# On-Demand Analysis Tools for Space Science (Hands-On Activities)

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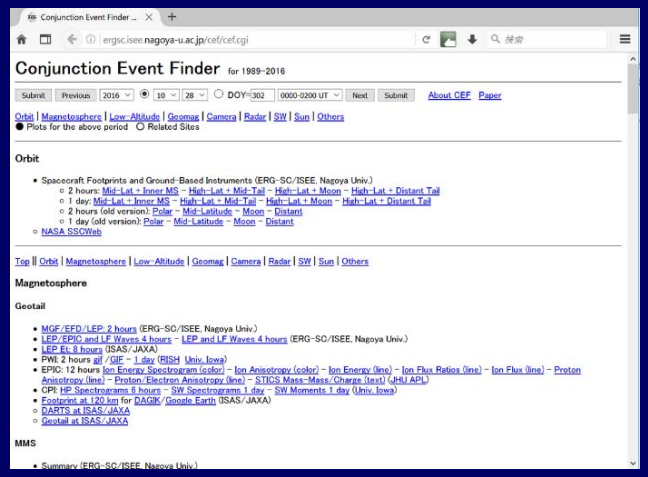
# ■ Introduction

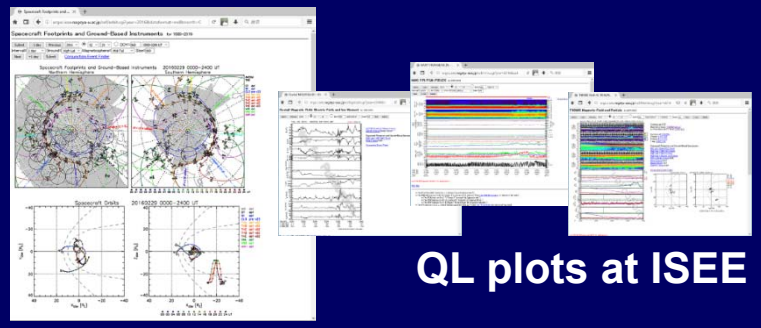
- In space science, we often need to check various kinds of data from various spacecraft-borne and ground-based instruments.
- To check and analyze data, we use:
  - Quick-look (QL) or ready-made plots
    - the easiest, quickest way to check data
    - CEF, IUGONET Type-A
  - On-demand plots-making tools
    - an easy way to check data and make plots
    - NASA CDAWeb, NASA SSCWeb, IUGONET Type-A
  - Analysis software
    - not so easy, for advanced serious analysis
    - SPEDAS

# ■ Conjunction Event Finder (CEF)

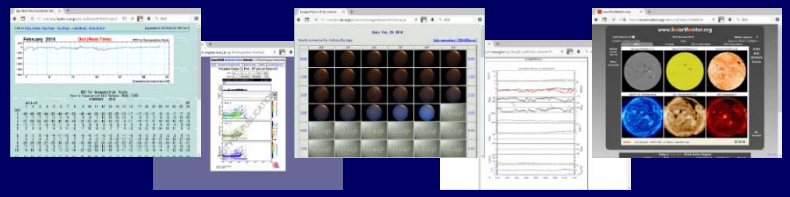
- https://ergsc.isee.nagoya-u.ac.jp/cef/cef.cgi
- Miyashita et al. (2011, doi:10.5047/eps.2011.01.003)
- Links to QL plots for various kinds of spacecraft and ground-based observations for a selected period.
- Browse QL plots one after another simply by clicking.
- Useful for finding conjunction events and planning future collaborations between spacecraft and ground-based observations.




>100 links to QL plots available at ISEE and other institute



QL plots at ISEE



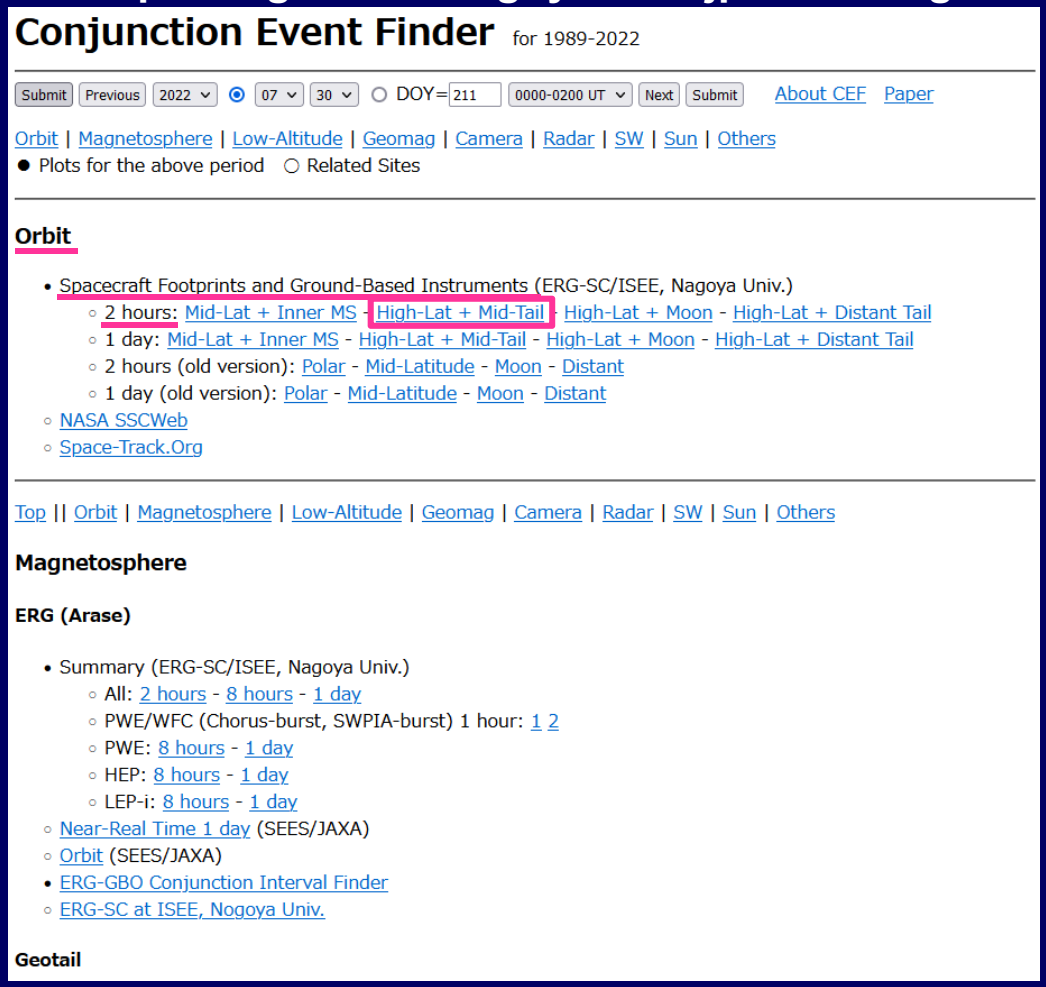
QL plots at other institutes

# ■ How to Use CEF (1-1)

- If you want to find an interesting event from a specific spacecraft or ground-based instrument
  - Open the website of QL plots (via the CEF).
  - Browse them one after another.

- Example:
  To find an interesting spacecraft conjunction
  - Open the CEF.
  - Click the link to "High-Lat + Mid-Tail" at "Orbit"
    - "Spacecraft footprints..."
    - "2 hours".

https://ergsc.isee.nagoya-u.ac.jp/cef/cef.cgi

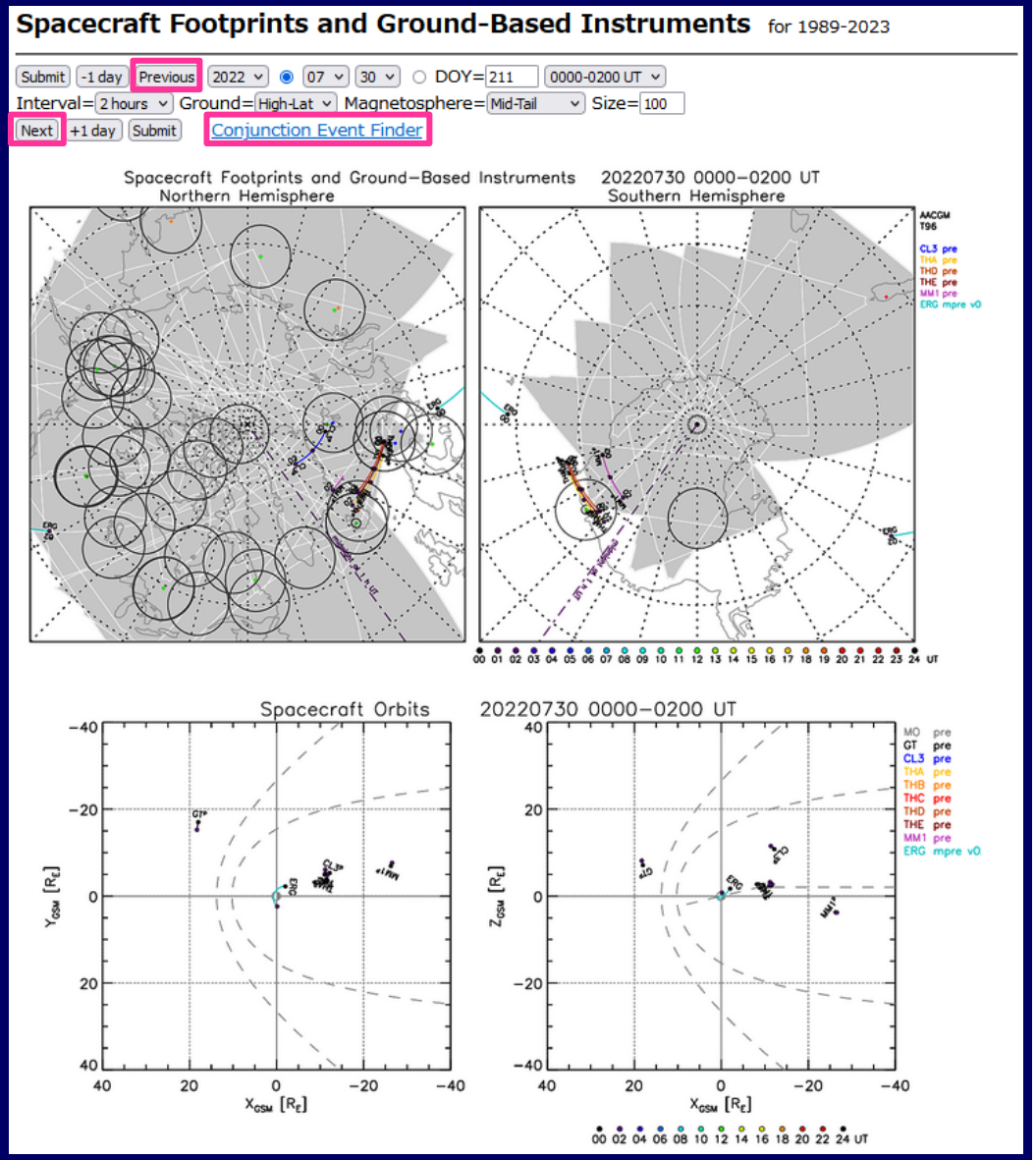


# ■ How to Use CEF (1-2)

- Click the "**Next**" button to show plots for the next interval.
- Click the "**Previous**" button to show plots for the previous interval.

- If you find an interesting event
- Click the link to "**Conjunction Event Finder**" to browse QL plots of various kinds of data.

https://ergsc.isee.nagoya-u.ac.jp/cef/orbit.cgi



# ■ How to Use CEF (2-1)

- If you already have an event or a time interval of interest

(1) Open the CEF (https://ergsc.isee.nagoya-u.ac.jp/cef/cef.cgi).

(2) Select the date and time period of interest at the top and click the "Submit" button, and the links to QL plots for the selected period will be generated.

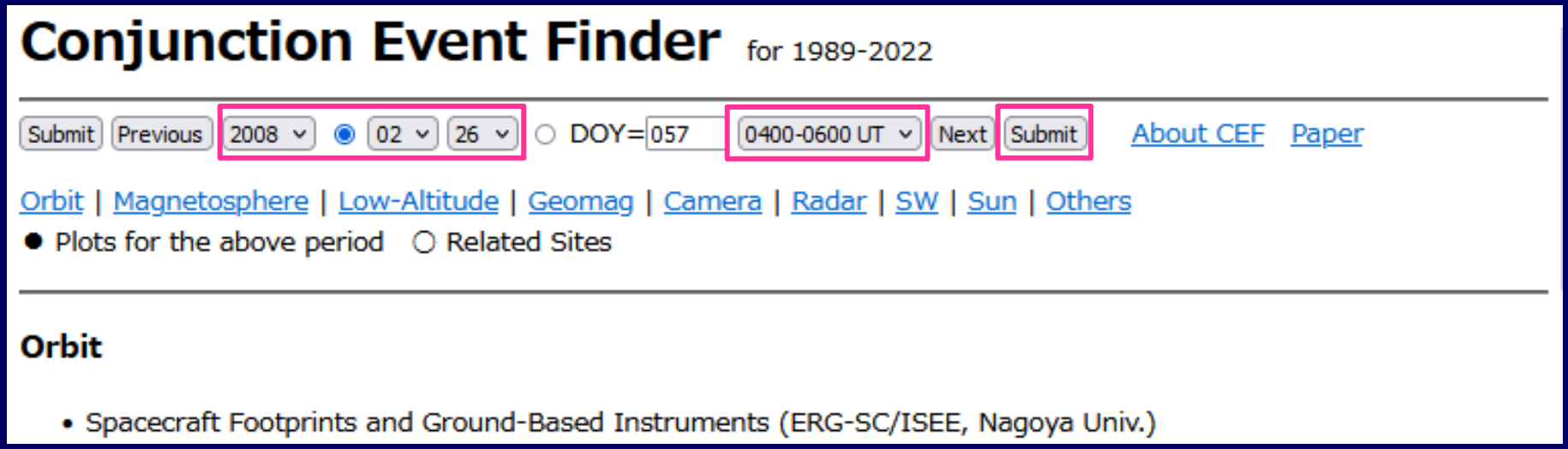
(3) Scroll down in the CEF and click links to spacecraft and instruments of interest.

- Note that some links are dead, because the selected projects do not cover the selected period, the data are unavailable for some reason, and/or the CEF has not been updated yet.
  Even so, the CEF is still useful.

# ■ How to Use CEF (2-2)

- Example events: The ~0357 UT and ~0450 UT substorms on 26 February 2008
  (Miyashita et al., 2018, doi:10.1029/2018GL078589;
  Angelopoulos et al, 2008, doi:10.1126/science.1160495)

(1) Open the CEF (https://ergsc.isee.nagoya-u.ac.jp/cef/cef.cgi).
(2) Select "2008", "02", "26", and "0400-0600 UT" at the top and click the "Submit" button, and the links to QL plots for the selected period will be generated.



# ■ How to Use CEF (2-3)

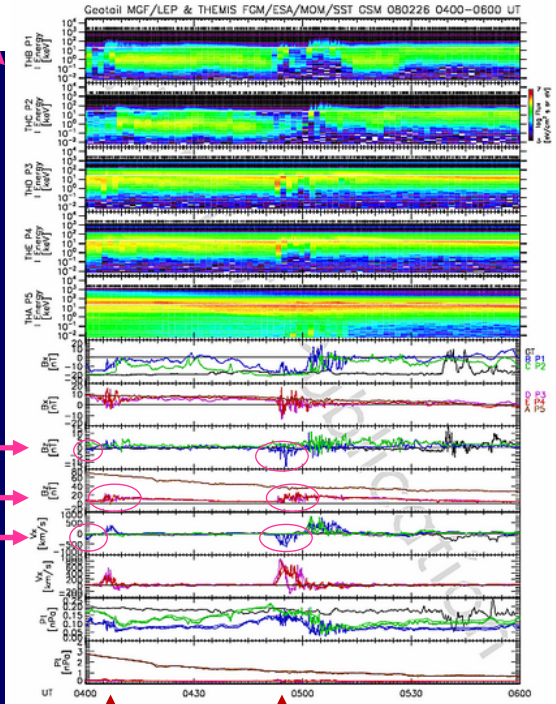
**(3-1) Scroll down the CEF page and click the link to "Multi-SC+Geotail" at "THEMIS" "L2 FGM/ESA/SST: 2 hours".**

**THEMIS**

- L2 FGM/ESA/SST: 2 hours Multi-SC+Geotail A B C D E (ERG-SC/ISEE, Nagoya Univ.)
- Summary: 2 hours A B C D E — 6 hours A B C D E — 1 day A B C D E (UCB SSL)
- THEMIS Mission Site at UCB SSL
- THEMIS Mission Site at NASA
- Taiwan AIDA for THEMIS at NCU
- ARTEMIS Mission Site at UCB SSL

**THEMIS Magnetic Field and Particle** for 2007-2022

Submit | -1 day | Previous | 2008 | 02 | 26 | DOY=057 | 0400-0600 UT | Multi-SC | Size=100 | Next | +1 day | Submit

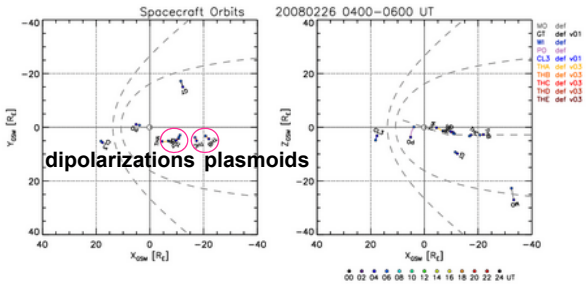



Summary at ISEE
Multi-SC 2 hours: THEMIS+Geotail
L2 FGM/ESA/SST 2 hours: A B C D E

Summary at UCB SSL
2 hours: A B C D E
6 hours: A B C D E
1 day: A B C D E

Spacecraft Footprints and Ground-Based Instruments:
Mid-Lat + Inner MS 2 hours
High-Lat + Mid-Tail 2 hours
High-Lat + Moon 2 hours
High-Lat + Distant Tail 2 hours
Mid-Latitude 2 hours (old)
Polar 2 hours (old)
Moon 2 hours (old)
Distant 2 hours (old)

Conjunction Event Finder



# ■ How to Use CEF (2-4)

**(3-2) Scroll down the CEF page or click the link "Camera", and click the link to "Keograms" at "THEMIS GBO ASI".**

Top || Orbit | Magnetosphere | Low-Altitude | Geomag | Camera | Radar | SW | Sun | Others

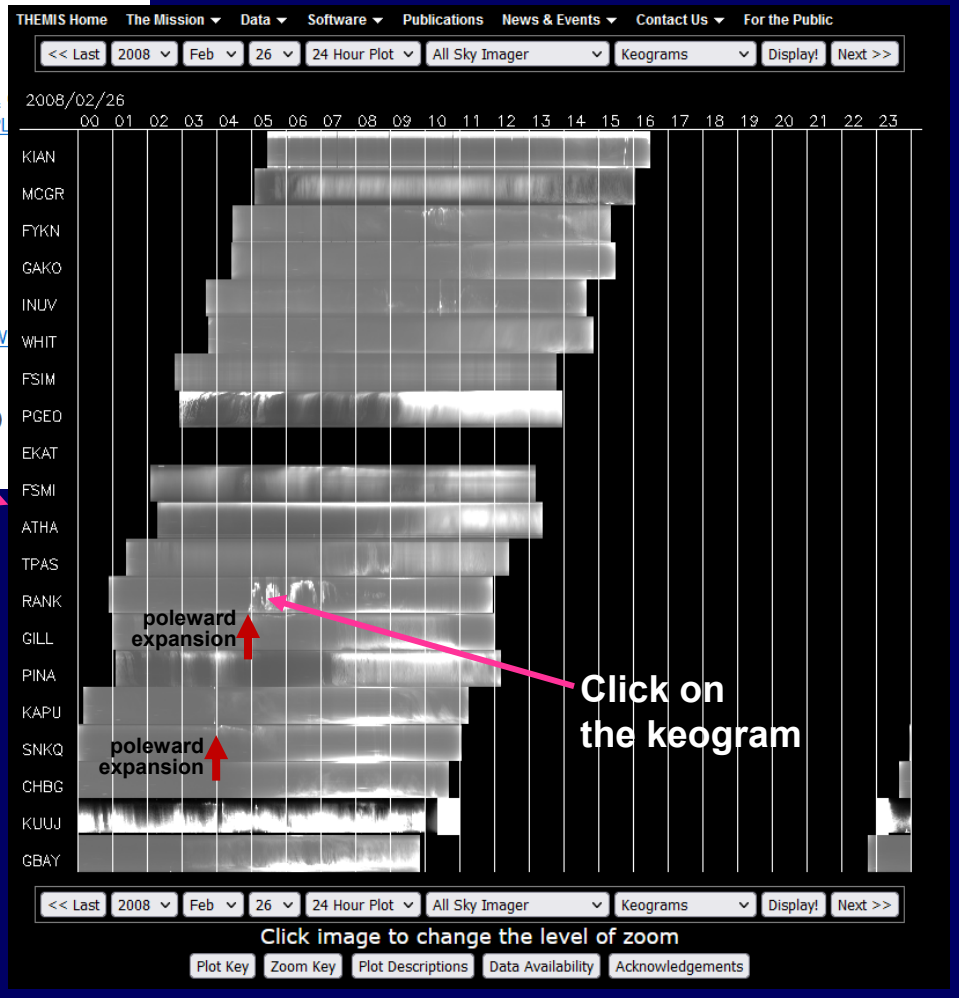
**Camera/Riometer/Ionosonde**

**Spacecraft-Borne**

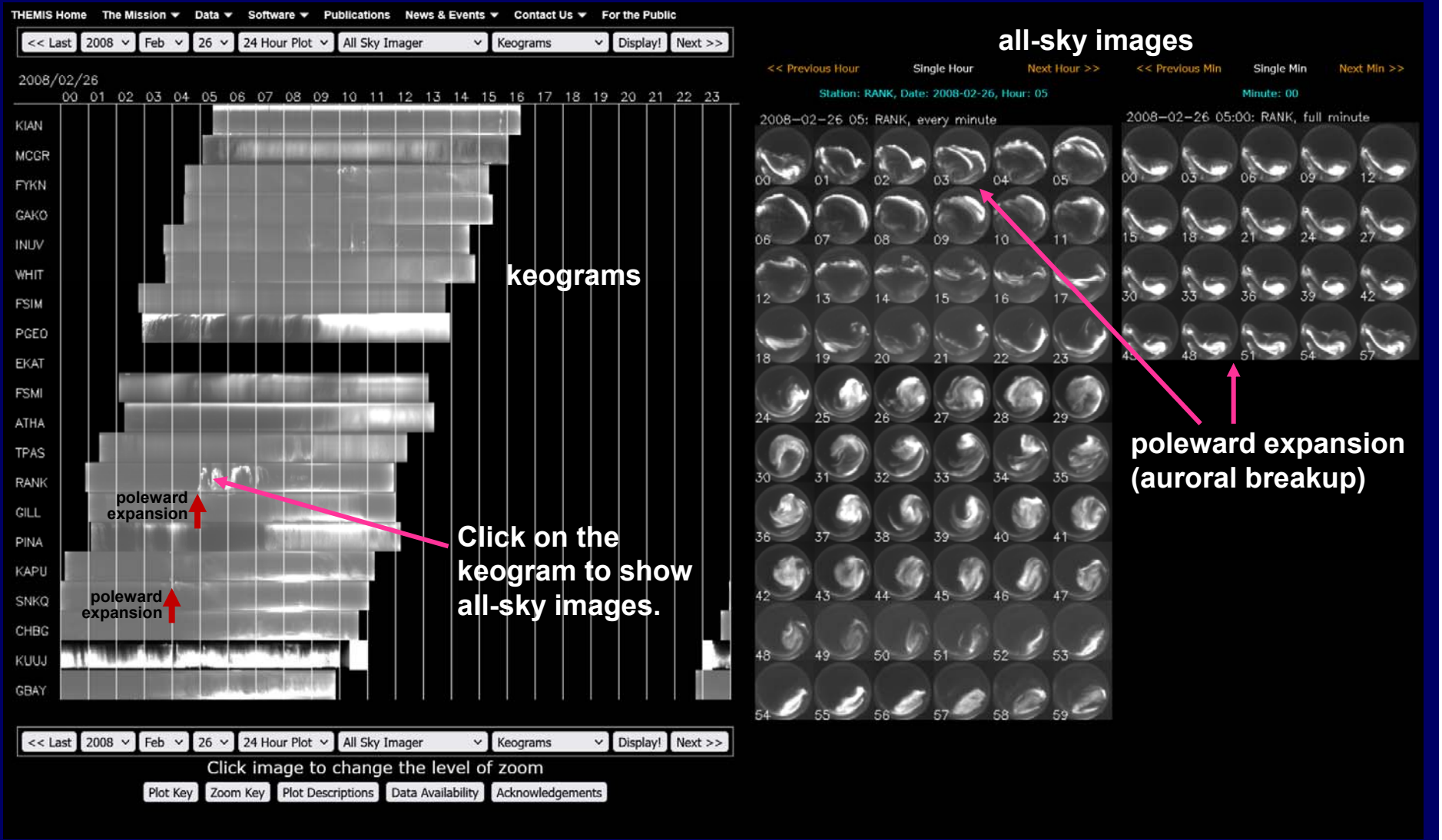
- Polar: UVI (NASA MSFC) - VIS 1 day (Univ. Iowa) - PIXIE 1 day Low High (Lockheed Martin)
- IMAGE FUV Auroral Images: 1 hour WIC 1 2 - S13 1 2 - S12 1 2 (NASA CDAWeb) — 1 day 0 1 2
- TIMED: GUVI Maps of Auroral Electron Mean Energy and Energy Flux 1 day (JHU APL) — JHU APL

**Ground-Based**

- OMTI Japanese Meridian and Canada: Map (ISEE, Nagoya Univ.)
- FMI ASC Northern Europe: Keogram 1 day previous day selected day - Map (FMI)
- NIPR ASC Norway Tromso: 1 Day (NIPR)
- NIPR ASC Svalbard Longyearbyen: 1 Day - Map (UNIS and NIPR)
- PsA + PWING EMCCD Northern Europe & Alaska: 1 Day (ERG-SC/ISEE, Nagoya Univ.) — PsA, PW
- THEMIS GBO ASI Canada-Alaska: 1 day Mosaic Summary Keograms REGO Keograms (UCB SSL)
- UofC Space Physics Data Portal Canada-Alaska: all instruments 1 day (Univ. Calgary)
- NORSTAR Canada: MSP 12 hours Churchill Line 486 nm all 557 nm all 630 nm all (Univ. Calgary)
- Univ. Calgary MSI Summary 1 hour (Univ. Calgary)
- GAIA Canada and Northern Europe



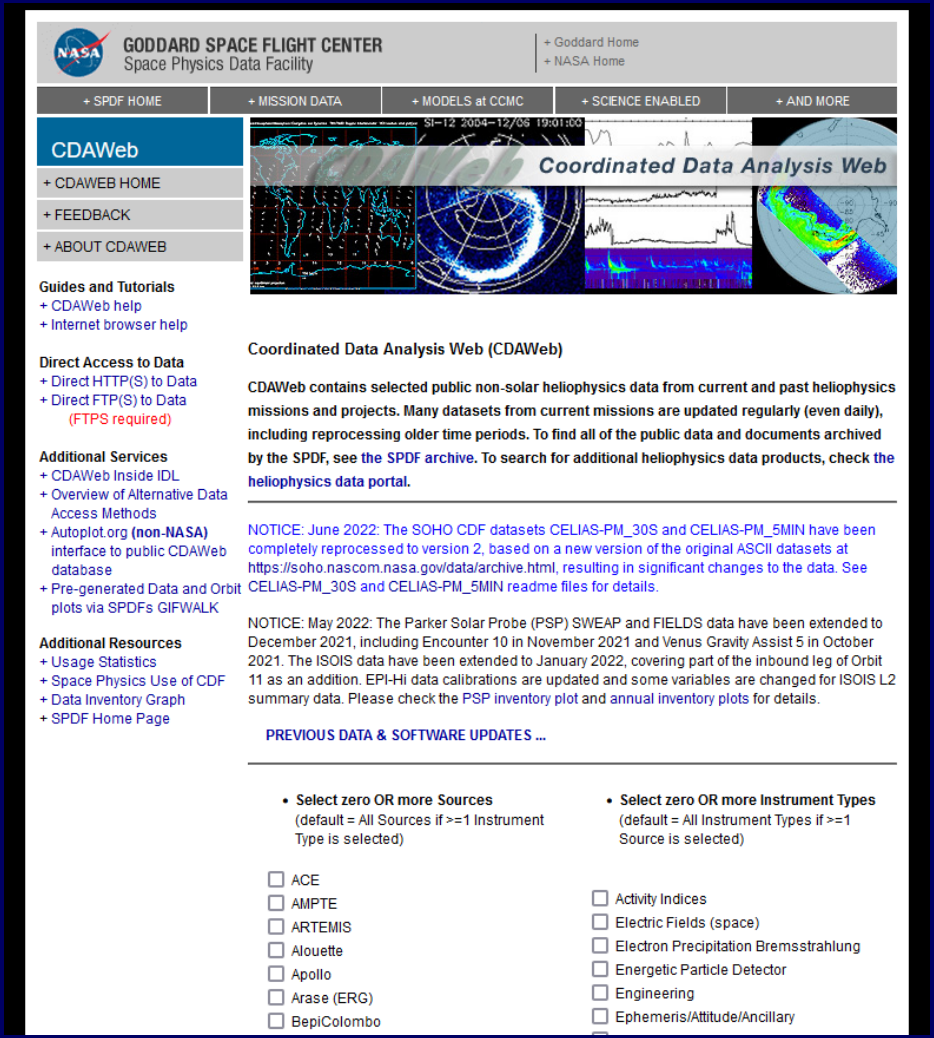
# ■ How to Use CEF (2-5)



# ■ NASA CDAWeb

- Coordinated Data Analysis Web
- https://cdaweb.gsfc.nasa.gov/
- Mainly for spacecraft data.
- Can make plots on demand and also download data.
- Can combine different data sets and specify a period flexibly.

(1) Select spacecraft and instrument types.
(2) Select data set.
(3) Input a period and select plot options and data parameters.

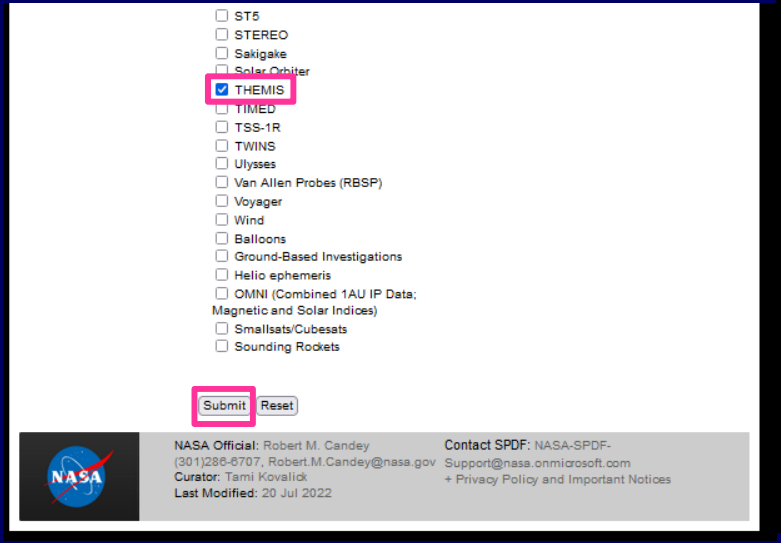


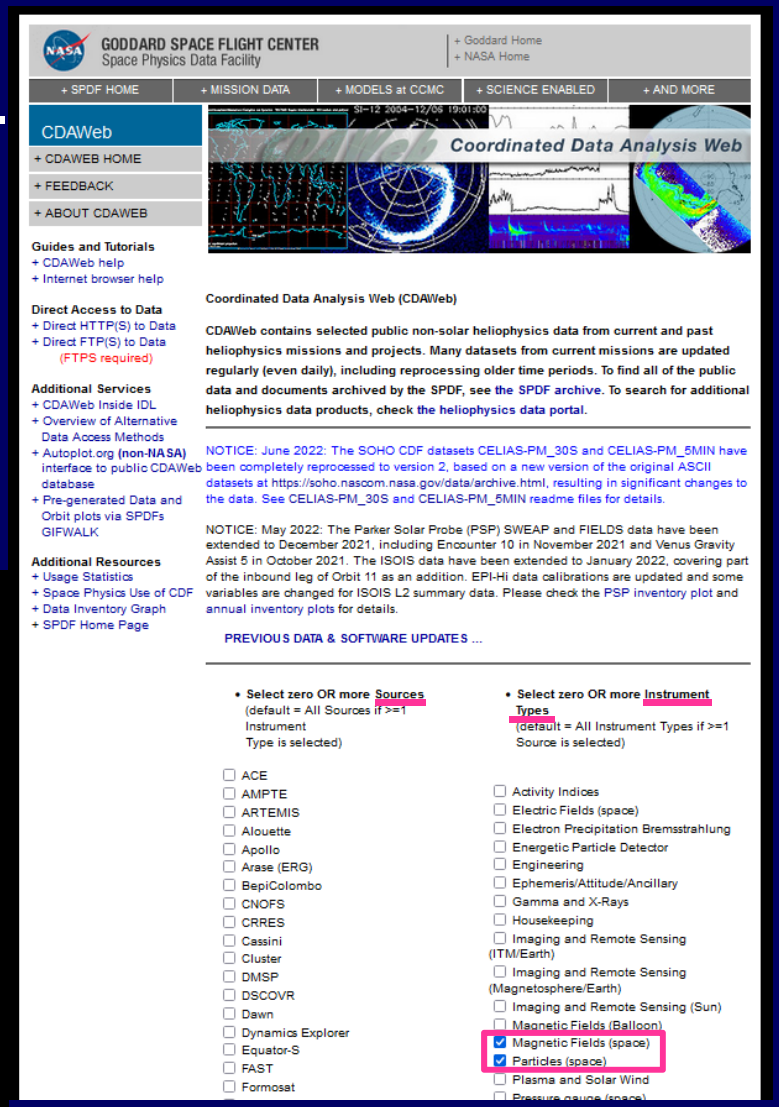
# How to Use CDAWeb (1)

- Example events: The ~0357 UT and ~0450 UT substorms on 26 February 2008

(1) Select spacecraft and instrument types.

- Select "THEMIS" from "Sources" (left), and "Magnetic Fields (space)" and "Particles (space)" from "Instrument Types (right).
- Click the "Submit" button.

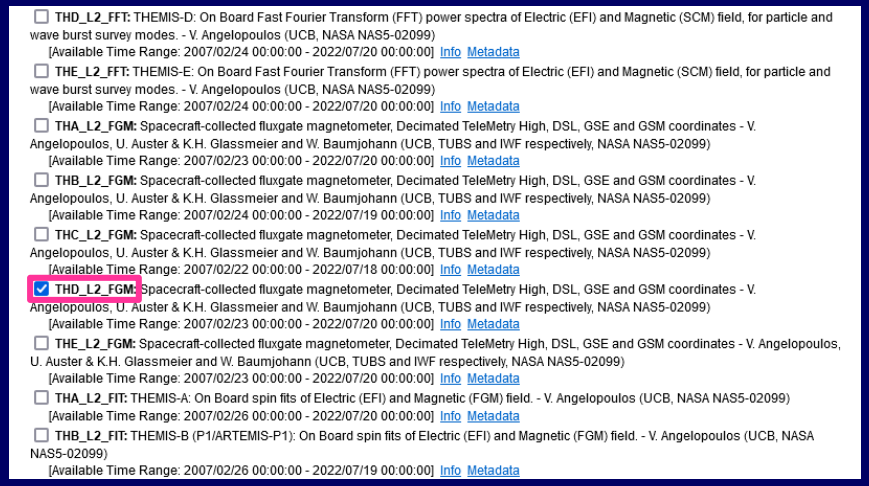


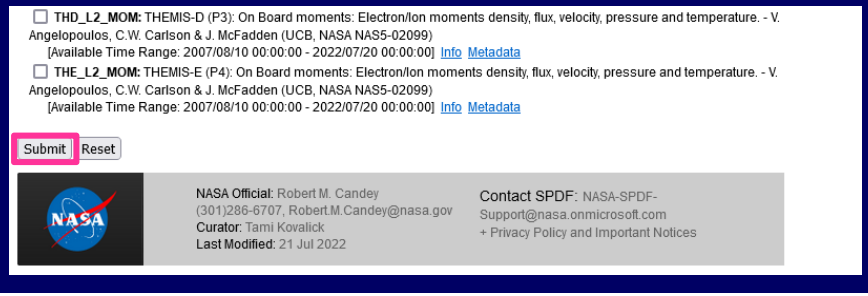



# ■ How to Use CDAWeb (2)

(2) Select data set.

- Click “Click here to CLEAR All checkboxes”.
- Select “THD_L2_ESA” and “THD_L2_FGM”.
- Click the “Submit” button.

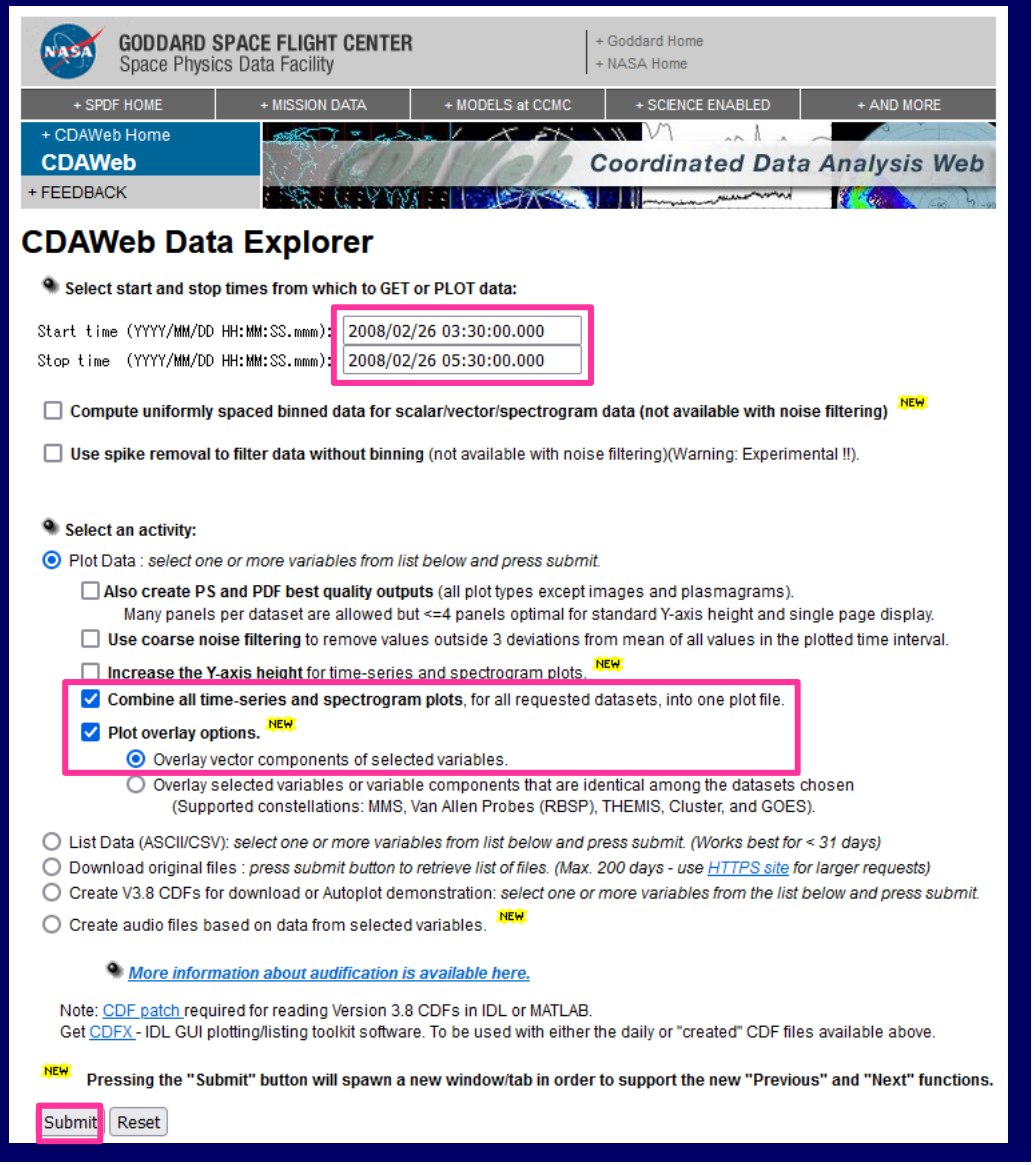



# ■ How to Use CDAWeb (3-1)

(3) Input a period and select plot options and data parameters.

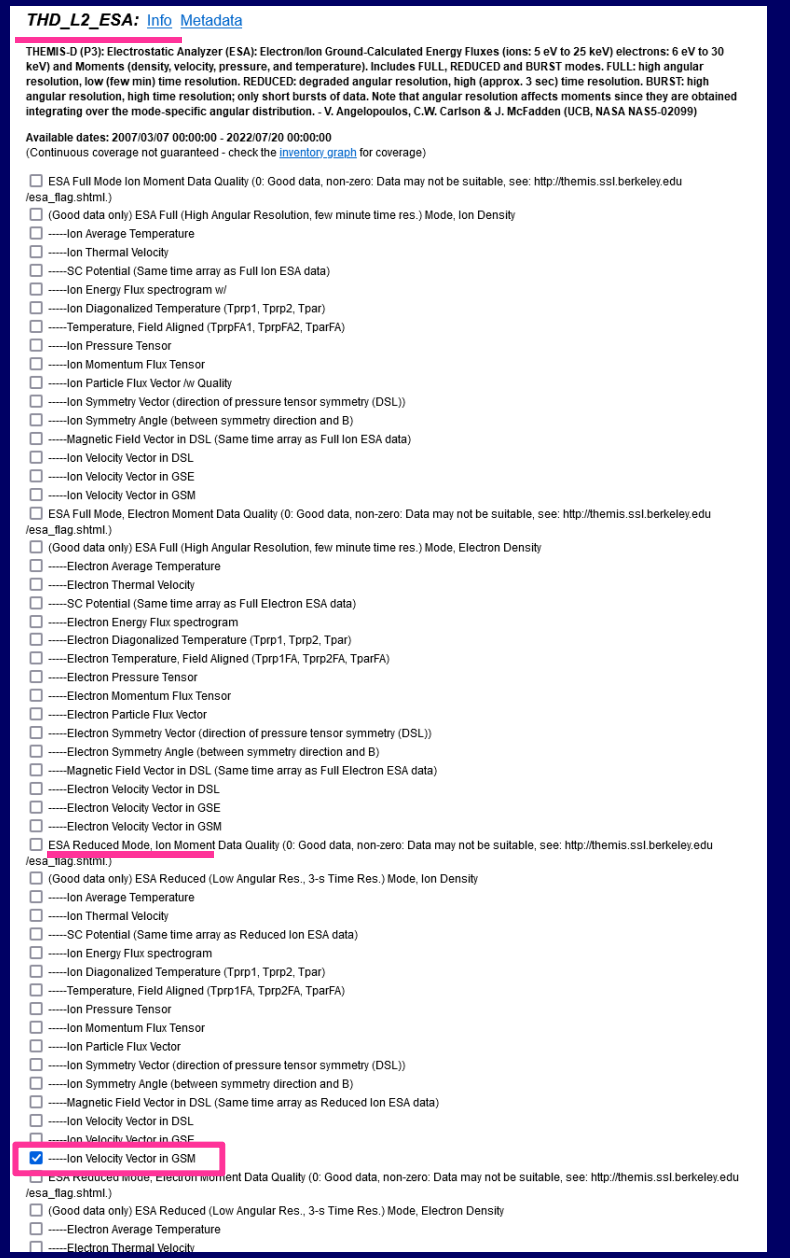
- Input a period.
  - Start time:
    2008/02/26 03:30:00.000
  - Stop time:
    2008/02/26 05:30:00.000
- Select plot options.
  - Check "Combine all time-series ... into one plot file".
  - Check "Plot overlay options" and then select "Overlay vector components of selected variables".
- Note that there are several other options, including downloading the data.



# ■ How to Use CDAWeb (3-2)

- Select data parameters.
  - For THD_L2_ESA:
    Select "Ion Velocity Vector in GSM" under "ESA Reduced Mode, Ion Moment".
  - For THD_L2_FGM:
    Select "FGS (spin-resolution/~3 sec) magnetic field B in XYZ GSM coordinates" under "FGM-FGS Data".

- Click the "Submit" button at the top or the bottom.

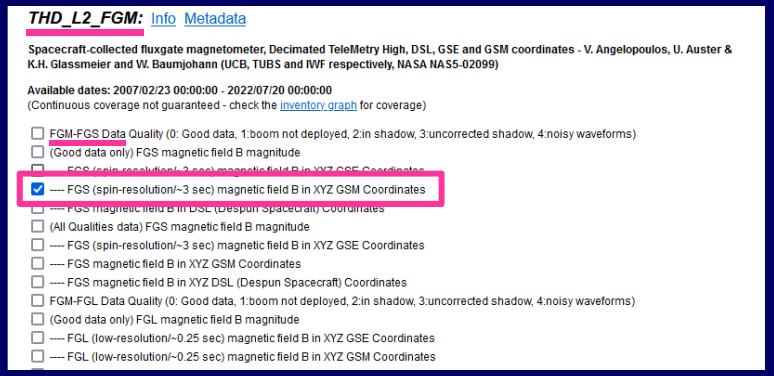


***THD_L2_ESA:*** Info Metadata

**THEMIS-D (P3): Electrostatic Analyzer (ESA): Electron/Ion Ground-Calculated Energy Fluxes (ions: 5 eV to 25 keV) electrons: 6 eV to 30 keV) and Moments (density, velocity, pressure, and temperature). Includes FULL, REDUCED and BURST modes. FULL: high angular resolution, low (few min) time resolution. REDUCED: degraded angular resolution, high (approx. 3 sec) time resolution. BURST: high angular resolution, high time resolution; only short bursts of data. Note that angular resolution affects moments since they are obtained integrating over the mode-specific angular distribution. - V. Angelopoulos, C.W. Carlson & J. McFadden (UCB, NASA NAS5-02099)**

**Available dates: 2007/03/07 00:00:00 - 2022/07/20 00:00:00**
(Continuous coverage not guaranteed - check the inventory graph for coverage)

- [ ] ESA Full Mode Ion Moment Data Quality (0: Good data, non-zero: Data may not be suitable, see: http://themis.ssl.berkeley.edu /esa_flag.shtml.)
- [ ] (Good data only) ESA Full (High Angular Resolution, few minute time res.) Mode, Ion Density
- [ ] -----Ion Average Temperature
- [ ] -----Ion Thermal Velocity
- [ ] -----SC Potential (Same time array as Full Ion ESA data)
- [ ] -----Ion Energy Flux spectrogram w/
- [ ] -----Ion Diagonalized Temperature (Tprp1, Tprp2, Tpar)
- [ ] -----Temperature, Field Aligned (TprpFA1, TprpFA2, TparFA)
- [ ] -----Ion Pressure Tensor
- [ ] -----Ion Momentum Flux Tensor
- [ ] -----Ion Particle Flux Vector /w Quality
- [ ] -----Ion Symmetry Vector (direction of pressure tensor symmetry (DSL))
- [ ] -----Ion Symmetry Angle (between symmetry direction and B)
- [ ] -----Magnetic Field Vector in DSL (Same time array as Full Ion ESA data)
- [ ] -----Ion Velocity Vector in DSL
- [ ] -----Ion Velocity Vector in GSE
- [ ] -----Ion Velocity Vector in GSM
- [ ] ESA Full Mode, Electron Moment Data Quality (0: Good data, non-zero: Data may not be suitable, see: http://themis.ssl.berkeley.edu /esa_flag.shtml.)
- [ ] (Good data only) ESA Full (High Angular Resolution, few minute time res.) Mode, Electron Density
- [ ] -----Electron Average Temperature
- [ ] -----Electron Thermal Velocity
- [ ] -----SC Potential (Same time array as Full Electron ESA data)
- [ ] -----Electron Energy Flux spectrogram
- [ ] -----Electron Diagonalized Temperature (Tprp1, Tprp2, Tpar)
- [ ] -----Electron Temperature, Field Aligned (Tprp1FA, Tprp2FA, TparFA)
- [ ] -----Electron Pressure Tensor
- [ ] -----Electron Momentum Flux Tensor
- [ ] -----Electron Particle Flux Vector
- [ ] -----Electron Symmetry Vector (direction of pressure tensor symmetry (DSL))
- [ ] -----Electron Symmetry Angle (between symmetry direction and B)
- [ ] -----Magnetic Field Vector in DSL (Same time array as Full Electron ESA data)
- [ ] -----Electron Velocity Vector in DSL
- [ ] -----Electron Velocity Vector in GSE
- [ ] -----Electron Velocity Vector in GSM
- [ ] ESA Reduced Mode, Ion Moment Data Quality (0: Good data, non-zero: Data may not be suitable, see: http://themis.ssl.berkeley.edu /esa_flag.shtml.)
- [ ] (Good data only) ESA Reduced (Low Angular Res., 3-s Time Res.) Mode, Ion Density
- [ ] -----Ion Average Temperature
- [ ] -----Ion Thermal Velocity
- [ ] -----SC Potential (Same time array as Reduced Ion ESA data)
- [ ] -----Ion Energy Flux spectrogram
- [ ] -----Ion Diagonalized Temperature (Tprp1, Tprp2, Tpar)
- [ ] -----Temperature, Field Aligned (Tprp1FA, Tprp2FA, TparFA)
- [ ] -----Ion Pressure Tensor
- [ ] -----Ion Momentum Flux Tensor
- [ ] -----Ion Particle Flux Vector
- [ ] -----Ion Symmetry Vector (direction of pressure tensor symmetry (DSL))
- [ ] -----Ion Symmetry Angle (between symmetry direction and B)
- [ ] -----Magnetic Field Vector in DSL (Same time array as Reduced Ion ESA data)
- [ ] -----Ion Velocity Vector in DSL
- [ ] -----Ion Velocity Vector in GSE
- [x] -----Ion Velocity Vector in GSM
- [ ] ESA Reduced Mode, Electron Moment Data Quality (0: Good data, non-zero: Data may not be suitable, see: http://themis.ssl.berkeley.edu /esa_flag.shtml.)
- [ ] (Good data only) ESA Reduced (Low Angular Res., 3-s Time Res.) Mode, Electron Density
- [ ] -----Electron Average Temperature
- [ ] -----Electron Thermal Velocity



***THD_L2_FGM:*** Info Metadata

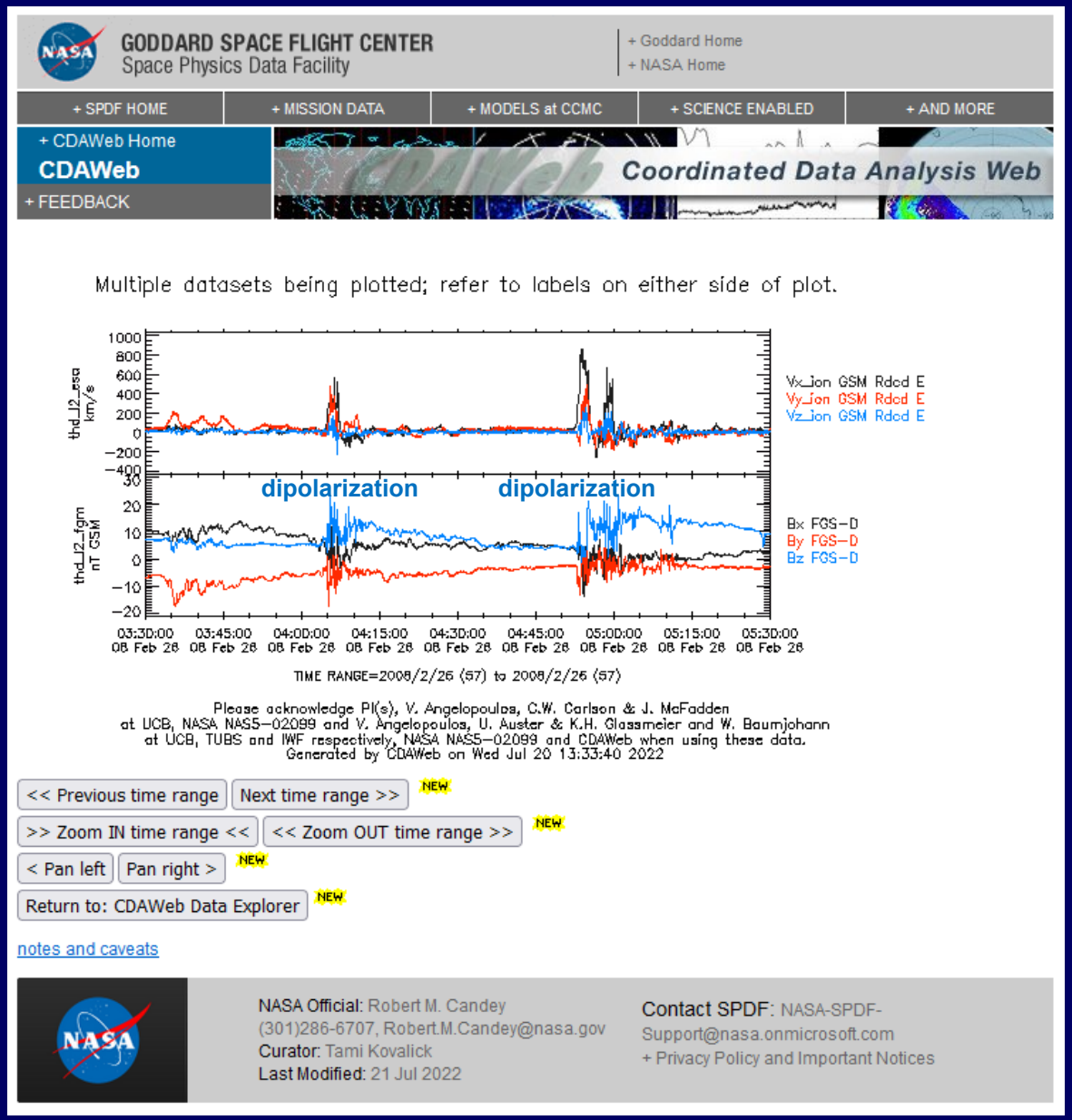
**Spacecraft-collected fluxgate magnetometer, Decimated TeleMetry High, DSL, GSE and GSM coordinates - V. Angelopoulos, U. Auster & K.H. Glassmeier and W. Baumjohann (UCB, TUBS and IWF respectively, NASA NAS5-02099)**

**Available dates: 2007/02/23 00:00:00 - 2022/07/20 00:00:00**
(Continuous coverage not guaranteed - check the inventory graph for coverage)

- [ ] FGM-FGS Data Quality (0: Good data, 1:boom not deployed, 2:in shadow, 3:uncorrected shadow, 4:noisy waveforms)
- [ ] (Good data only) FGS magnetic field B magnitude
- [ ] ---- FGS (spin-resolution/~3 sec) magnetic field B in XYZ GSE Coordinates
- [x] ---- FGS (spin-resolution/~3 sec) magnetic field B in XYZ GSM Coordinates
- [ ] ---- FGS magnetic field B in XYZ DSL (Despun Spacecraft) Coordinates
- [ ] (All Qualities data) FGS magnetic field B magnitude
- [ ] ---- FGS (spin-resolution/~3 sec) magnetic field B in XYZ GSE Coordinates
- [ ] ---- FGS magnetic field B in XYZ GSM Coordinates
- [ ] ---- FGS magnetic field B in XYZ DSL (Despun Spacecraft) Coordinates
- [ ] FGM-FGL Data Quality (0: Good data, 1:boom not deployed, 2:in shadow, 3:uncorrected shadow, 4:noisy waveforms)
- [ ] (Good data only) FGL magnetic field B magnitude
- [ ] ---- FGL (low-resolution/~0.25 sec) magnetic field B in XYZ GSE Coordinates
- [ ] ---- FGL (low-resolution/~0.25 sec) magnetic field B in XYZ GSM Coordinates

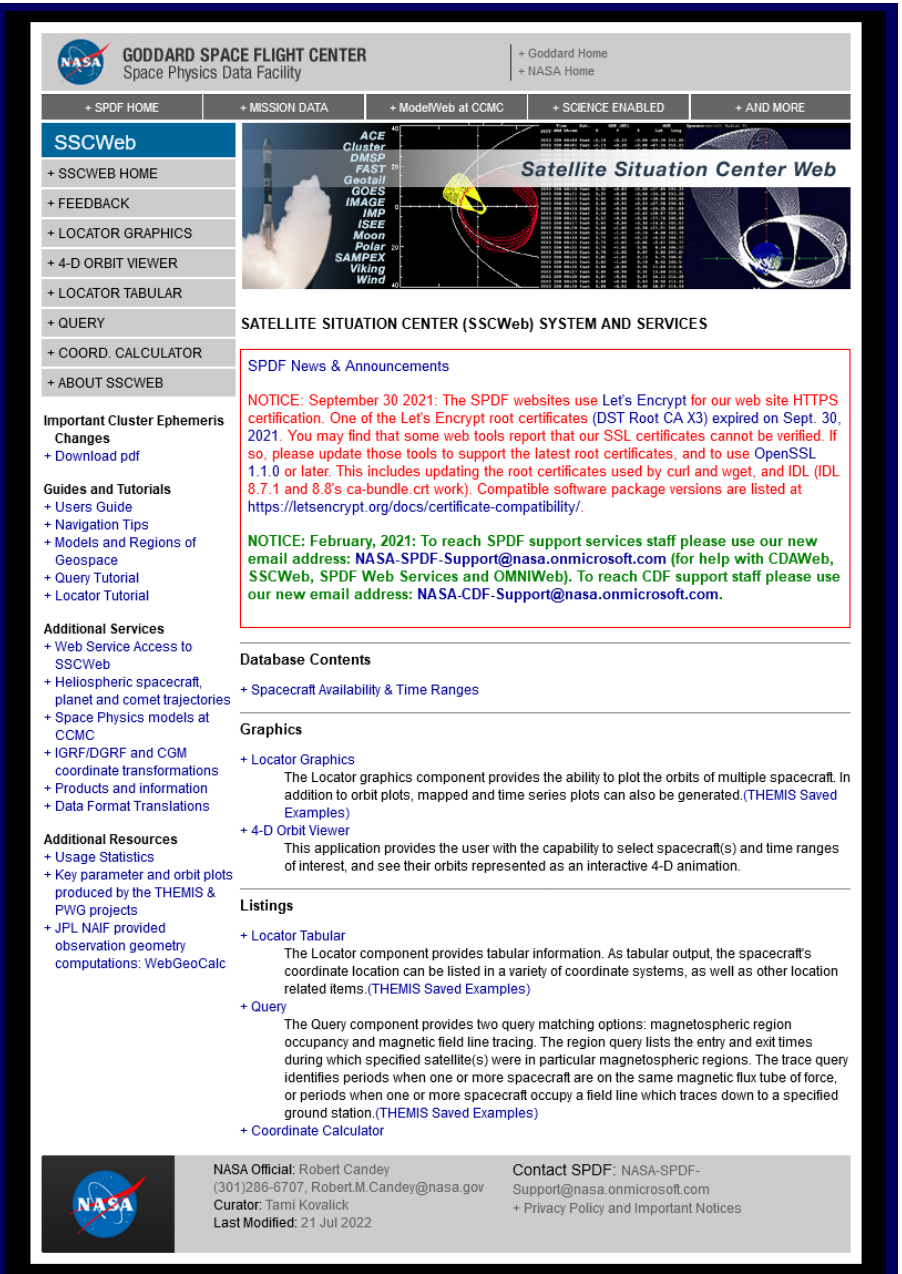
# How to Use CDAWeb (4)

**(4) Plot.**

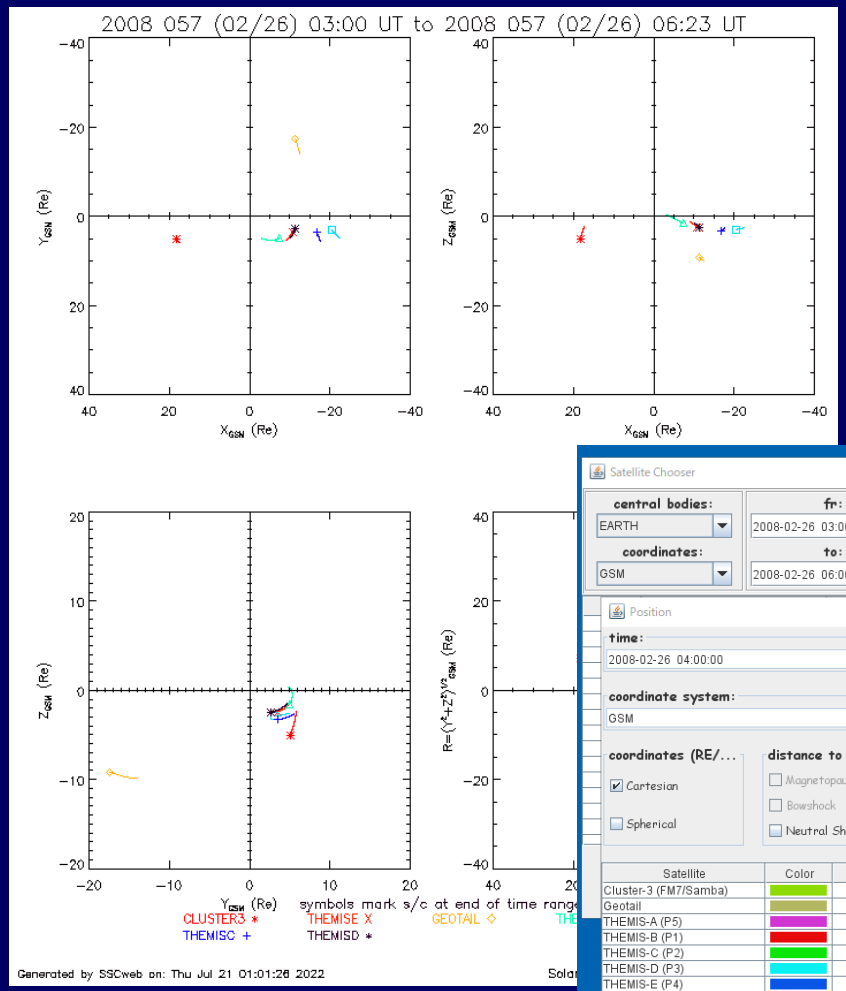


# ■ NASA SSCWeb

- Satellite Situation Center
- https://sscweb.gsfc.nasa.gov/
- Orbit data of many spacecraft (definitive and predictive)
- Can make plots on demand and also download data.
- Can combine different spacecraft and specify a period flexibly.
- More options than CDAWeb

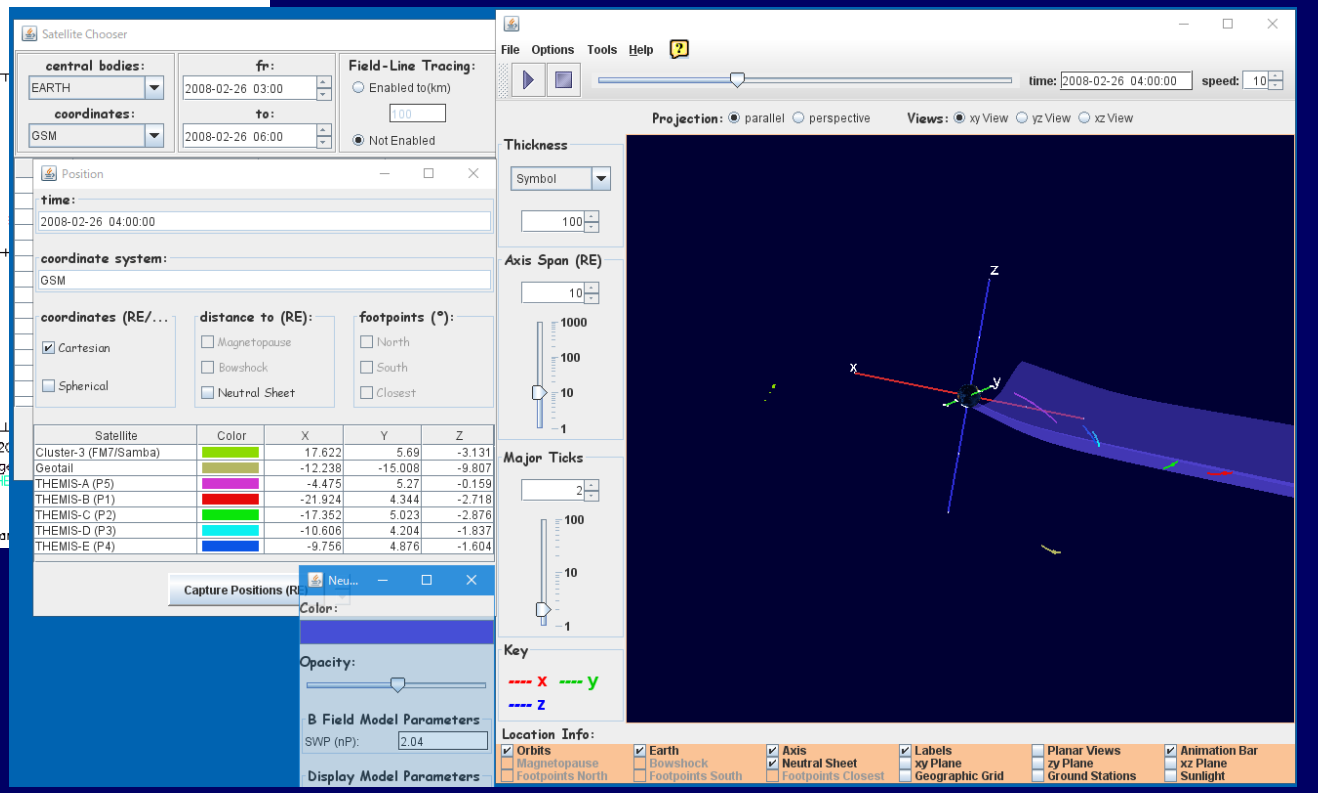


# ■ NASA SSCWeb




**Locator Graphics**
**(on demand on browsers)**

**SSC 4D Orbit Viewer**
**(Java-based software)**



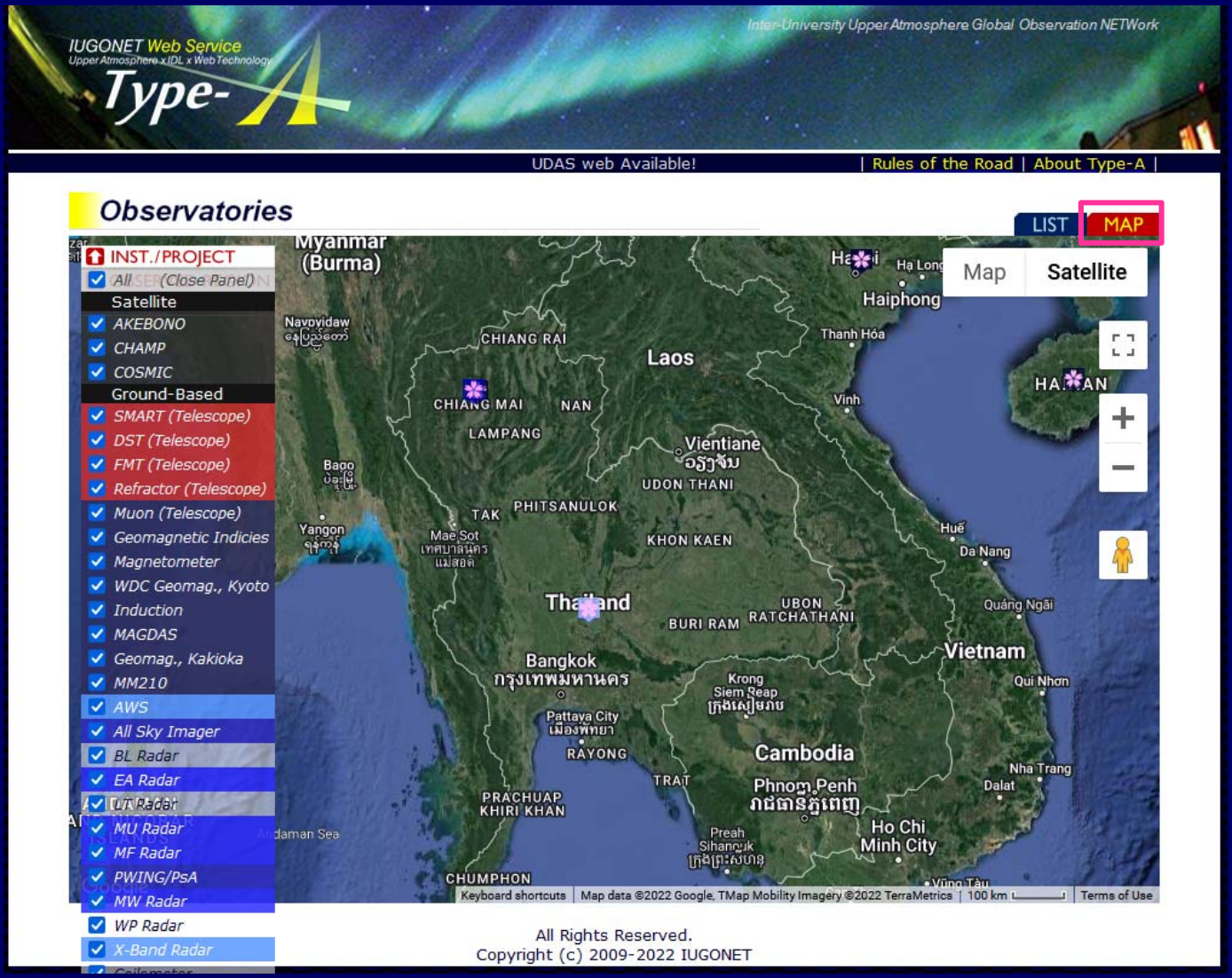
# ■ IUGONET Type-A

- Inter-university Upper atmosphere Global Observation NETwork (http://search.iugonet.org/)
- Tanaka et al. (2022, doi:10.1002/gdj3.170)

- Various kinds of ground-based instrument related to Japanese projects
- Display QL plots, make plots on demand, and also download data.

# ■ How to Use IUGONET Type-A (1)

## One instrument can be selected from the MAP.




**OMTI Fabry-Perot interferometer wind data at Chiang Mai and LF radio wave data at Saraburi are also registered.**

# ■ How to Use IUGONET Type-A (2-1)

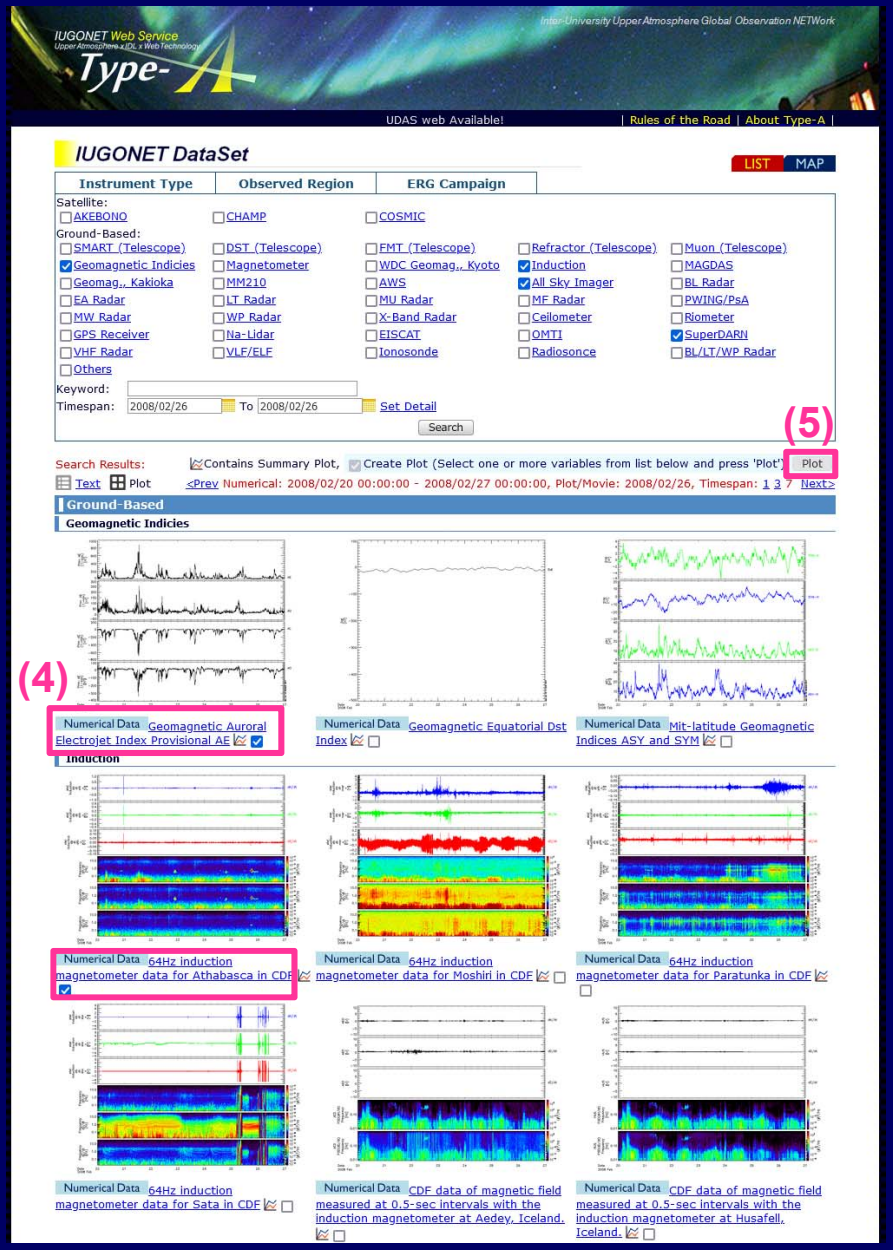
To search for data and show QL plots

(1) Select instruments and specify a time span.

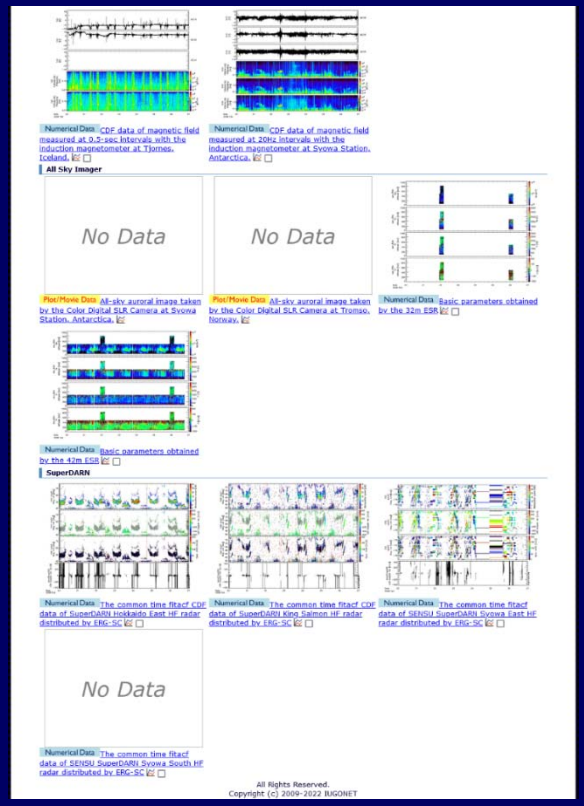
(2) Click the “Search” button.

(3) Click the “Plot” button to show QL plots.

# ■ How to Use IUGONET Type-A (2-2)




To make a plot
for a specified period
(4) Check data of interest
under the QL plots.
(5) Click the “plot” button.



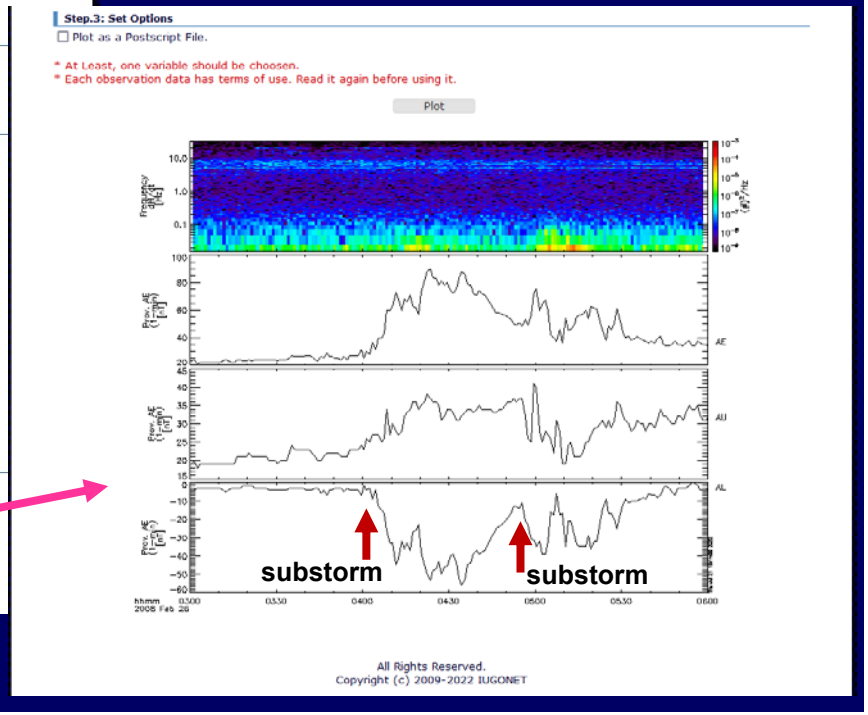
# ■ How to Use IUGONET Type-A (2-3)

**To make a plot for a specified period**

**(6) Specify a time span.**

**(7) Select parameters.**

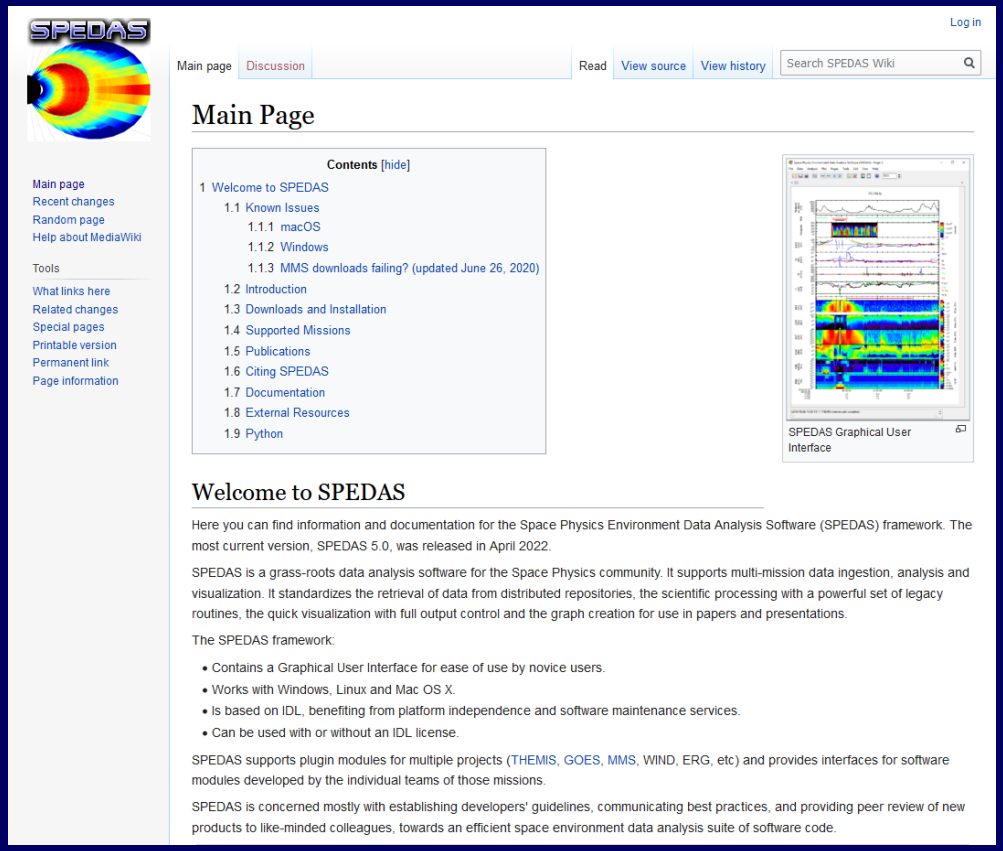
**(8) Click the "Plot" button to make a plot.**

# ■ SPEDAS

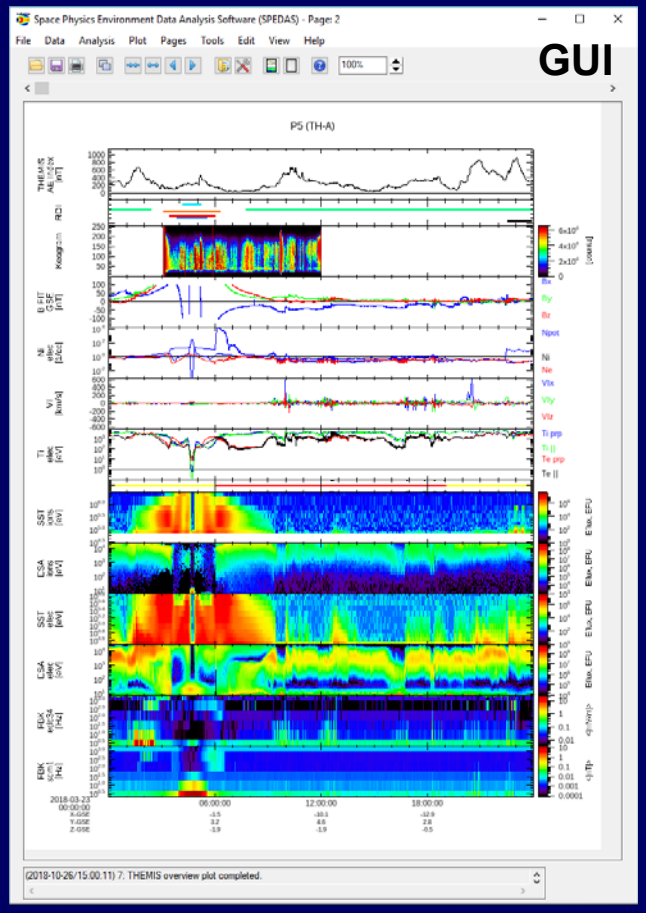
- Space Physics Environment Data Analysis Software
- http://spedas.org/wiki
- Angelopoulos et al. (2019, doi:10.1007/s11214-018-0576-4)
- For advanced serious analysis of various spacecraft and ground-based data
- Works with Windows, Linux and Mac OS X.
- Written in IDL and Python

→ - Customized analysis and plot
  - Incorporate your own data into SPEDAS



# ■ How to Use SPEDAS

- **Works in graphical user interface and command line.**




**GUI**

MMS data analysis using SPEDAS: an introduction

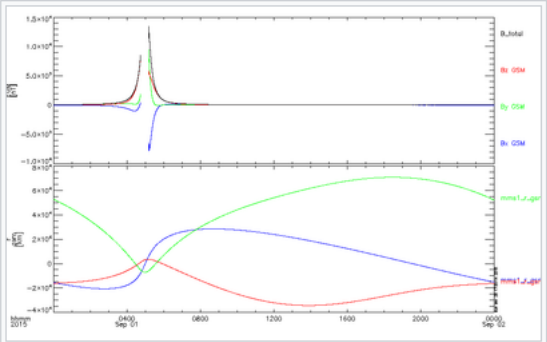
**Command line**

This video shows a step-by-step introduction on how to use SPEDAS to make a simple plot:

http://www.youtube.com/watch?v=390FguKn7w4

This is the script that can be run in IDL:

```
pro test_mms1

 mms_init

 ; Select a time range
 trange = ['2015-09-01/21:15', '2015-09-01/21:25']

 ; Select a probe
 probe = 1

 ; Load FGM data
 mms_load_fgm, probe=probe, trange=trange,
level='l2'

 ; Load position data
 mms_load_mec, probe=probe, trange=trange, level='l2'

 ; Select quantities to plot
 vars = ['mms1_fgm_b_gsm_srvy_l2', 'mms1_mec_r_gsm']

 ; Plot data
 tplot, vars

end
```



Screenshot of example test_mms1

**Download and plot data by only a few commands.**

- **A lot of manuals can be found at the website and in the SPEDAS source code files.**