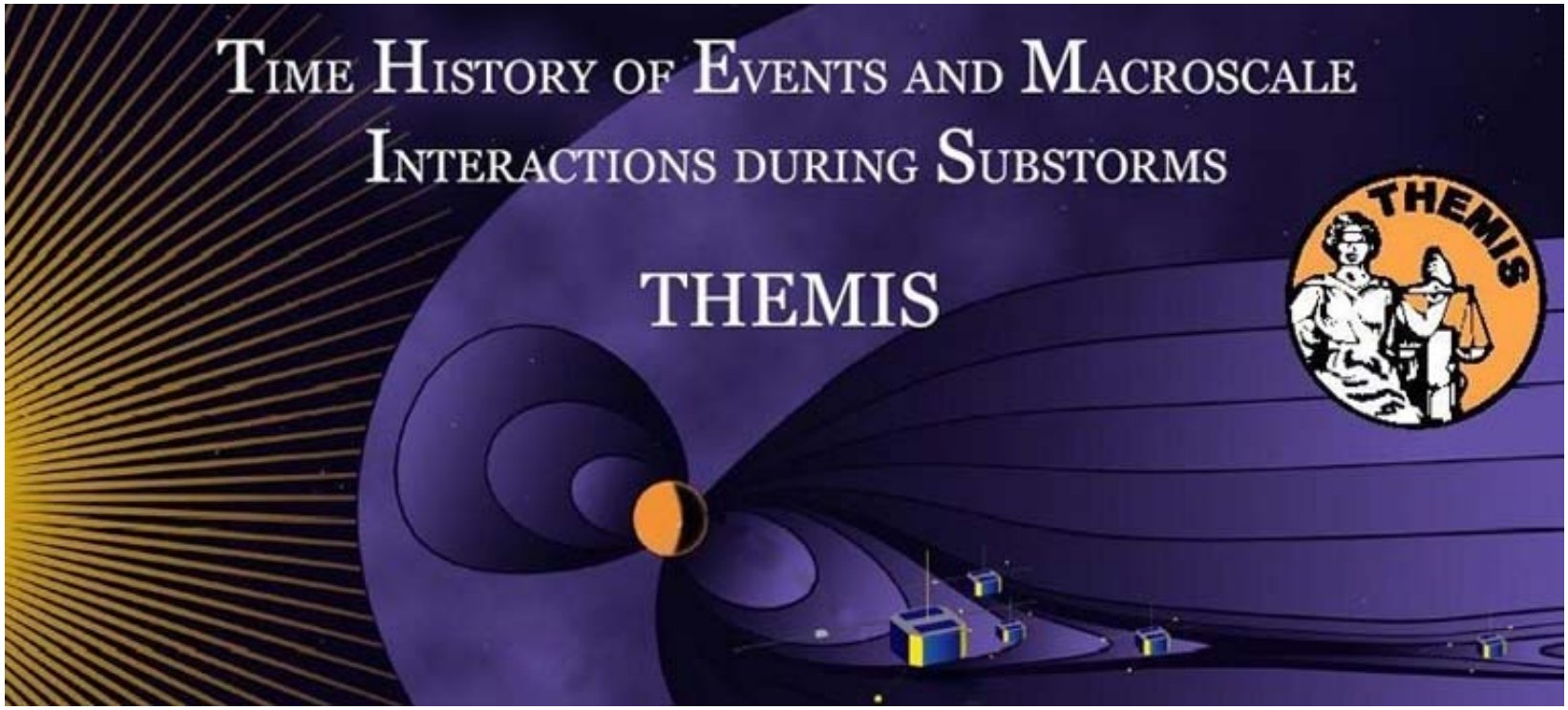


Science Software – v6.0 Training

GEM – Santa Fe, NM

June, 2011

Agenda

10:00	Introduction	C. Russell
10:05	Science Data Status Report	C. Russell
10:10	THEMIS Web Site	C. Russell
10:15	THEMIS Data Analysis Software	C. Russell
10:30	Coordinate Transforms	P. Cruce
10:35	Plotting	P. Cruce
10:45	Mini-Language	P. Cruce
11:00	THEMIS Graphical User Interface (GUI)	C. Russell/ P. Cruce
11:40	THEMIS Ground Based Observatories (GBO)	P. Cruce
11:50	SPDF – CDAWeb	P. Cruce

ftp://apollo.ssl.berkeley.edu/p ub/THEMIS /3 Ground Systems /3.2 Science Operations/ Science Operations Documents/

THEMIS Data Analysis Software

Organization	Contributors
UC Berkeley	D Larson, H Frey, J Bonnell, J McFadden, A Keiling J McTiernan, J Lewis
UCLA	V Angelopoulos, P Cruce, C Russell, H Leinweber, A Flores, K Ramer, B Kerr, M Feuerstein, L Philpott
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

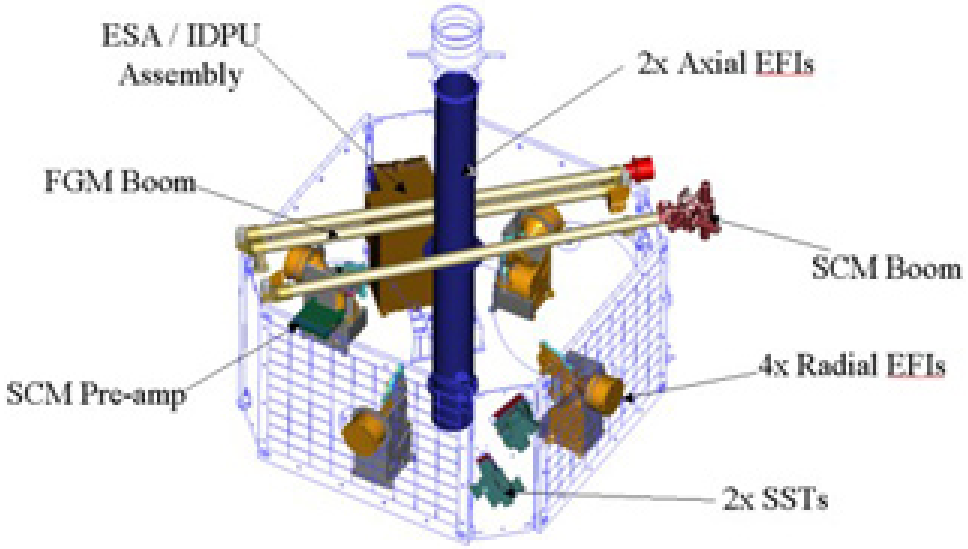
Space Based Instruments

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.

V6.0 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 2009,
  Mosaics, movies for full mission
- GMAG — L2 CDF files with ground magnetometer data from 50 stations. That includes one from Greenland, 7 from Augsburg College, 11 from the University of Alaska, one from University of Athabasca, 6 from the University of Alberta, and 24 THEMIS EPO/GBO sites. Adding 3 new sites from Universi of Athabasca and 25 new sites from Norway, Greenland, and Denmark by Oct 2010.
- 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 Data Analysis Software (TDAS) Version 6.0 was released Spring 2011.

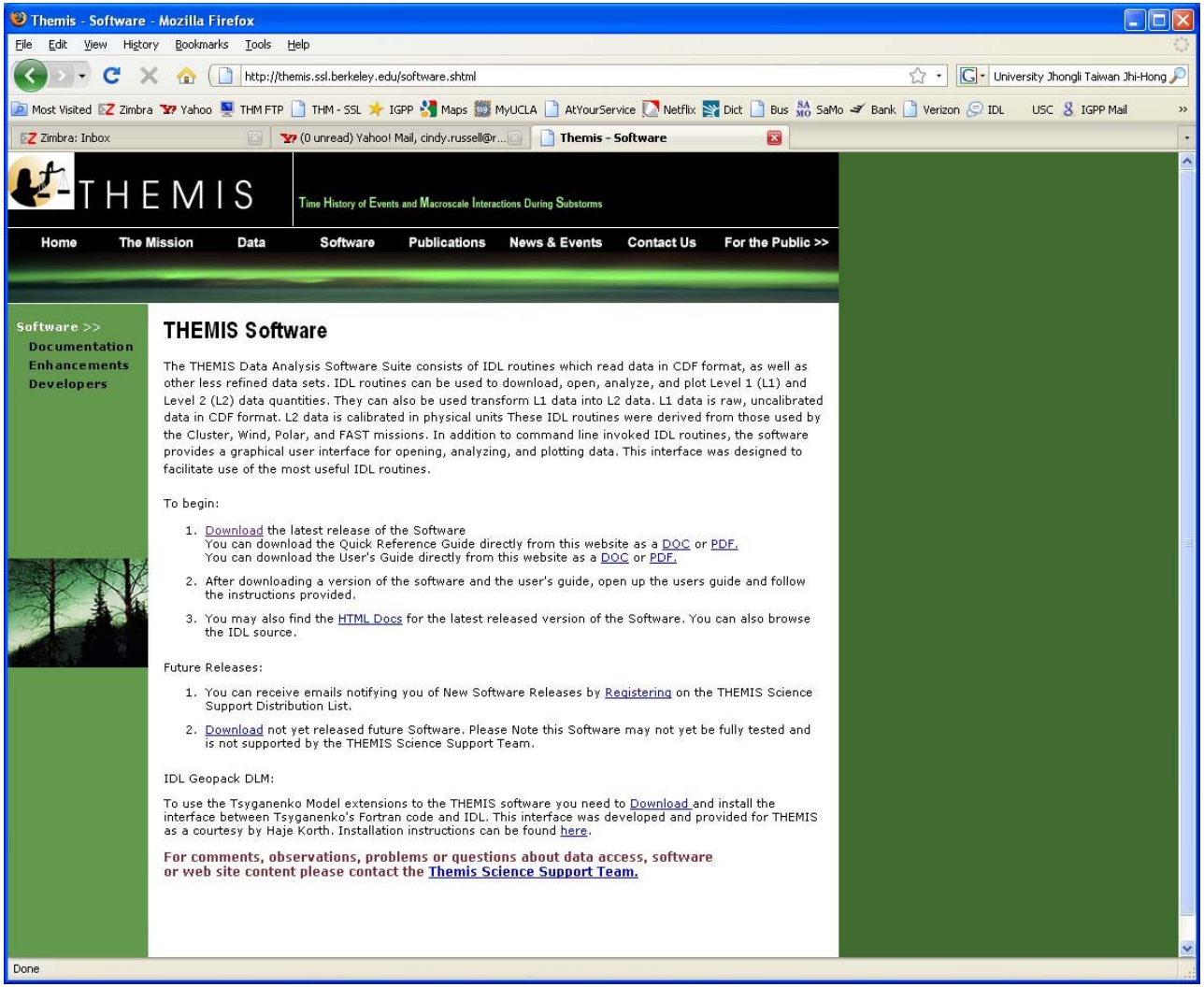
- **Source Code**
  - Enhancements to slices functionality:
    - 2D slices nearest neighbor interpolation added
    - 3D option now interpolates across gaps
    - Speeded up re-gridding process
    - Capability added to export to postscript
    - ESA/SST data can be combined
    - Contamination/Background removal options
  - Code added to calculate L-shell values
  - Keyword options were added to thm_state_roi, thm_part_moments, thm_load_gmag
  - Modifications made to improve themis document reading in GUI.
  - Software now supports the newer version of Haje Korth's IDL Geopack DLM, version 7.5
  - Improved tplot_ascii and write_ascii routines

- **Science Data**
  - New SST calibration code modified to support energy calibration parameters.
  - Code added to remove ESA background from penetrating electrons and ions.
  - Patch to L0->L1 spin model processing

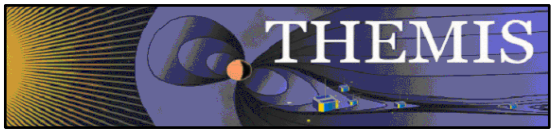
THEMIS Main Web Page

http://themis.ssl.berkeley.edu

THEMIS Software Web Page

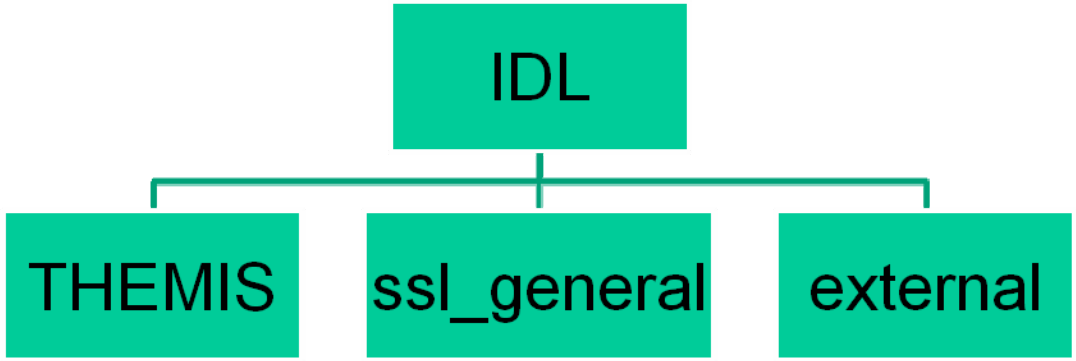


THEMIS_Science_Support@ssl.berkeley.edu



Software Objectives

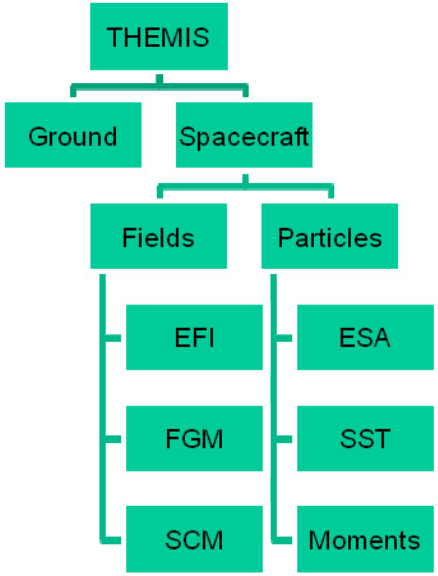
- THEMIS Data Analysis Software (TDAS) Objectives
  - Powerful, Flexible Command Line Interface
  - GUI provides easy access to data, analysis tools, and graphics
- IDL based (library of routines –but no main program!).
- Code is available to everyone
- It is not required to analyze level 2 data.
- Functionally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



- **THEMIS (idl/themis/) –** routines specific to THEMIS
- **ssl_general (idl/ssl_general/) –** general routines
- **external (idl/external/) –** external libraries

THEMIS Specific Routines (idl/themis/)

- Instrument specific routine organization
  - Load Data
  - Calibrate Data
  - Coordinate Transformations
  - Crib Sheet Examples

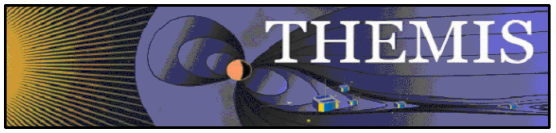


General routines (idl/ssl_general)

- Library of generic routines useful for building mission-specific load routines
  - CDF reading/writing routines
  - File retrieval routines
  - Miscellaneous routines
- Plotting routines
  - Uses “tplot variables”: strings that associate data together with metadata and plotting parameters.
  - Routines to manipulate/plot tplot variables
- Data Export routines
- Data Processing routines

External Libraries (idl/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
  - Required for Intel Mac, regardless of IDL version
  - X11 – may need to be installed.
  - Mouse click-through
    - one-time X11 configuration necessary for proper operation

```
defaults write com.apple.x11 wm_click_through -bool
  true
```

- 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 6.0. http://themis.ssl.berkeley.edu/socware/tdas_6_00/tdas_6_00.zip
- Set up the IDL path
  - Windows and IDLDE on any platform: File->Preferences
  - UNIX-like systems (Mac OS X, Linux, Solaris)

```
In .cshrc:
setenv IDL_PATH '<IDL_DEFAULT>:+/path/to/tdas'
 -Or-
In .bashrc or .bash_profile:
export IDL_PATH='<IDL_DEFAULT>:+/path/to/tdas'
```

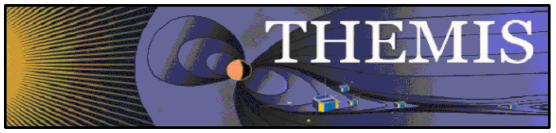
- Set path to Data Directory
  - Data directory will be created automatically at
    - C:/data/themis (Windows)
    - ~/data/themis (UNIX/LINUX/Max OS X)
  - Run thm_ui_config from command line or THEMIS GUI if you need to change this.

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		*	*	

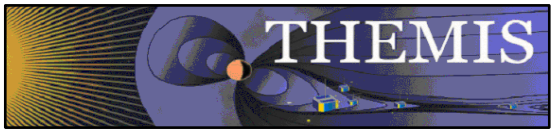
Notes:
(-) data reduction and analysis routines available: see crib sheet

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

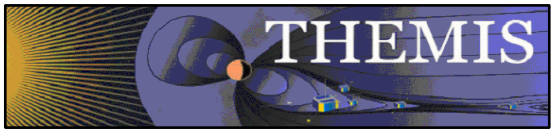
IDL>.run thm_crib_asi

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.
  - knows coordinate system of input from metadata
- 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
- 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:

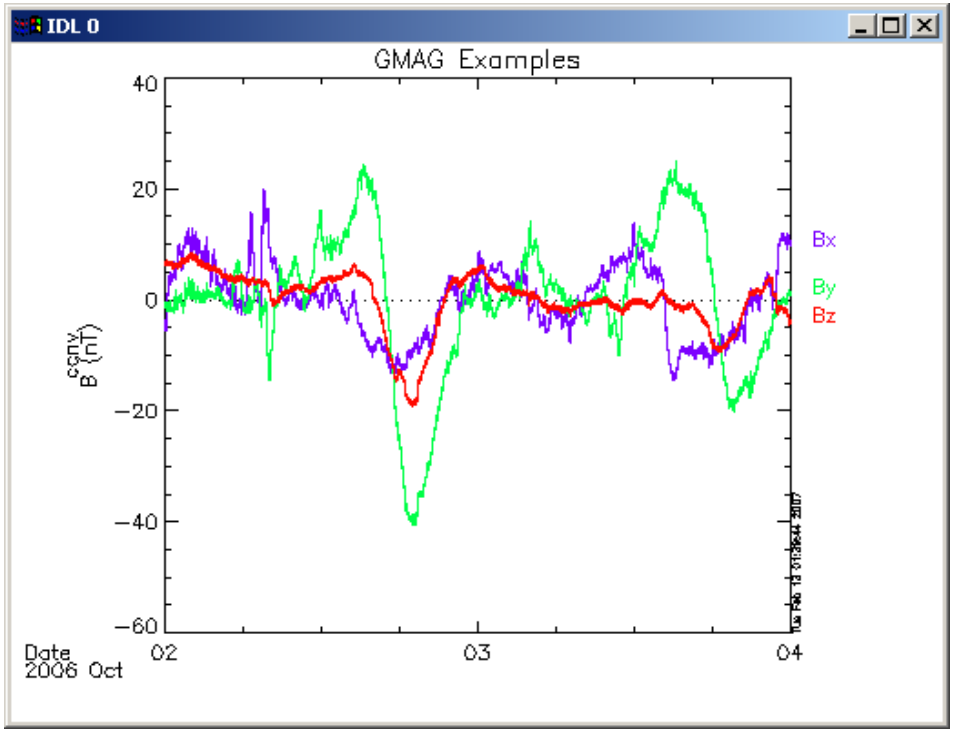
```
tt89,'thc_state_pos',newname='model_field'
fac_matrix_make,'model_field' ,other_dim=
 'xgse', newname = 'fac_mat'
tvector_rotate, 'fac_mat', 'thc_peir_velocity',
 newname = 'ion_velocity_model_fa'
```

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

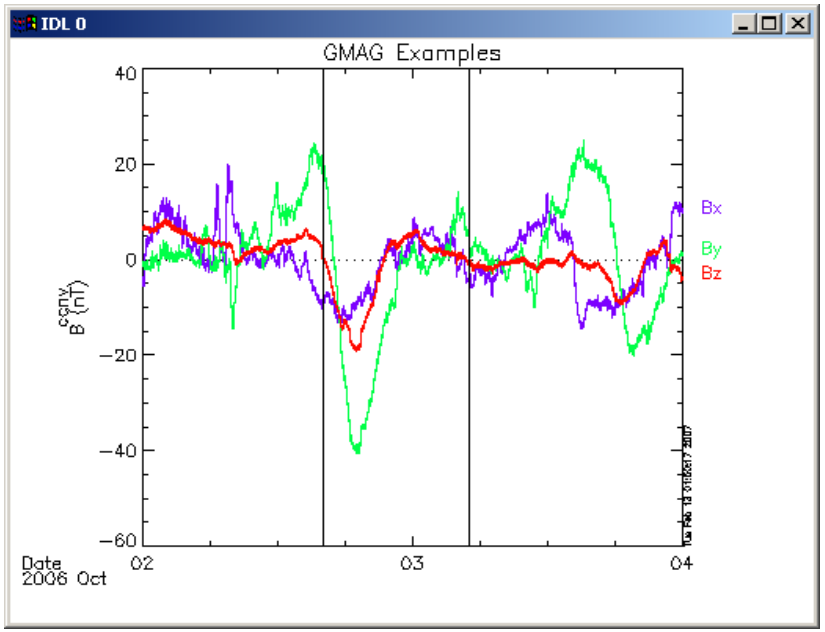
Command Line Example 1

- 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'

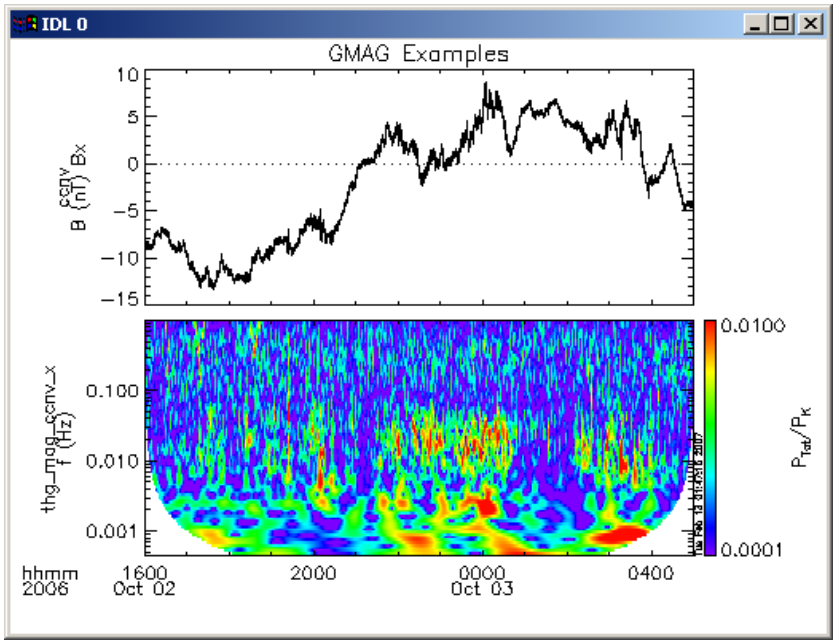


Command Line Example 2

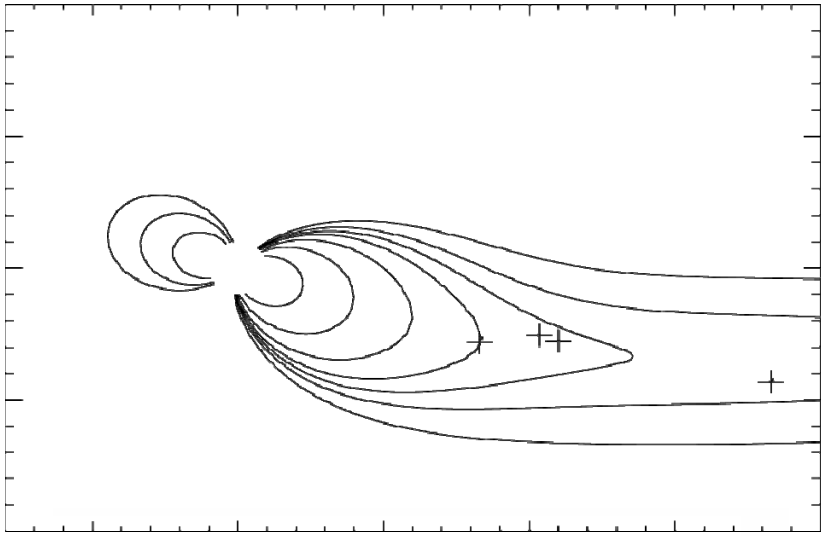
- Wavelet transform on an interval of interest
  - Define and display the interval
    - » Tr = ['2006-10-2/16:00','2006-10-3/05']
    - » timebar,tr



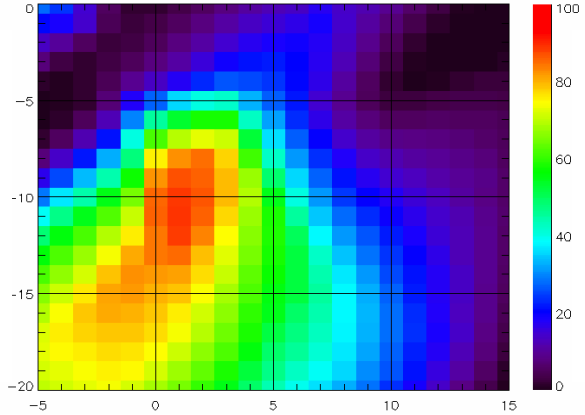
- Split the 3-vector into components:
  - » split_vec,'thg_mag_ccnv'
- Compute transform of one component
  - » wav_data,'thg_mag_ccnv_x',/kol $,trange=tr ,maxpoints=24l*3600*2
- Set color limits (log scale)
  - » zlim,'*pow', .0001,.01,1
- Plot it.
  - » tplot,'*ccnv_x*',trange=tr



Plotting Examples

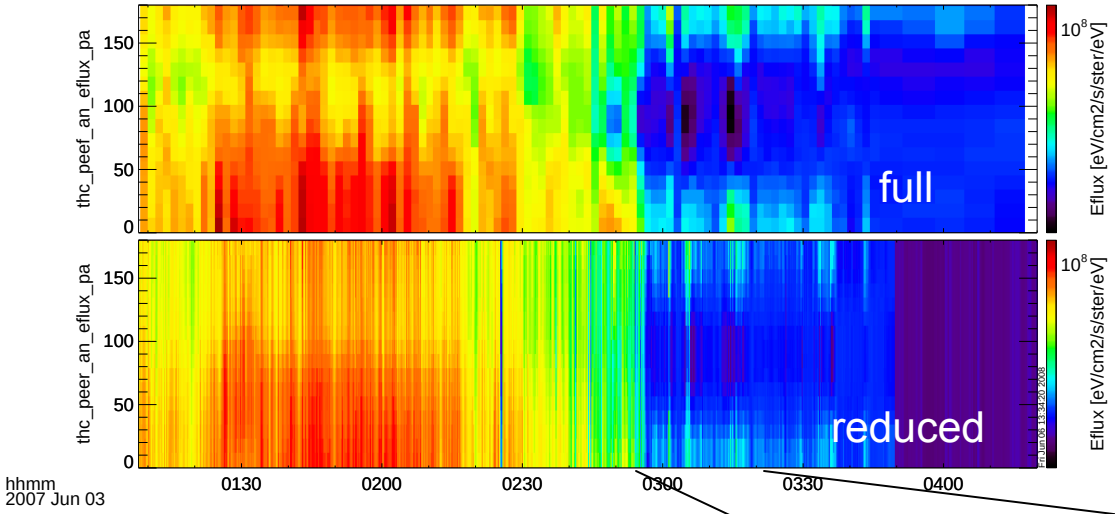


tplotxy can be used to plot isotropic position plots. Like plots of magnetic field models and spacecraft position



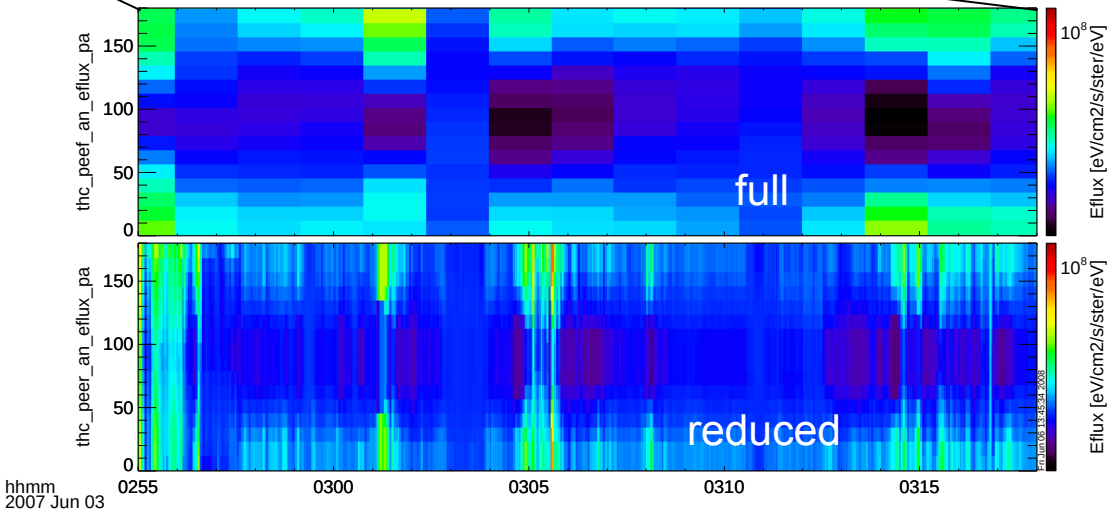
Plotxyz can be used to plot 3 dimensional isotropic data, with any axis.(Not restricted to time-series.)

Plotting Angular Spectra



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

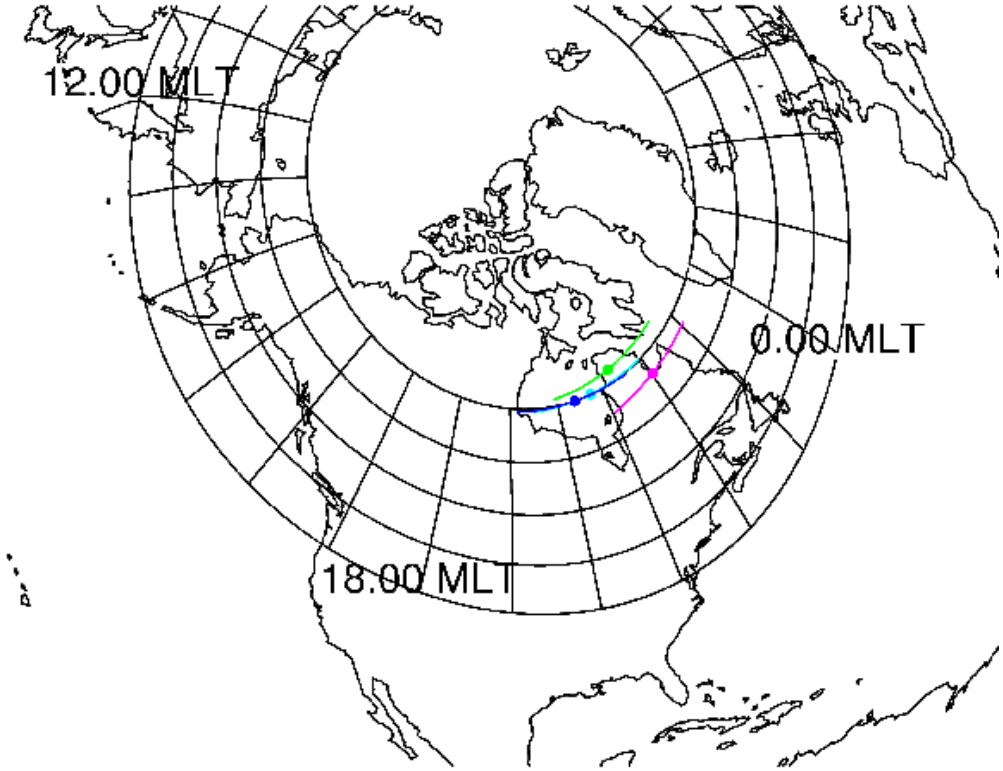
```
thm_part_getspec, $
probe=['c'], $ ;select probe
trange=['07-06-03/01:08', $  ;select timerange
        '07-06-03/04:20'], $
data_type=['peef','peer'], $ ;select data type
angle='pa', $ ;select pitch angle spectra
regrid=[32,16] ;set resolution of pitch/gyro
spectra
```



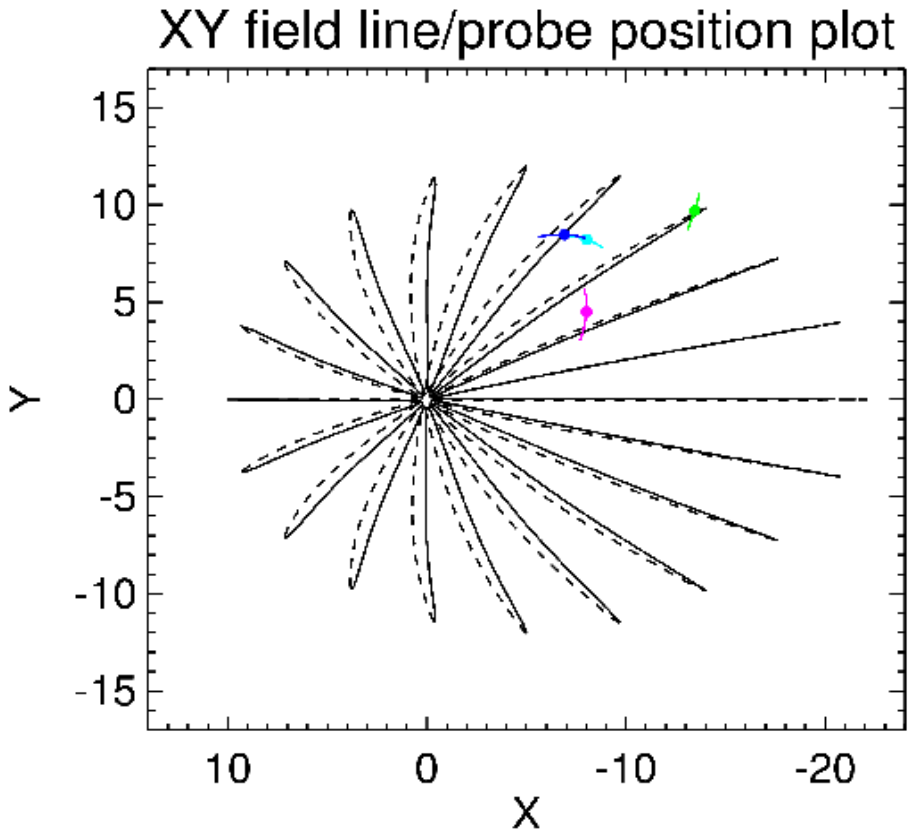
Trace / Orbit Plots

- 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/

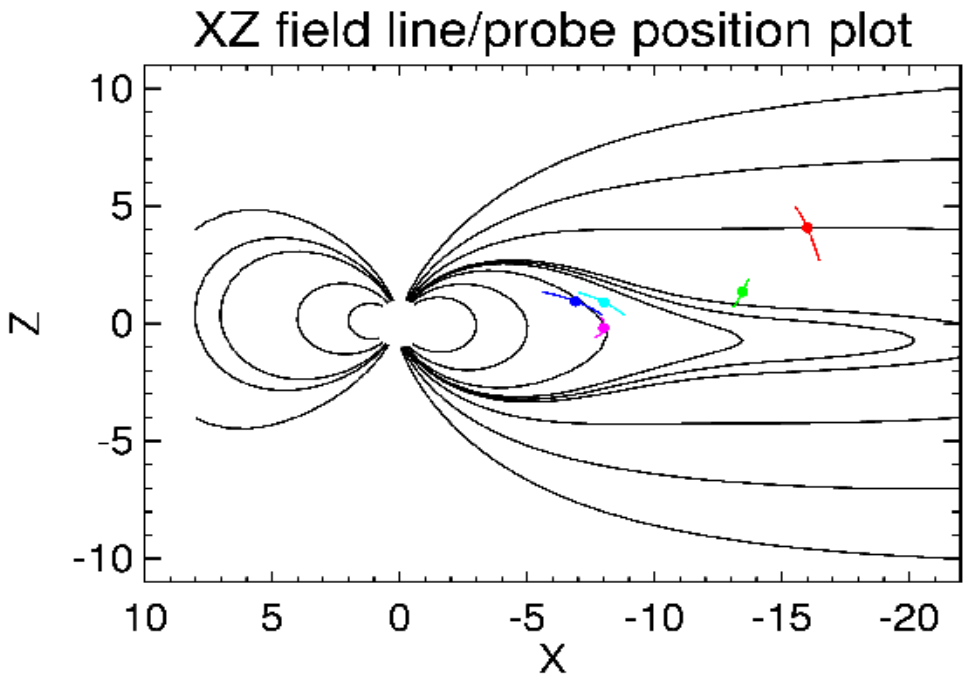
Trace/Orbit Plots - AACGM/Iono Trace Plot



Trace / Orbit Plots – XY Plot



Trace / Orbit Plots – XZ Plot

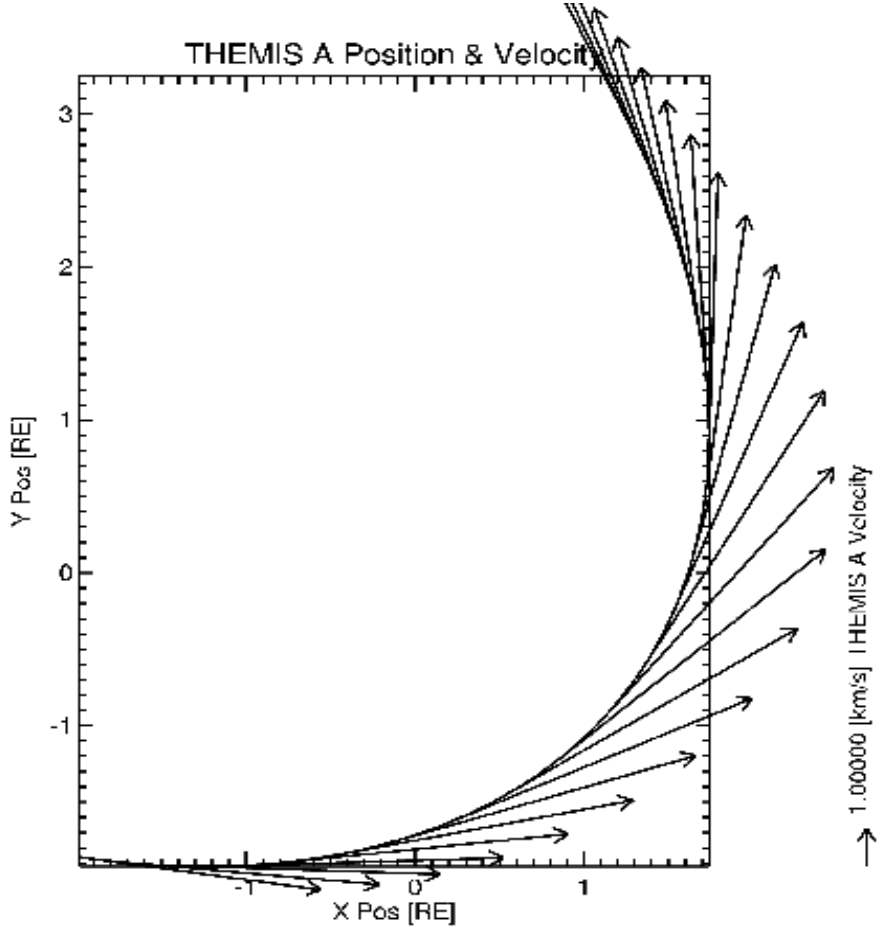


THEMIS – Mini Language

- 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)'

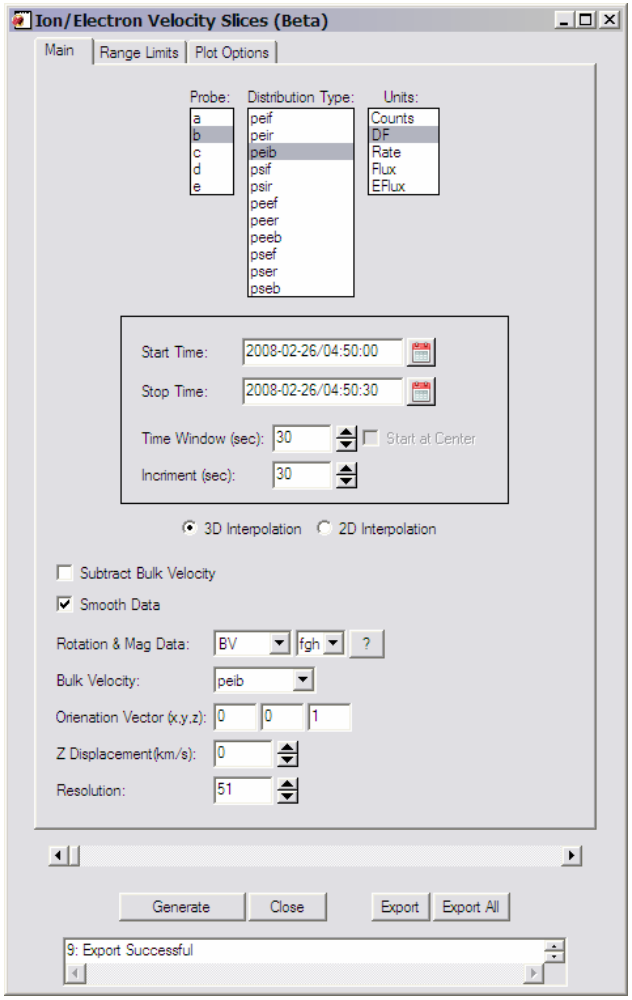
Additional examples can be found in themis/examples/thm_crib_calc.pro

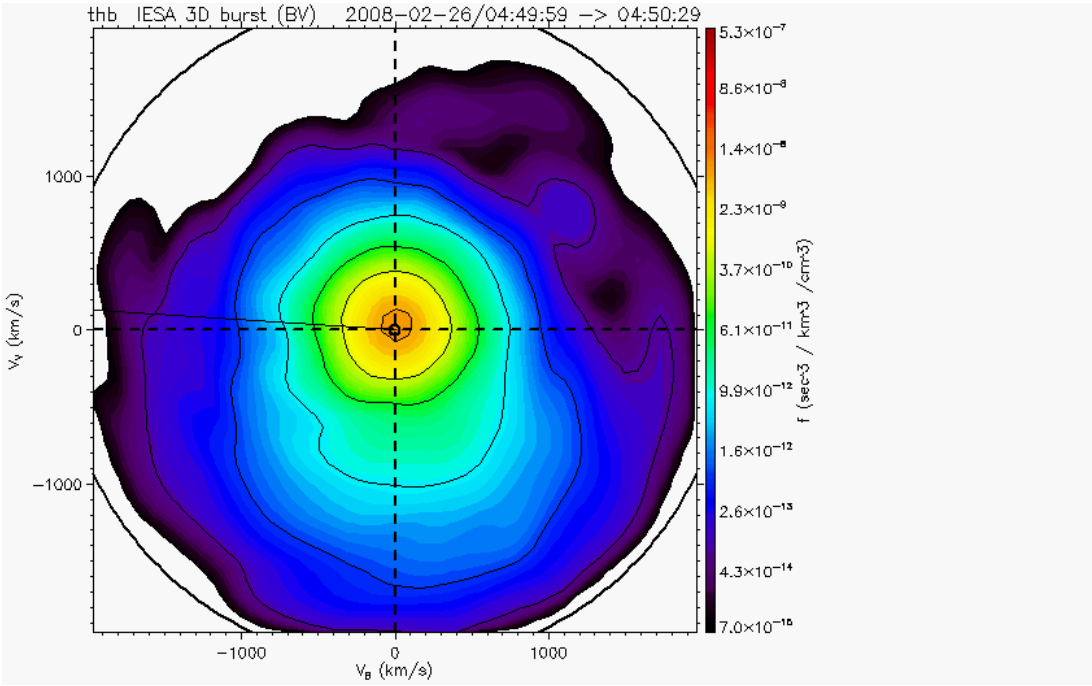
Plotxyvec – Position/Velocity Plot

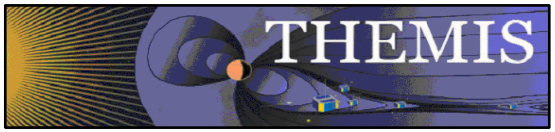


Ion Electron Velocity Slices(Beta)

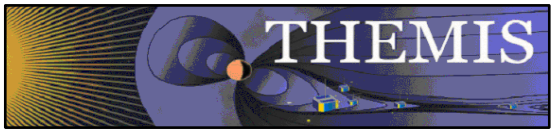
Beta support for Slices of 3d particle Velocity distributions are supported in the bleeding edge. Code can be started by typing: thm_ui_slice2d or can be accessed from the GUI by selecting Analysis->Velocity Slices







THEMIS Data Analysis Software Graphical User Interface

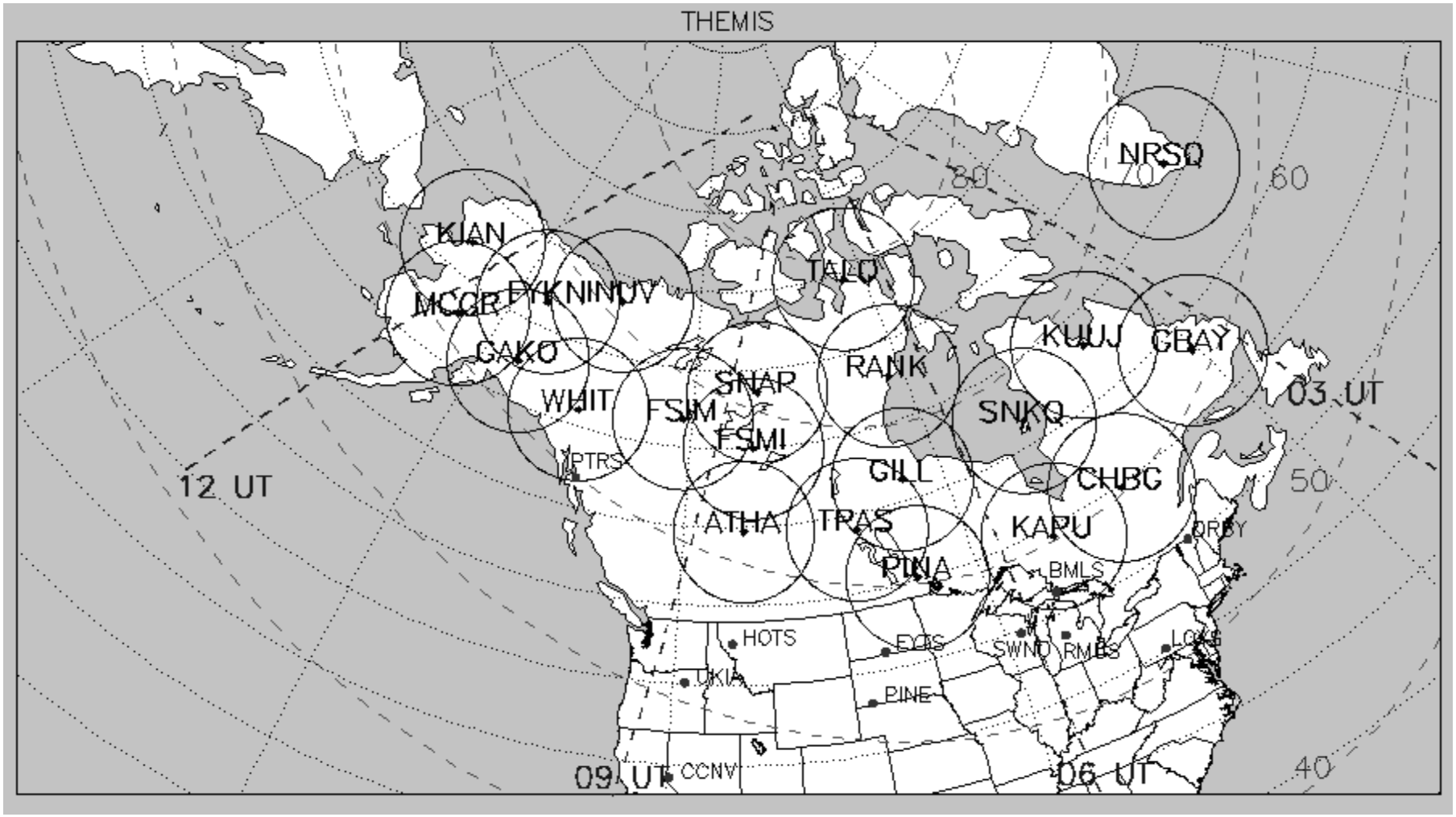


THEMIS software for GBO all-sky imager
Thm_crib_asi.pro

Harald U. Frey

(updated October 2010)

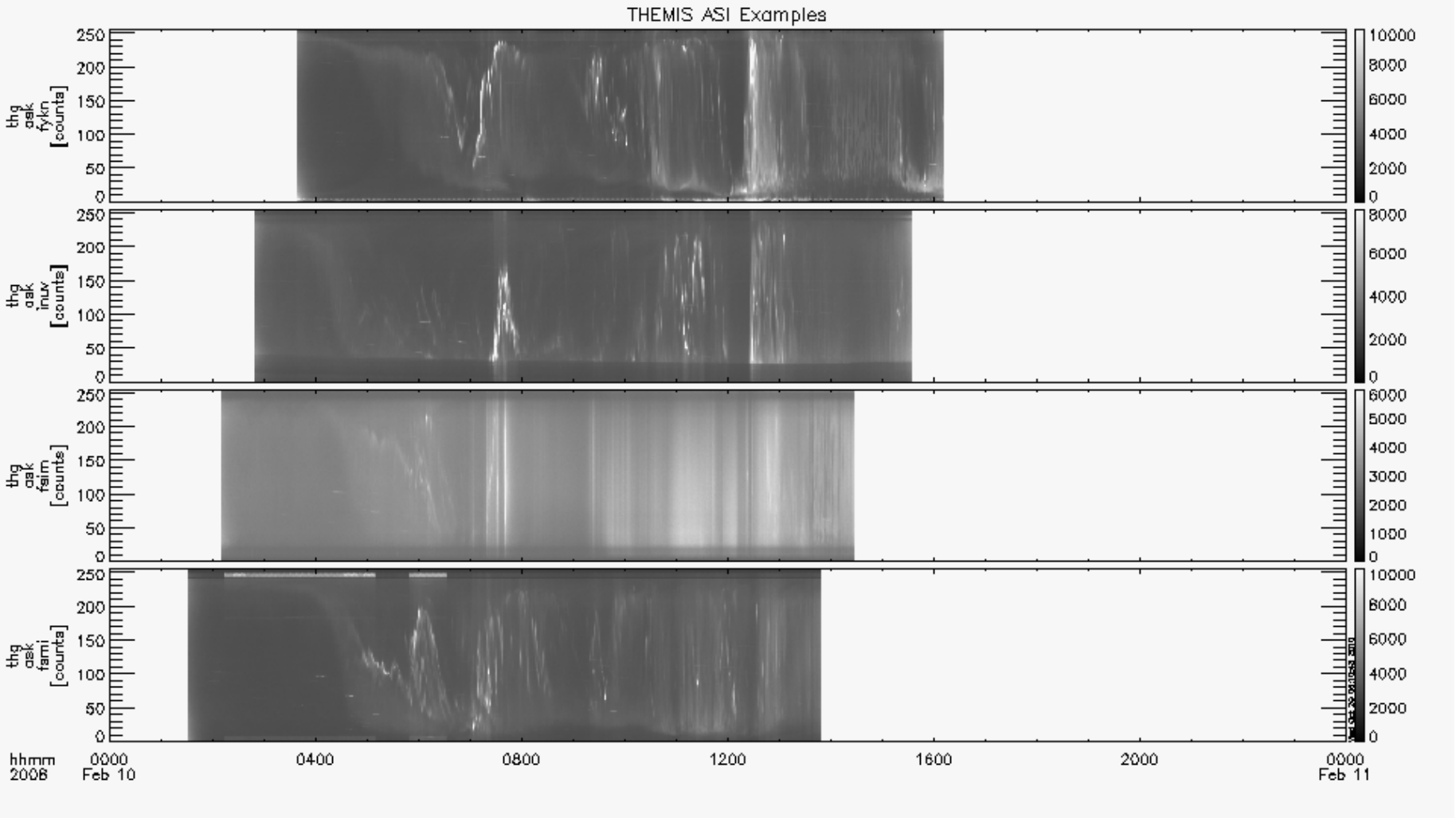
THEMIS GBO network



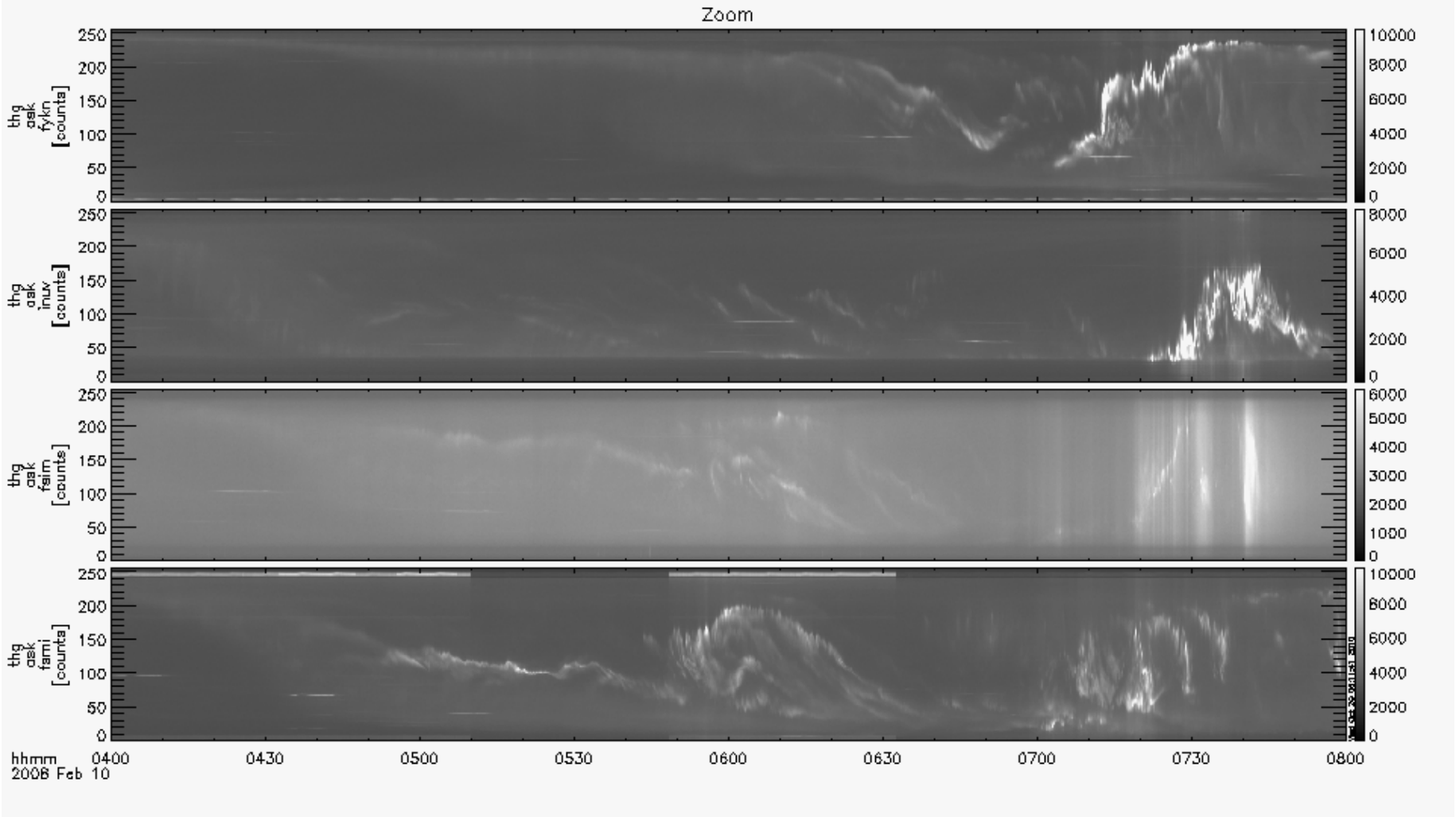
All-sky imager data products

1. Keograms along local magnetic meridian
   - Delivered daily jpeg-compressed
   - Reprocessed ½ year later with full resolution images
2. Geomagnetically mapped thumbnail images
   - Delivered daily using square-root intensity compression
   - 1024 pixels within +-8^{o} magnetic Latitude and ~+-12^{o} Longitude
   - 3 seconds temporal resolution
3. 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

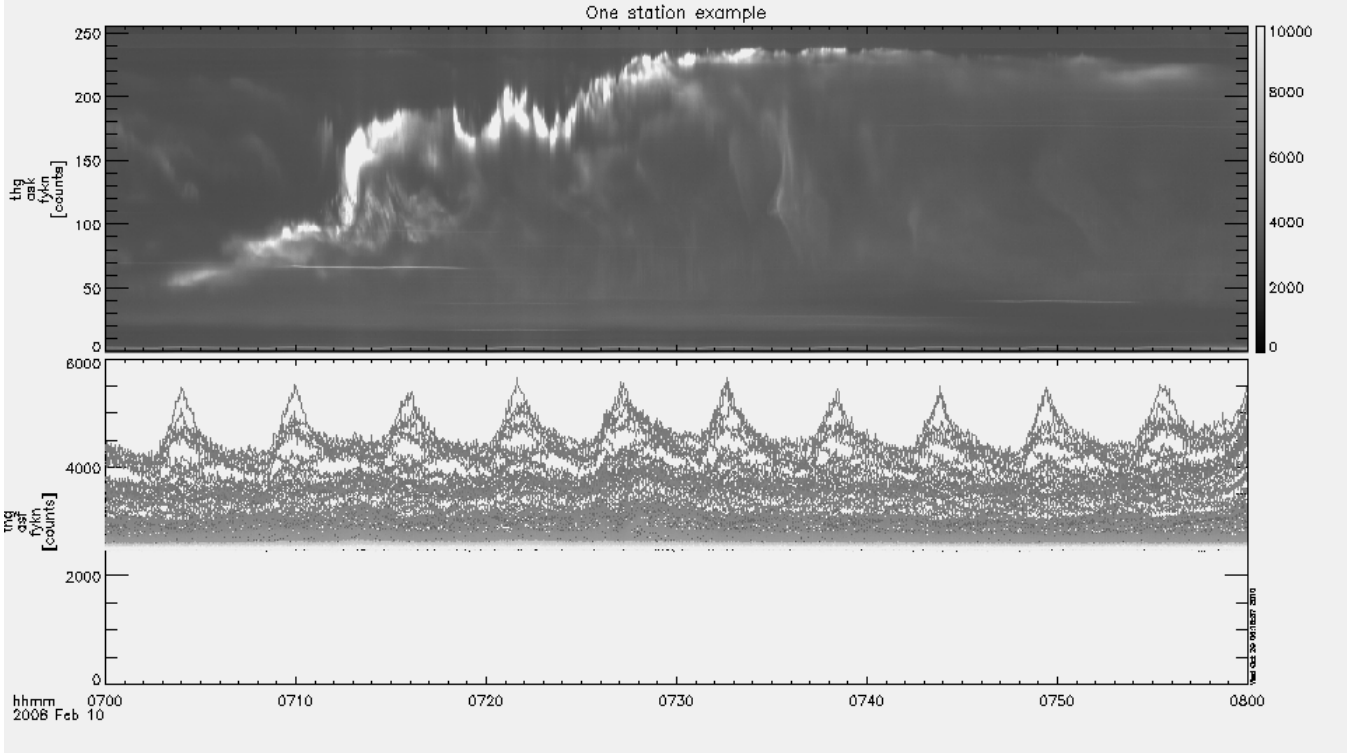
Daily overview of selected keograms

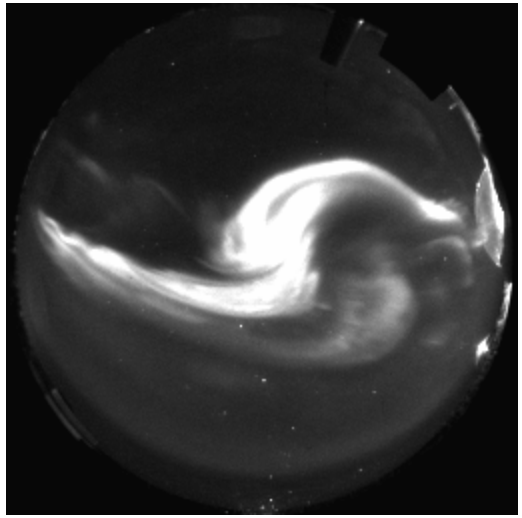


Zoom into interesting time

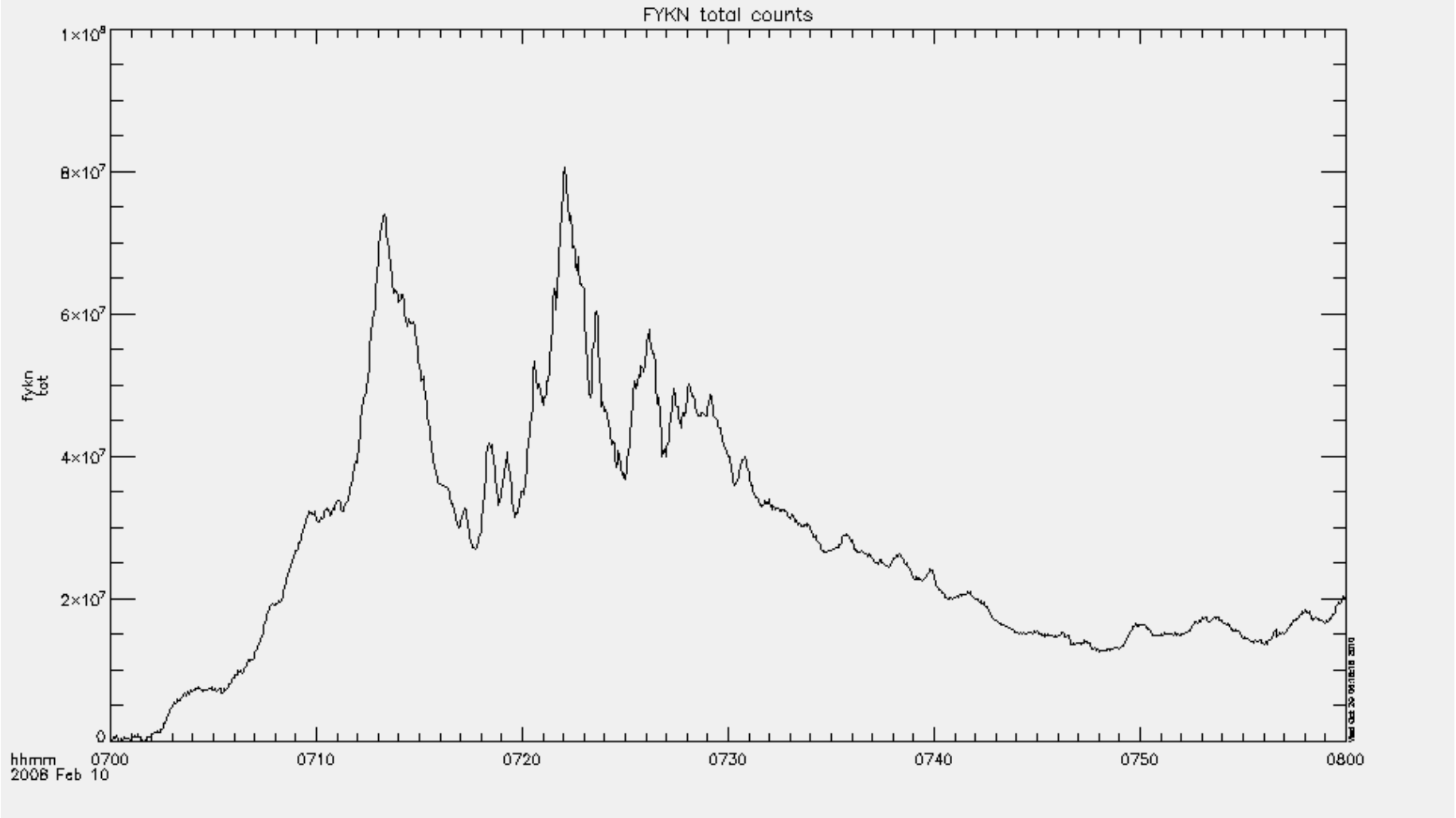


Watch “movie” of single station

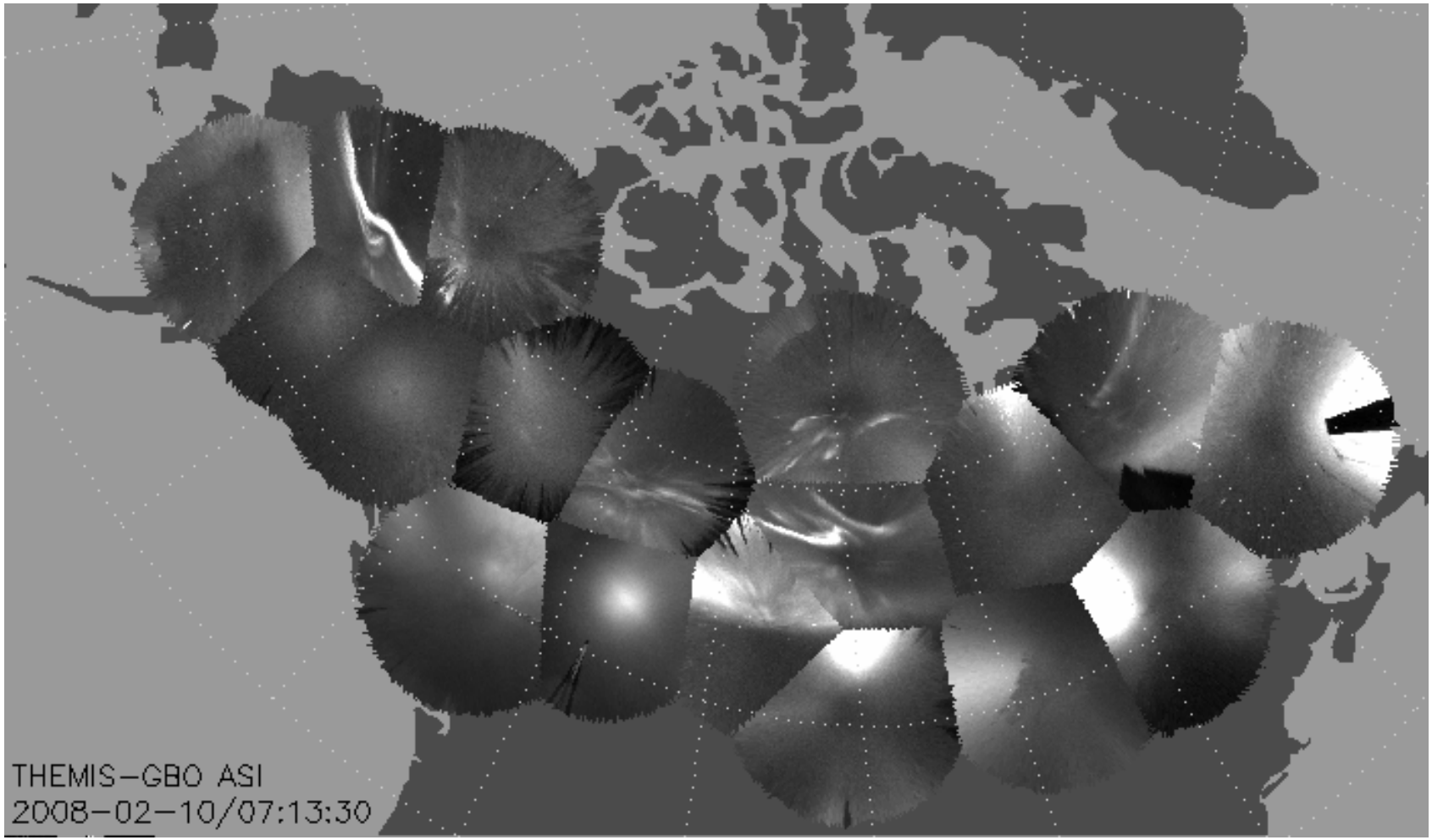




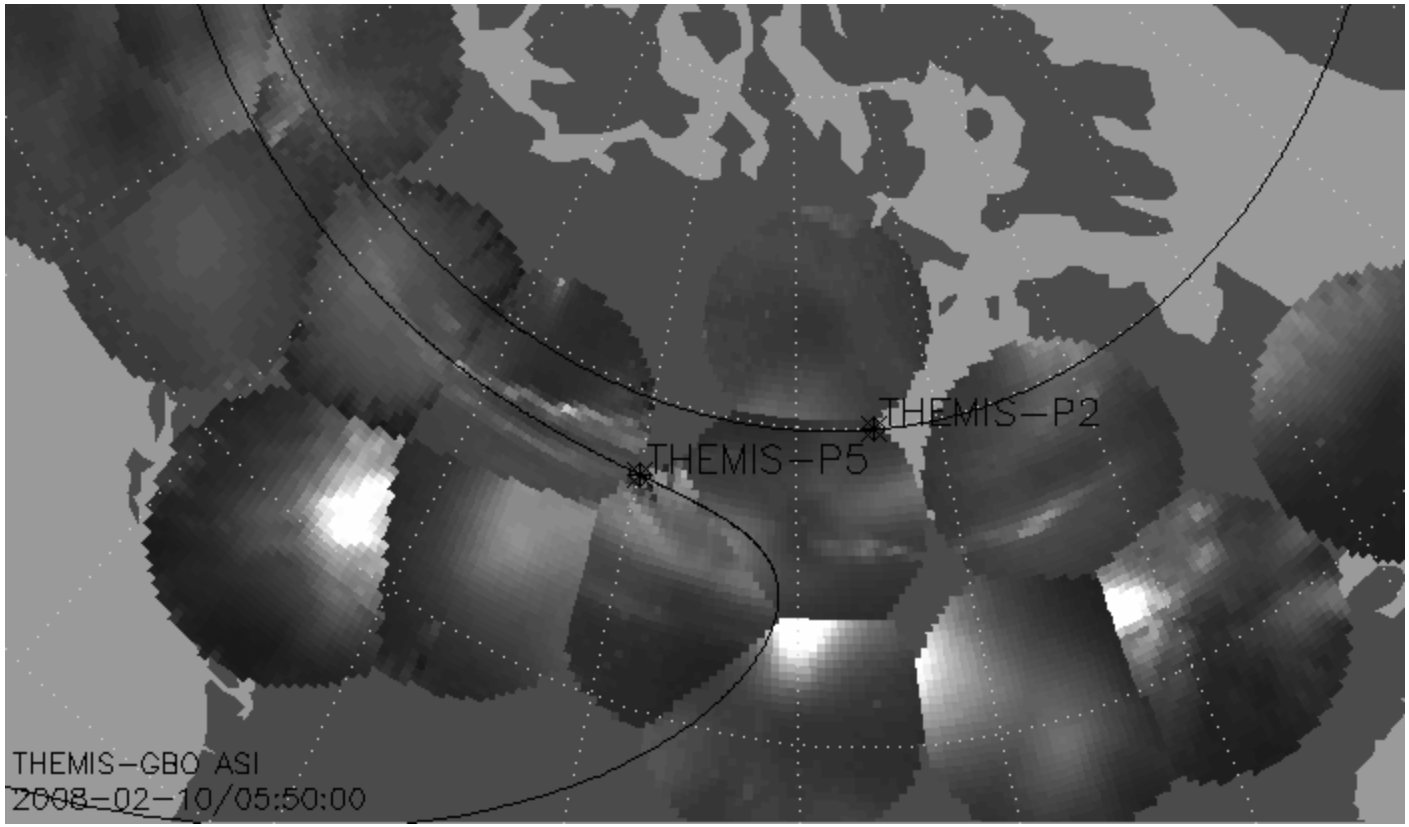
Total number of counts in images to see major increase (substorm onset)



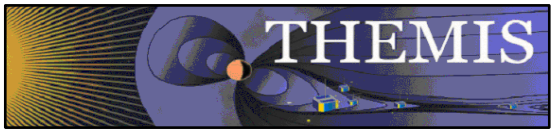
Mosaic of whole GBO array from full resolution images



Mosaic with S/C footprint From thumbnail images

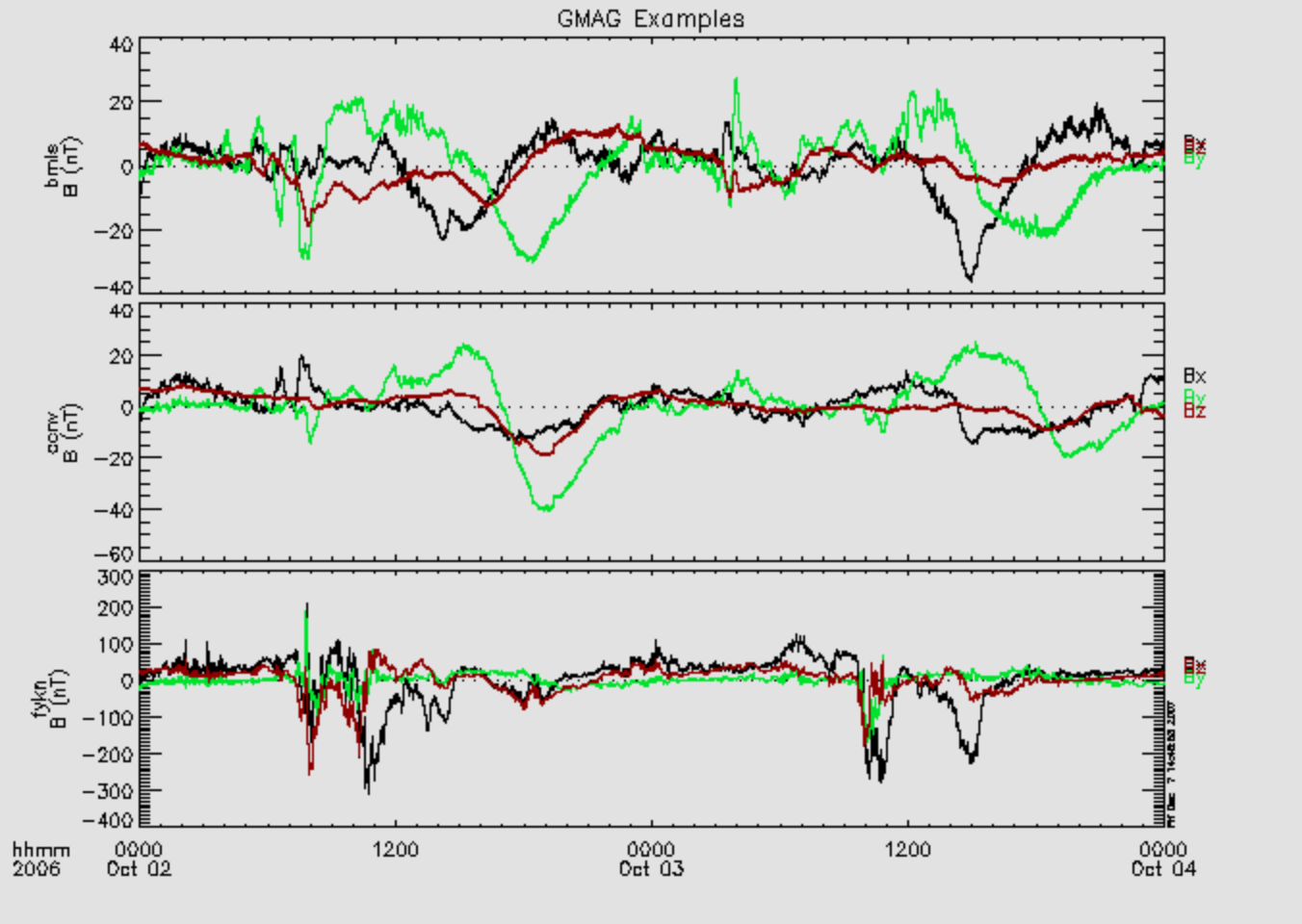


Black line marks footprint of THEMIS-P2 and P5 during whole night
Asterisk marks location at time of mosaic



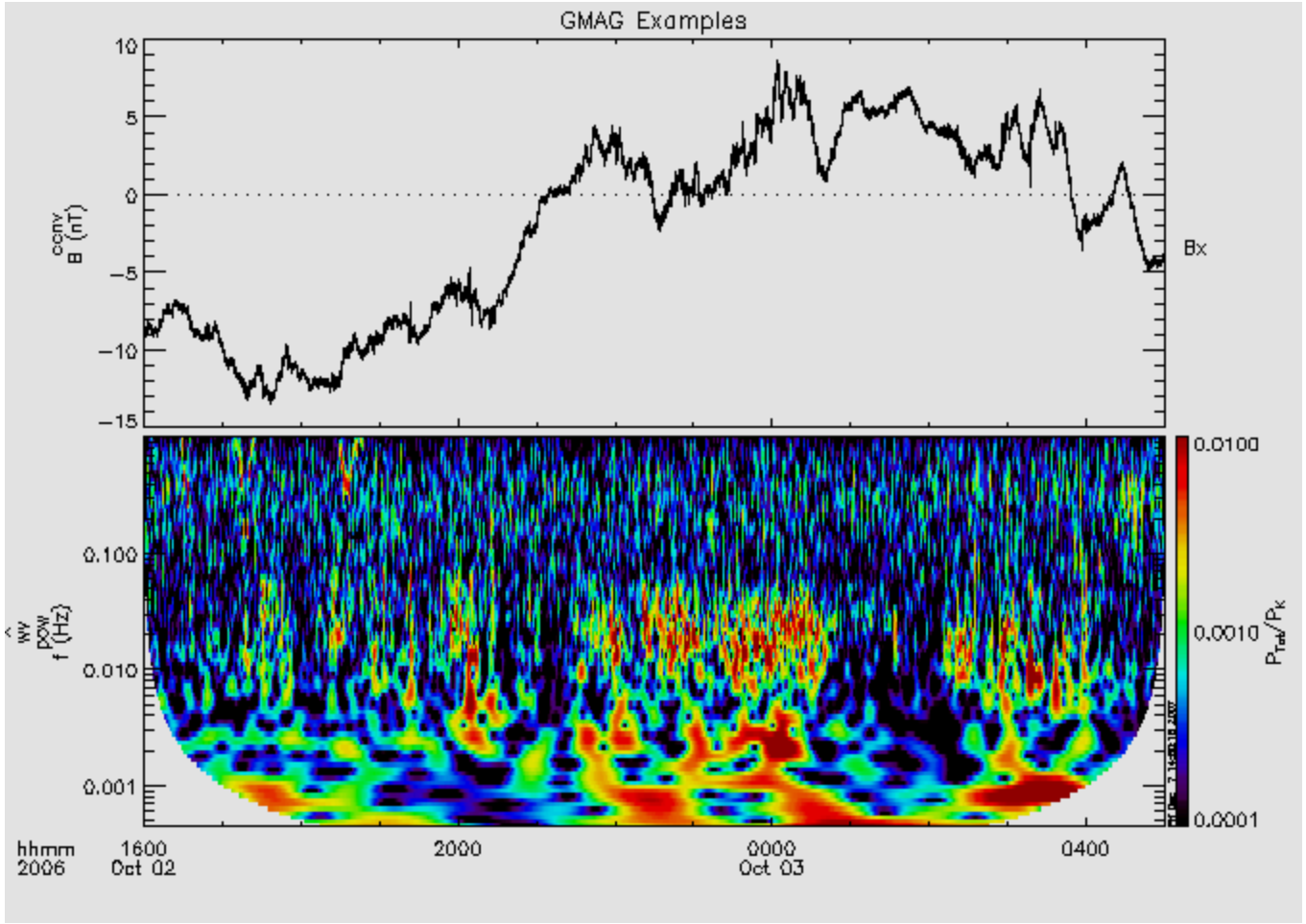
Ground magnetometer Examples
Thm_crib_gmag.pro

Three station example

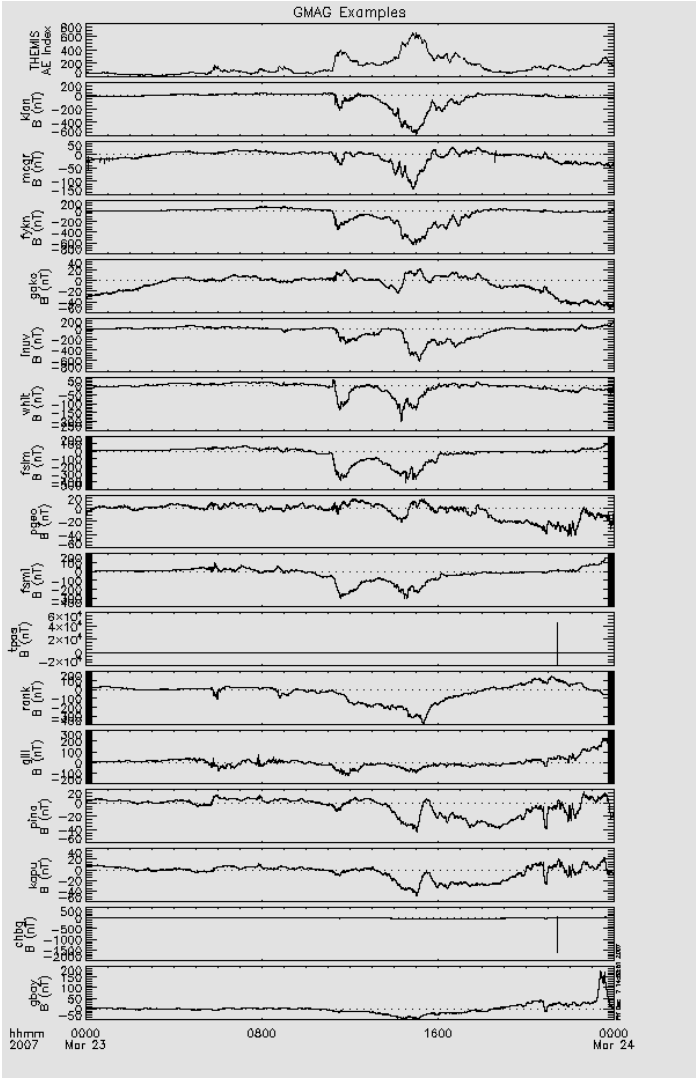


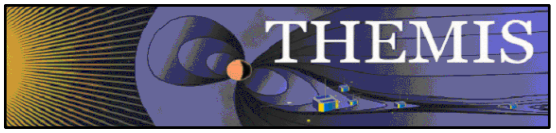
GMAG Data With Average Subtracted

Wavelet transform example



Pseudo-AE of network





Data and Orbits at SPDF

CDF:

CDF V3.3.0 is in its final testing phase. It adds file validation and sanity checks while accessing CDF files. This addresses potential security vulnerabilities, e.g. data overflow in applications caused by compromised files. Additional functionality and performance improvements were made in the IDL and MATLAB library support. .

CDAWeb THEMIS Data:

May 7, 2009: THEMIS FGM dataset files being reprocessed at Berkeley and re-ingested into CDAWeb

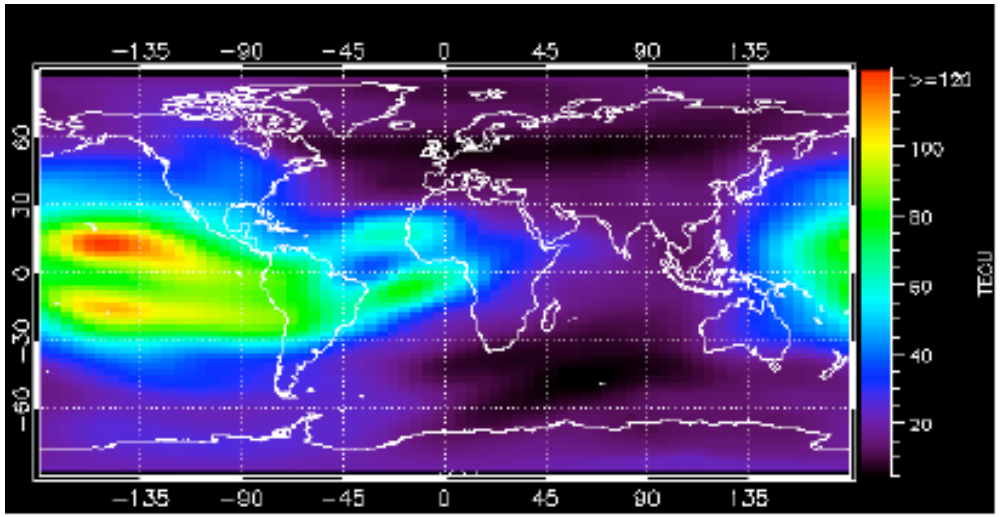
Sep 2008 - Jun 2009: Magnetometer data added from several additional ground stations for a total of now 44 stations from the GBO (31), GEONS (11), and GIMA (2) networks (most recent NAIN, CDRT and NRSQ).

CDAWeb THEMIS-related Data:

Eight new geomagnetic activity index variables added to the OMNI 1min and 5min datasets: AE, AL, AU, SYM/D, SYM/H, ASY/D, ASY/H, PC ; already available in OMNI-1hour: daily Rz and F10.7 , 3-hour Kp and ap, 1-hour Dst, AE, AL, AU, and PC

New on CDAWeb - Global images and movies of Total Electron Content (TEC) deduced from Global Positioning Satellites (GPS_TEC2HR_IGS) (1998 through present). Excellent data set for monitoring the global ionospheric response to magnetic storms.

Global GPS-TEC image showing the typical Equatorial Anomaly signature with crests on both sides of the magnetic equator.

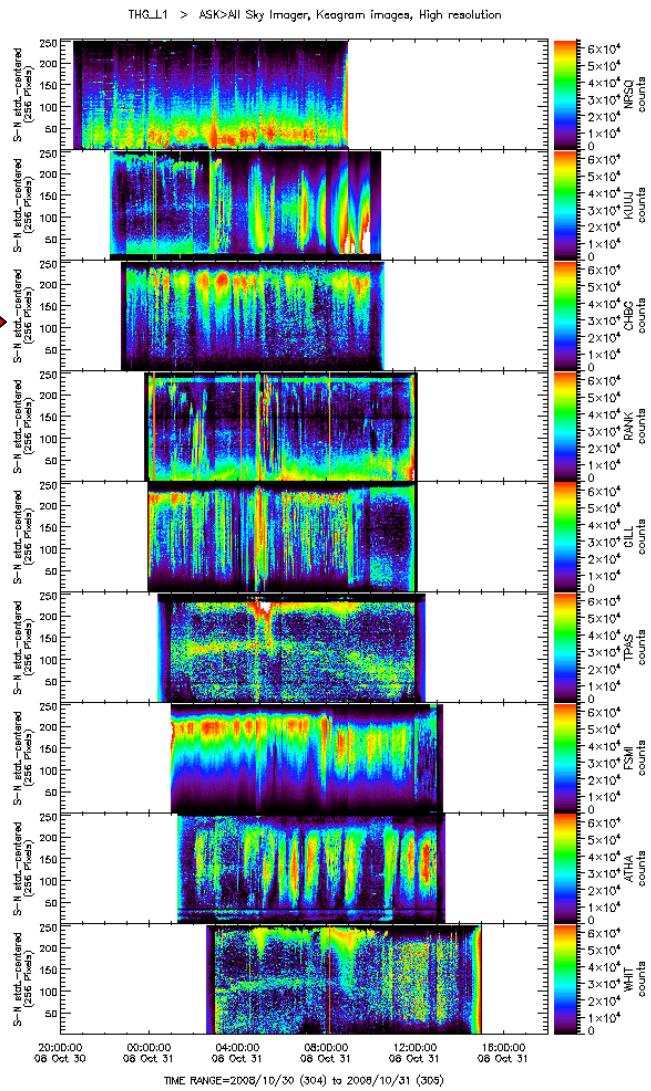


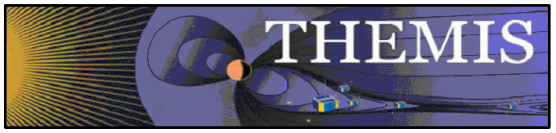
CDAWeb: THEMIS Data Summary

- **Level-2 Data from all 5 Satellites for FGM, ESA, SST, FBK, FFT, & FIT data quantities.**
- **Ground Magnetometer Data from 44 stations (31 GBO, 11 GEONS, 2 GIMA)**
- **Keograms from 23 All-Sky-Imagers (ASI) going back to 2005.**
- **All data updated daily (auto-ingest) from THEMIS data site.**
- **GIF-Walk: pre-generated Magnetopause Crossing Survey plots (David Sibeck, NASA GSFC)**

  http://cdaweb.gsfc.nasa.gov/cgibin/gif_walk

- **State files with definitive orbits (bi-weekly updates) in all coordinate systems used in SSC and incl. magnetic traces. Very popular data set.**





Common Data Format- CDF

CDF Version 3.2.2 release, fixes memory leak and Read Only mode problems, and includes some changes for the tool programs.

CDF Patch for Matlab

CDF Patch for IDL 6+ (strongly recommended)

CDF Java Network Launching Protocol latest development