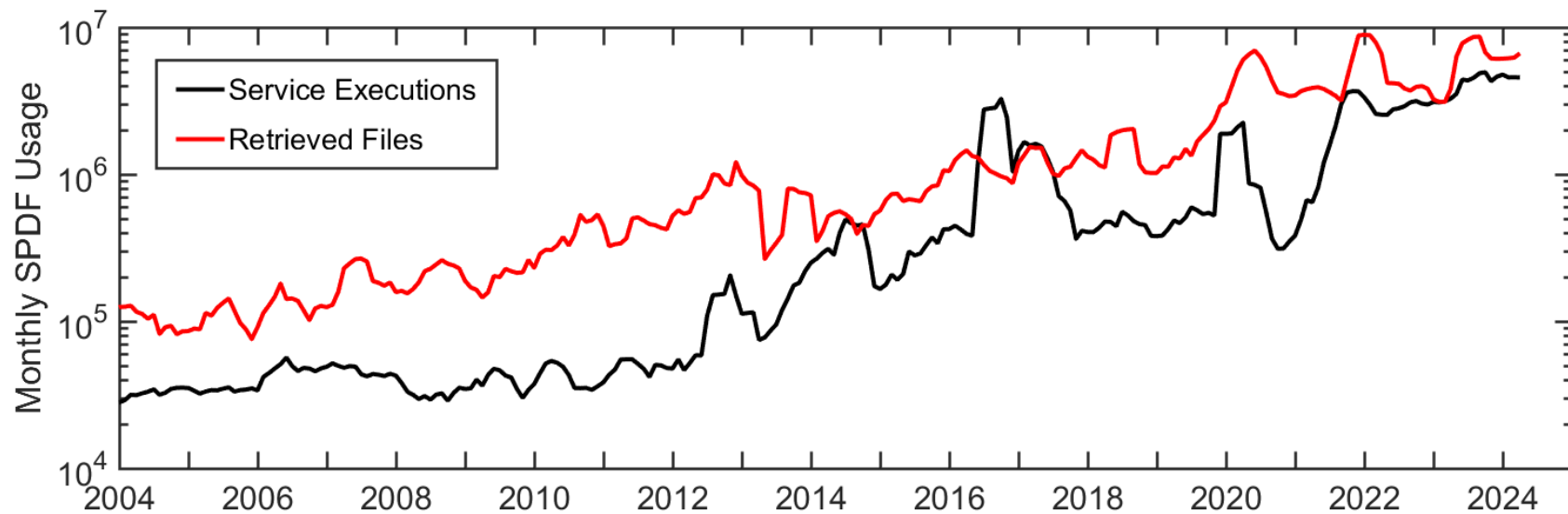
Autoplot



Automated Multi-Dataset Analysis (AMDA)



Summary



- SPDF archives and serves observational space physics data relevant to NASA heliophysics science objectives in order to promote correlative and collaborative research across discipline and mission boundaries
- SPDF provides three main science-enabling services: CDAWeb, SSCWeb, and COHWeb
- SPDF welcomes community feedback/input to improve our services
 - Updating the ISTP metadata standards
 - Serving research generated data and plots
 - Developing more interactive data explorer (e.g., making multi-dimensional data more digestible rather than depending on heavy usage of additional software packages)