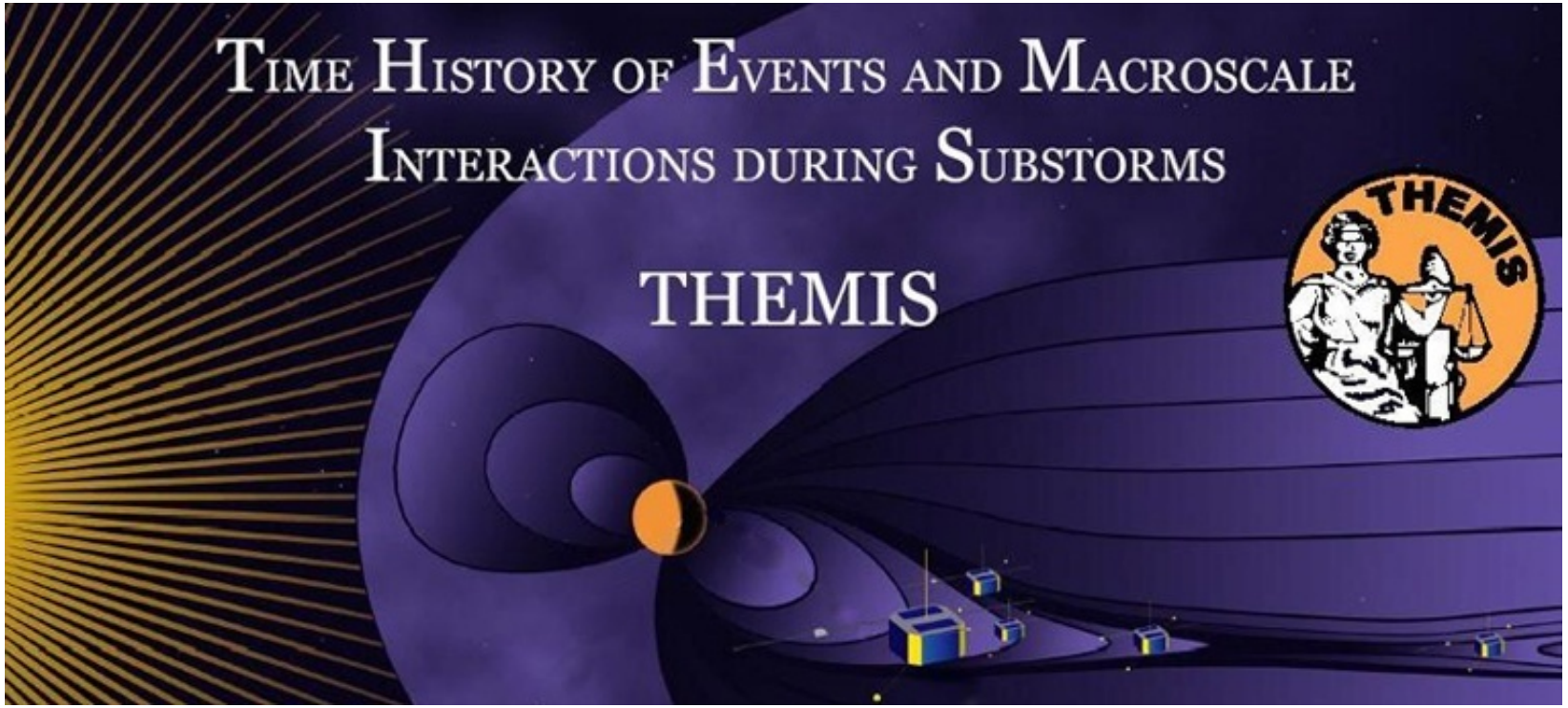


Science Software – v8.00 Training

GEM – Snowmass, CO

June 2013

What's new in TDAS?

Support for TT2000 times
IDL 8+ support. (Recommend IDL 8.2.3 for 8+ users)
MAG coordinate transform in cotrans
Many new gmags: NRCan, McMac, PG1/PG2
Legend options menu in GUI
Numerous improvements in velocity slices
Better file_http_copy server compatibility
Improvements in SST calibrations
Calc/mini_language supports keywords & automatic interpolation.
SPEDAS GUI API: ERG & IUGONET plugins
Date support to 1800s and earlier
Much much more!

THEMIS Data Analysis Software

Organization	Contributors
UC Berkeley	D Larson, H Frey, J Bonnell, J McFadden, A Keiling J McTiernan, B Sadeghi, N Hatzigeorgiu, J Lewis
UCLA	V Angelopoulos, P Cruce, C Russell, H Leinweber, A Flores, K Ramer, B Kerr, M Feuerstein, L Philpott, E Grimes
SP Systems	K Bromund
APL	H Korth
NASA/GSFC	V Kondratovich
MPE	E Georgescu
TUBS	U Auster
CETP	P Robert, O LeContel
Calgary	B Jackel, E Donovan

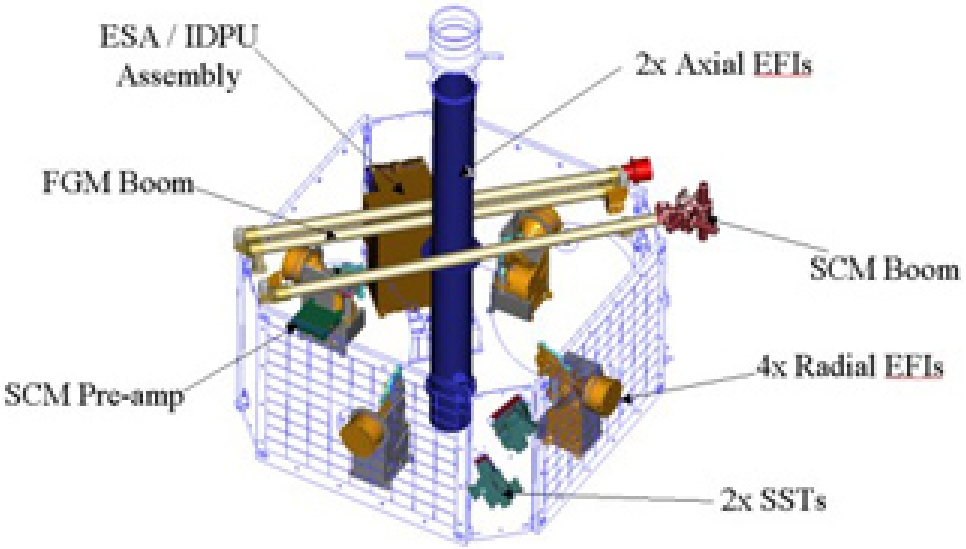
Space Based Instruments

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/Processed Data

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

Data Definitions

- 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.

V7.01 Science Software/Data Status Report

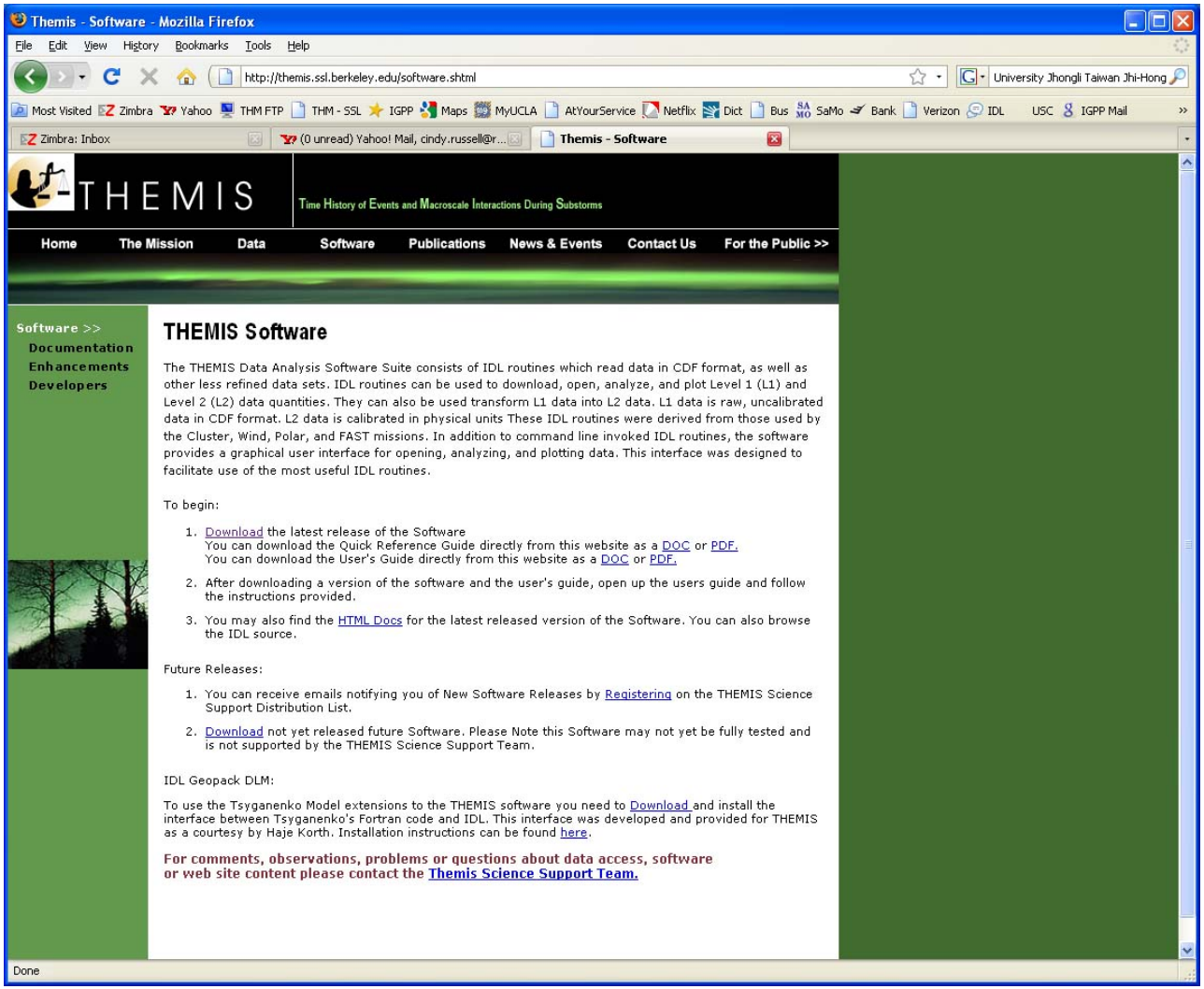
- General Loads, introduces and calibrates all L1 quantities, all instruments
  Loads calibrated L2 quantities
- STATE L1 STATE available since launch, V03 STATE (improved attitude and spin phase corrections)
- FGM L1, L2 data available since early March 2007
- FIT / FFT / FBK - L1, L2 data available 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 80 stations. That includes one from Greenland, 7 from Augsburg College, 11 from the University of Alaska, 4 from University of Athabasca, 7 from the University of Alberta, 29 from Norway, Greenland, and Denmark, and 22 THEMIS EPO/GBO sites.
- 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

THEMIS Main Web Page

http://themis.ssl.berkeley.edu

THEMIS Software Web Page

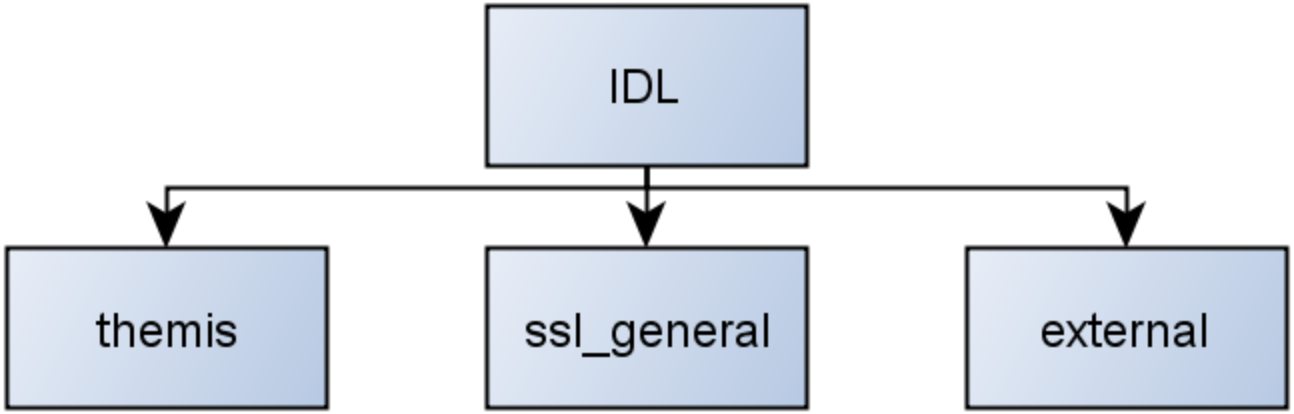


THEMIS_Science_Support@ssl.berkeley.edu

Software Objectives

- 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

Software Organization



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

System Requirements

- 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
- For Mac, system configurations are required to run IDL
  - Recommend IDL 8.2.3 for Mac users.
  - Detailed installation instructions in tdas quickstart guide on website
- See THEMIS User's Guide for full information, available at: ftp://apollo.ssl.berkeley.edu/pub/THEMIS/

- 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
- 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.

Data / Directory structure

- 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 THEMS GUI widget
    - Environment variables

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

Variable Names

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*

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	ElectoStatic Analyzer				*
thm_load_esa_pkt	ElectoStatic 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	Spaceraft Trigger		*		
thm_load_bau	BAU Housekeeping		*	*	

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

Crib Sheets for Loading, Processing and Plotting

thm_crib_asi
thm_crib_dproc
thm_crib_efi
thm_crib_esa_da
thm_crib_esa_moments
thm_crib_export
thm_crib_fac
thm_crib_fbk
thm_crib_fft
thm_crib_fgm
thm_crib_fit
thm_crib_gmag
thm_crib_mom
thm_crib_mva
thm_crib_overplot
thm_crib_part_getspec
thm_crib_scm
thm_crib_sst
thm_crib_state
thm_crib_tplot
thm_crib_tplotxy
thm_crib_twavpol
thm_crib_part_slice2d
thm_map_examples

IDL>.run thm_crib_asi

or cut and paste, or copy and modify

Coordinate Transformations

- 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‘, ouf_suffix = ‘geo’

Plotting & Analysis Routines

- 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

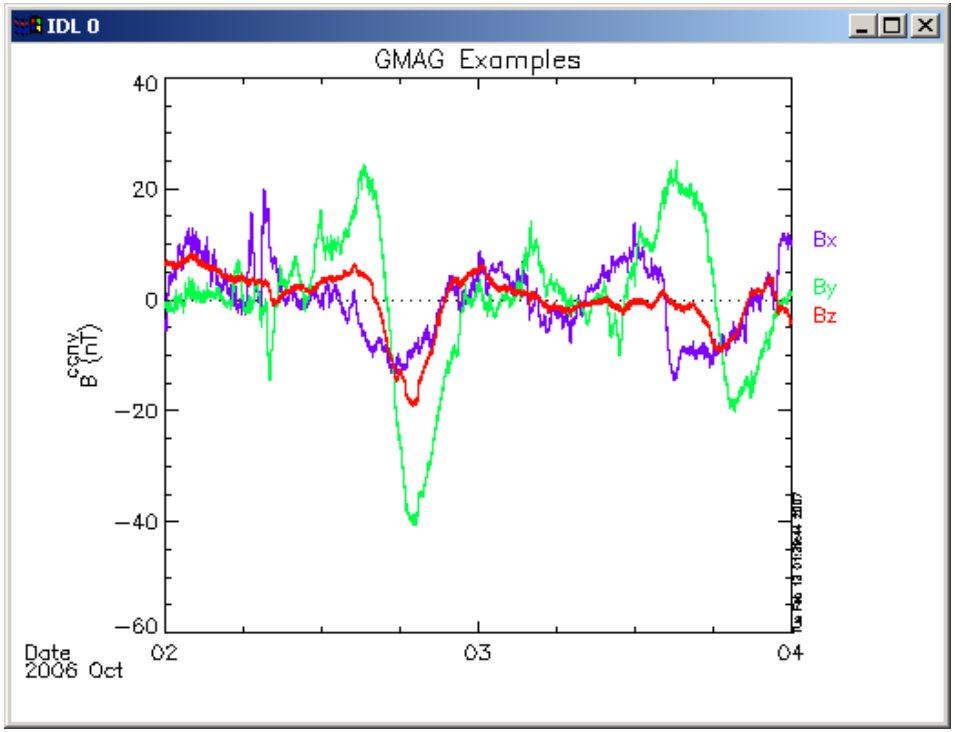
- tvector_rotate
- fac_matrix_make
- thm_fac_matrix_make
- minvar_matrix_make
- enp_matrix_make
- rxy_matrix_make
- sse_matrix_make
- gsm2lmn

Tsyganenko Model

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

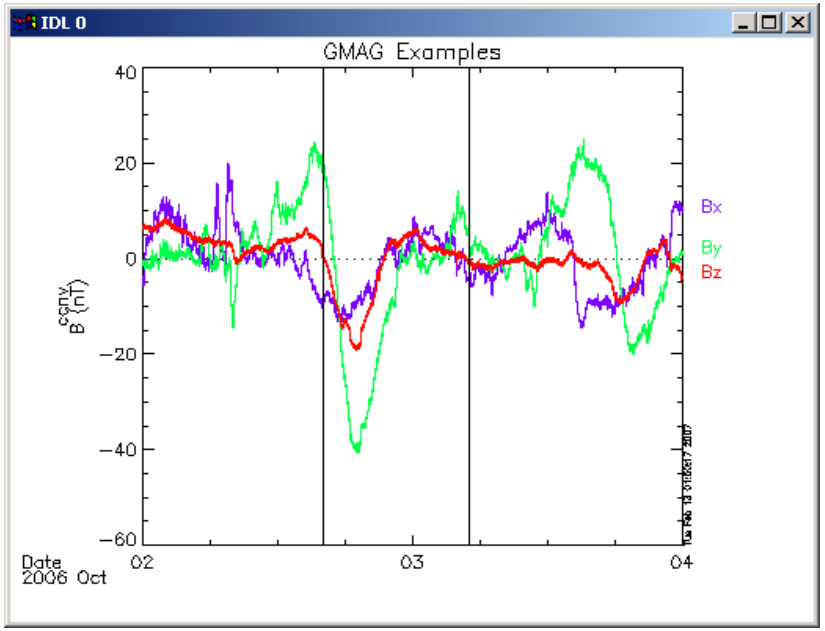
Command Line Example 1

- 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'

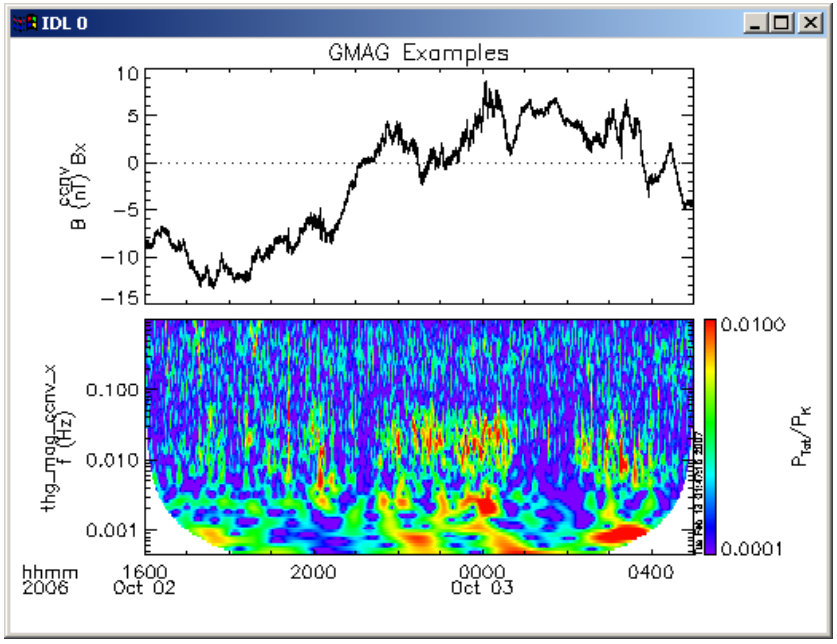


Command Line Example 2

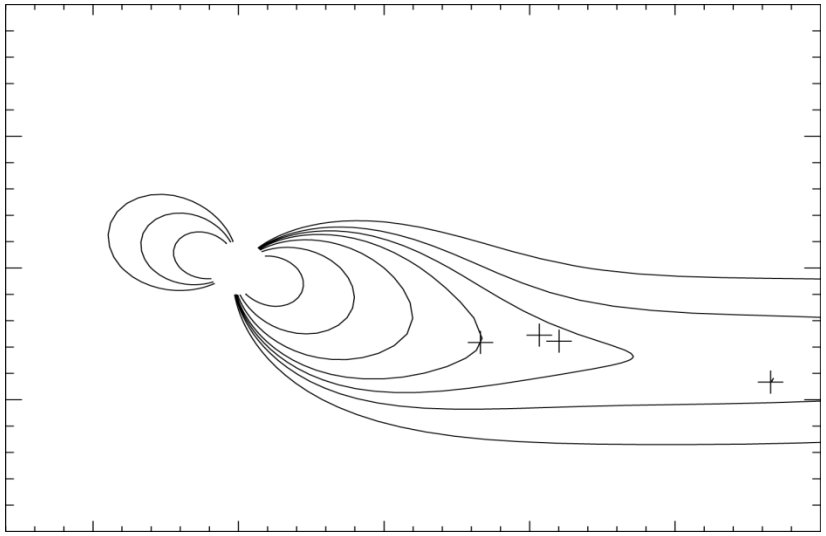
- Wavelet transform on an interval of interest
  - Define and display the interval
    - » Tr = ['2006-10-2/16:00','2006-10-3/05']
    - » timebar,tr



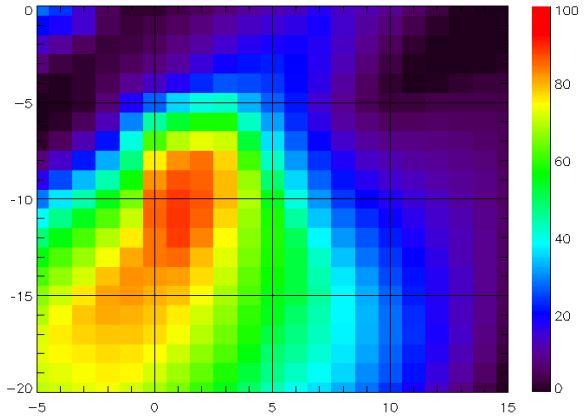
- Split the 3-vector into components:
  - » split_vec,'thg_mag_ccnv'
- Compute transform of one component
  - » wav_data,'thg_mag_ccnv_x',/kol $,trange=tr ,maxpoints=24l*3600*2
- Set color limits (log scale)
  - » zlim,'*pow', .0001,.01,1
- Plot it.
  - » tplot,'*ccnv_x*',trange=tr



Plotting Examples

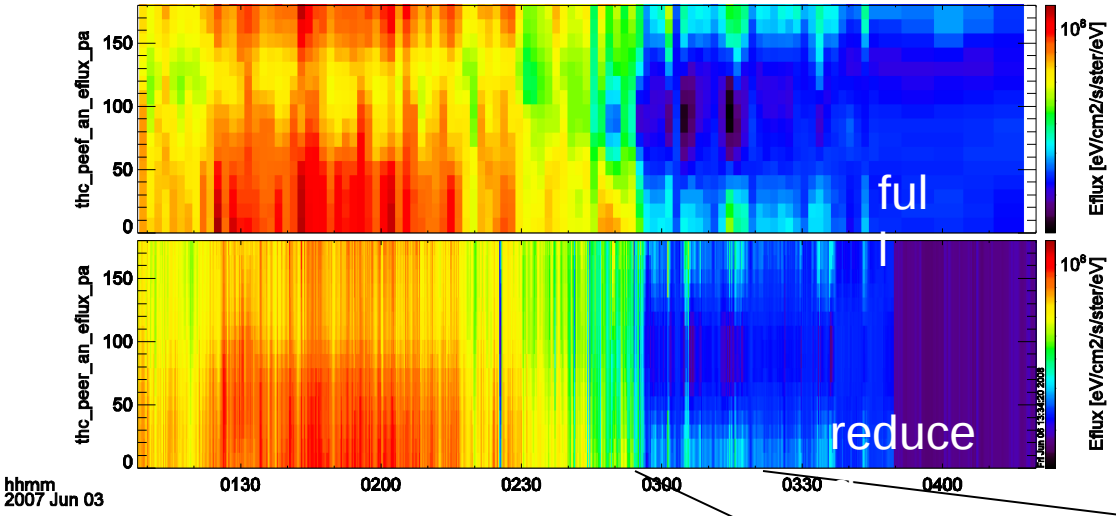


tplotxy can be used to plot isotropic position plots. Like plots of magnetic field models and spacecraft position



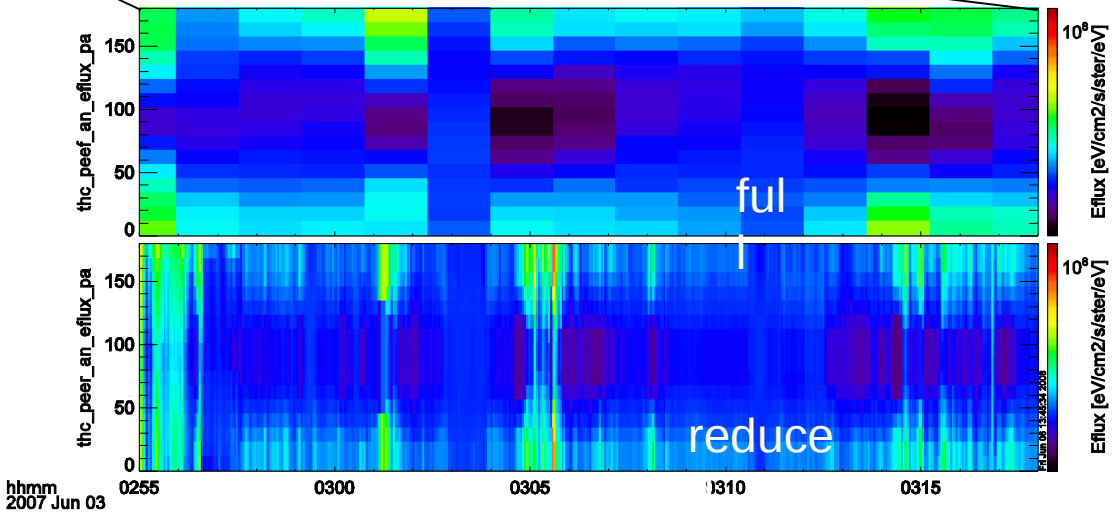
Plotxyz can be used to plot 3 dimensional isotropic data, with any axis.(Not restricted to time-series.)

Plotting Angular Spectra



Pitch angle spectra for full and reduced mode electron ESA data. Plotted using tplot.

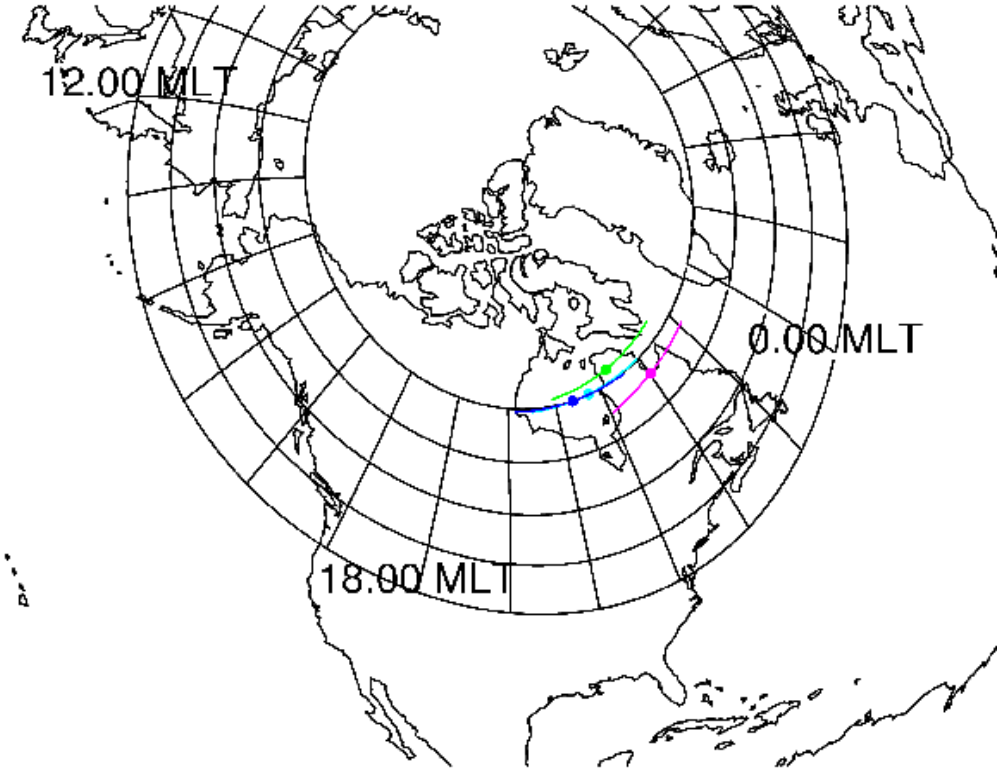
```
thm_part_getspec, $
probe=['c'], $ ;select probe
trange=['07-06-03/01:08', $  ;select timerange
        '07-06-03/04:20'], $
data_type=['peef','peer'], $ ;select data type
angle='pa', $ ;select pitch angle spectra
regrid=[32,16] ;set resolution of pitch/gyro
spectra
```



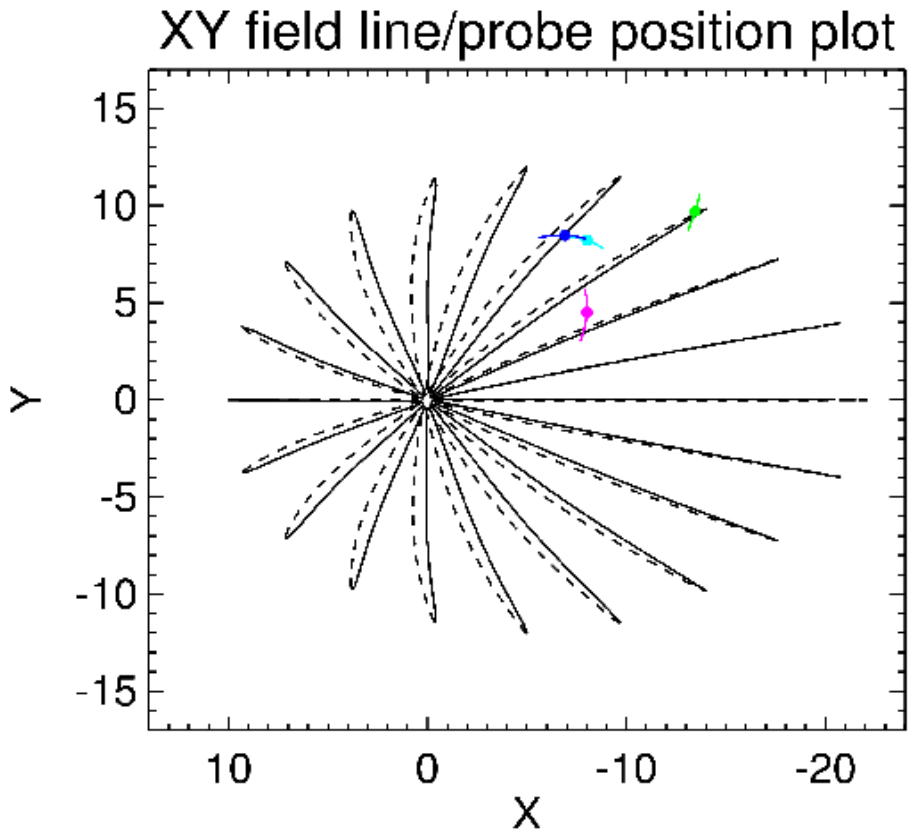
Trace / Orbit Plots

- New routines have been added to perform different 2d projections of 3d data.
  This 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 also 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/

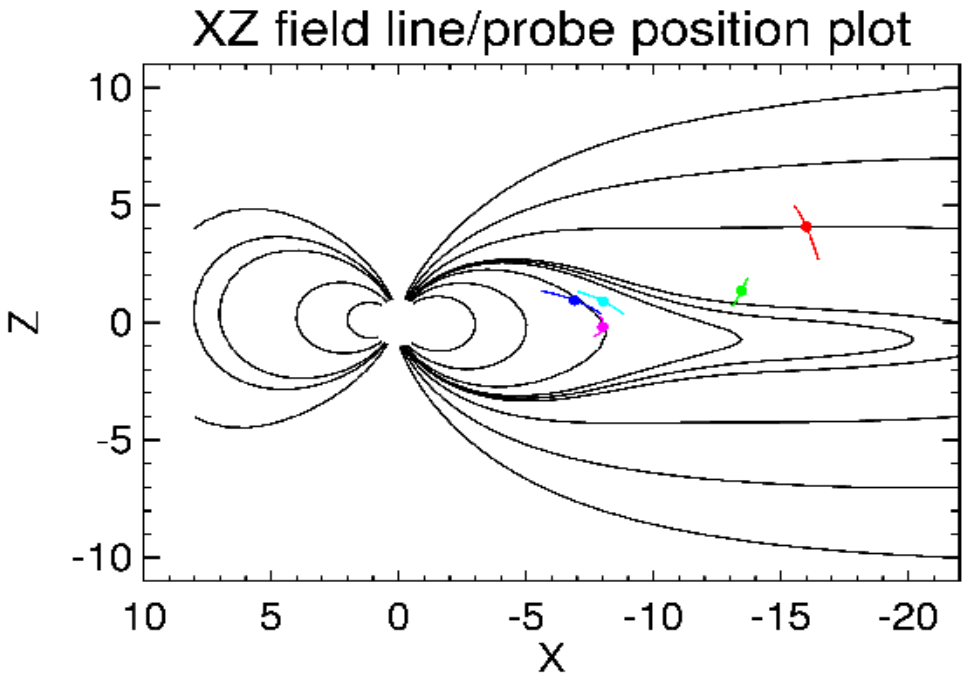
Trace/Orbit Plots - AACGM/Iono Trace Plot



Trace / Orbit Plots – XY Plot



Trace / Orbit Plots – XZ Plot

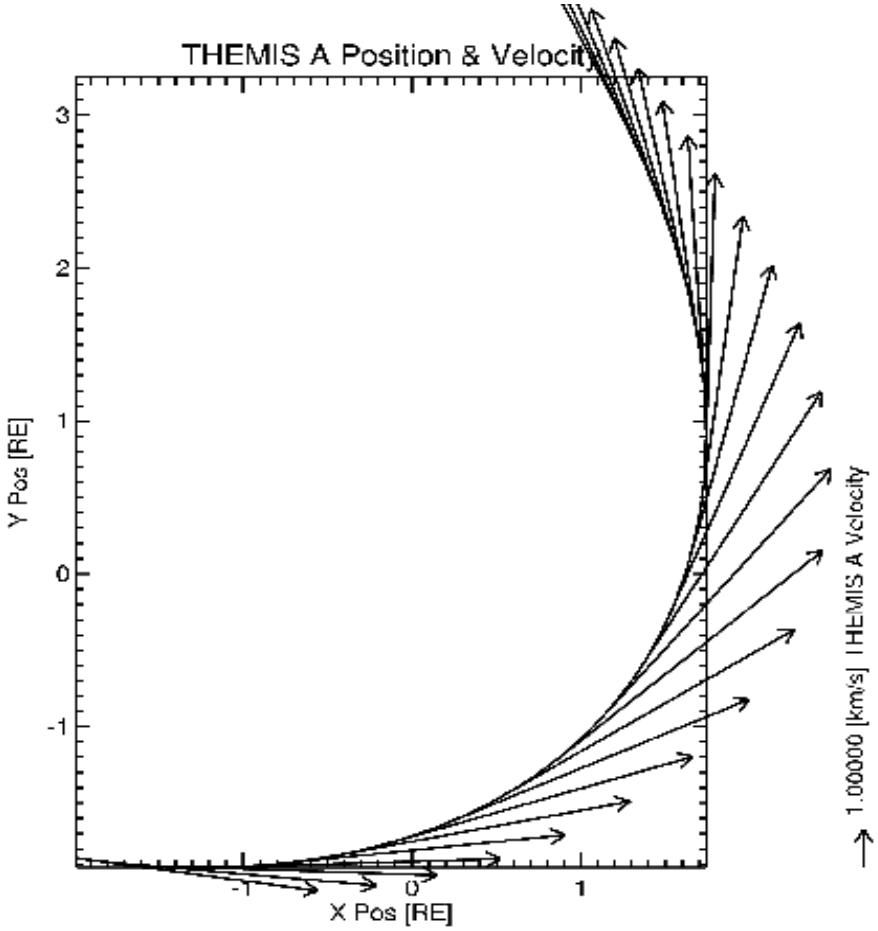


THEMIS – Mini Language

- 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

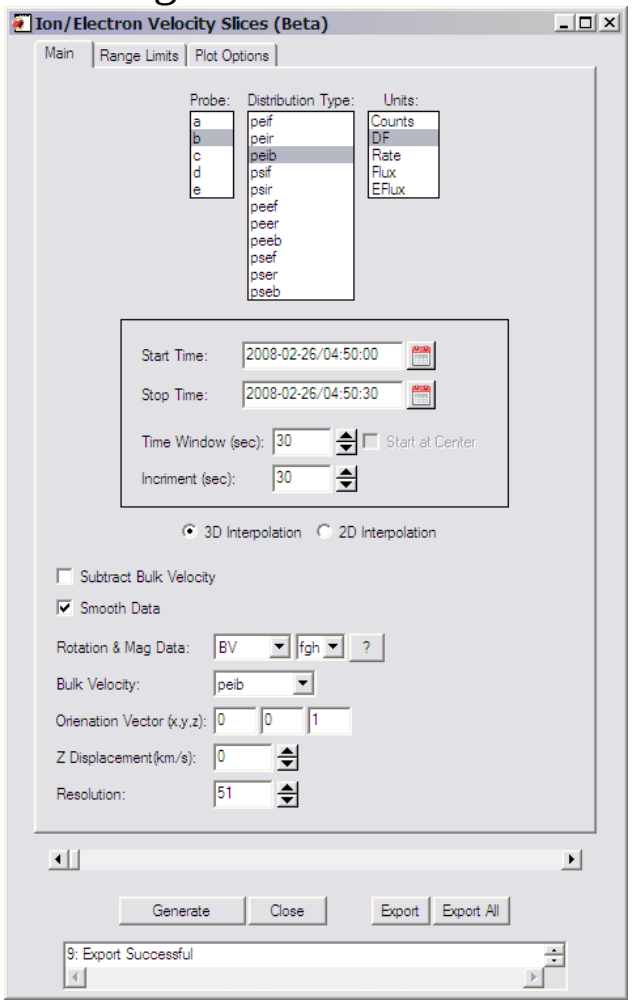
Plotxyvec – Position/Velocity Plot

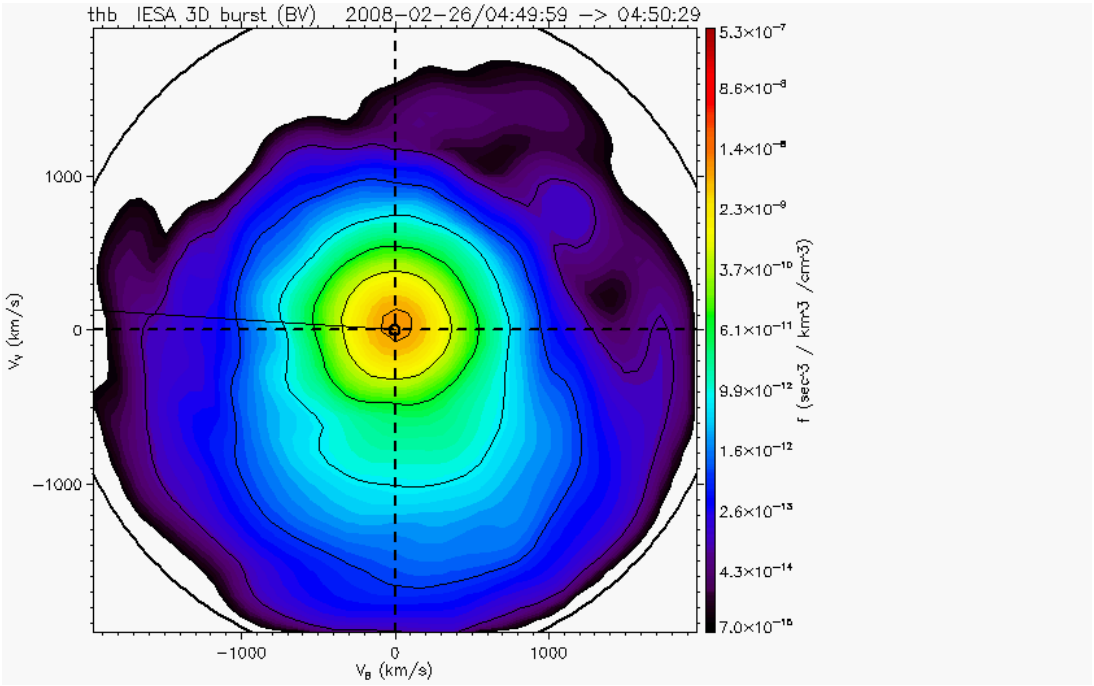


Ion/Electron Velocity Slices

Beta support for Slices of 3d particle Velocity distributions are supported in the bleeding edge.

Code can be started by typing: thm_ui_slice2d or can be accessed from the GUI by selecting



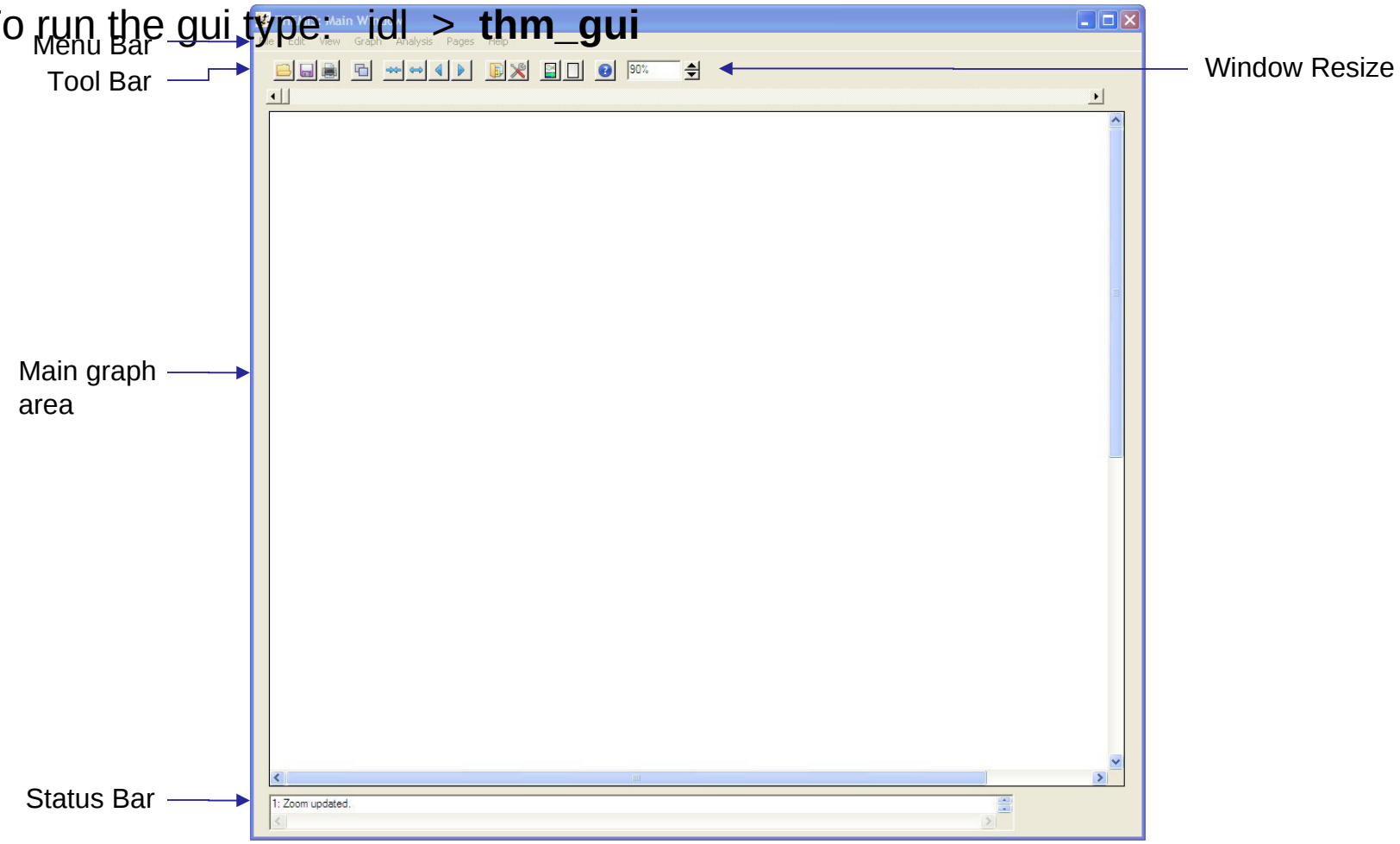


THEMIS Data Analysis Software Graphical User Interface

Graphical User Interface

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

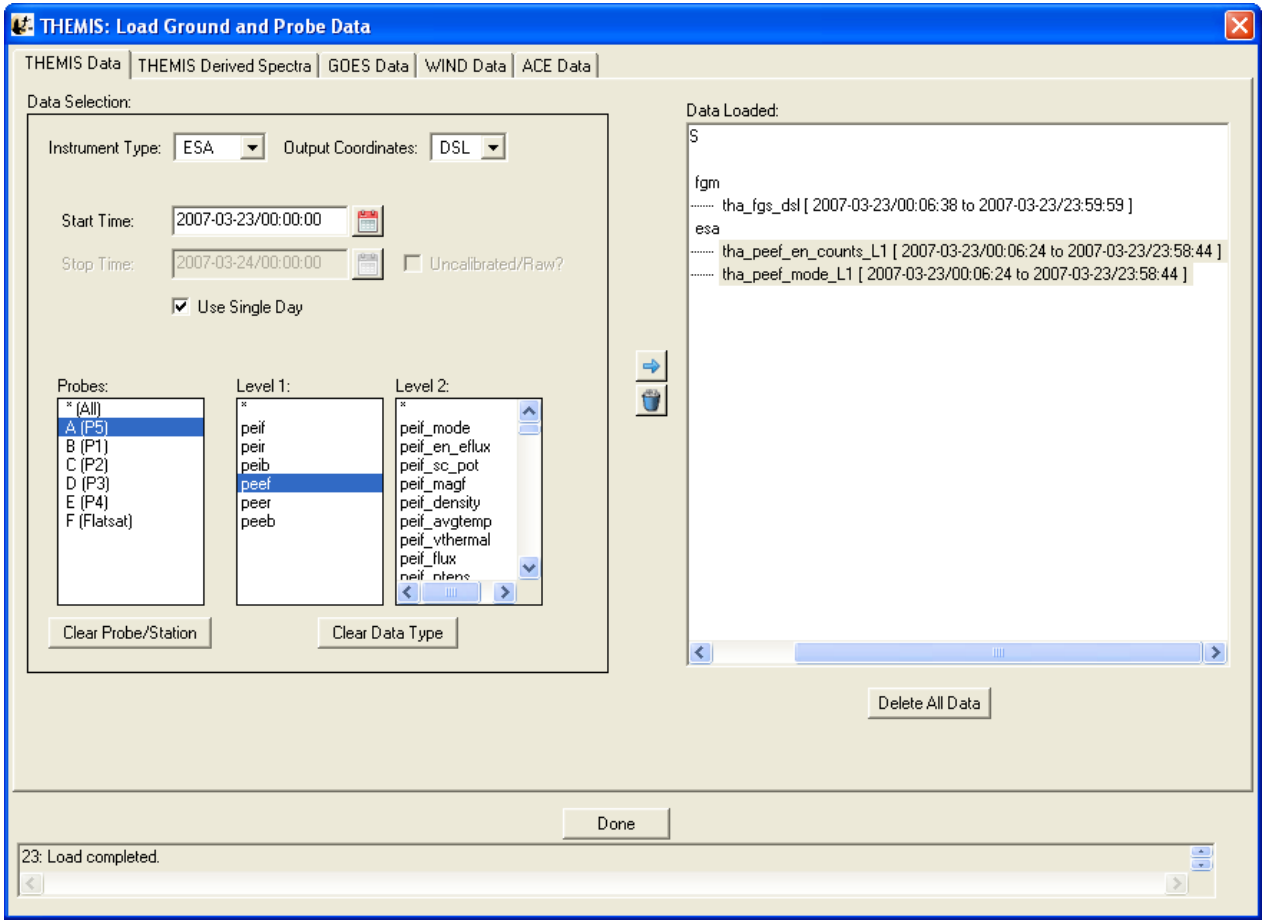
To run the gui type: idl > **thm_gui**



Loading Data – GUI

To Load Data:

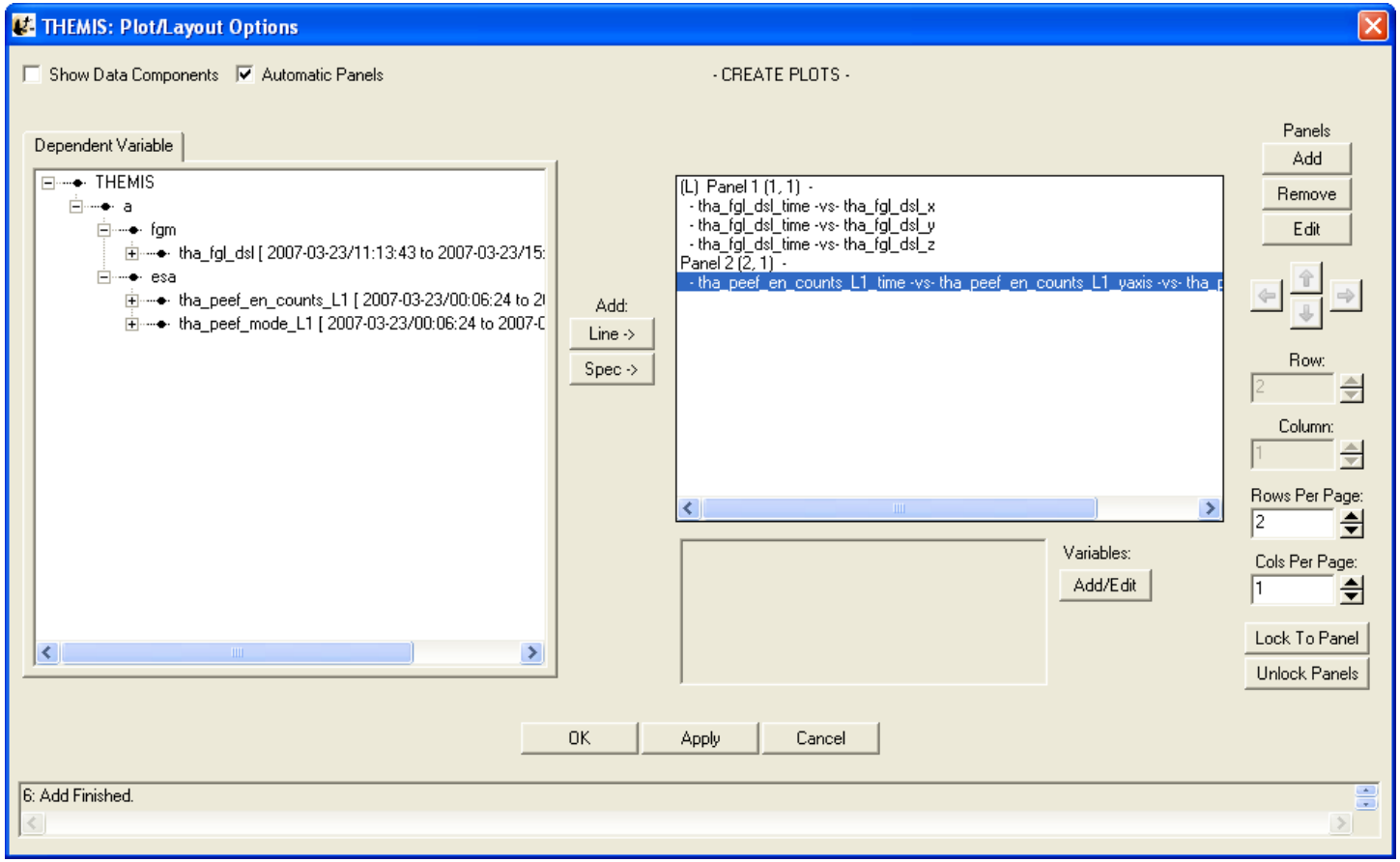
Select Load Data under the File menu
Select Instrument Type: fgm, Level2: fgs_dsl, Click Right arrow button
Select Instrument Type: esa, Level1: peef, Click Right arrow button



Plotting Data - GUI

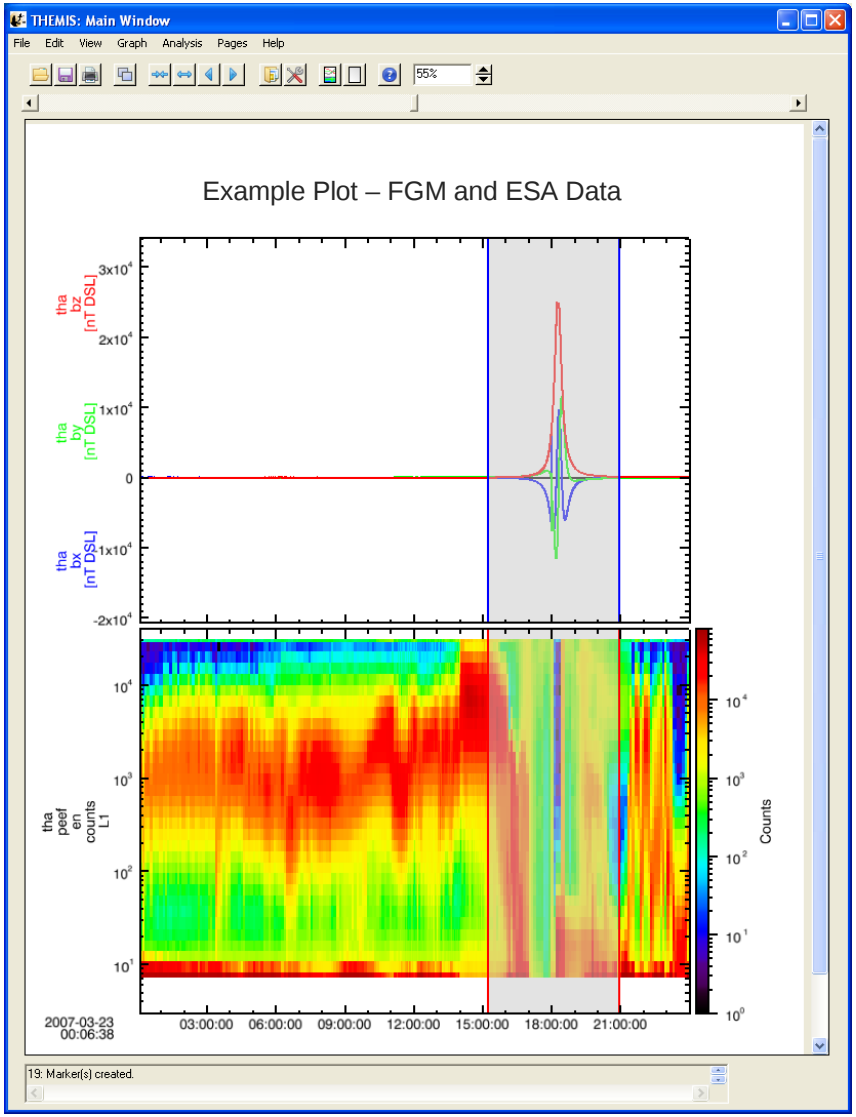
To Plot Data:

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



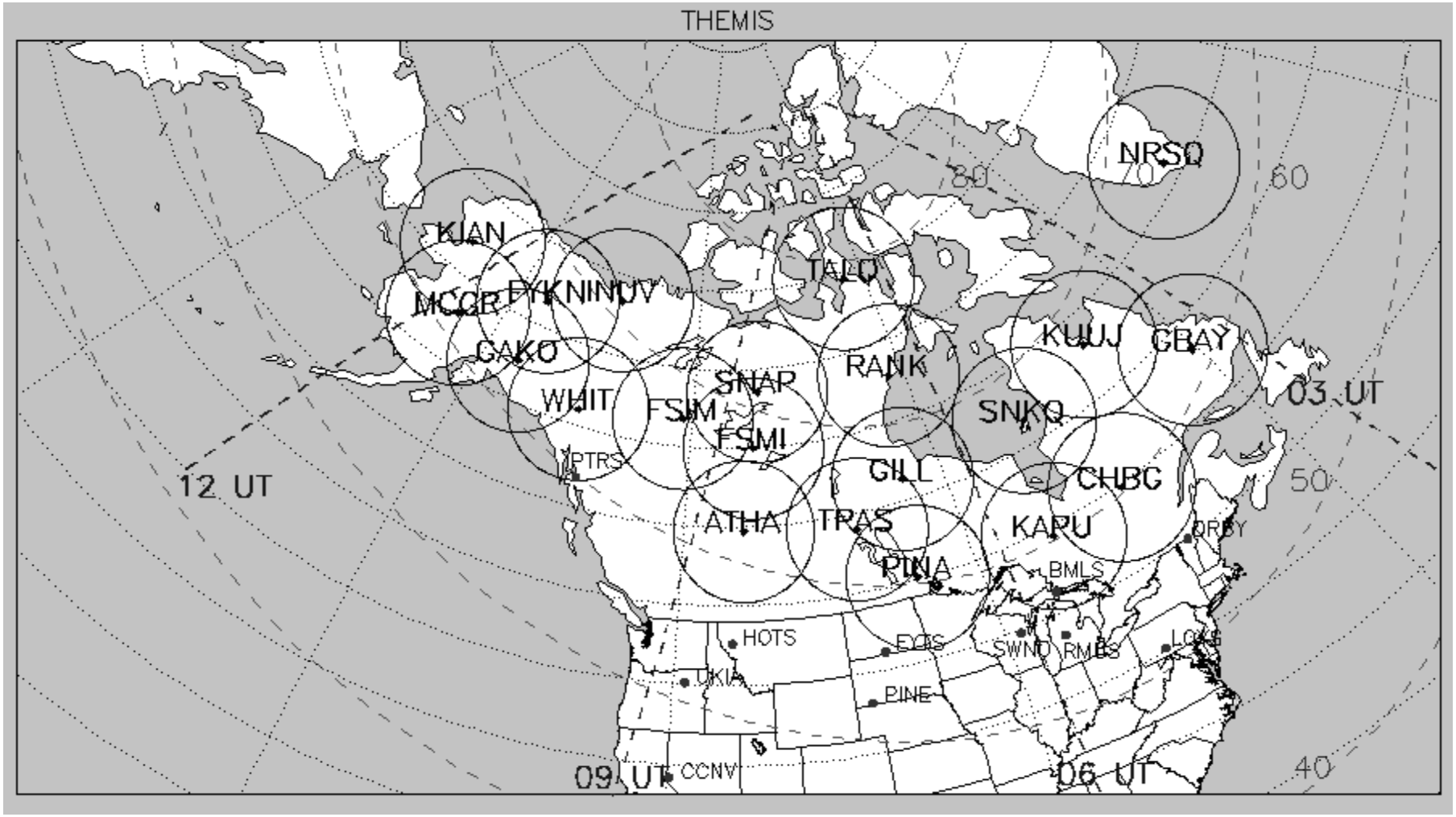
Plotting Data - GUI

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



THEMIS software for GBO all-sky imager
Thm_crib_asi.pro
Harald U. Frey
(updated November 2011)

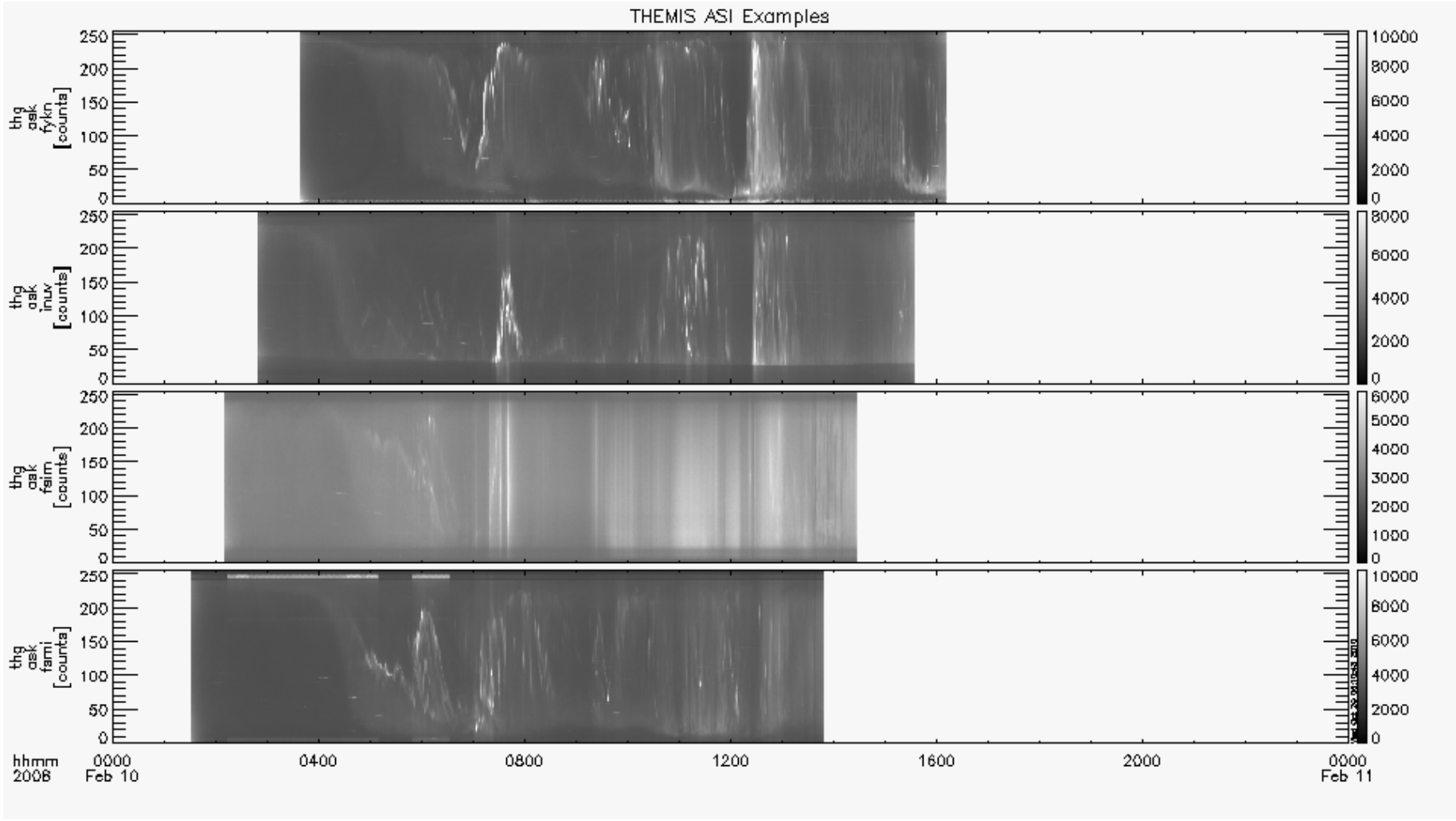
THEMIS GBO network



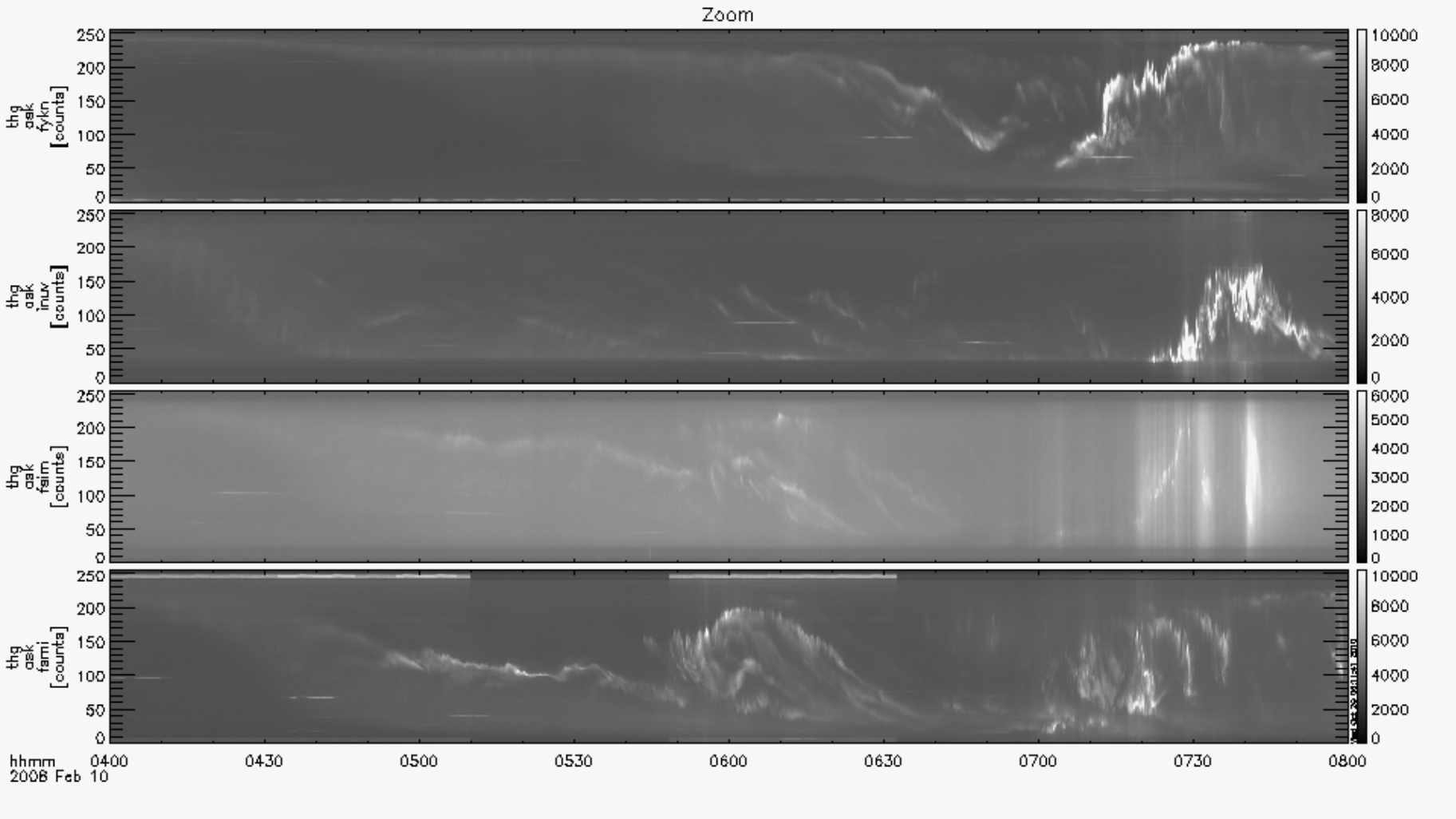
All-sky imager data products

1. Keograms along local magnetic meridian
   - Delivered daily jpeg-compressed
   - Reprocessed ½ year later with full resolution images
1. Geomagnetically mapped thumbnail images
   - Delivered daily using square-root intensity compression
   - 1024 pixels within +-8o magnetic Latitude and ~+-12o Longitude
   - 3 seconds temporal resolution
1. Full resolution images
   - 256x256 pixels covering about 600 km radius around station
   - Delivered about ½ year later
   - 3 seconds temporal resolution
   - Full 16 bit intensity scale

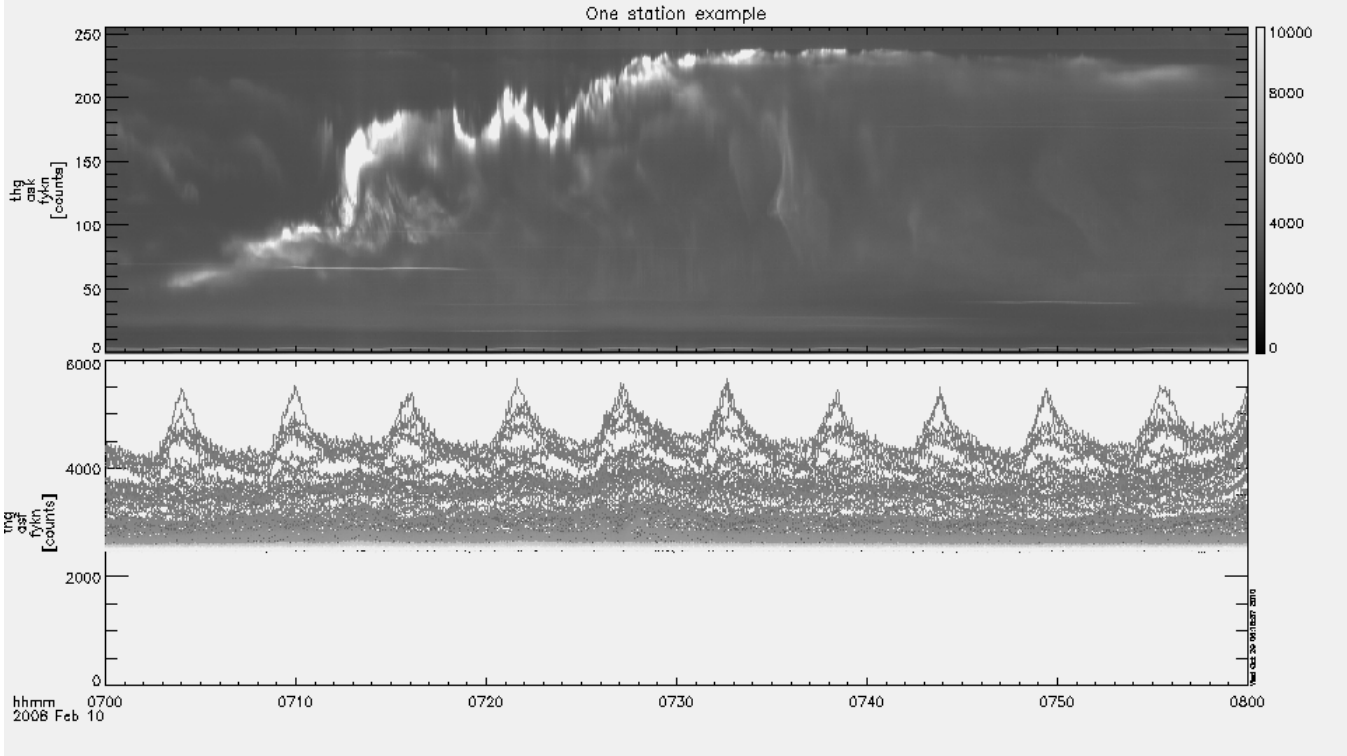
Daily overview of selected keograms

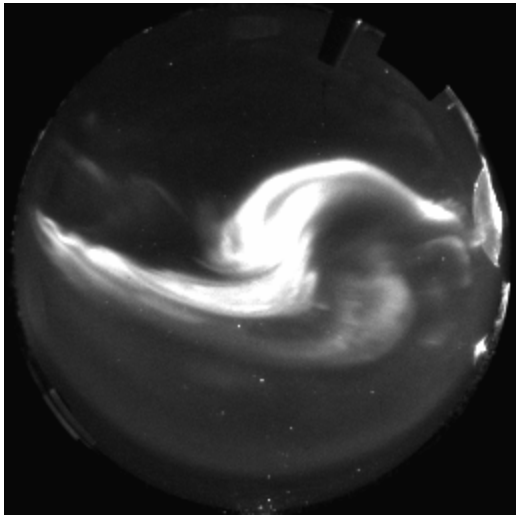


Zoom into interesting time

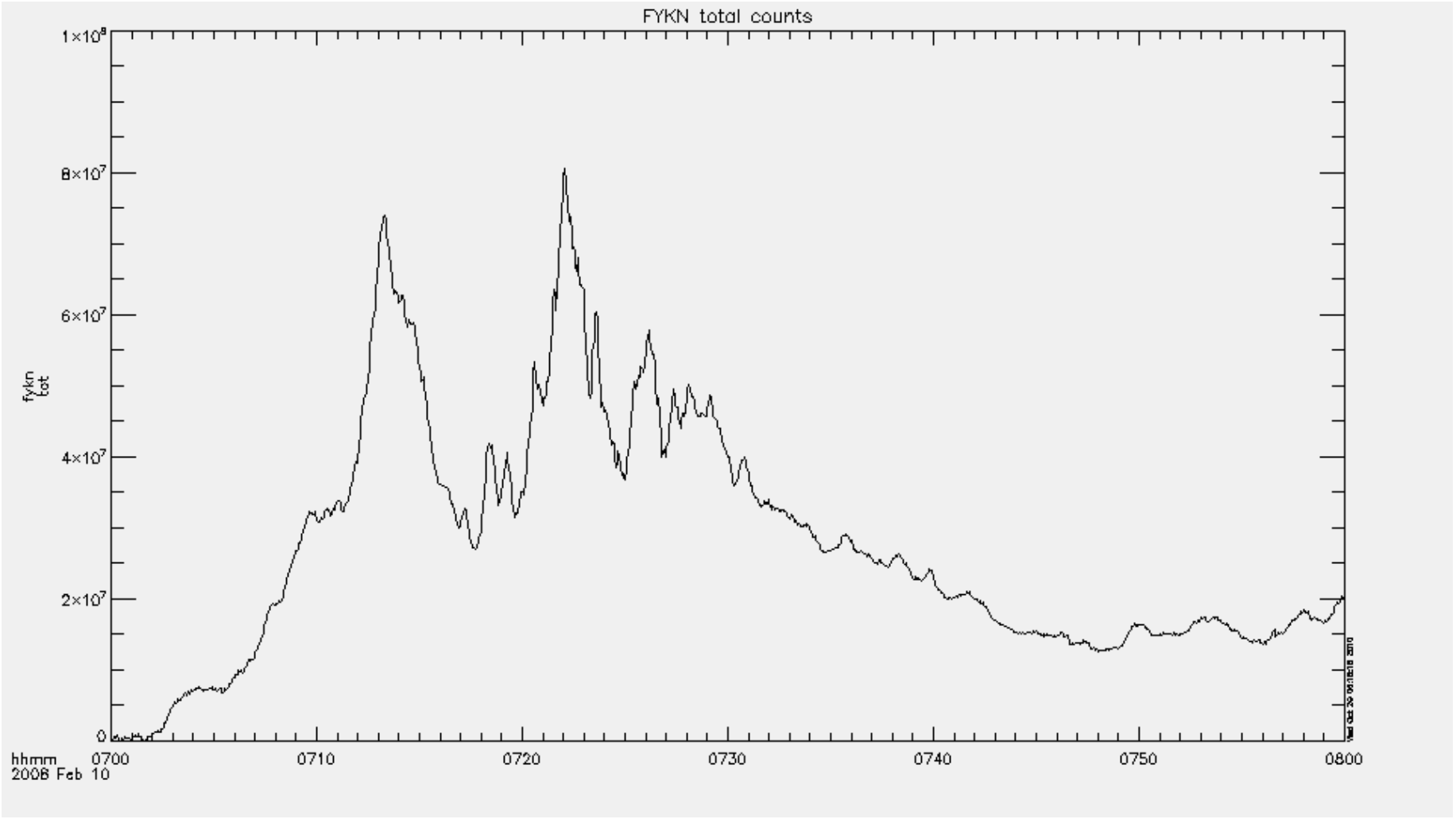


Watch “movie” of single station

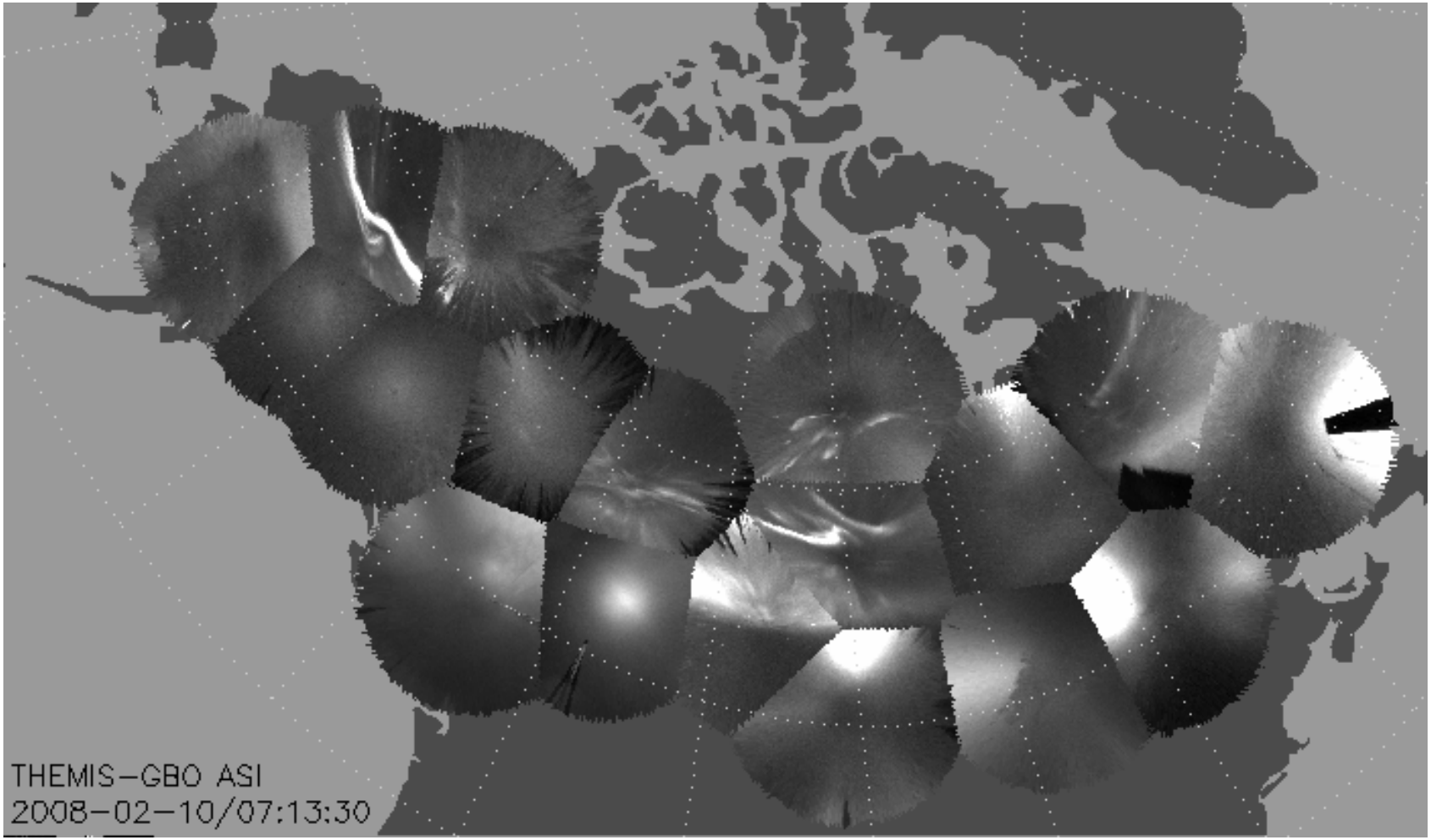




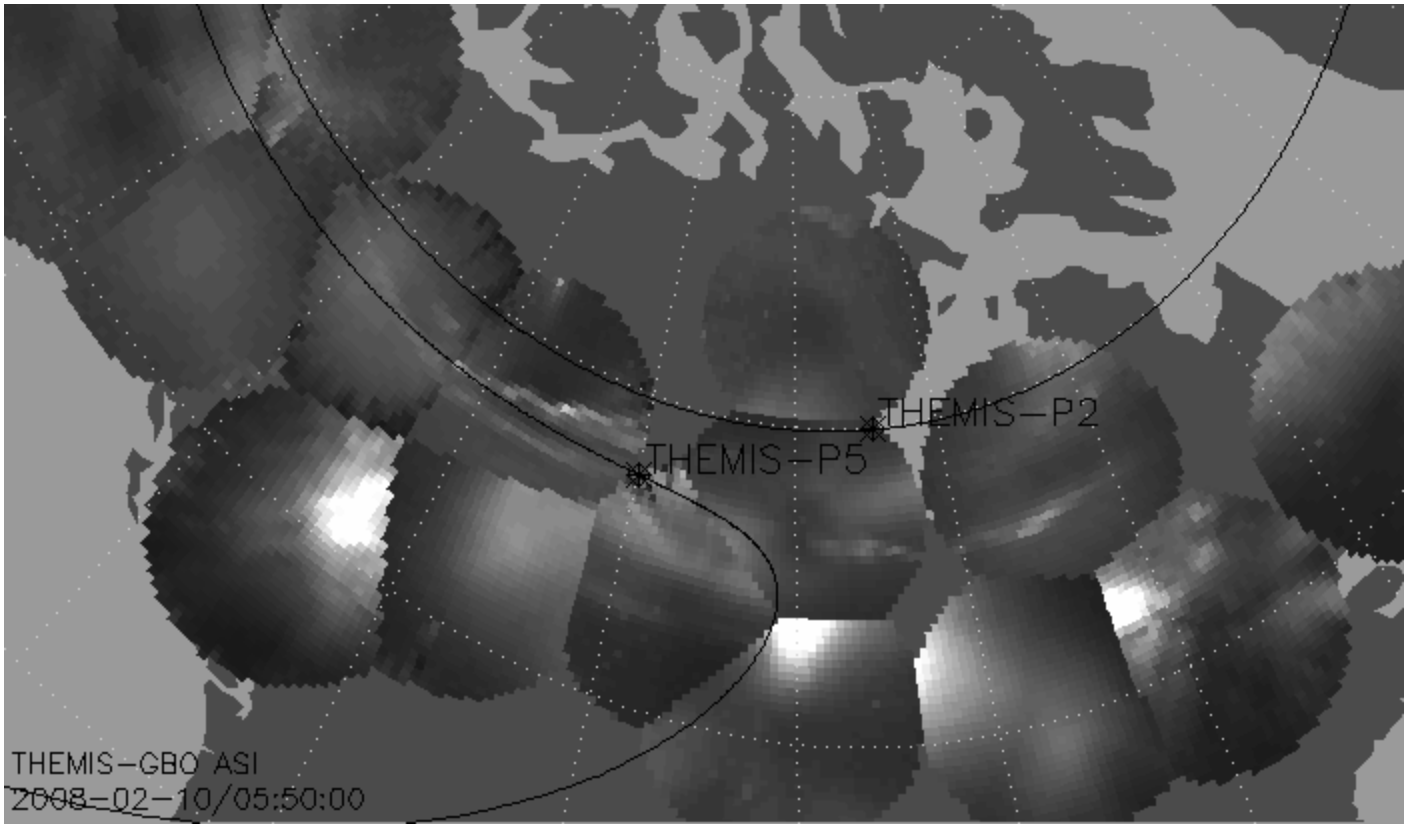
Total number of counts in images to see major increase (substorm onset)



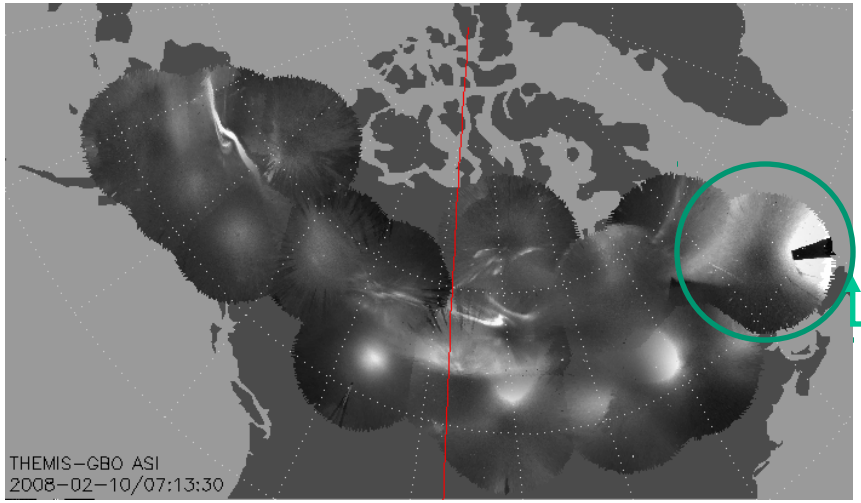
Mosaic of whole GBO array from full resolution images

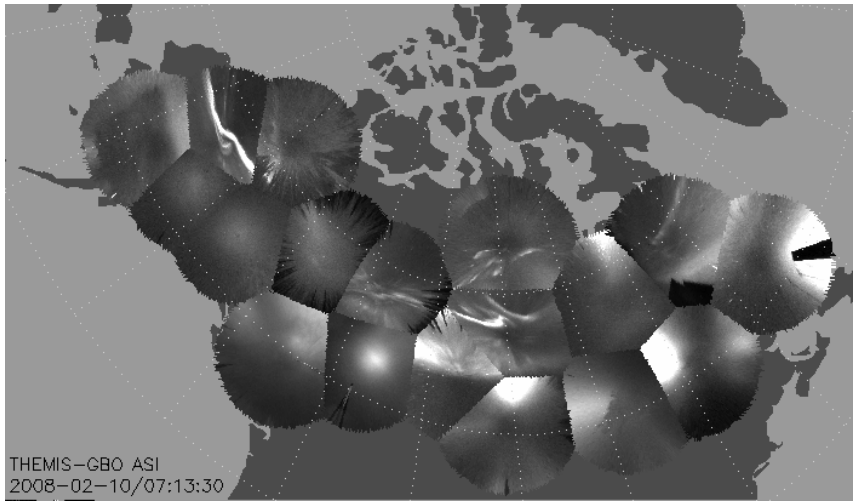


Mosaic with S/C footprint From thumbnail images



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



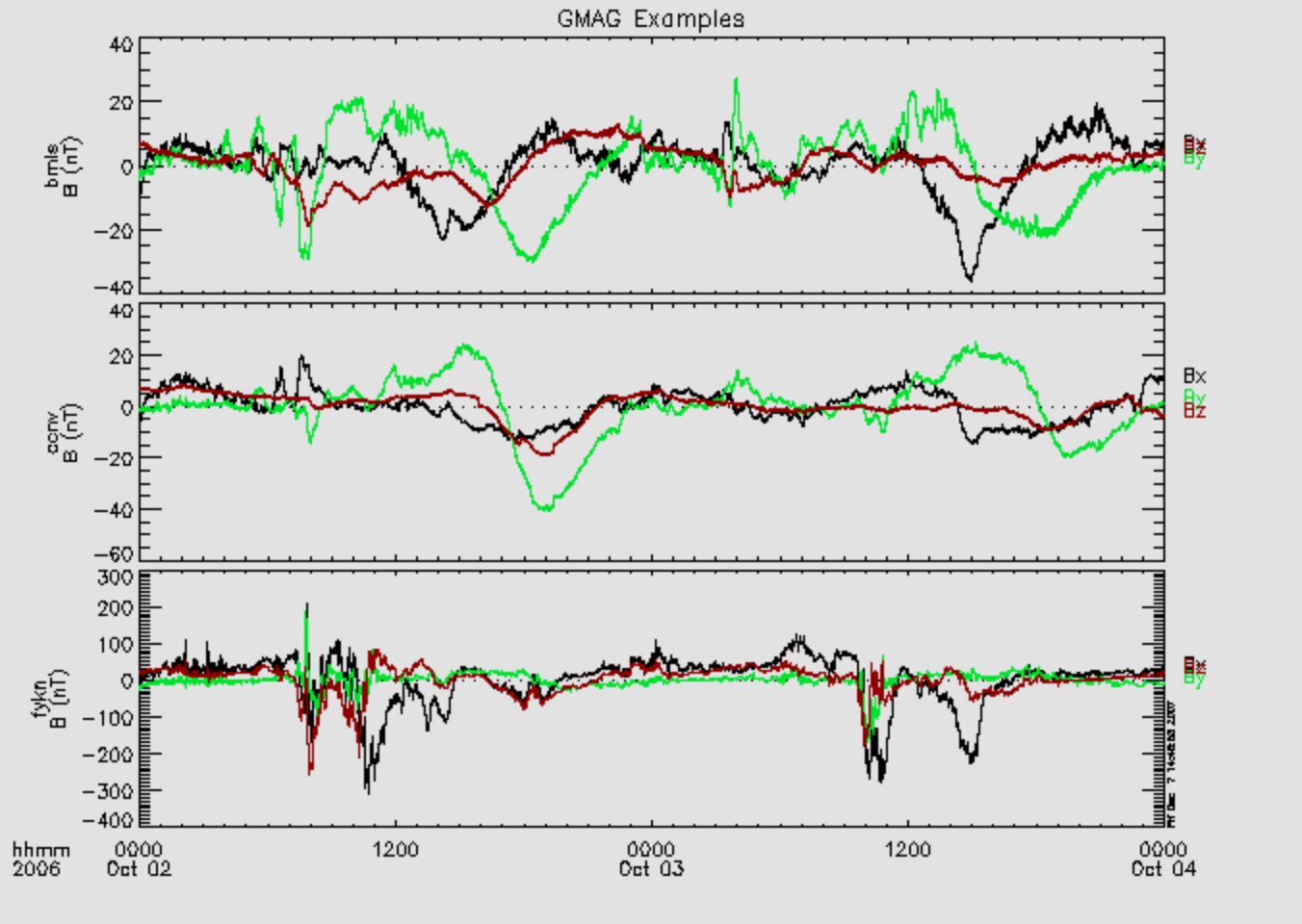


Mosaic of whole GBO array with merged full resolution images

- 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!!!!!!!!!

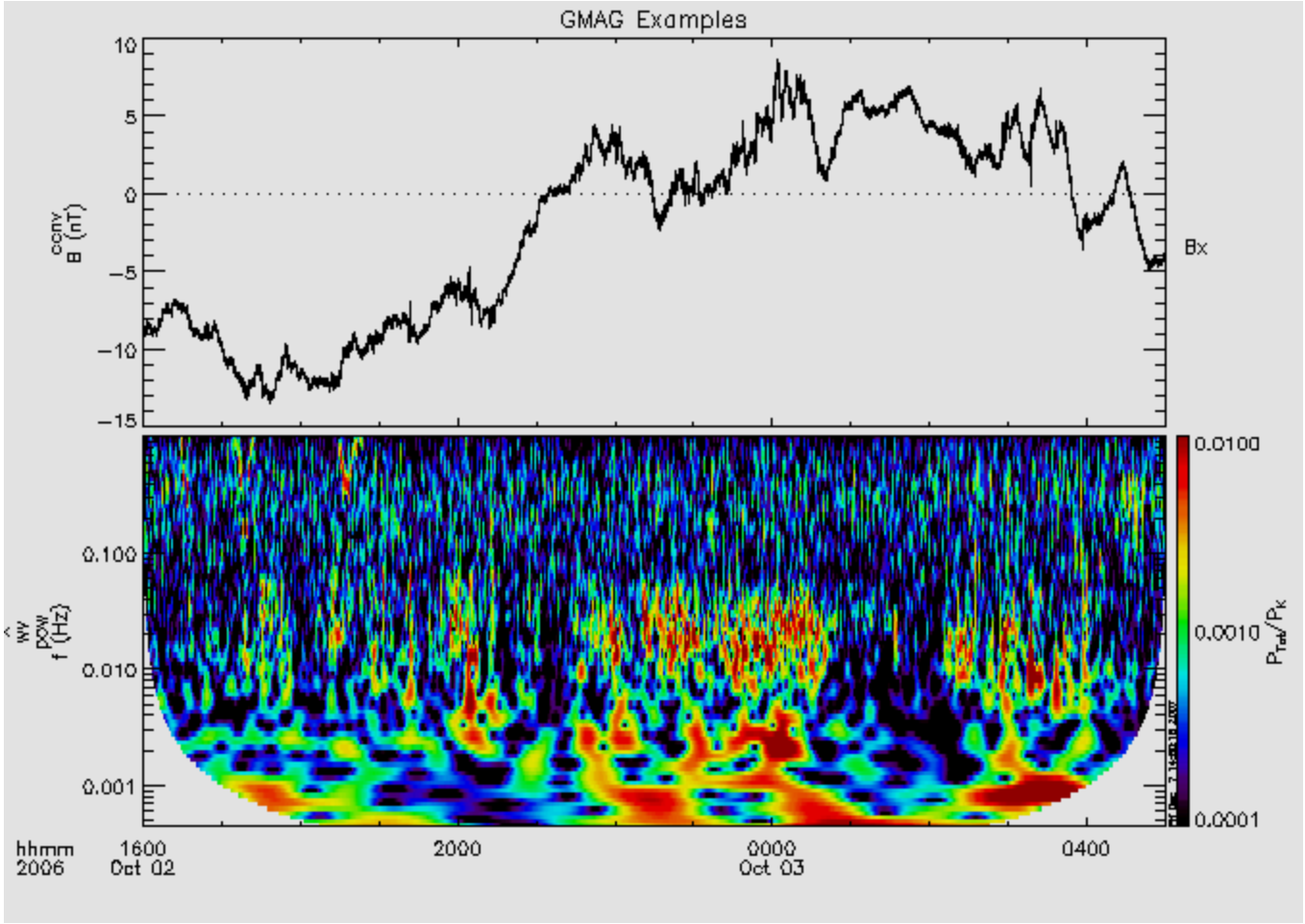
Ground magnetometer Examples
Thm_crib_gmag.pro

Three station example



GMAG Data With Average Subtracted

Wavelet transform example



Pseudo-AE of network