

# Science Software – v8.00 Training

GEM – San Francisco, CA

December 2013



## What's new in TDAS?



- New code for particle product generation.
- Updated SST calibrations - better dead layer corrections
- Beta code to generate combined ESA & SST particle products.
- SST L2 CDFs planned to be available before TDAS 9.
- SPEDAS GUI API: ERG & IUGONET plugins
- Improved GUI support for loading geomagnetic and solar indices data
- Updated command line and GUI support for GOES 08-15 magnetometer, particle and Xray data
- Added support for loading netCDF files into tplot
- TDAS now serves data from over 125 ground based magnetometers
- New capability to download data sets from CDA web

**This presentation can be found at:**

[http://themis.ssl.berkeley.edu/themisftp/3 Ground Systems/3.2 Science Operations/Science Operations Documents/Science Software Data Analysis Presentations/](http://themis.ssl.berkeley.edu/themisftp/3%20Ground%20Systems/3.2%20Science%20Operations/Science%20Operations%20Documents/Science%20Software%20Data%20Analysis%20Presentations/)



## THEMIS Data Analysis Software

### Organization

### Contributors

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## V7.01 Science Software/Data Status Report

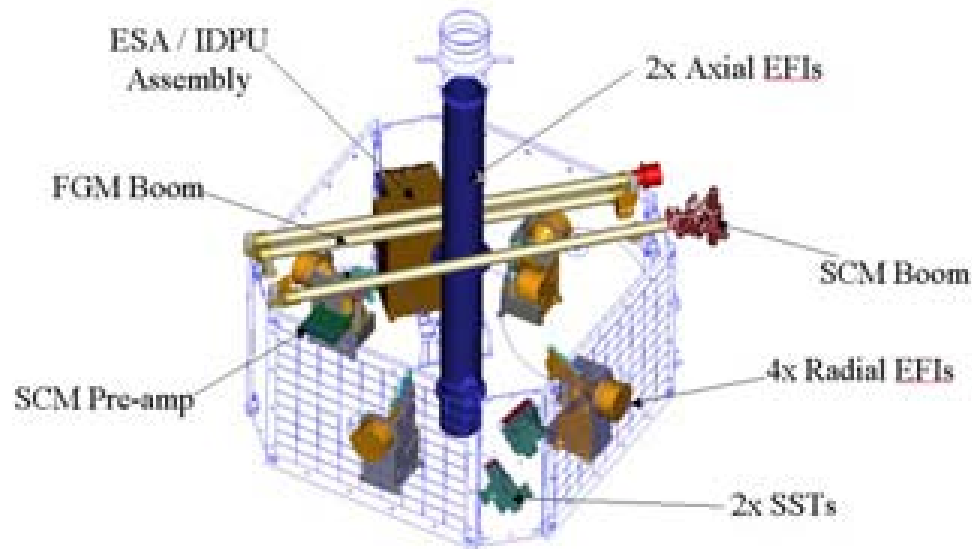
- General Loads, introduces and calibrates all L1 quantities, all instruments  
Loads calibrated L2 quantities
- STATE L1 STATE available since launch, V03 STATE (improved attitude and spin phase corrections)
- FGM L1, L2 data available since early March 2007
- FIT / FFT / FBK - L1, L2 data available since early March 2007
- SCM L1 data available since early March 2007  
L2 frequency spectrograms (FBK) available now  
L2 SCM available since May 2010
- EFI All L1 data available from TH-C since May 2007, TH-D,E since Jun 7  
L2 EFI now available 2011
- ESA No L1 data, only L0 data – however, read-in is transparent to user  
All data available since ESA turn-on, i.e., mid-March  
L2 omnidirectional energy spectrograms, ground moments available now.
- MOM On-board moments available from August 2007 on. L2 moments (from ESA only) available.
- SST L1 data available since SST turn-on, mid-March  
L2 omnidirectional energy spectrograms available now
- ASI L1 thumbnail images from 21 stations available.  
L1 full-resolution images available up to **April 2011**  
Mosaics, movies for full mission
- GMAG L2 CDF files with ground magnetometer data from THEMIS and
- Other Missions
  - GOES – High-resolution (0.5s) magnetometer data from GOES 10, 11 and 12 satellites from September 2007–December 2008 for each satellite.
  - ACE - The ACE data consists of magnetometer values in GSM coordinates with one minute averages and Solar Wind Electron Proton Alpha Monitor data

## FIELDS INSTRUMENTS:

EFI - Electric Field Instruments  
FGM - Flux Gate Magnetometer  
SCM - Search Coil  
Magnetometers

## PARTICLE INSTRUMENTS:

ESA - Electrostatic Analyzer  
SST - Solid State Telescope



## GROUND BASED:

ASI – All-Sky Imager Array  
GMAG – Magnetometer Array

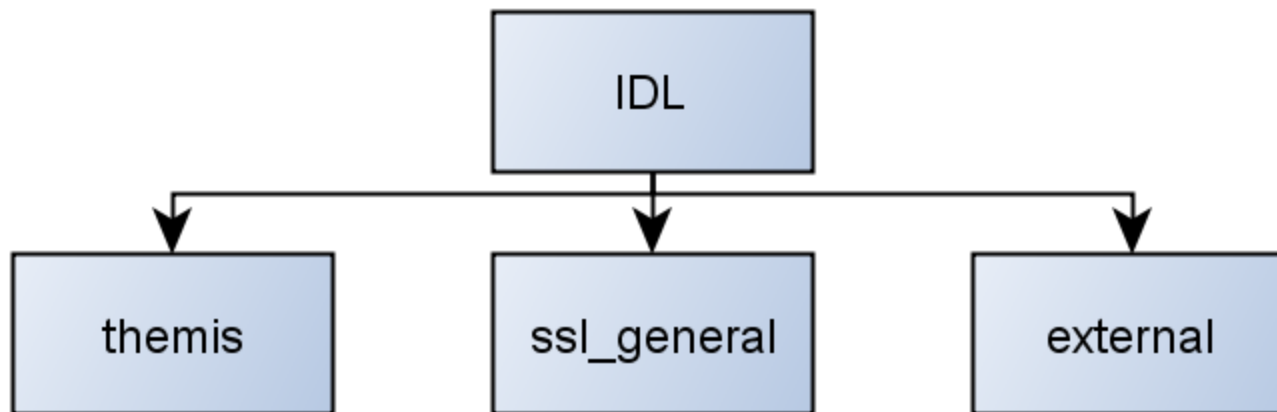


## PROCESSED DATA:

FBK – Filter Bank  
FIT – Onboard Spin-Fit  
FFT – Fast Fourier Transform  
MOM – Onboard Moments  
STATE – Spacecraft state vectors



- THEMIS Data Analysis Software (TDAS) Objectives
  - Powerful, Flexible Command Line Interface
  - GUI provides easy access to data, analysis tools, and graphics
- IDL based (library of routines –but no main program!).
- Code is available to everyone
- It is not required to analyze level 2 data.
- Easily tailored for other missions.
- Functionally separates the tasks into:
  - Reading/Importing
  - Manipulating
  - Plotting
- Platform independent. Works on:
  - Solaris
  - Linux
  - Windows, Vista
  - Mac OS X



### **themis**

- Routines specific to THEMIS
- Organized by Instrument
- Load and Calibrate Data, Coordinate Transforms, Analysis routines

### **ssl\_general**

- Library of generic routines useful for building mission-specific load routines
- Plotting (tplot), Data Processing, and Data Import/Export Routines

### **external**

- CDAWlib – from NASA SPDF, reads/plots CDF data
- IDL\_GEOPACK – Magnetic field modelling kit





- Windows, Solaris, LINUX, PPC Mac or Intel Mac.
- IDL 6.2 or higher required
- IDL Patch Recommended
  - Required for IDL 6.2, (Strongly recommended for IDL 6.4 and up)
  - [http://cdf.gsfc.nasa.gov/html/cdf\\_patch\\_for\\_idl6x\\_new.html](http://cdf.gsfc.nasa.gov/html/cdf_patch_for_idl6x_new.html)
- For Mac, system configurations are required to run IDL
  - Recommend IDL 8.2.3 for Mac users.
  - Detailed installation instructions in TDAS Quick Start Guide on website
- See THEMIS User's Guide for full information, available at: <ftp://apollo.ssl.berkeley.edu/pub/THEMIS/>



# THEMIS Software Web Page



The screenshot shows a Mozilla Firefox browser window displaying the THEMIS Software web page. The browser's address bar shows the URL <http://themis.ssl.berkeley.edu/software.shtml>. The page has a dark green header with the THEMIS logo and the tagline "Time History of Events and Macroscale Interactions During Substorms". Below the header is a navigation menu with links for Home, The Mission, Data, Software, Publications, News & Events, Contact Us, and For the Public >>. The main content area is titled "THEMIS Software" and contains the following text:

The THEMIS Data Analysis Software Suite consists of IDL routines which read data in CDF format, as well as other less refined data sets. IDL routines can be used to download, open, analyze, and plot Level 1 (L1) and Level 2 (L2) data quantities. They can also be used transform L1 data into L2 data. L1 data is raw, uncalibrated data in CDF format. L2 data is calibrated in physical units. These IDL routines were derived from those used by the Cluster, Wind, Polar, and FAST missions. In addition to command line invoked IDL routines, the software provides a graphical user interface for opening, analyzing, and plotting data. This interface was designed to facilitate use of the most useful IDL routines.

To begin:

1. [Download](#) the latest release of the Software  
You can download the Quick Reference Guide directly from this website as a [DOC](#) or [PDF](#).  
You can download the User's Guide directly from this website as a [DOC](#) or [PDF](#).
2. After downloading a version of the software and the user's guide, open up the users guide and follow the instructions provided.
3. You may also find the [HTML Docs](#) for the latest released version of the Software. You can also browse the IDL source.

Future Releases:

1. You can receive emails notifying you of New Software Releases by [Registering](#) on the THEMIS Science Support Distribution List.
2. [Download](#) not yet released future Software. Please Note this Software may not yet be fully tested and is not supported by the THEMIS Science Support Team.

IDL Geopack DLM:

To use the Tsyganenko Model extensions to the THEMIS software you need to [Download](#) and install the interface between Tsyganenko's Fortran code and IDL. This interface was developed and provided for THEMIS as a courtesy by Haje Korth. Installation instructions can be found [here](#).

For comments, observations, problems or questions about data access, software or web site content please contact the [Themis Science Support Team](#).

<http://themis.ssl.berkeley.edu>  
[THEMIS\\_Science\\_Support@ssl.berkeley.edu](mailto:THEMIS_Science_Support@ssl.berkeley.edu)

- **Installation**
  - Download and expand the latest TDAS release .zip file. The latest version is 8.00.  
[http://themis.ssl.berkeley.edu/socware/tdas\\_8\\_00/tdas\\_8\\_00.zip](http://themis.ssl.berkeley.edu/socware/tdas_8_00/tdas_8_00.zip)
- **Set up the IDL path**
  - File->Preferences
  - Then IDL->Paths
  - Select “insert”
  - Select the location of downloaded TDAS
  - Use arrows to move directory above <IDL\_DEFAULT>
- **Set path to Data Directory**
  - Data directory will be created automatically at
    - C:/data/themis (Windows)
    - ~/data/themis (UNIX/LINUX/Max OS X)
  - Run thm\_ui\_config from command line or THEMIS GUI if you need to change this.



## Usage Conventions:

- **Use IDL keywords to determine functionality**
  - Data Levels - Calibrated Level 1 data is the default (Except for SST and ESA data, which are handled differently).
  - Data type and Probe keywords determine which data is loaded and/or created through the calibration process
  - Get\_Support\_Data keyword needed in thm\_load\_state to load data needed by thm\_cal\* and thm\_cotrans routines
  - To load uncalibrated data, set type = 'raw' (For all but SST, ESA)
- **IDL Command Line Examples:**
  - timespan,'2007-07-07',1 ;choose a time range
  - thm\_load\_state, probe = 'a', /get\_support\_data
  - thm\_load\_fgm, probe='a', coord='gsm', datatype='fgl', level=1



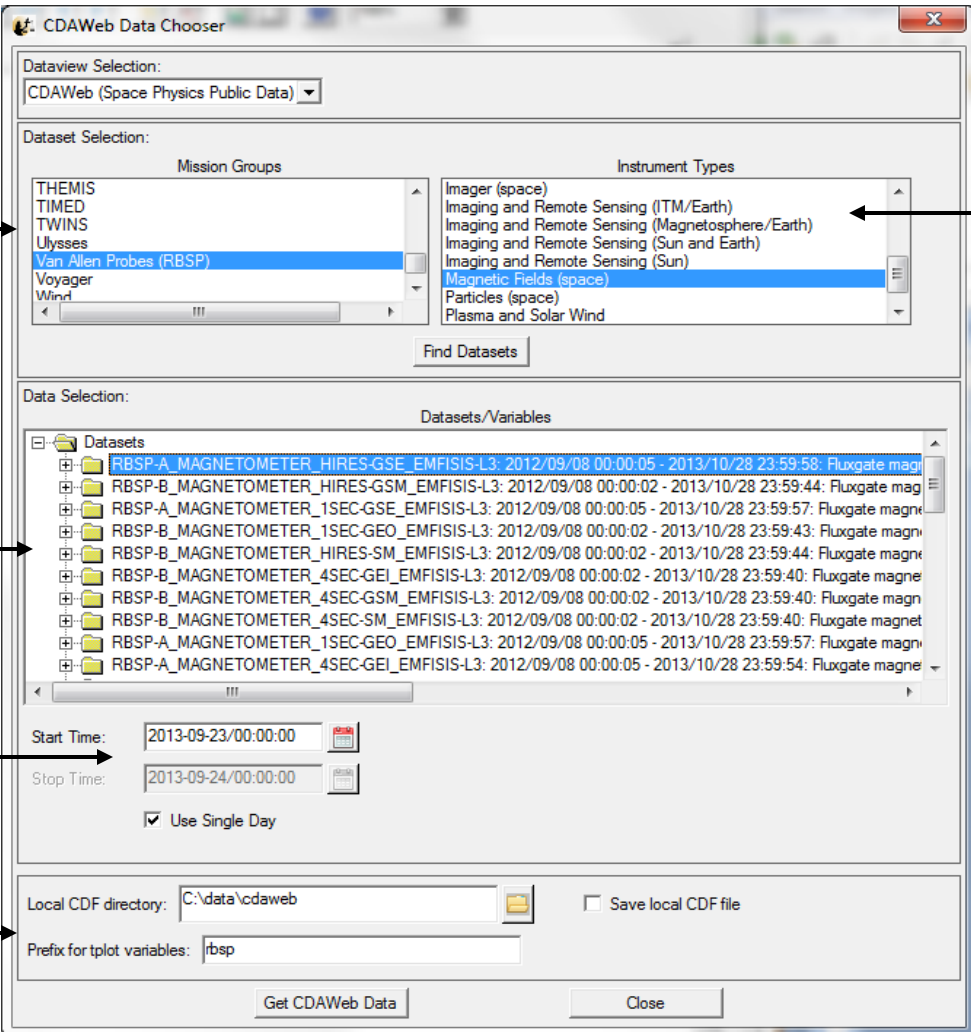
## Load Routine Summary

Name	Description	Level 0	Level 1		Level 2
			Raw	Calibrated	
thm_load_asi	All-Sky Imager		*	(-)	
thm_load_ask	All-Sky Keogram		*	(-)	
thm_load_efi	Electric Fields Instrument Waveforms		*	*	*
thm_load_esa	ElectroStatic Analyzer				*
thm_load_esa_pkt	ElectroStatic Analyzer	*			
thm_load_fbk	Fields Filter Bank		*	*	*
thm_load_fft	On-Board Fields Fast Fourier Transform		*	*	*
thm_load_fgm	Flux Gate Magnetometer Waveforms		*	*	*
thm_load_fit	On-Board Fields Spin-Fit		*	*	*
thm_load_gmag	Ground Magnetometer				*
thm_load_hsk	Housekeeping		*	*	
thm_load_mom	On-Board Particle Moments		*	*	*
thm_load_scm	Search Coil Magnetometer Waveforms		*	*	*
thm_load_sst	Solid State Telescope		*	(-)	*
thm_load_state	Orbit and Attitude		V3		
thm_load_pseudoae	THEMIS gmag Derived AE-Index			*	
thm_load_slp	Solar Lunar Position, Attitude, Velocity				*
thm_load_scmode	Spacecraft Mode			*	
thm_load_trg	Spacecraft Trigger		*		
thm_load_bau	BAU Housekeeping		*	*	

### Notes:

(-) data reduction and analysis routines available: see crib sheet

## GUI has new capability to download data sets from CDAWeb



The screenshot shows the CDAWeb Data Chooser window with the following sections and annotations:

- Dataview Selection:** CDAWeb (Space Physics Public Data)
- Dataset Selection:**
  - Mission Groups:** THEMIS, TIMED, TWINS, Ulysses, Van Allen Probes (RBSP), Voyager, Wind. *Annotation: Mission Names*
  - Instrument Types:** Imager (space), Imaging and Remote Sensing (ITM/Earth), Imaging and Remote Sensing (Magnetosphere/Earth), Imaging and Remote Sensing (Sun and Earth), Imaging and Remote Sensing (Sun), Magnetic Fields (space), Particles (space), Plasma and Solar Wind. *Annotation: Type of Instrument*
  - Find Datasets:** Button
- Data Selection:**
  - Datasets/Variables:** List of datasets including RBSP-A\_MAGNETOMETER\_HIRES-GSE\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_HIRES-GSM\_EMFISIS-L3, RBSP-A\_MAGNETOMETER\_1SEC-GSE\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_1SEC-GEO\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_HIRES-SM\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_4SEC-GEI\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_4SEC-GSM\_EMFISIS-L3, RBSP-B\_MAGNETOMETER\_4SEC-SM\_EMFISIS-L3, RBSP-A\_MAGNETOMETER\_1SEC-GEO\_EMFISIS-L3, RBSP-A\_MAGNETOMETER\_4SEC-GEI\_EMFISIS-L3. *Annotation: Datasets/Variables*
  - Time Widgets:** Start Time: 2013-09-23/00:00:00, Stop Time: 2013-09-24/00:00:00, Use Single Day checkbox. *Annotation: Time Widgets*
  - Path and File Name selection:** Local CDF directory: C:\data\cdaweb, Save local CDF file checkbox, Prefix for tplot variables: rbsp. *Annotation: Path and File Name selection*
  - Buttons:** Get CDAWeb Data, Close



## Crib Sheets for Loading, Processing and Plotting

- Crib sheets document command line features & show common usage.
- Currently 73 crib sheets in TDAS.
- Found in several locations:
  - `ssl_general/examples/` (tplot)
  - `themis/examples/basic` (for major features & new users)
  - `themis/examples/advanced` (obscure, technical, or experimental features)
  - `themis/examples/deprecated` (old crib sheets, for documentation, may not run)
- Crib sheets can be executed or copy & pasted into the command line.
- Contain many comments to describe usage details.
- Many written by instrument PIs.



Probe specification. Example: tha

- a – can be one of [a-e] specifies probe

Particle data. Example: tha\_peif

- p – particles
- e – ESA, s – SST
- i – ions, e – electrons
- f – full, r – reduced, m – moments, b – burst

FGM data. Example: tha\_fgl

- l – low telemetry rate, h – high telemetry rate,  
e – engineering decimated high rate, s – spin fit.

Electric Fields and SCM. Example: tha\_efs

- ef - efi, sc – scm, fb – fbk, ff – fft
- s – spin fit, f – full orbit or fast survey, p – particle burst,  
w – waves burst.

Wildcards are accepted in names when plotting and data processing:

- th?\_fg?
- th[ab]\_fg[lh]
- th?\_state\*





- The software operates on Level 1 and Level 2 data.
- Data Level Definitions:
  - Level 0 Data
    - Raw files (\*.pkt) one per APID.
    - Only used for loading ESA data.
  - Level 1 Data
    - CDF (Common Data Files) files (\*.cdf)
    - Files contain raw, un-calibrated data. i.e. counts, DAC units.
    - Requires TDAS software to interpret. Calibration is done by default when Level 1 data is input.
  - Level 2 Data
    - CDF files – contain physical quantities – TDAS software is not needed for interpretation.
    - Files available for ESA, FBK, FIT, FFT, FGM, MOM, SST, EFI – can be downloaded from SPDF.



- Data Directory structure is large!
  - ~3GB/day for all probes (L1 data)
- Directory hierarchy keeps directory size manageable
  - Software performs automatic file retrieval.
  - Software maintains directory hierarchy.
- Behaviour of Automatic File Retrieval is configurable
  - ‘No Download’ mode for stand-alone operation.
  - ‘No Update’ mode to preserve local modifications.
  - Root directory determined automatically, is configurable.
  - Available configuration methods:
    - thm\_ui\_config IDL widget
    - Button on THEMIS GUI widget
    - Environment variables

- **thm\_cotrans**
  - transforms to/from any of the following coordinate systems
  - updates metadata in output.
- **Currently Supported Geophysical Coordinate Systems**
  - SPG Spinning Probe Geometric
  - SSL Spinning SunSensor L-vectorZ
  - DSL Despun SunSensor L-vectorZ
  - GEI Geocentric Equatorial Inertial
  - GSE Geocentric Solar Ecliptic
  - GSM Geocentric Solar Magnetospheric
  - SM Solar Magnetic
  - GEO Geographic Coordinate System
  - SSE Selenocentric Coordinate System
  - SEL Selenographic Coordinate System
  - MAG Geomagnetic Coordinate System
- **Example (previously loaded FGM and STATE data)**
  - `thm_cotrans, 'th?_fg?', out_coord='geo', out_suffix = 'geo'`



- Plotting
  - tplot
  - tplotxy
  - plotxy
  - plotxyz
  - tplot\_names
  - tlimit
  - get\_data
  - store\_data

## Example:

```
tt89,'thc_state_pos',newname='model_field'  
    fac_matrix_make,'model_field',other_dim=  
'xgse', newname = 'fac_mat'  
    tvector_rotate, 'fac_mat', 'thc_peir_velocity',  
newname = 'ion_velocity_model_fa'
```

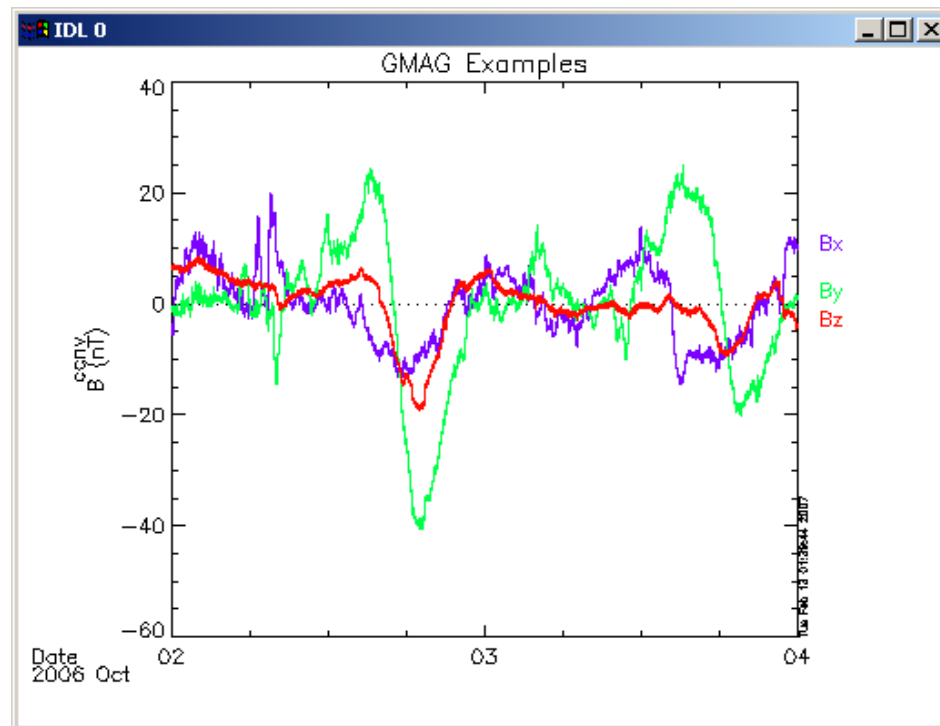
## Analytic Coordinate Transformations

- tvector\_rotate
- fac\_matrix\_make
- thm\_fac\_matrix\_make
- minvar\_matrix\_make
- enp\_matrix\_make
- rxy\_matrix\_make
- sse\_matrix\_make
- gsm2lmn

## Tsyganenko Model

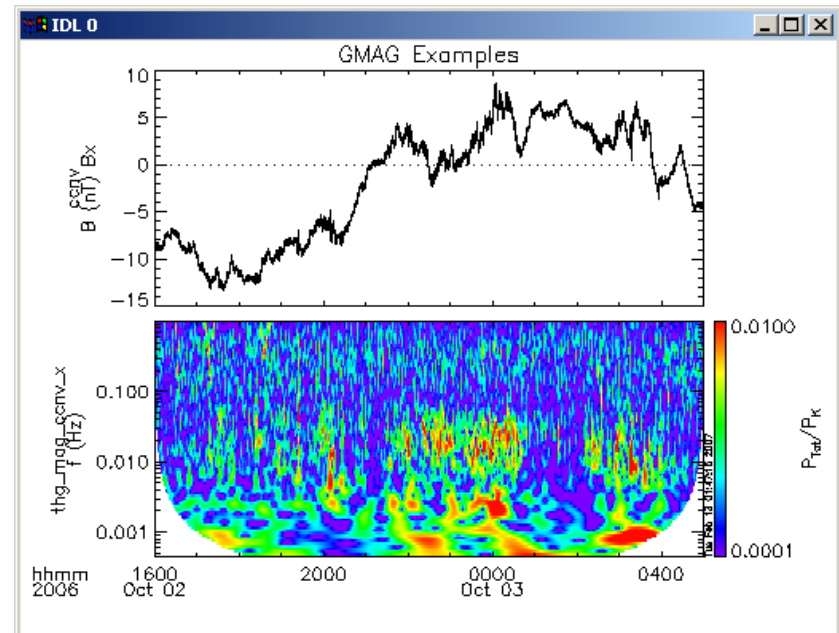
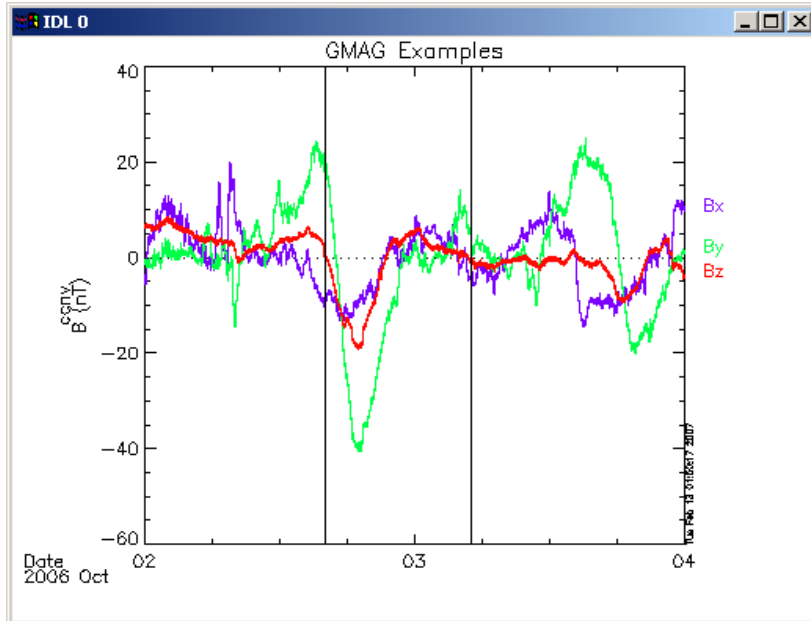
- (t)trace2iono
- (t)trace2equator
- (t)t89
- (t)t96
- (t)t01
- (t)t04s

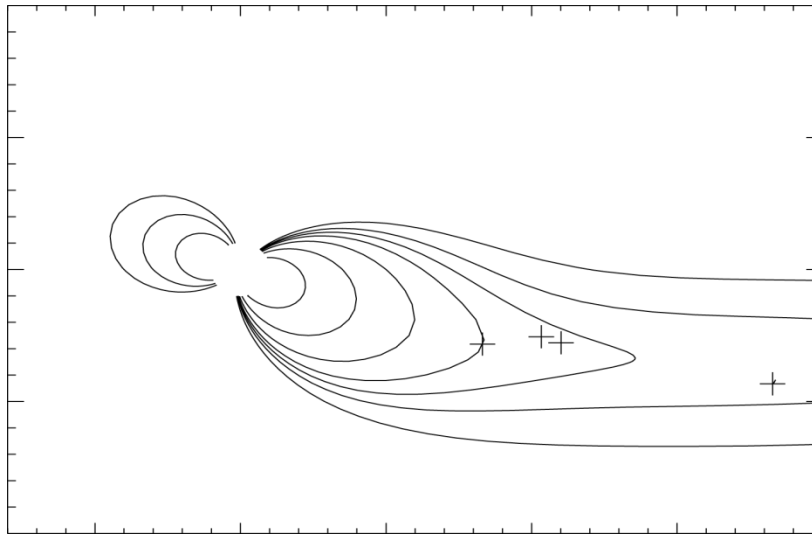
- To load data:
  - » `timespan,'6-10-2',2,/days`
  - » `thm_load_gmag,site='ccnv',$/`  
`subtract_average`
- To plot data:
  - » `options,'thg_mag_ccnv',$/`  
`labels=['Bx','By','Bz']`
  - » `tplot_options,'title',$/`  
`'GMAG Examples'`
  - » `tplot,'thg_mag_ccnv'`



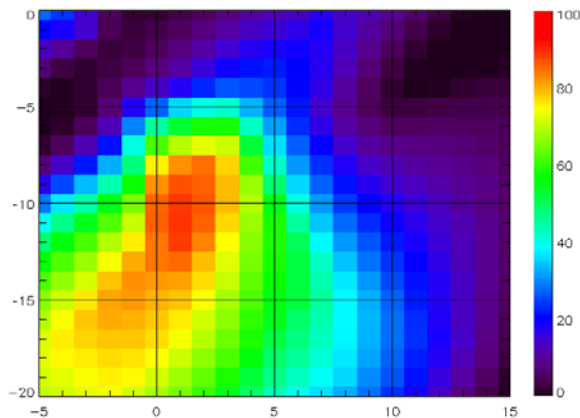
- Wavelet transform on an interval of interest
  - Define and display the interval
    - » `Tr = ['2006-10-2/16:00','2006-10-3/05']`
    - » `timebar,tr`

- Split the 3-vector into components:
  - » `split_vec,'thg_mag_ccnv'`
- Compute transform of one component
  - » `wav_data,'thg_mag_ccnv_x',/kol $ ,trange=tr ,maxpoints=241*3600*2`
- Set color limits (log scale)
  - » `zlim,'*pow',.0001,.01,1`
- Plot it.
  - » `tplot,'*ccnv_x*',trange=tr`





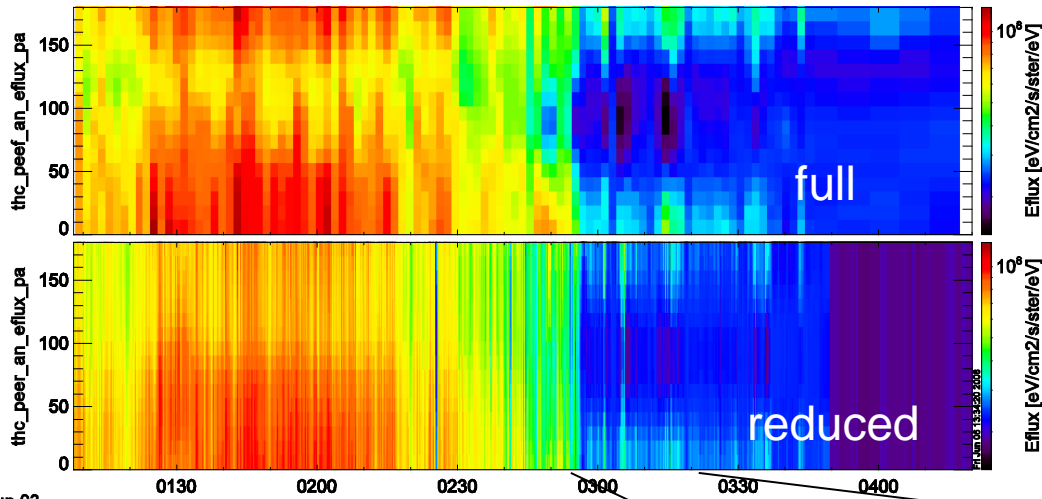
tplotxy can be used to plot isotropic position plots. Like plots of magnetic field models and spacecraft position



Plotxyz can be used to plot 3 dimensional isotropic data, with any axis. (Not restricted to time-series.)



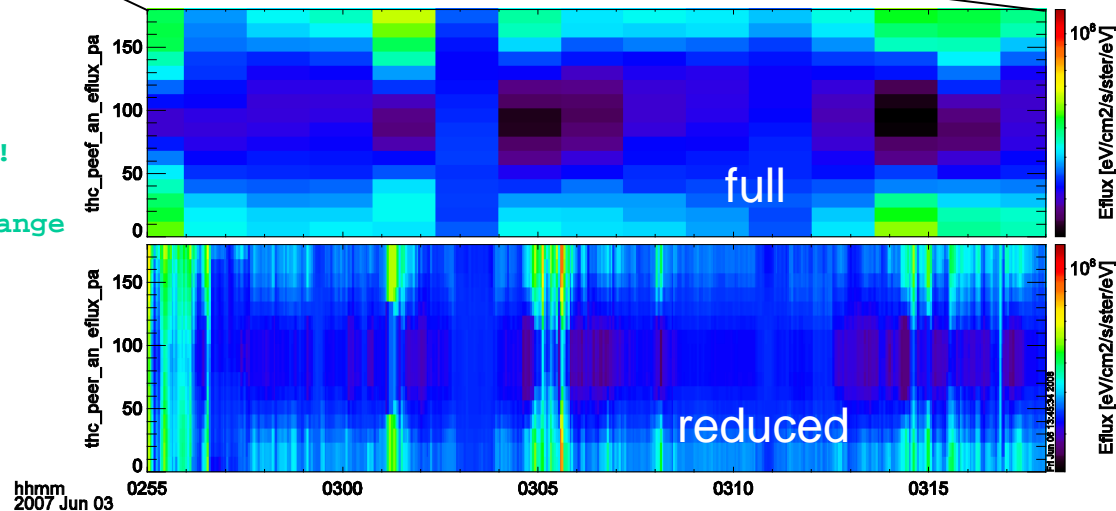
# Plotting Angular Spectra



Pitch angle spectra for full and reduced mode electron ESA data. Plotted using tplot. See: thm\_crib\_part\_products.pro

hhmm  
2007 Jun 03

```
thm_part_products, $ ;new particle routine!  
probe='c', $ ;select probe  
trange=['07-06-03/01:08', $ ;select timerange  
       '07-06-03/04:20'], $  
data_type='peef, $ ;select data type  
outputs='pa' ;select pitch angle spectra
```



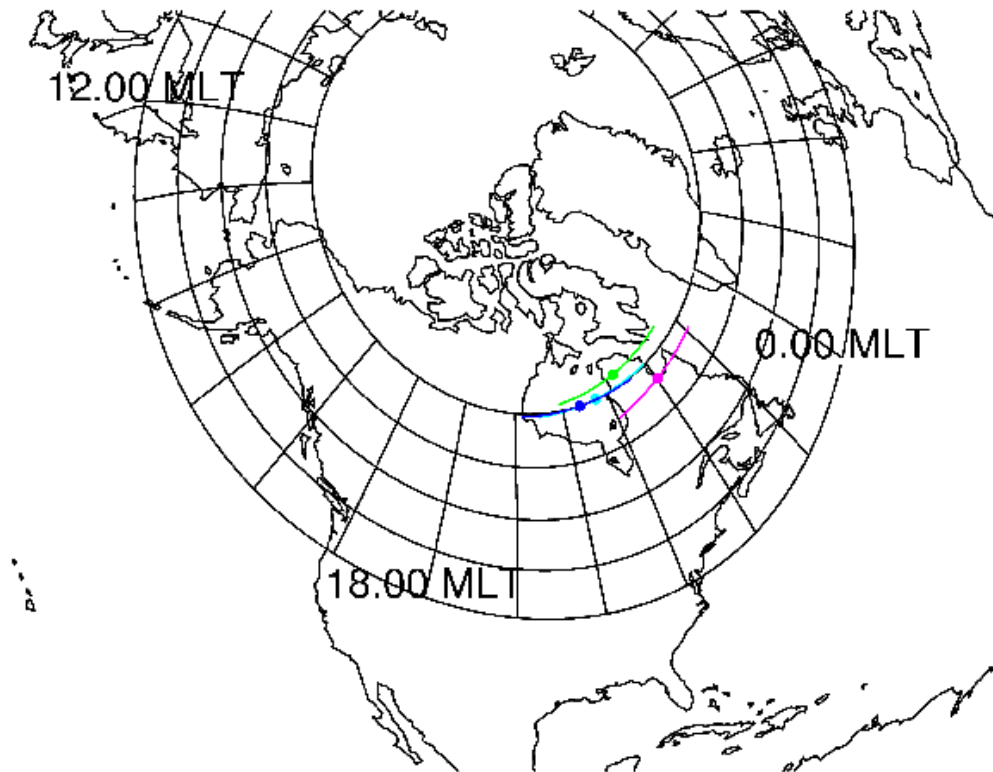
hhmm  
2007 Jun 03





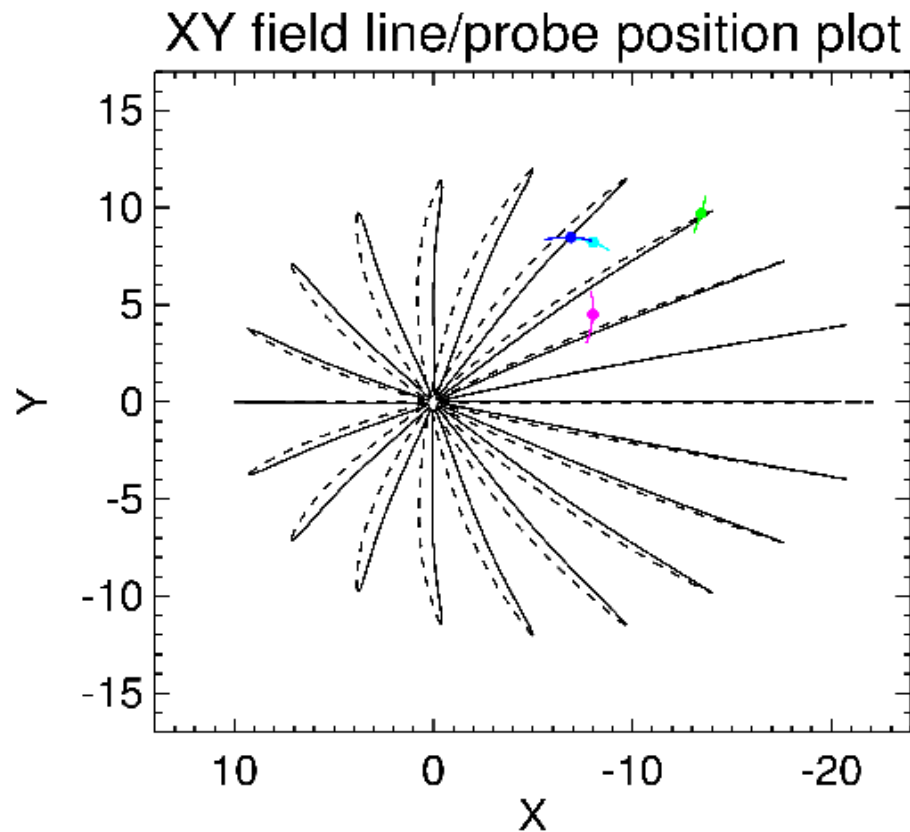
- New routines have been added to perform different 2d projections of 3d data. This is particularly useful for plotting orbits and field lines.
- A Tsyganenko interface has been added to TDAS that allows us to calculate model field lines for T89,T96,T01,&T04 models. Field lines can be Traced.
- Examples of these routines can be found in  
themis/examples/thm\_crib\_trace.pro,  
themis/examples/thm\_crib\_plotxy.pro and  
themis/examples/thm\_crib\_tplotxy
- The graphics in the next slide were generated with thm\_crib\_trace.pro  
Example: `.run thm_crib_trace.pro`
- A routine was added to plot an arbitrarily sized and spaced AACGM coordinate grid on a world map.
- NEW (09/02/2010): IDL GEOPACK v7.3 released and includes updated IGRF coefficients valid through 2015 with extrapolation to 2020.  
[http://dysprosium.jhuapl.edu/idl\\_geopack/](http://dysprosium.jhuapl.edu/idl_geopack/)

## Trace/Orbit Plots - AACGM/Iono Trace Plot



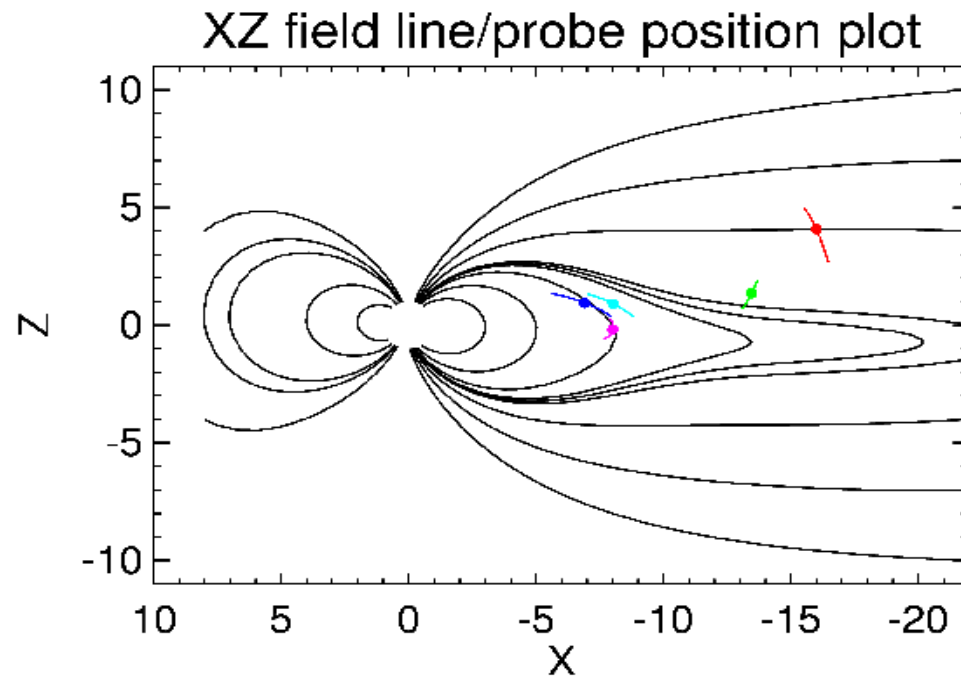


## Trace / Orbit Plots – XY Plot





## Trace / Orbit Plots – XZ Plot

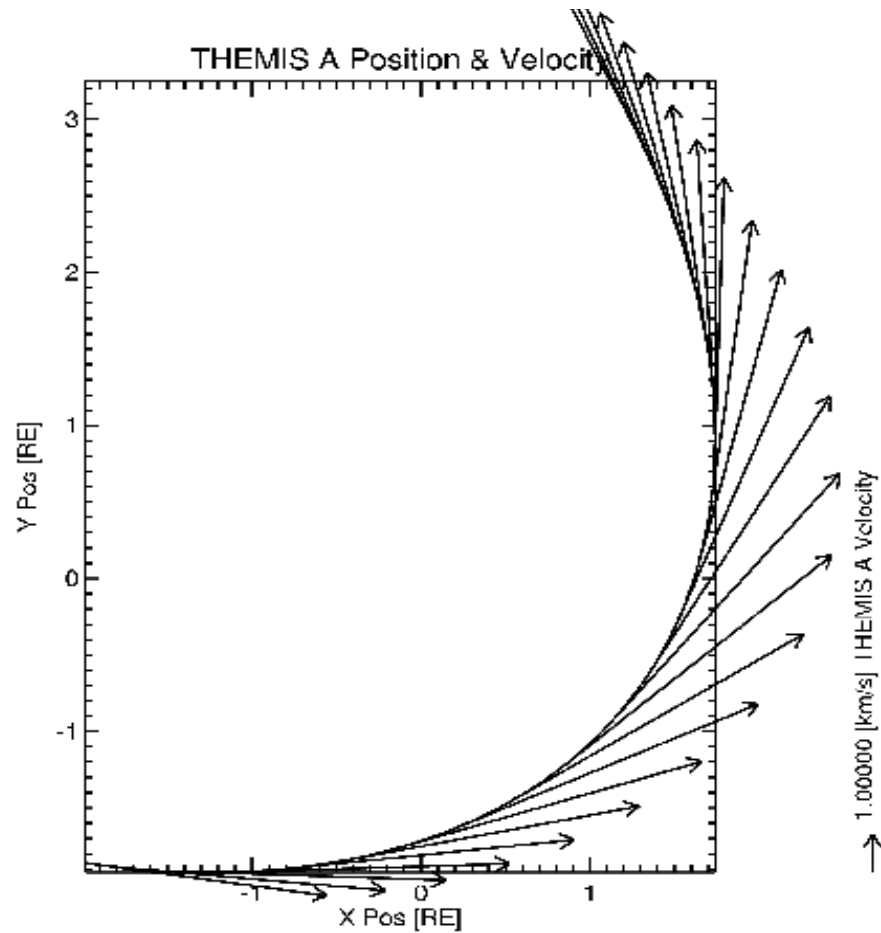


## THEMIS – Mini Language

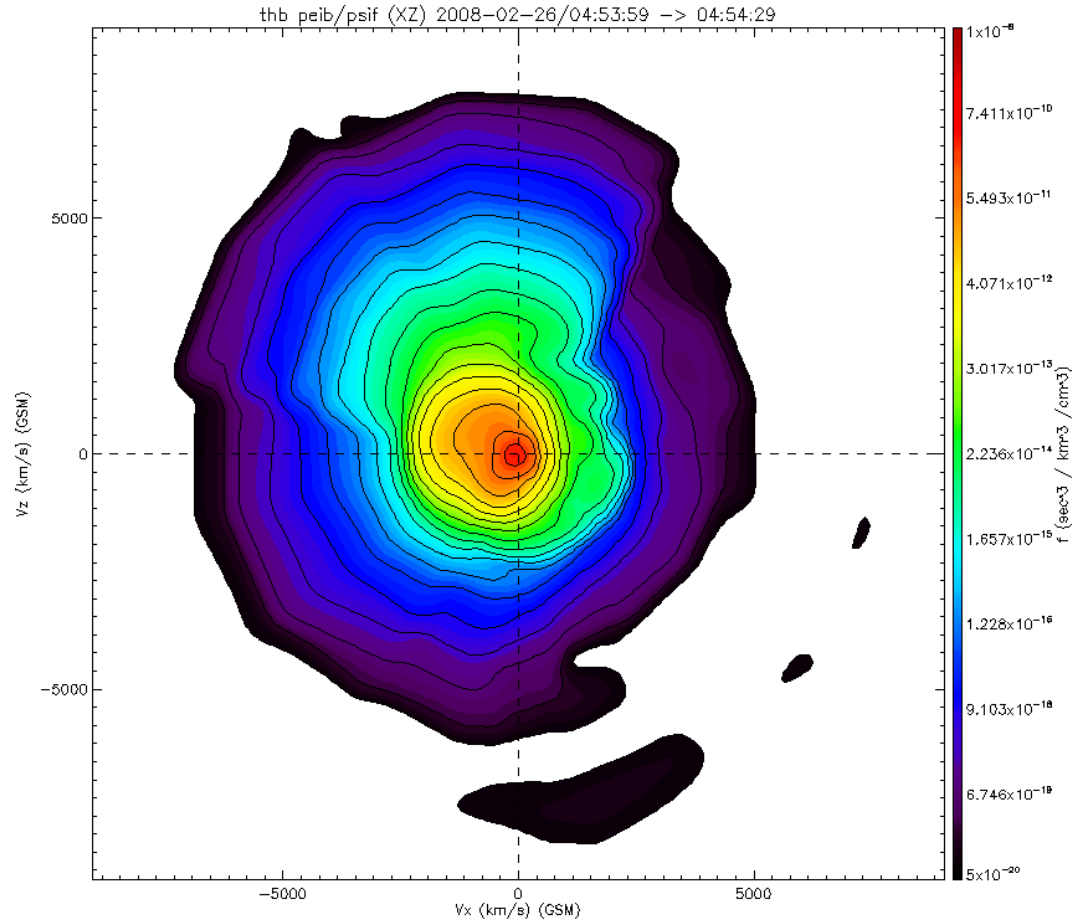
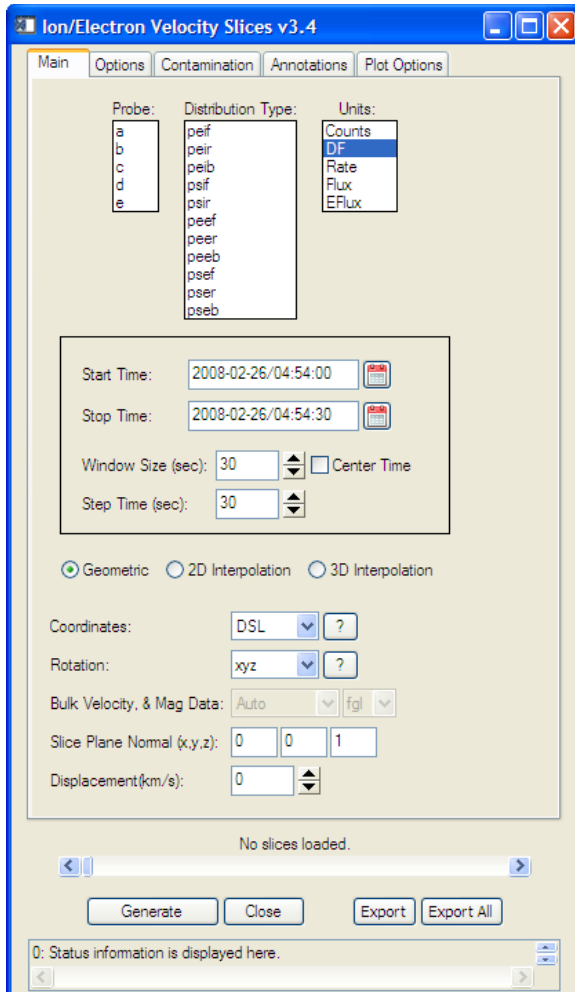
- Simple scripting language has been written in IDL.
- This language allows access to some data analysis functionality in the IDL virtual machine and eases manipulations of time series data.(tplot)
- This language allows composition of statements and functions with order of operations to give significant flexibility in statement construction.
- Examples:
  - 1: Position to RE: `calc, "tha_pos_re" = "tha_state_pos"/6374.4'`
  - 2: Natural log of total esa density:  
`calc, "tha_density_log" = ln("tha_peir_density"+"tha_peer_density")`
  - 3: Store tplot data in non-tplot idl variable: `calc, 'var_data = "tha_efs"`
  - 4: Average Magnetic Pressure:  
`calc, 'Pb_avg = mean(0.01*total("tha_fgs_dsl"^2,2)/25.132741)'`

Additional examples can be found in `themis/examples/thm_crib_calc.pro`

## Plotxyvec – Position/Velocity Plot



The GUI can be started with `thm_ui_slice2d`; the crib sheet `thm_crib_part_slice2d` demonstrates command line usage.





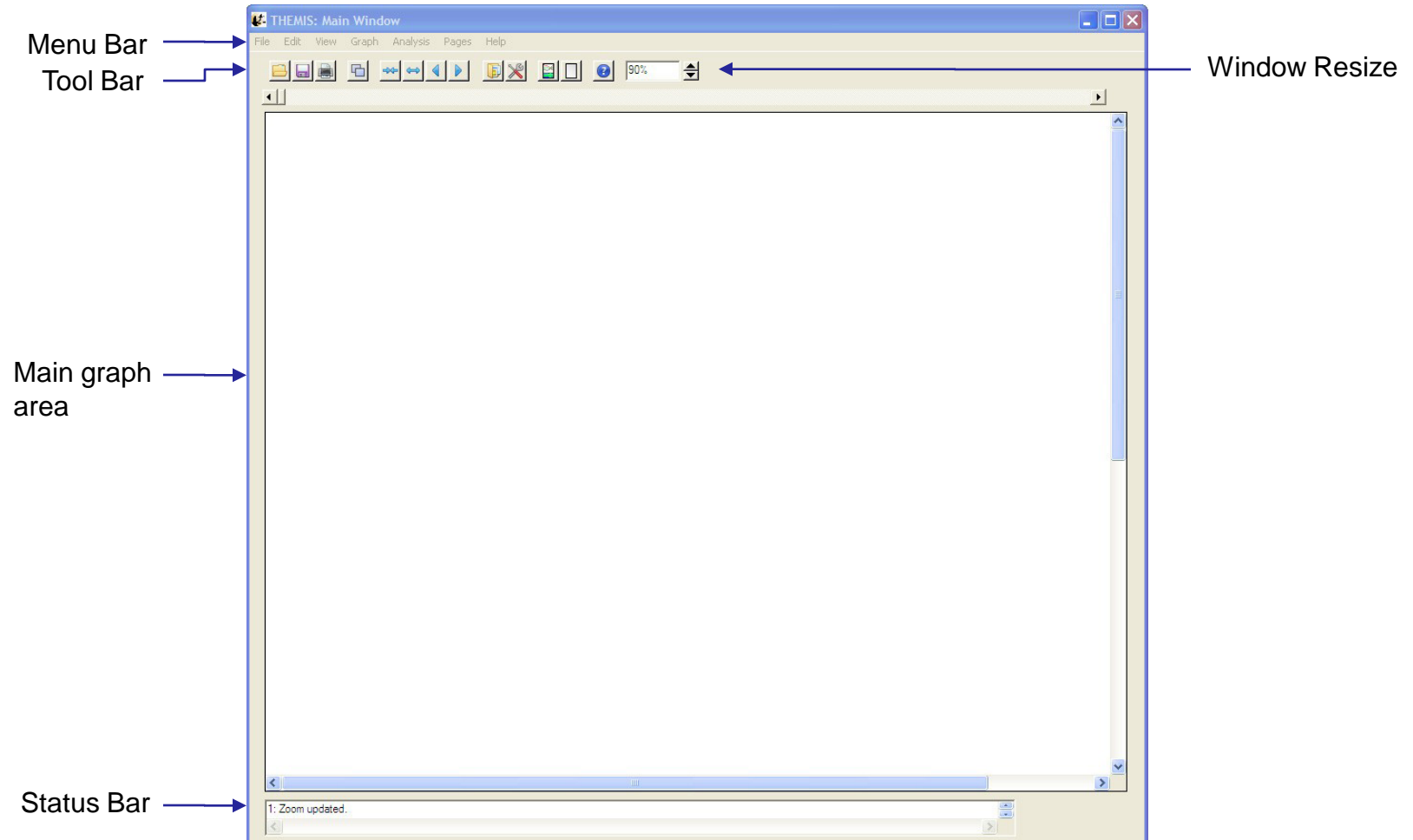
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# THEMIS Data Analysis Software Graphical User Interface



The GUI is the quickest and easiest way to learn TDAS functionality

To run the gui type: `idl > thm_gui`





# Loading Data – GUI

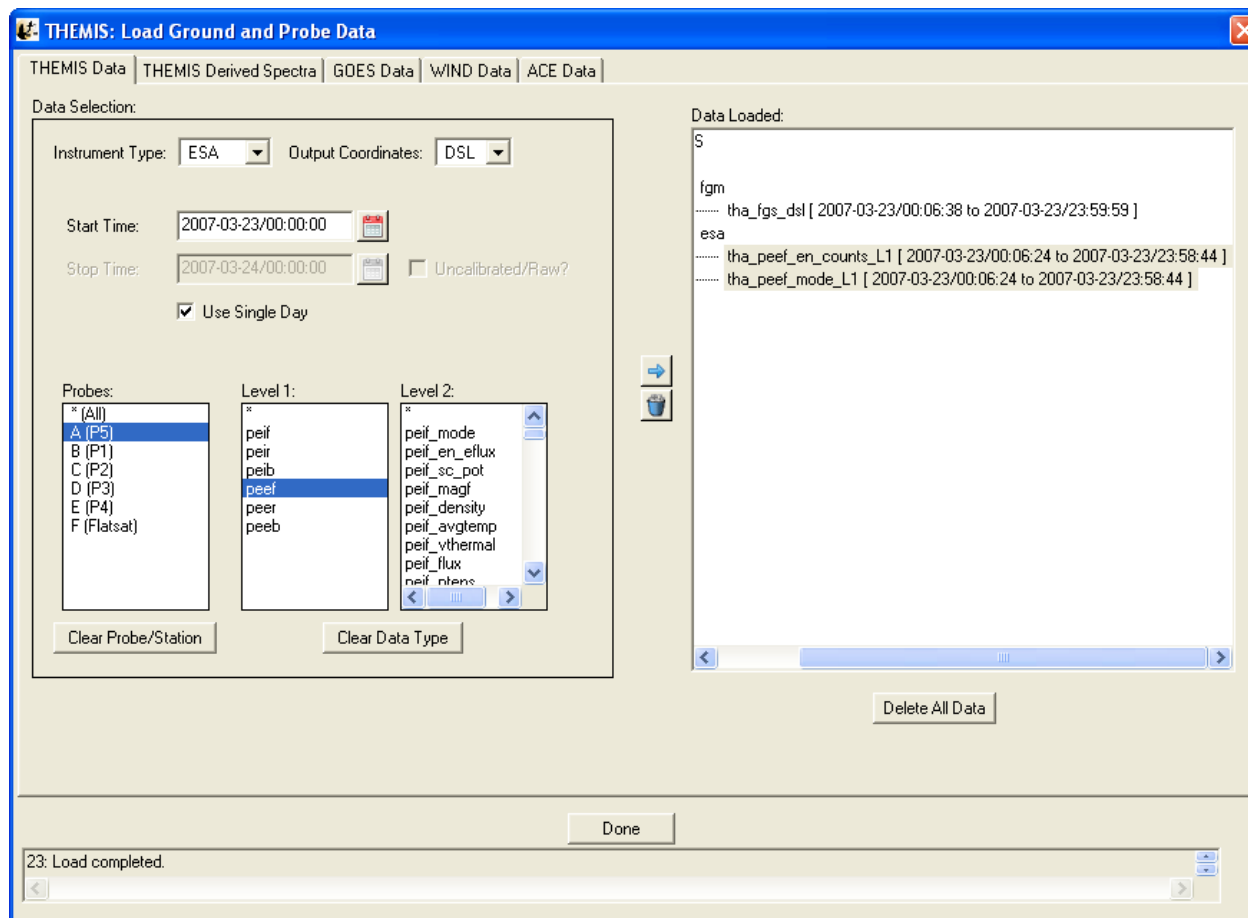


## To Load Data:

Select Load Data under the File menu

Select Instrument Type: fgm, Level2: fgs\_dsl, Click Right arrow button

Select Instrument Type: esa, Level1: peef, Click Right arrow button



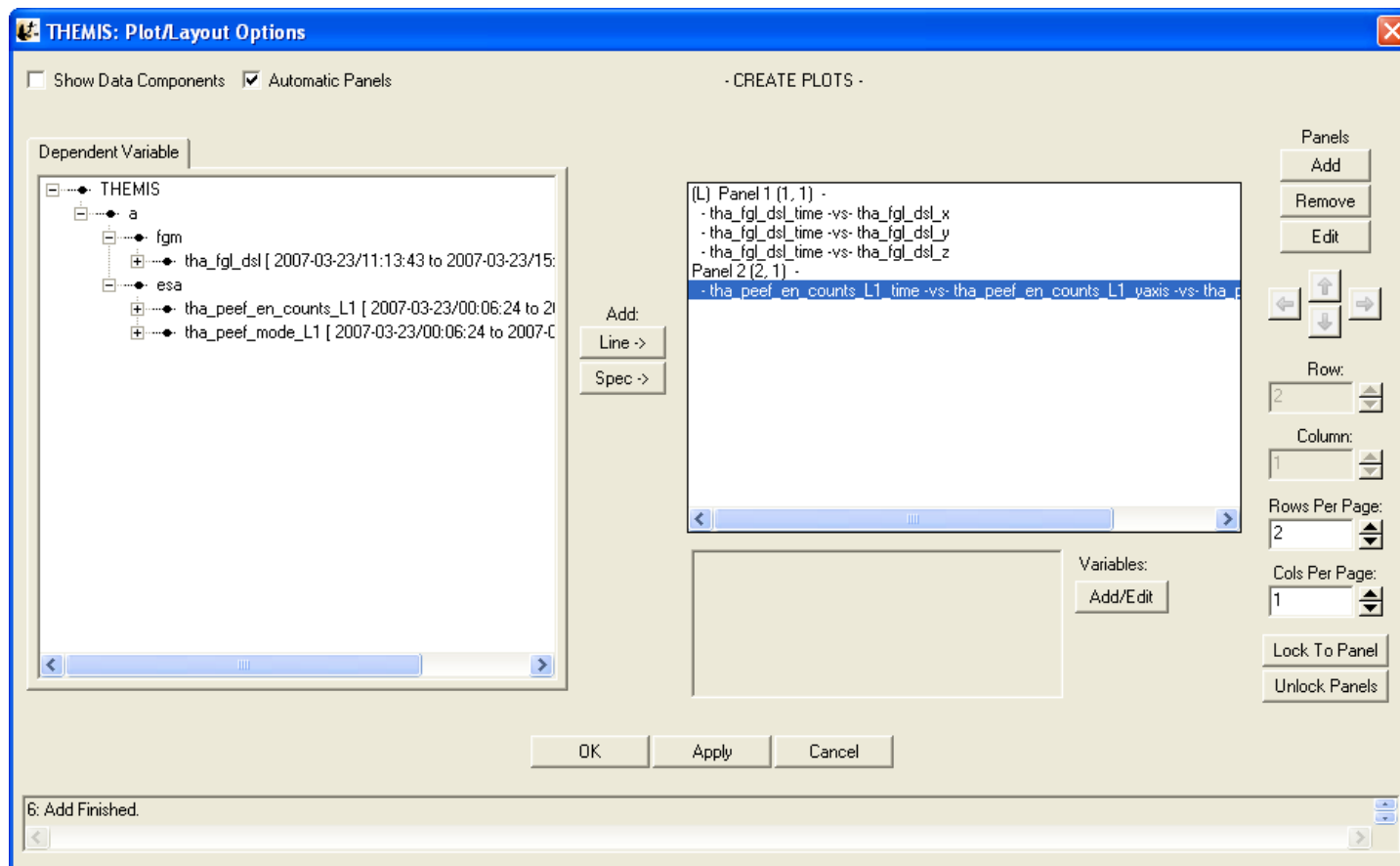
## To Plot Data:

Select Plot/Layout Options... under the Graph menu

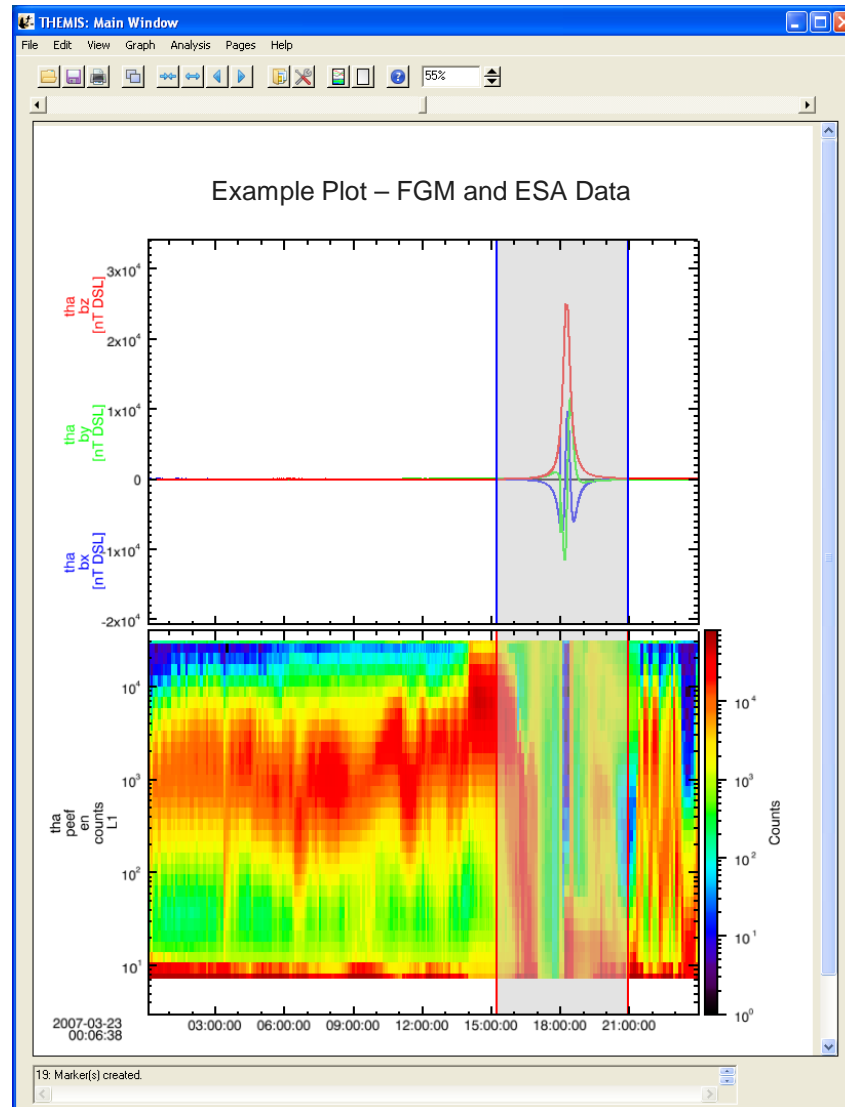
Select tha\_fgl\_dsl, Click Line button

Click Panels Add button, Select tha\_fgl\_dsl

Click Panels Add button, Select tha\_peef\_en\_counts\_L1



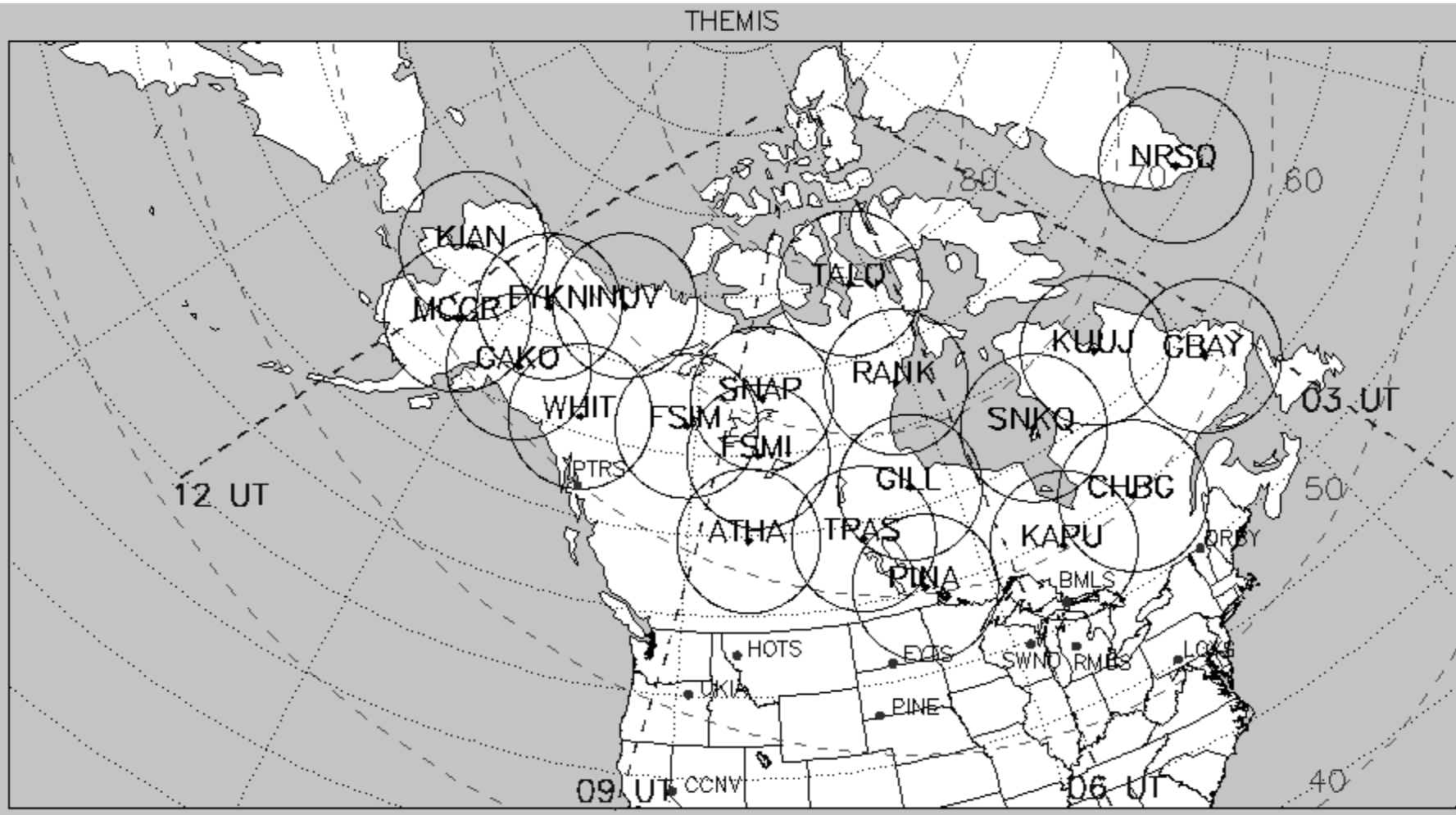
With a few clicks of the button the user can load, analyze, and plot data.





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THEMIS software for GBO all-sky imager  
Thm\_crib\_asi.pro  
Harald U. Frey  
(updated November 2011)





## 1. Keograms along local magnetic meridian

- ⤴ Delivered daily jpeg-compressed
- ⤴ Reprocessed  $\frac{1}{2}$  year later with full resolution images

## 2. Geomagnetically mapped thumbnail images

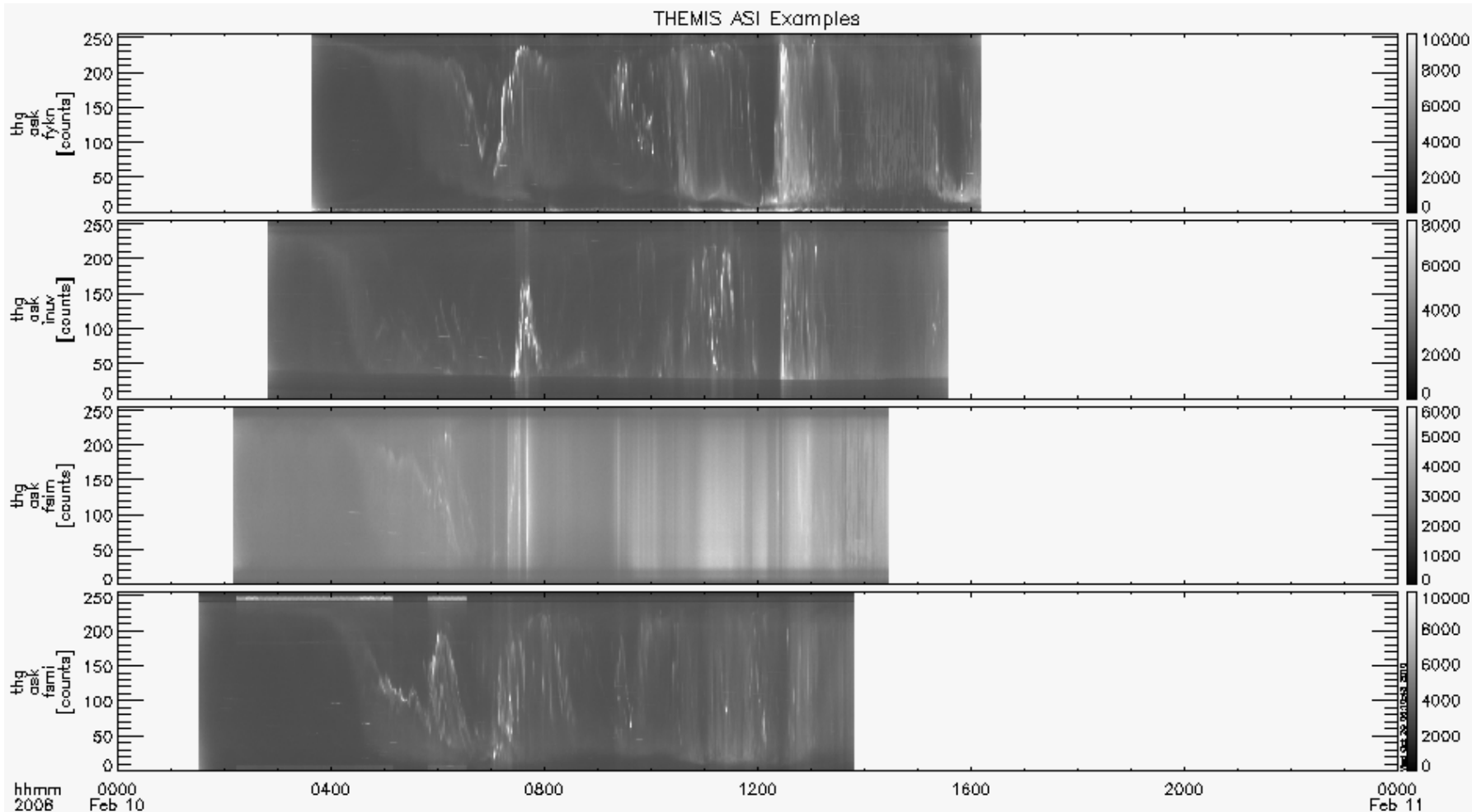
- ⤴ Delivered daily using square-root intensity compression
- ⤴ 1024 pixels within  $\pm 80$  magnetic Latitude and  $\sim \pm 120$  Longitude
- ⤴ 3 seconds temporal resolution

## 3. Full resolution images

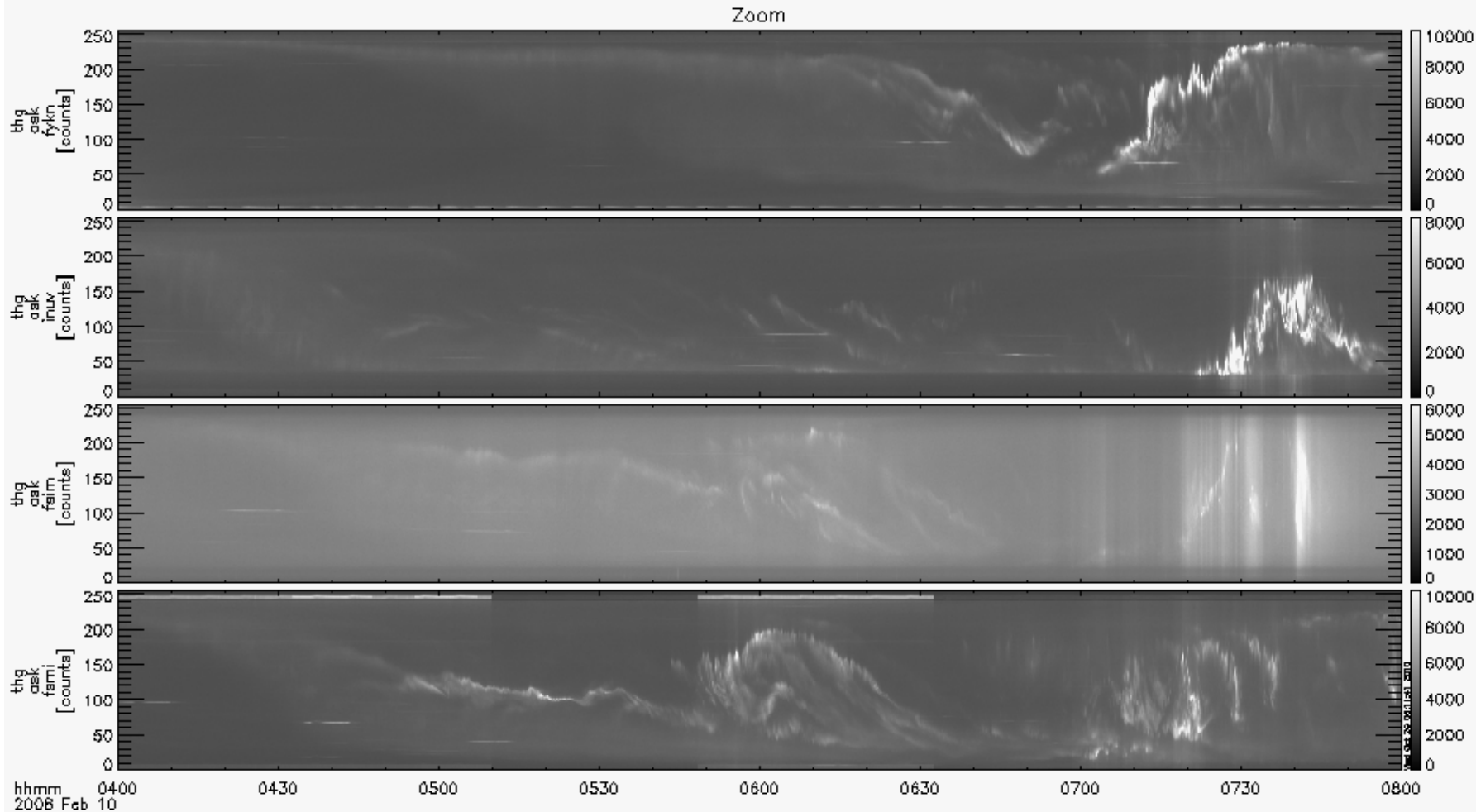
- ⤴ 256x256 pixels covering about 600 km radius around station
- ⤴ Delivered about  $\frac{1}{2}$  year later
- ⤴ 3 seconds temporal resolution
- ⤴ Full 16 bit intensity scale

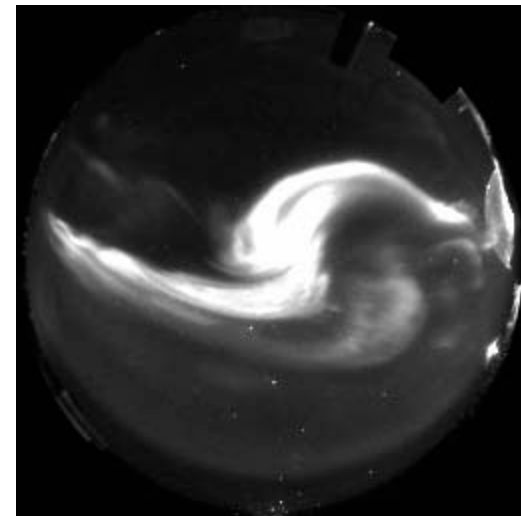
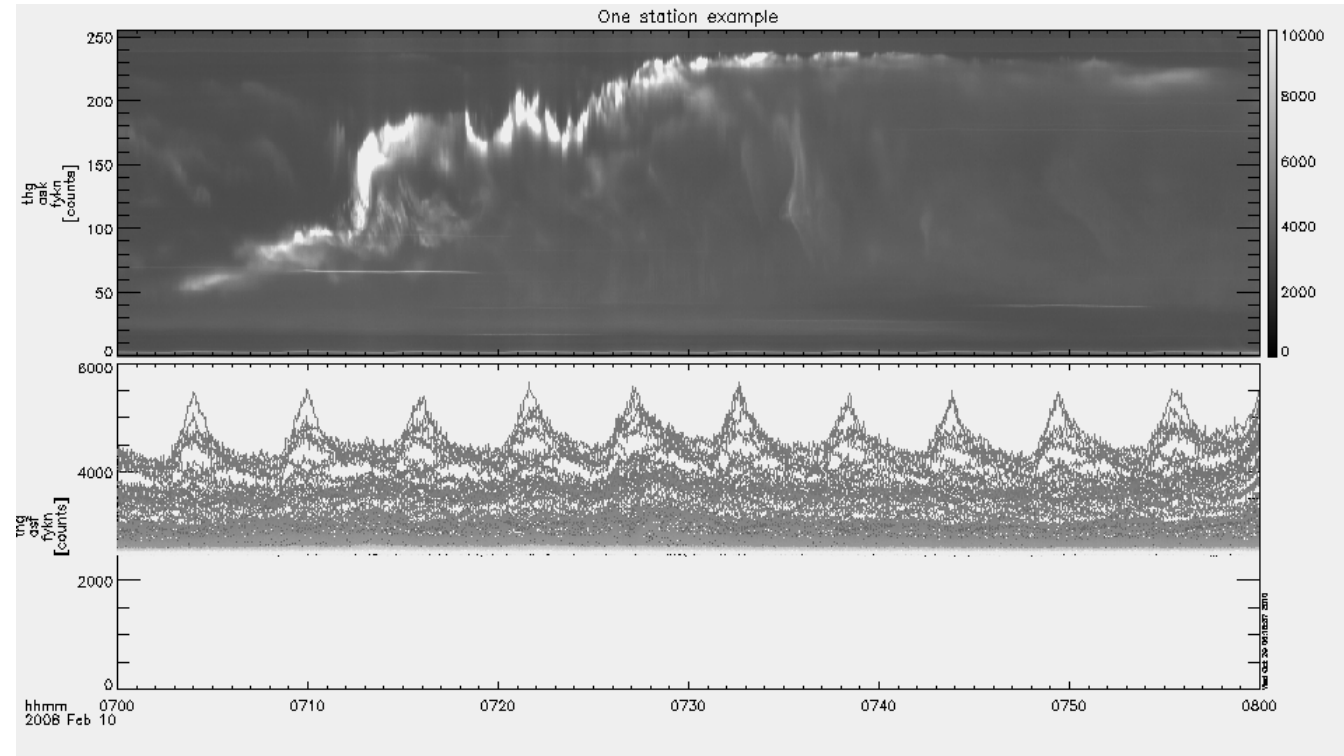


# Daily overview of selected keograms



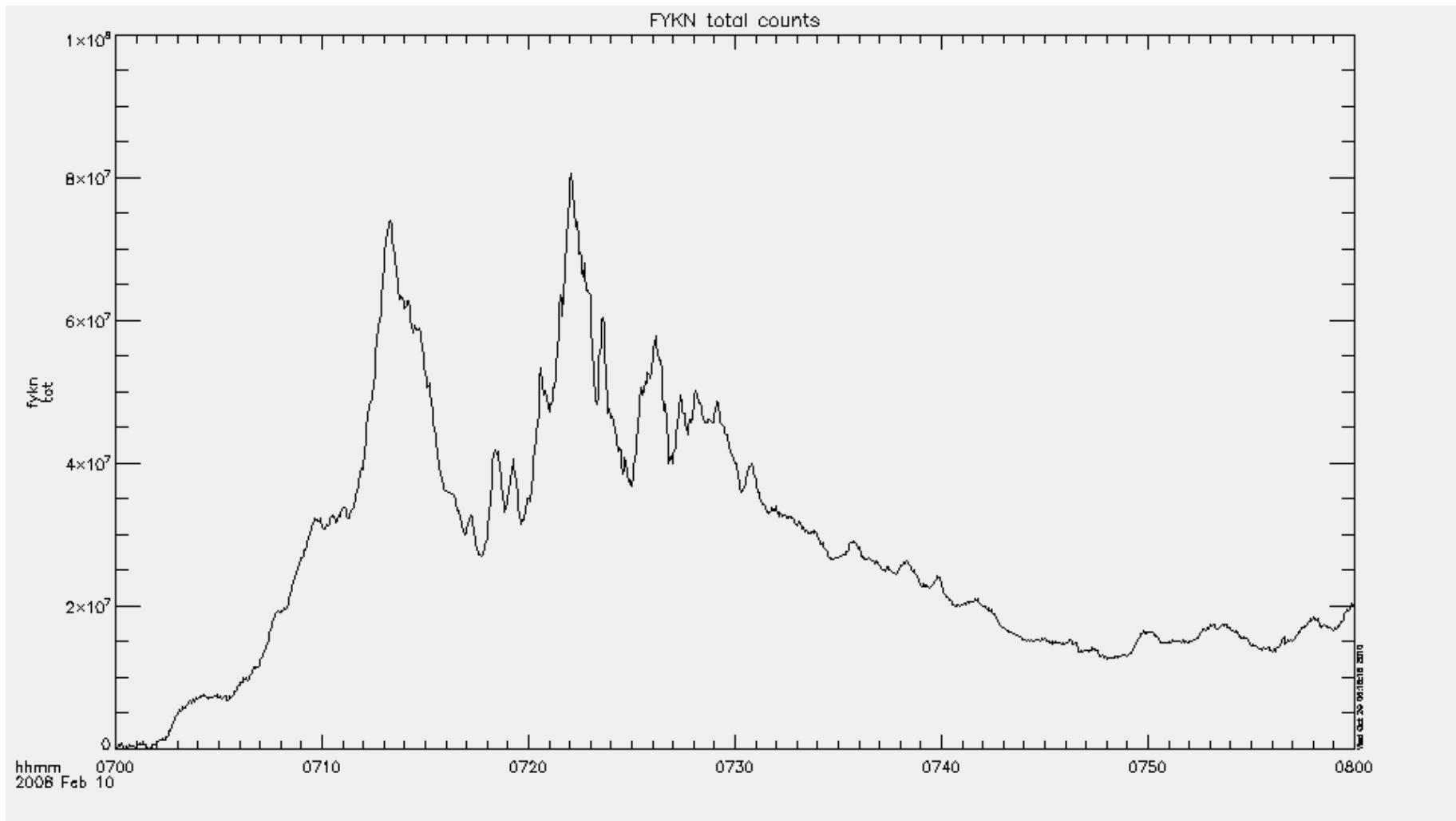






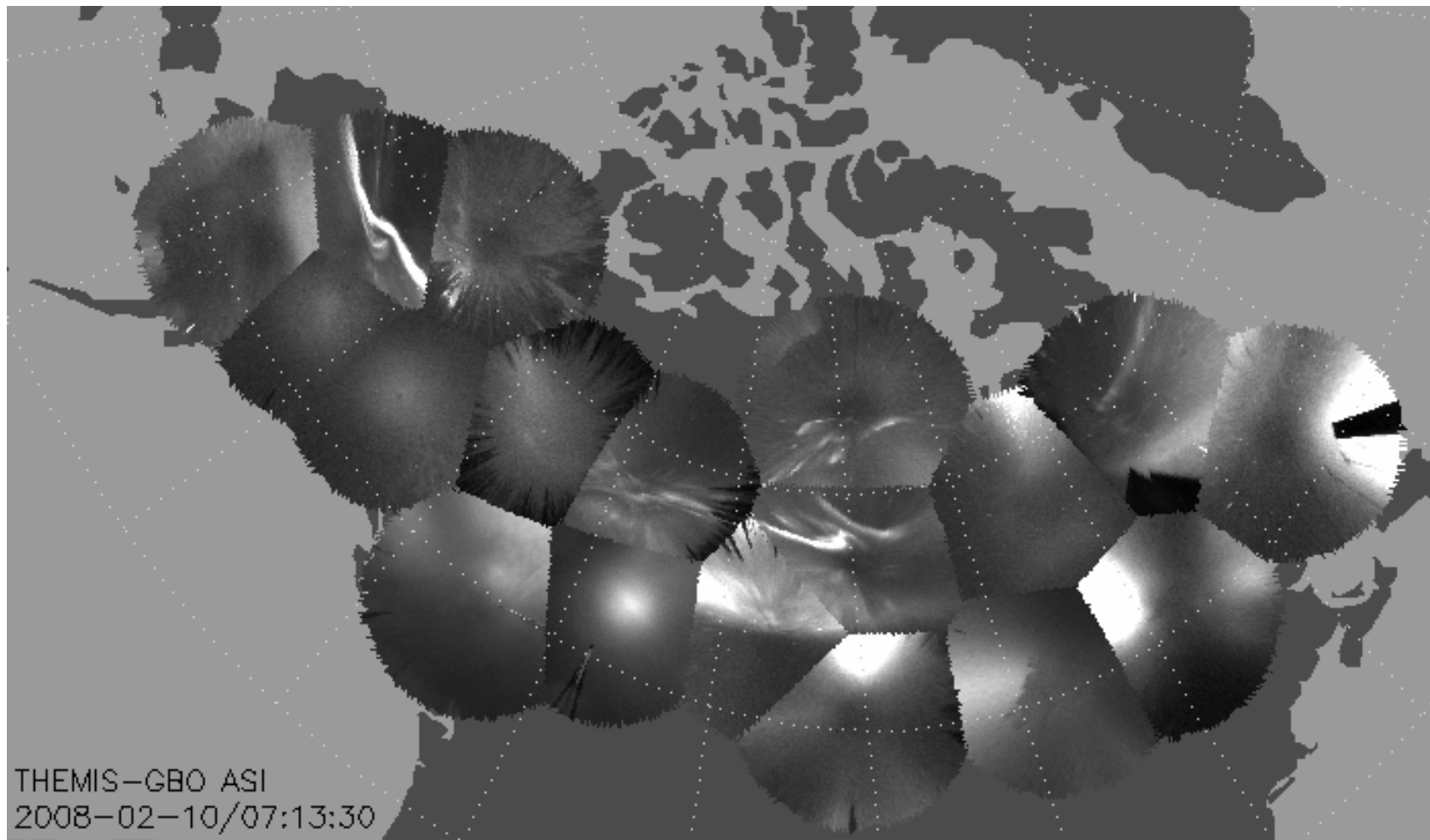


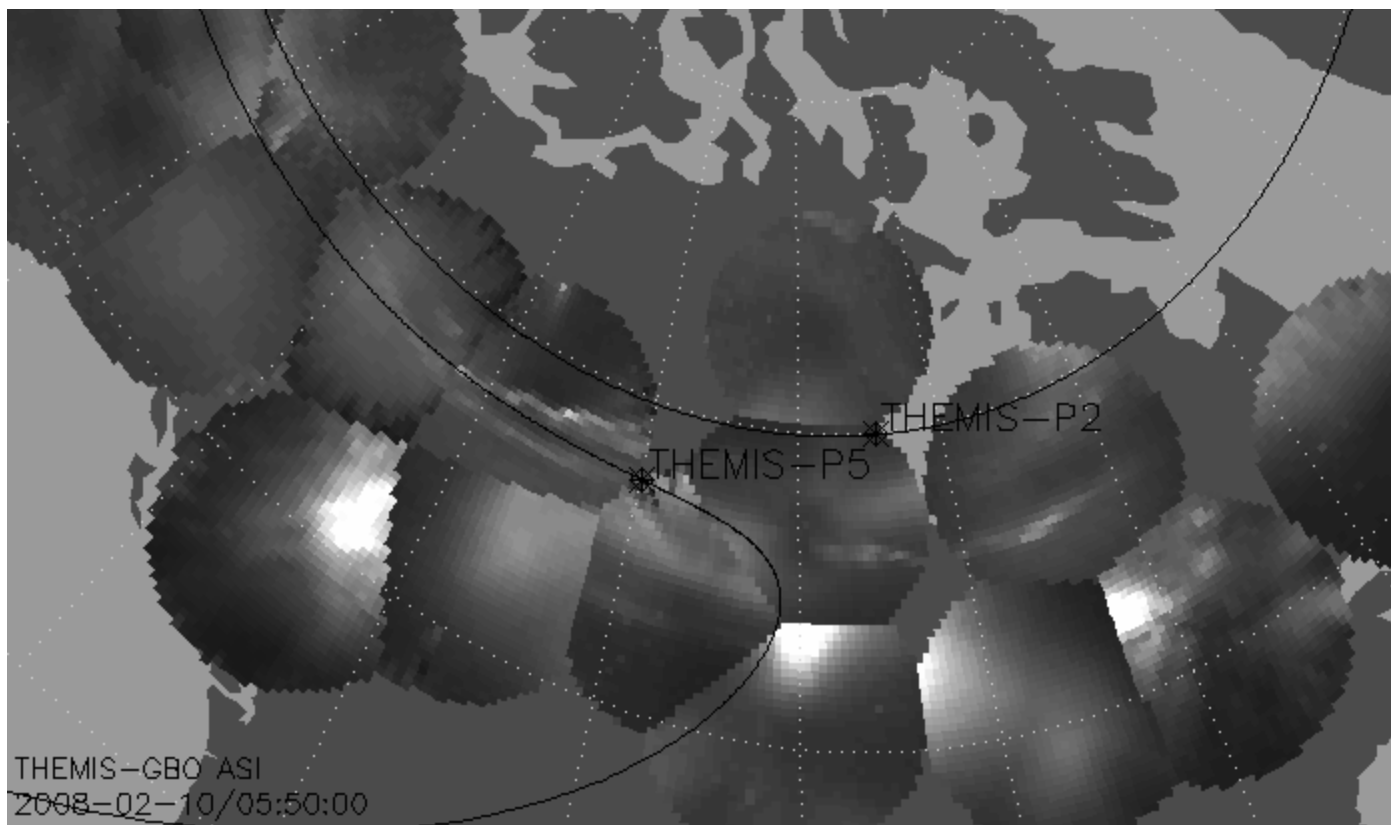
# Total number of counts in images to see major increase (substorm onset)



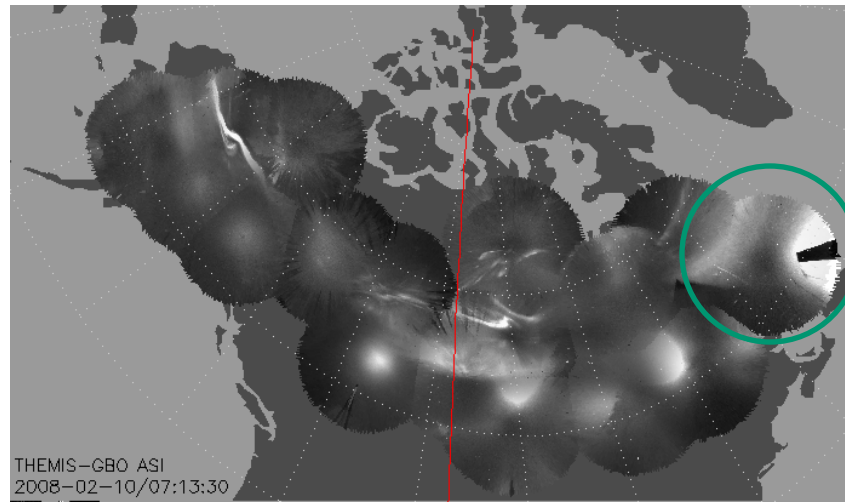


# Mosaic of whole GBO array from full resolution images

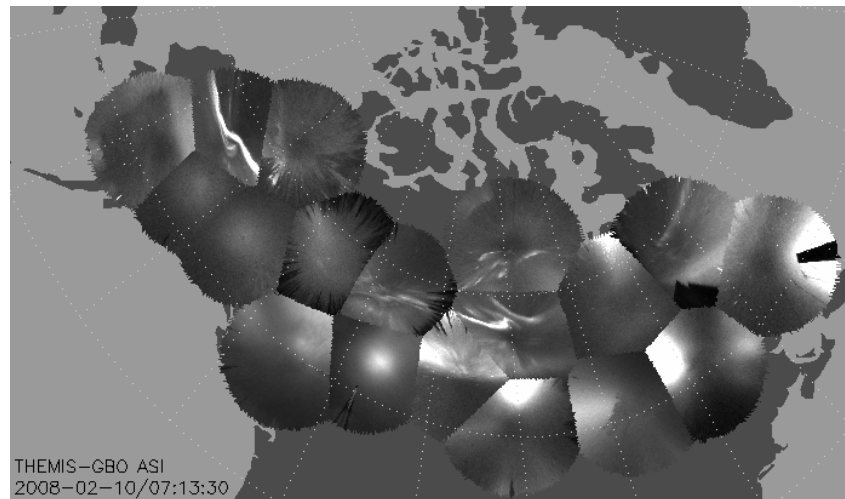




Black line marks footprint of THEMIS-P2 and P5 during whole night  
Asterisk marks location at time of mosaic



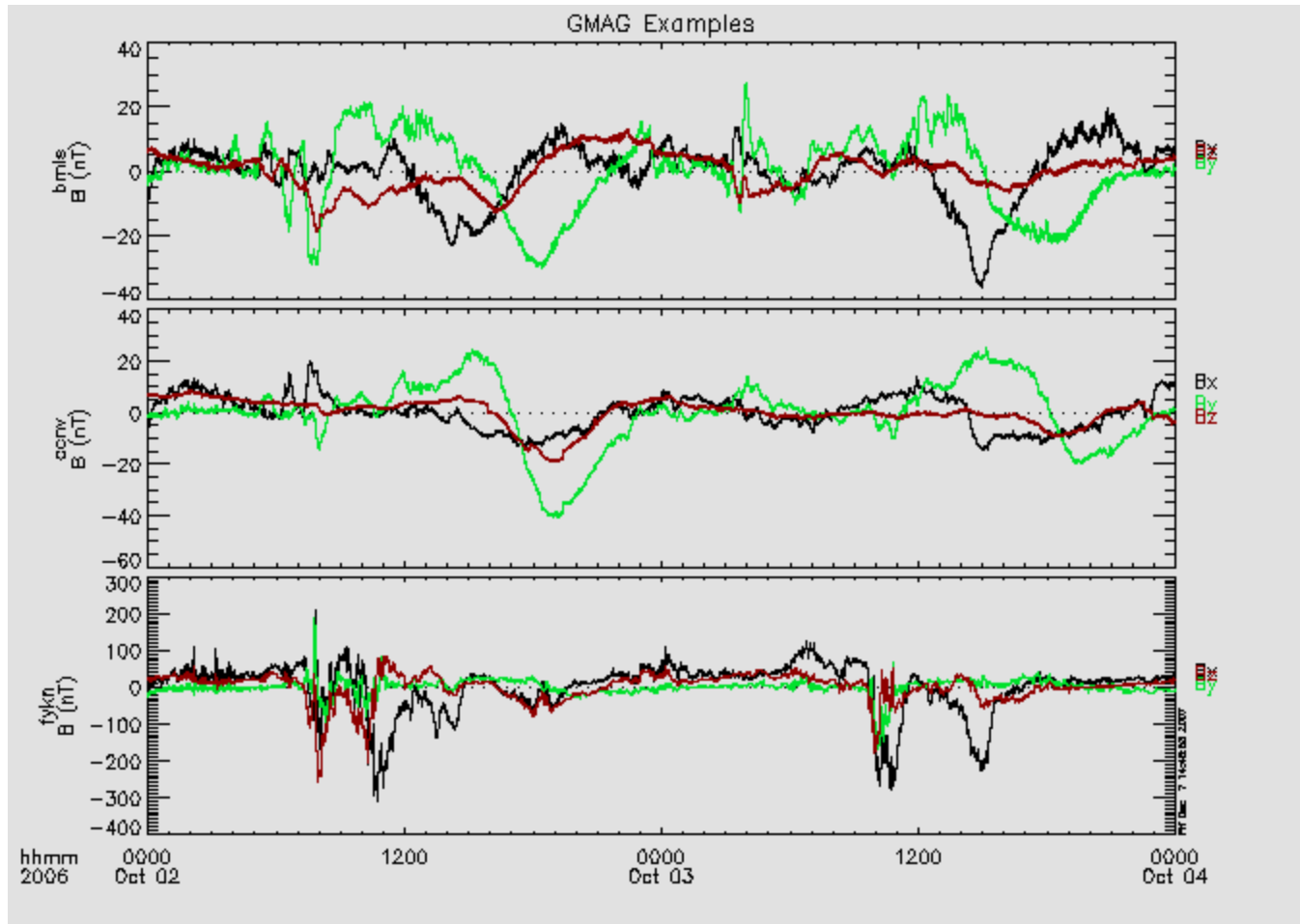
Mosaic of whole GBO array with merged full resolution images



- Compare merged mosaic to normal mosaic below
- There may still be remaining issues with transitions
- Depending on computer it may take up to 5 minutes to finish one merged mosaic
- Selecting fewer stations speeds up calculation and may remove sharp borders
- !!!!!!! THIS SOFTWARE IS STILL NOT PERFECT!!!!!!

# Ground magnetometer Examples

## Thm\_crib\_gmag.pro



GMAG Data With Average Subtracted



