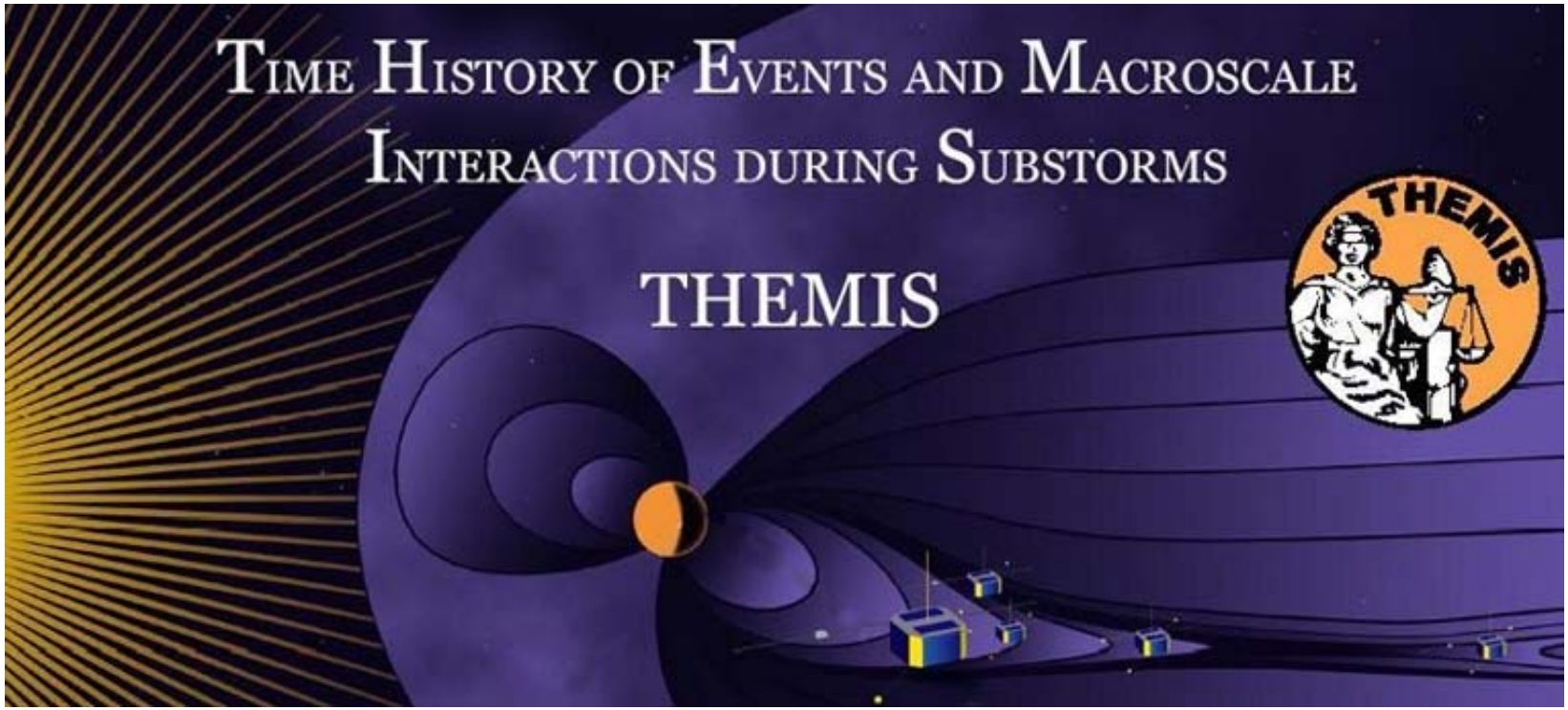

Science Software – v5.00 Training

GEM – Snowmass, Colorado

June, 2009

Agenda

10:30	Introduction	C. Goethel
10:35	THEMIS Web Site	C. Goethel
10:40	V5.00 Science Software/Data Status Report	C. Goethel
10:45	THEMIS Science Data Analysis Software	C. Goethel
11:10	Coordinate Transformation, Plotting, Mapping Tools, Mini-Language	P. Cruce
11:30	V5.00 THEMIS Graphical User Interface (GUI)	C. Goethel
12:15	THEMIS Ground Based Observatories (GBO)	P. Cruce
12:30	SPDF – CDAWeb	P. Cruce

V5.00 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) - Soon
- 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 Summer 2009
- EFI — All L1 data available from TH-C since May 2007, TH-D,E since Jun 7
  L2 EFI available Fall 2009
- 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
- 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 November 2008,
  Mosaics, movies for full mission
- GMAG
  L2 cdf files with ground magnetometer data from 51 stations. That includes one from Greenland and seven from Augsburg College. The Greenland data for the NRSQ station is updated daily and data is provided from October 2008 to present. The other 14 Greenland stations data is provided from 2007 through February 2009. Acknowledgement to Hans Gleisner of the Danish Meteorological Institute for the Greenland data and to Mark Engebretson and Erik Steinmetz for the Augsburg College data.
- Other Missions
  GOES – The GOES high-resolution (0.5s) magnetometer data is from GOES 10, 11 and 12 satellites from September 2007–June 2008 for each satellite. Acknowledgement to Howard Singer at NOAA Space Weather Prediction Center for the data.
  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

Organization	Contributors
UC Berkeley	D Larson, H Frey, J Bonnell, J McFadden, A Keiling
	J McTiernan, J Lewis
UCLA	V Angelopoulos, P Cruce, B Kerr, C Goethel, M Feuerstein,
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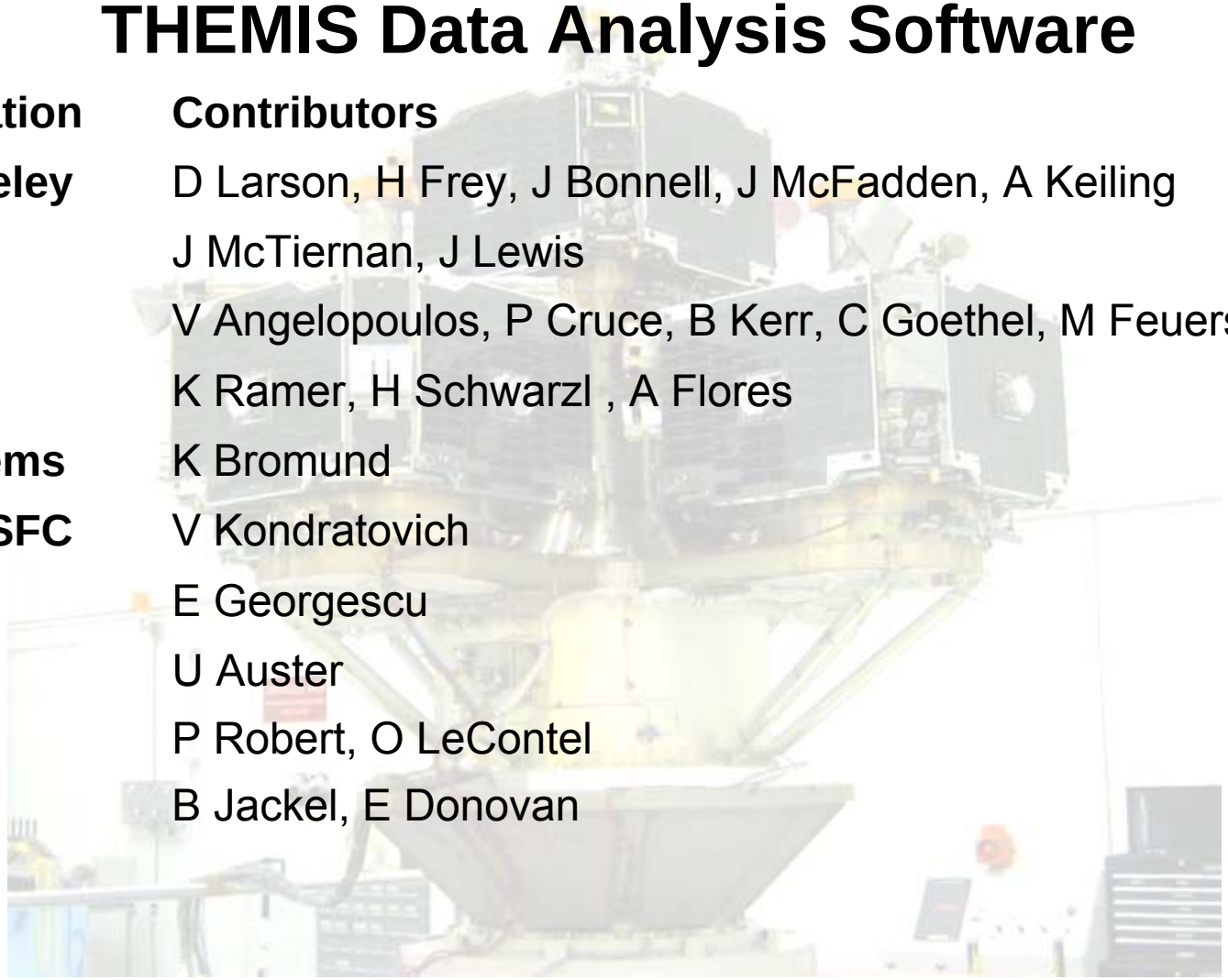
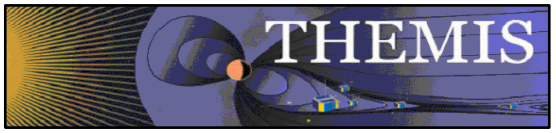
MPE	E Georgescu
TUBS	U Auster
CETP	P Robert, O LeContel
Calgary	B Jackel, E Donovan



Overview

- Software Objectives
  - Powerful, Flexible Command Line Interface
  - GUI to provide Easy Access to Key Features
- Software Installation
- Data Distribution
- Key Routines, crib sheets.
- Examples

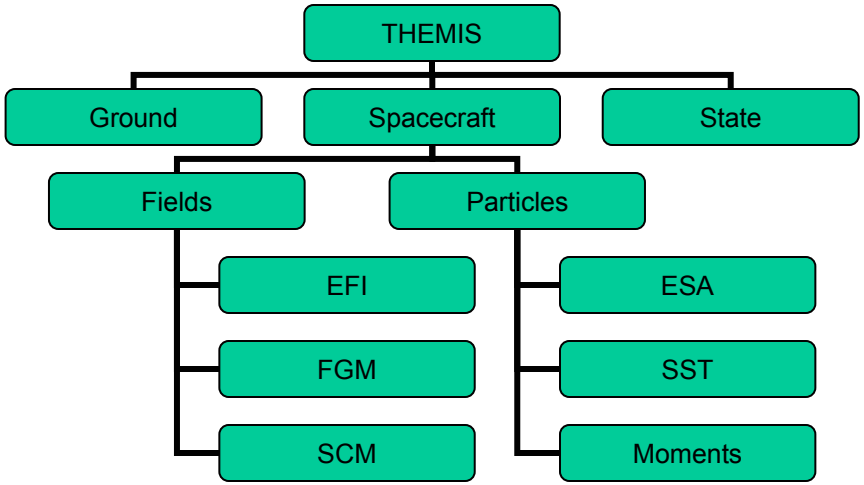


Software Objectives

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

THEMIS Specific Routines (idl/themis/)

- Instrument specific routine organization
  - Load Data
  - Calibrate Data



- Transforming Data
- Crib Sheet Examples

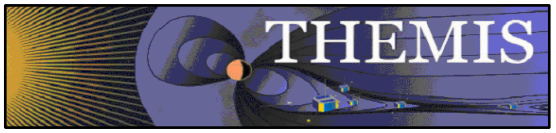
.

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

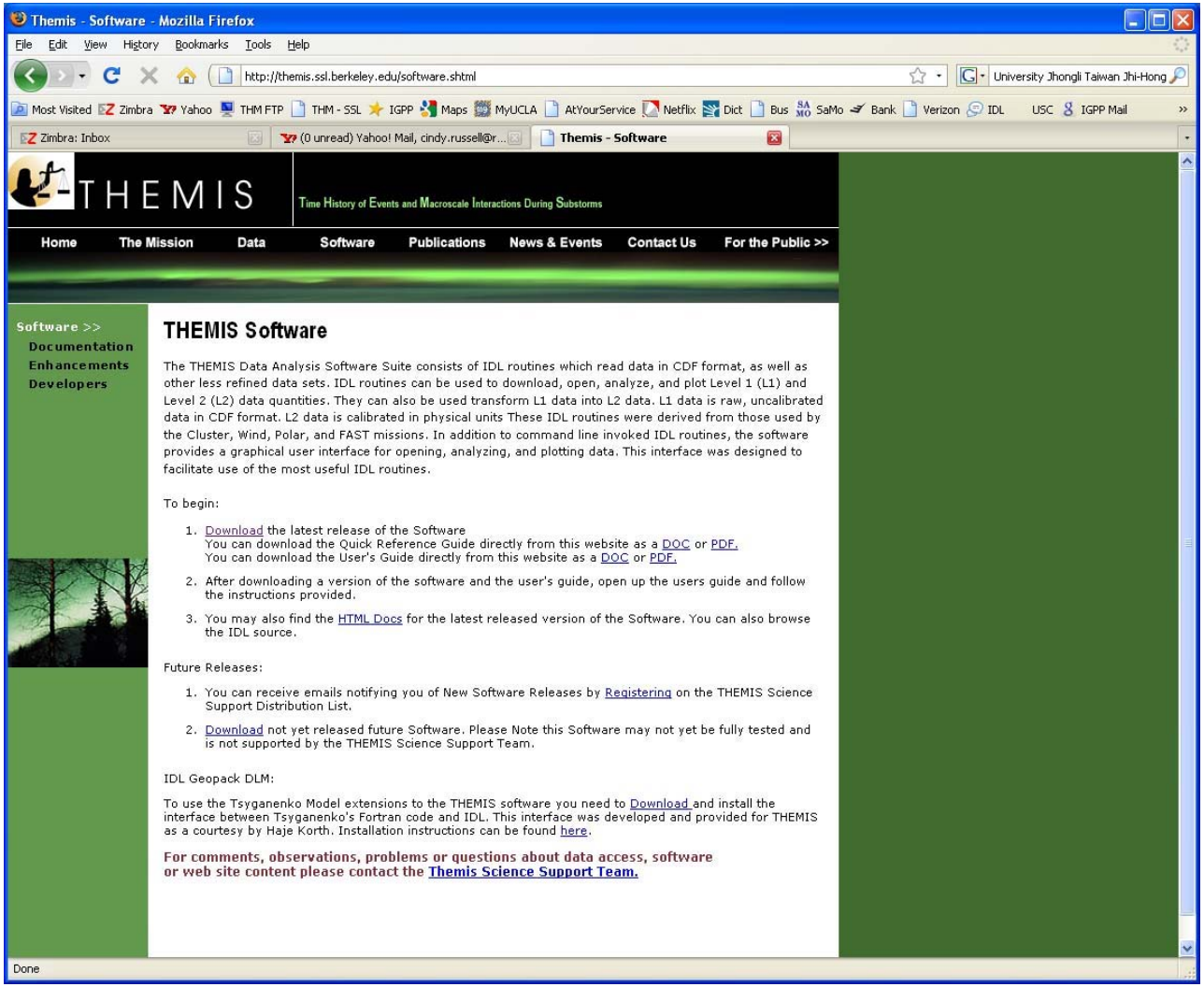
- Windows, Solaris, LINUX, PPC Mac or Intel Mac.
- IDL 6.2 or higher required
- IDL Patch Recommended
  - Required for Intel Mac, regardless of IDL version
  - Required for IDL 6.2, (Strongly recommended for IDL 6.4 and 7.0)
  - http://cdf.gsfc.nasa.gov/html/cdf_patch_for_idl6x_new.html
- For Mac, system 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/

THEMIS Main Web Page

THEMIS Software Web Page



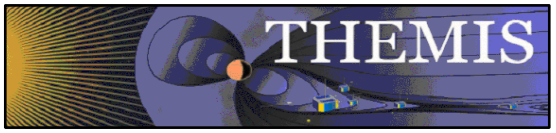
- Installation
  - Download and expand the latest TDAS release .zip file. The latest version is 5.00. http://themis.ssl.berkeley.edu/socware/tdas_5_00/tdas_5_00.zip
- Set up the IDL path
  - Windows and IDLDE on any platform: File->Preferences
  - UNIX-like systems (Mac OS X, Linux, Solaris)

```
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 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, uncalibrated 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, FGM, MOM*, SST – can be downloaded from SPDF. *(except for MOM)



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

Load Routine Summary

Name	Description	L0	L1		L2
			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 waveform		*	(*)	
thm_load_sst	Solid State Telescope		*	-	*
thm_load_state	Orbit and Attitude		v2		

Notes:
(*) calibration routine available but still under development
- data reduction and analysis routines available: see crib sheet

Usage Conventions:

Use keywords to determine functionality

level - Calibrated Level 1 data is the default (Except for SST and ESA data, which is handled differently).

datatype and probe keywords determine which data is loaded and/or created through calibration process

/get_support_data keyword is needed in thm_load_state to load data required by thm_cal* and thm_cotrans routines.

To load uncalibrated data, set type = ‘raw’ (For all but SST, ESA)

Example from IDL Command Line:

```
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*

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_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 in a single call
  - 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
- Example (using 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

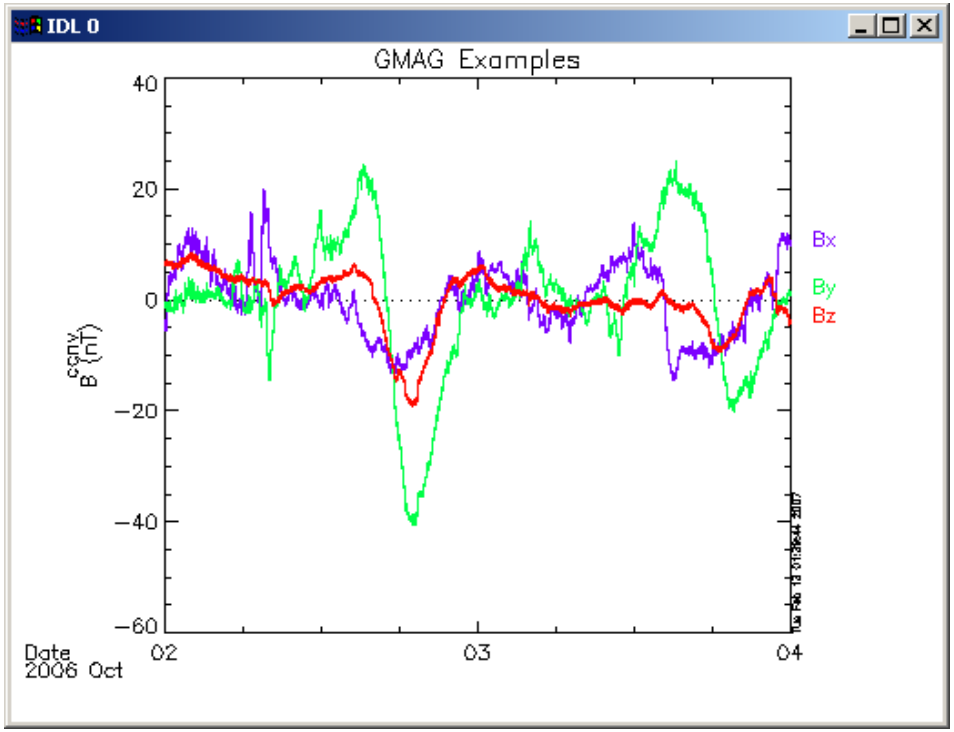
- tvector_rotate
- fac_matrix_make
- thm_fac_matrix_make
- minvar_matrix_make

Tsyganenko Model

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

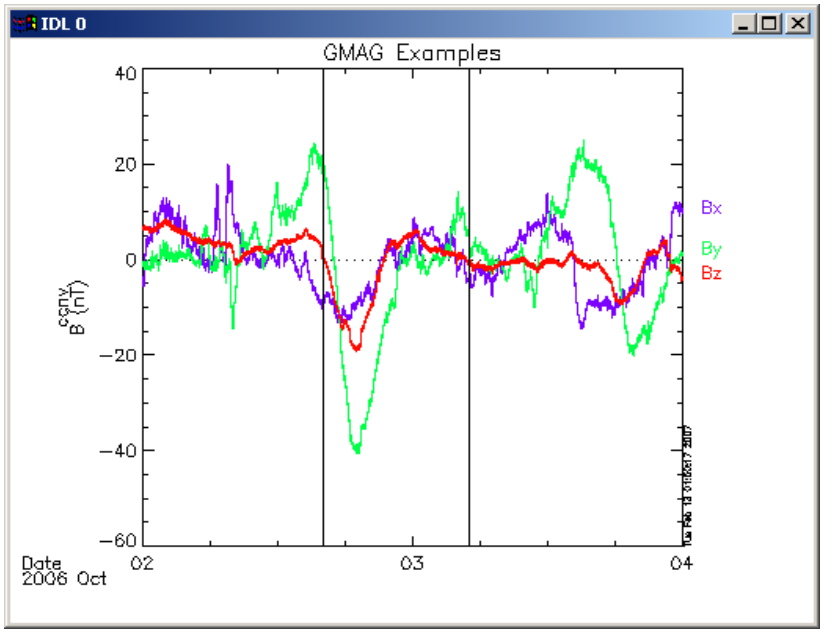
Command Line Example 1

- 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'

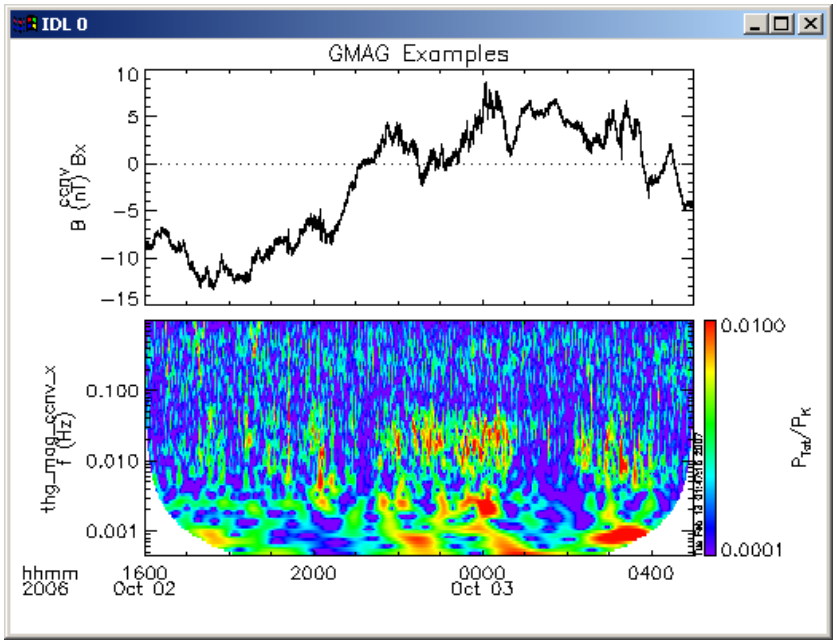


Command Line Example 2

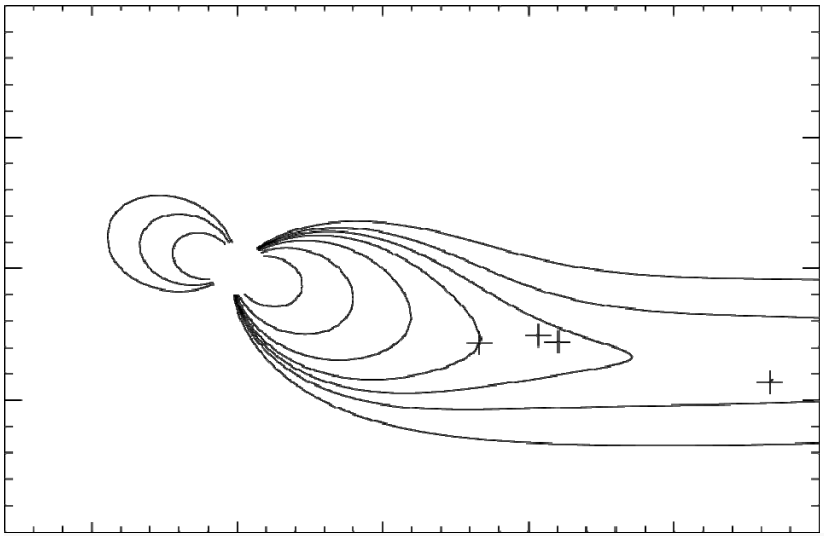
- Wavelet transform on an interval of interest
  - Define and display the interval
    - » Tr = ['2006-10-2/16:00','2006-10-3/05']
    - » timebar,tr



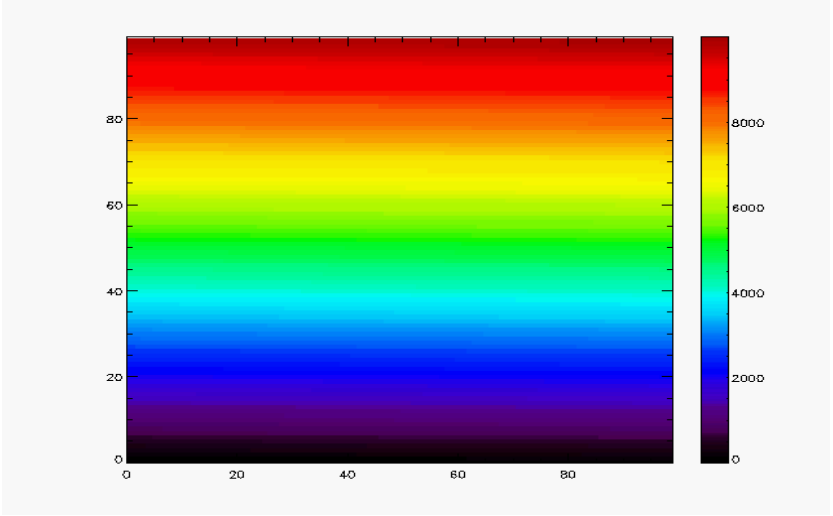
- Split the 3-vector into components:
  - » split_vec,'thg_mag_ccnv'
- Compute transform of one component
  - » wav_data,'thg_mag_ccnv_x',/kol $,trange=tr ,maxpoints=24l*3600*2
- Set color limits (log scale)
  - » zlim,'*pow', .0001,.01,1
- Plot it.
  - » tplot,'*ccnv_x*',trange=tr



Plotting Examples

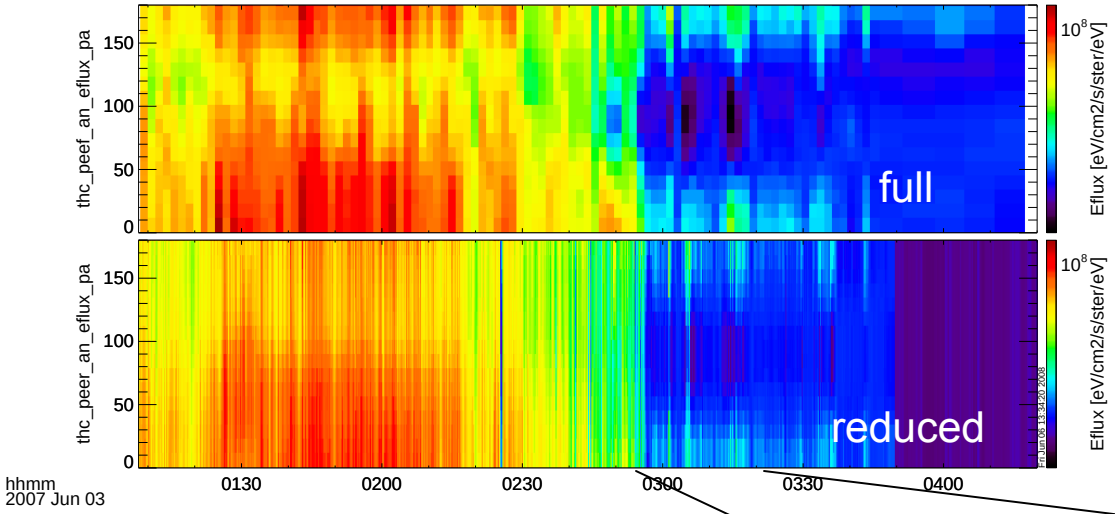


tplotxy can be used to plot isotropic position plots. Like plots of magnetic field models and spacecraft position



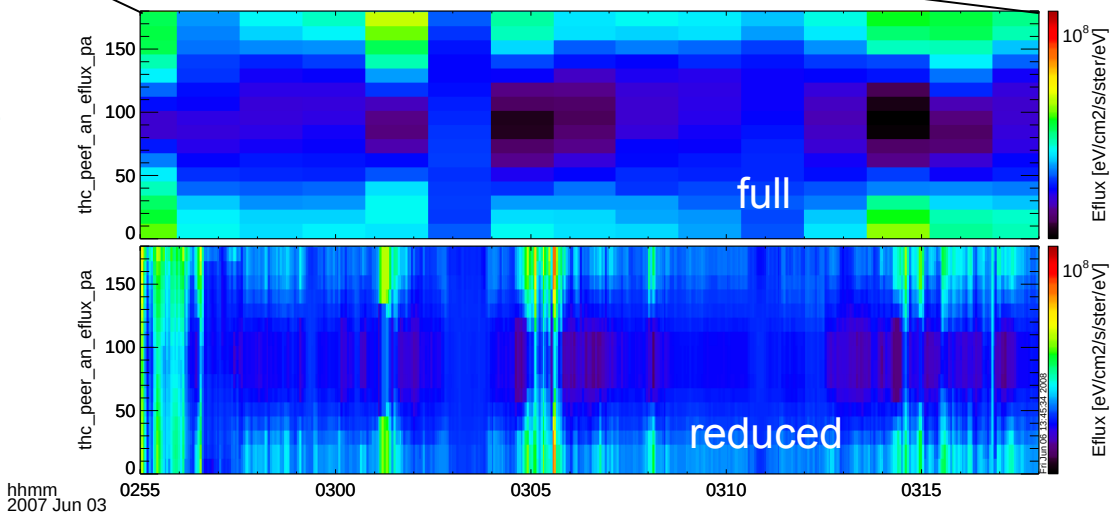
Plotxyz can be used to plot 3 dimensional isotropic data, with any axis.(Not restricted to time-series.)

Plotting Angular Spectra



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

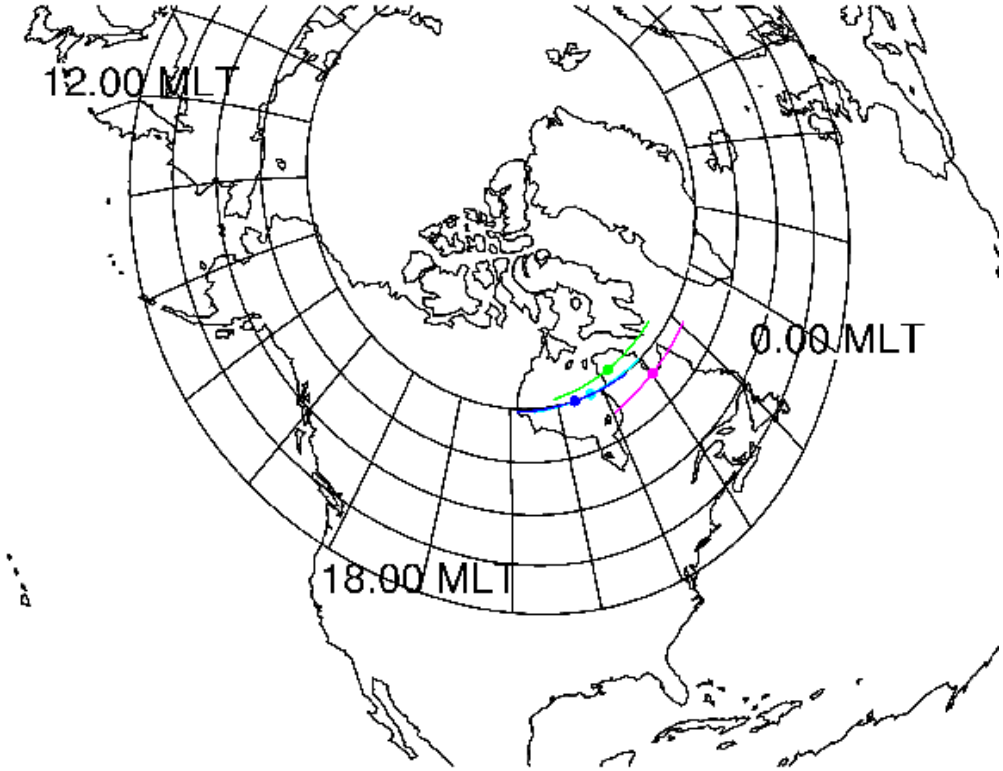
```
thm_part_getspec, $
probe=['c'], $ ;select probe
trange=['07-06-03/01:08', $  ;select timerange
        '07-06-03/04:20'], $
data_type=['peef','peer'], $ ;select data type
angle='pa', $ ;select pitch angle spectra
regrid=[32,16] ;set resolution of pitch/gyro
spectra
```



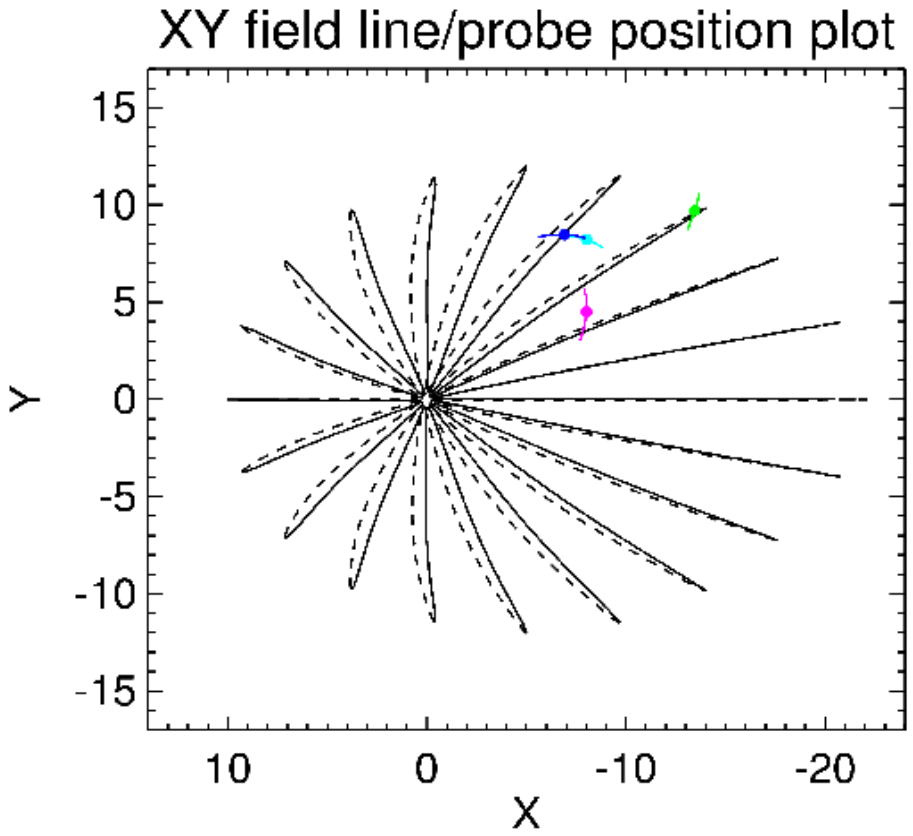
Trace / Orbit Plots

- 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 this 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.

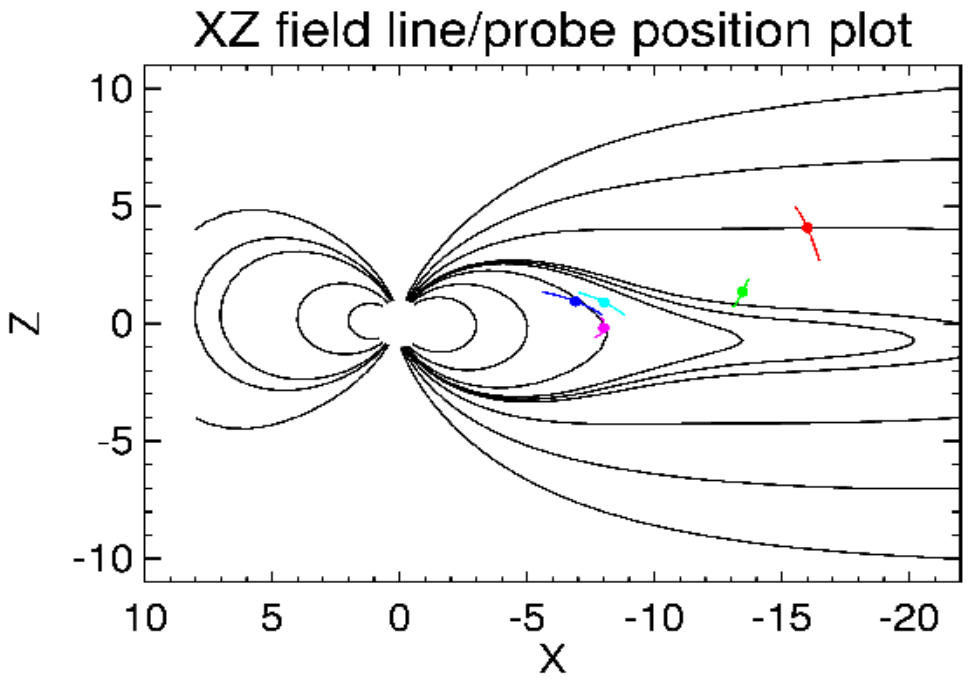
Trace/Orbit Plots - AACGM/Iono Trace Plot



Trace / Orbit Plots – XY Plot



Trace / Orbit Plots – XZ Plot

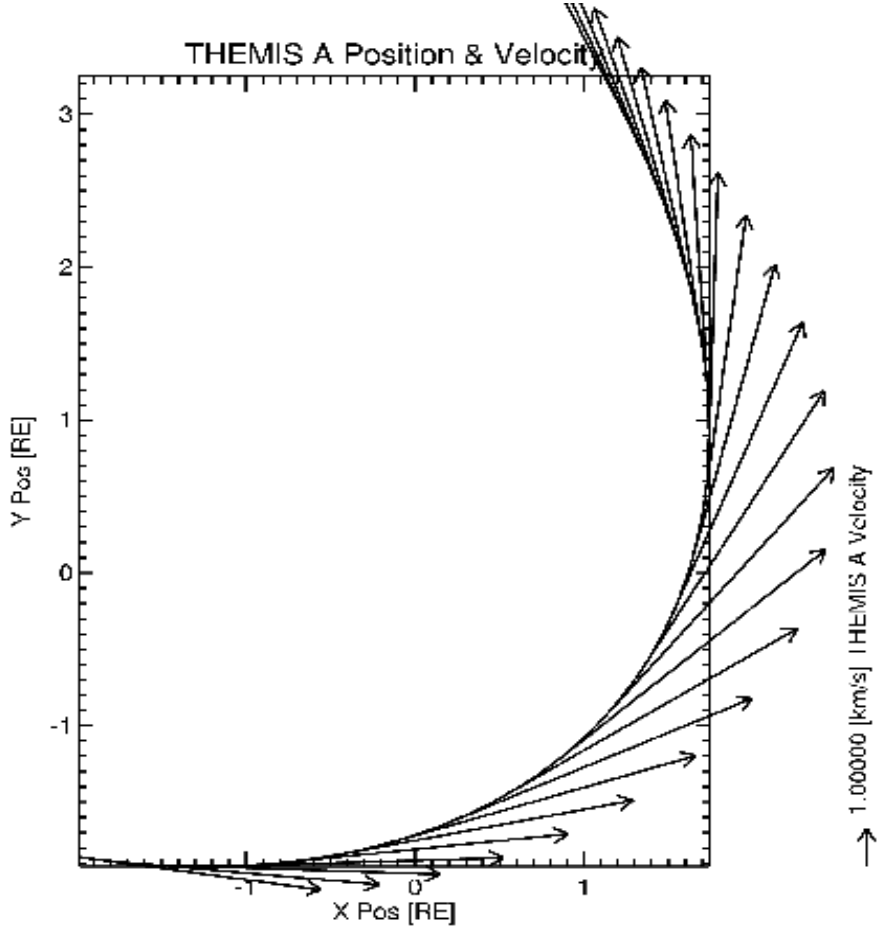


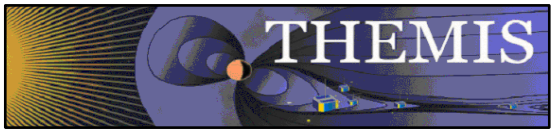
THEMIS – Mini Language

- 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

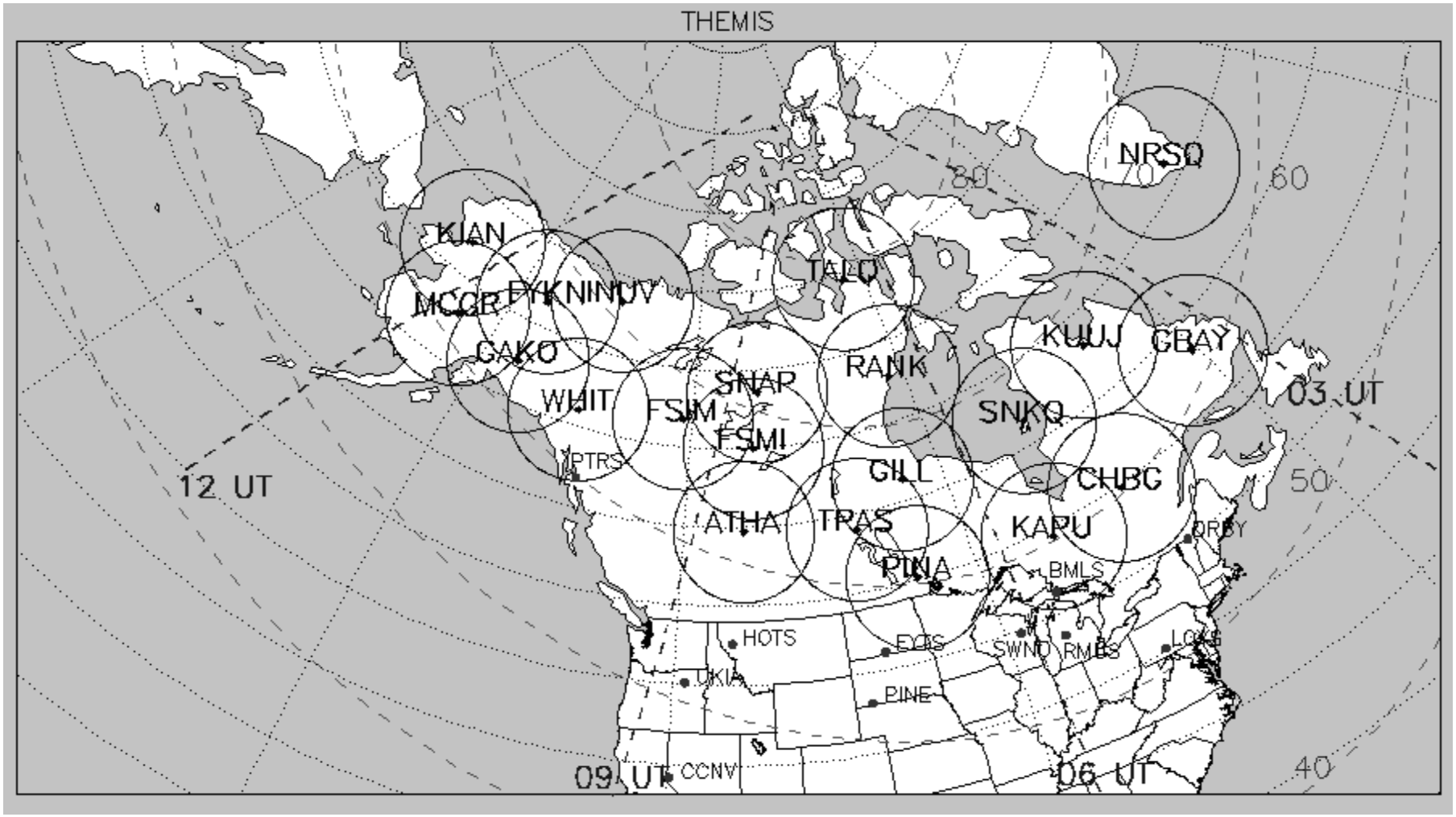
Plotxyvec – Position/Velocity Plot





THEMIS software for GBO all-sky imager
Thm_crib_asi.pro
Harald U. Frey

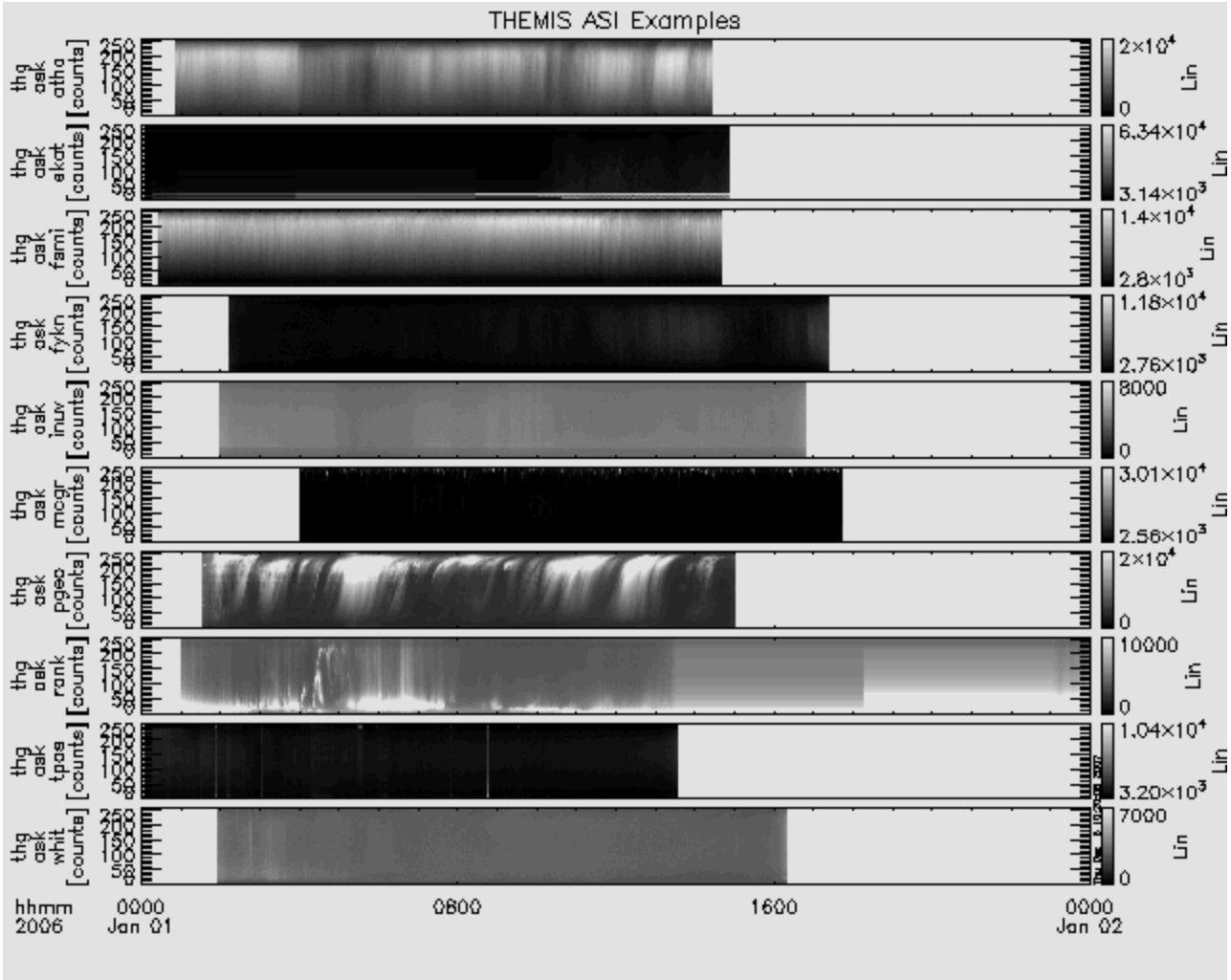
THEMIS GBO network



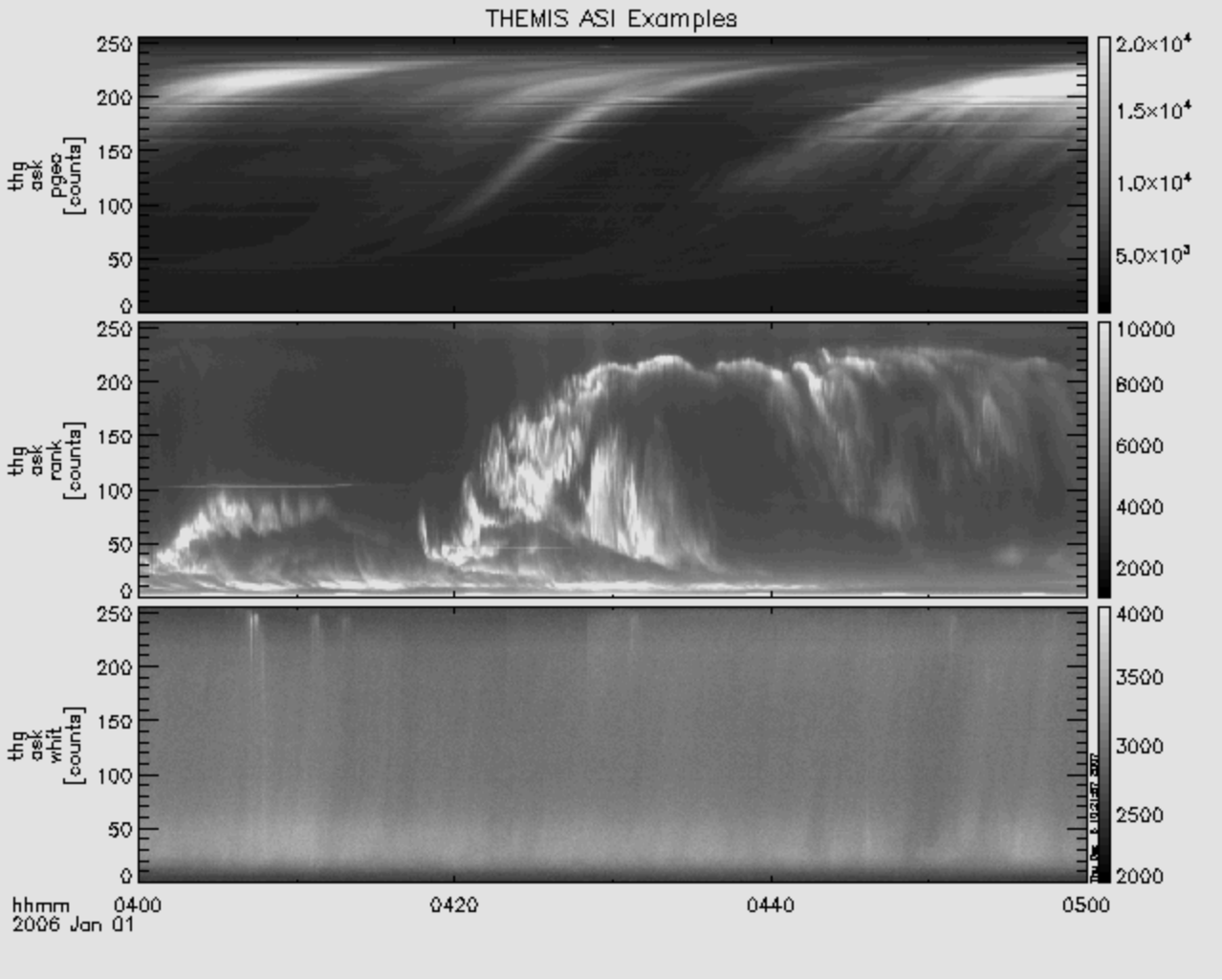
All-sky imager data products

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 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

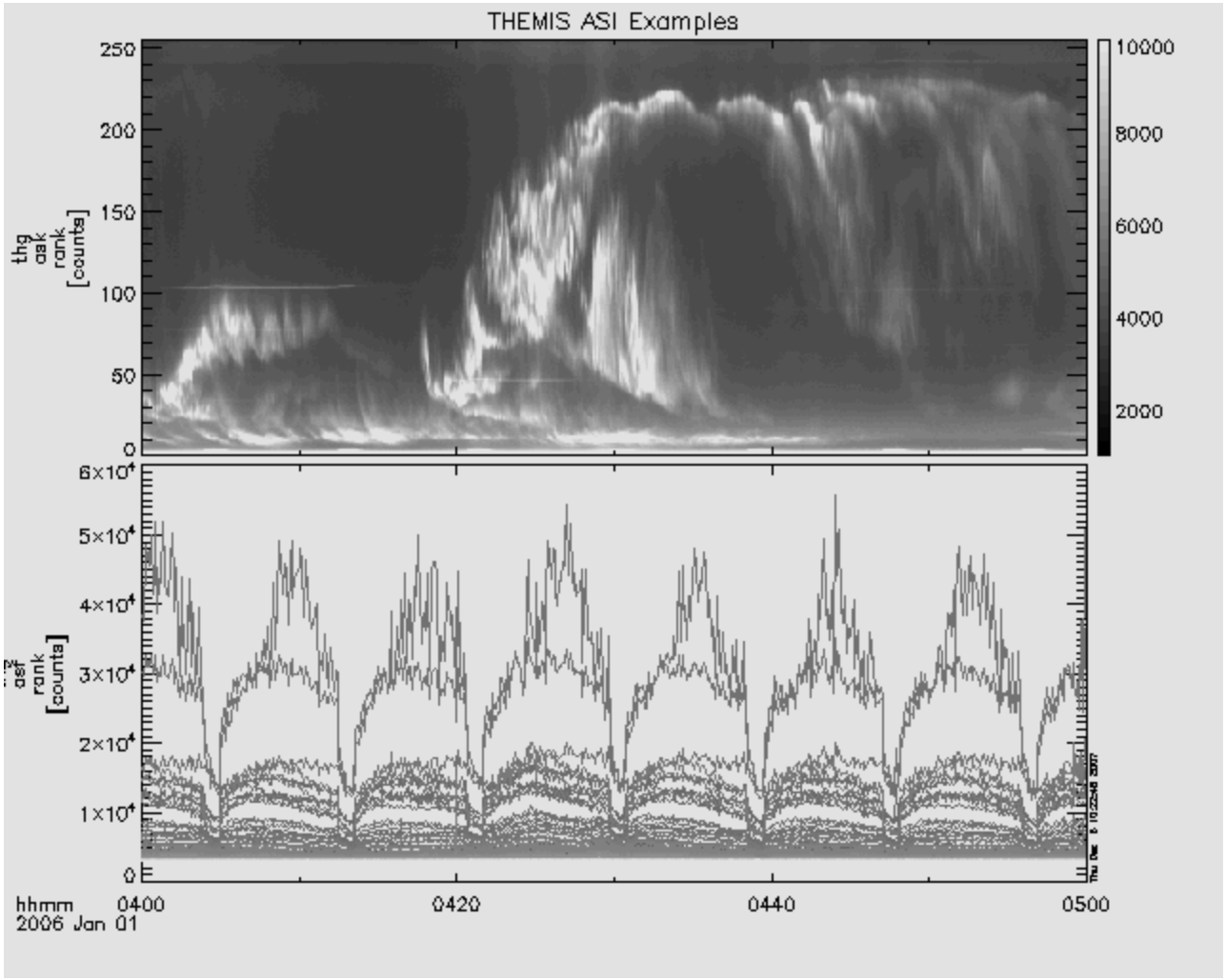
Daily overview of available keograms

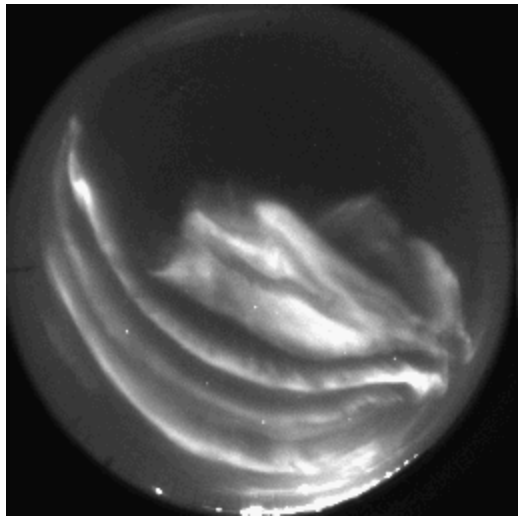


Zoom into interesting time

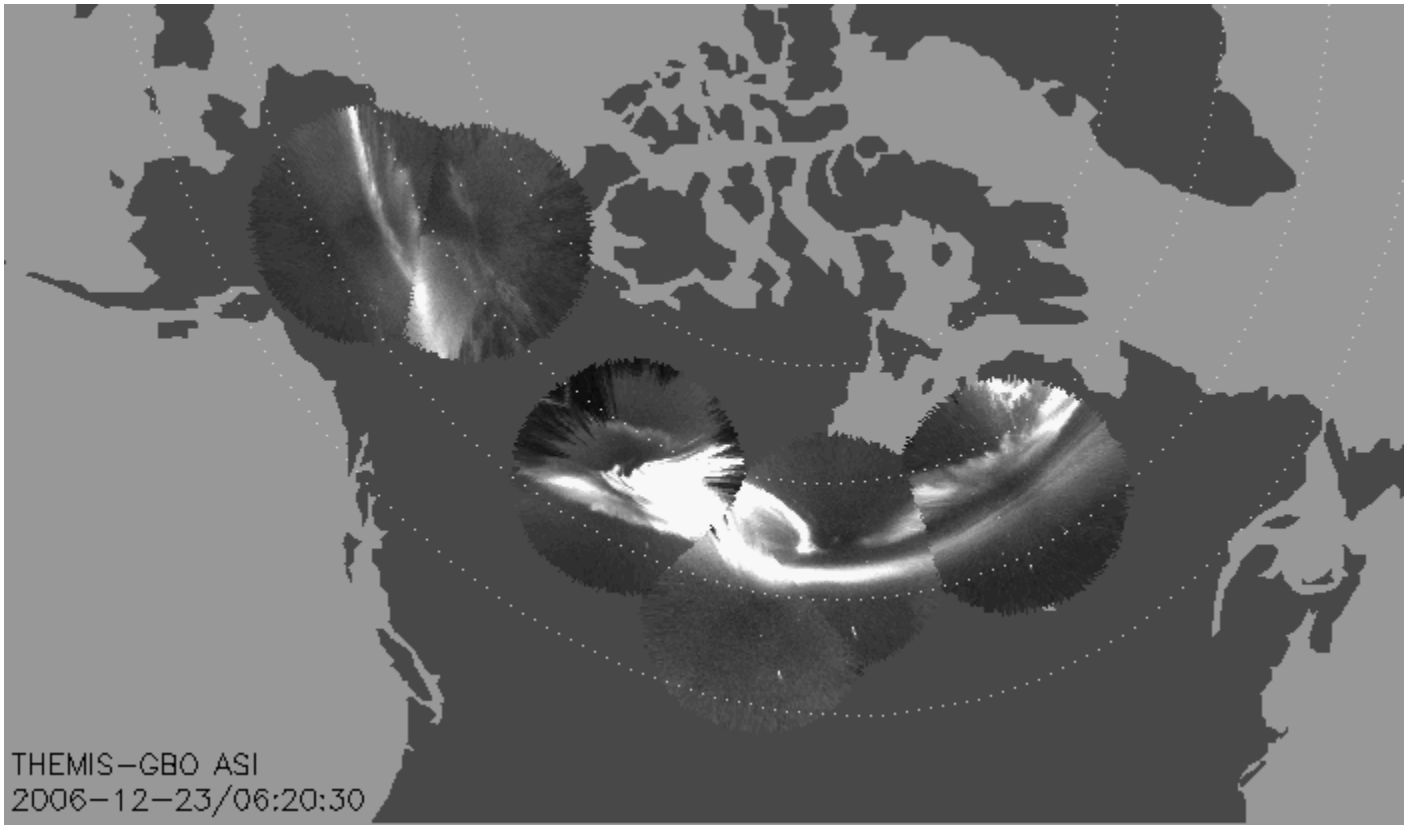


Watch “movie” of single station

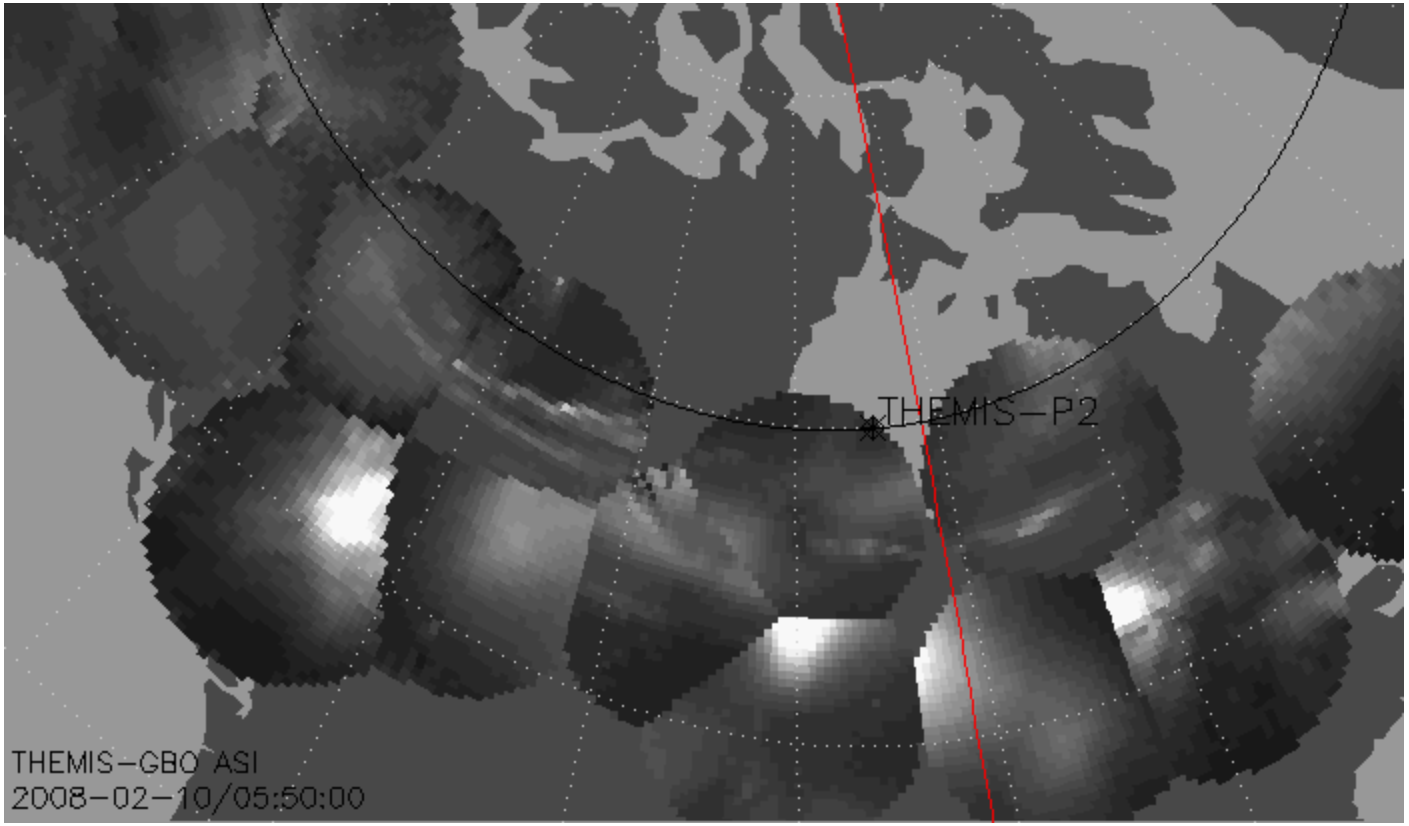




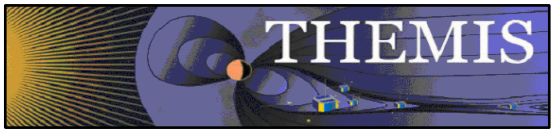
Mosaic of whole GBO array from full resolution images



Mosaic with S/C footprint From thumbnail images

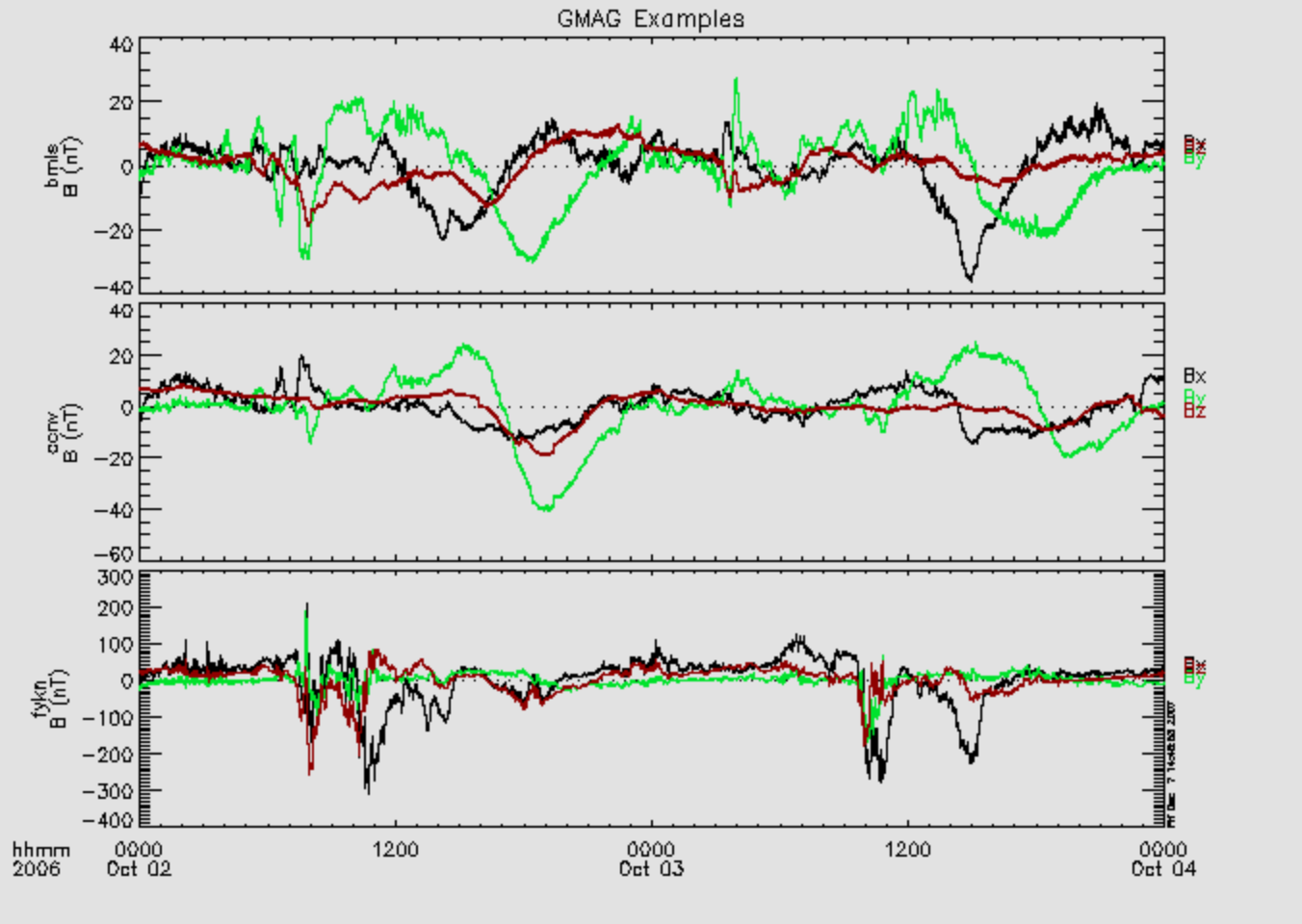


Black line marks footprint of THEMIS-P2 during whole night
Asterisk marks location at time of mosaic



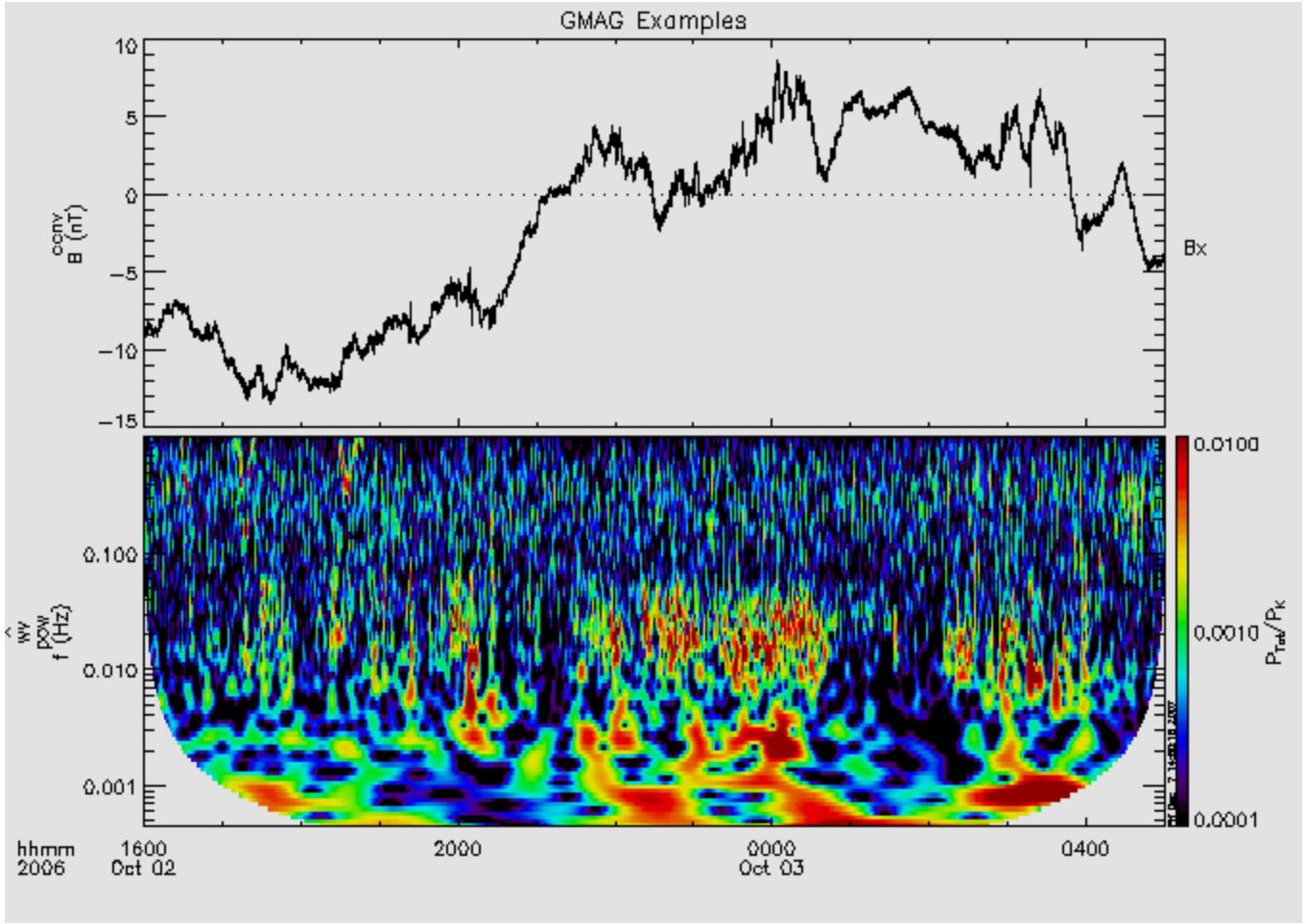
Ground magnetometer Examples
Thm_crib_gmag.pro

Three station example

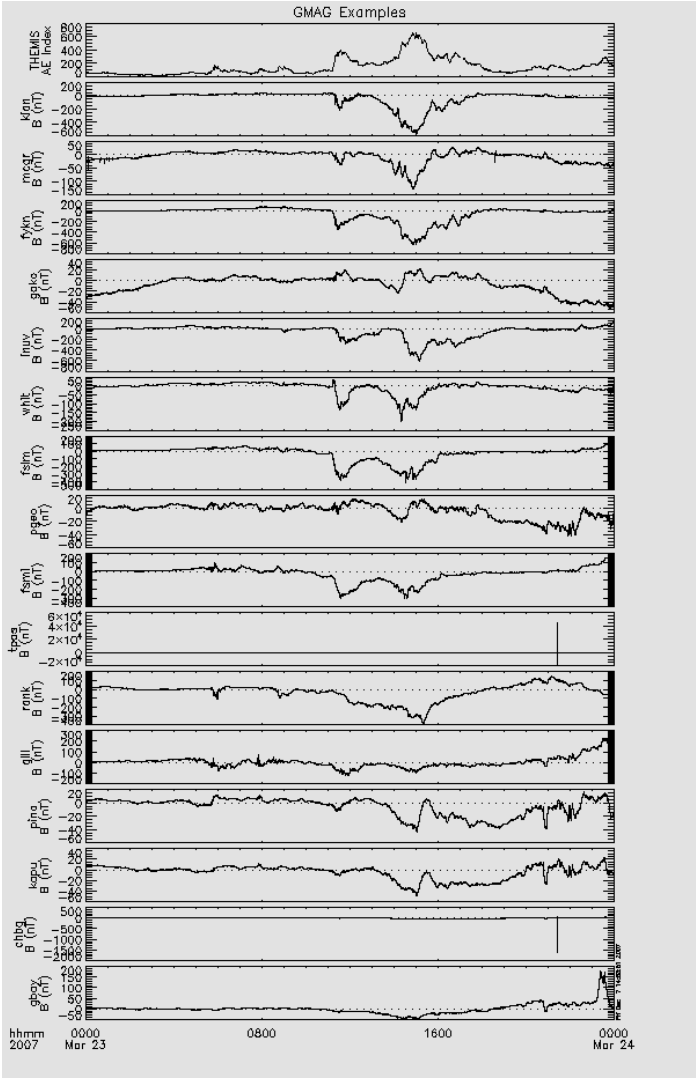


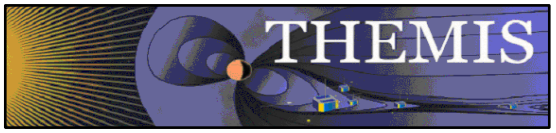
GMAG Data With Average Subtracted

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

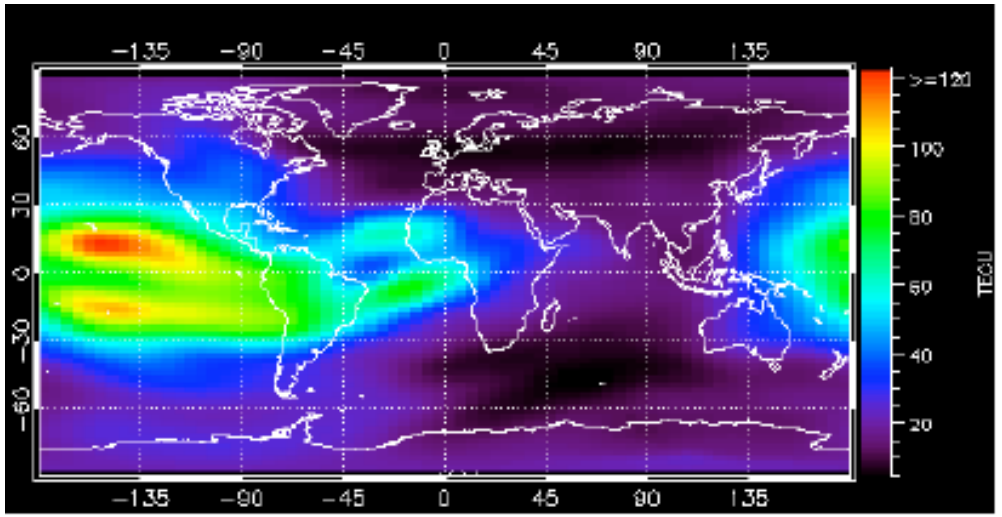
Sep 2008 - Jun 2009: Magnetometer data added from several additional ground stations for a total of now 44 stations from the GBO (31), GEONS (11), and GIMA (2) networks (most recent NAIN, CDRT and NRSQ).

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.**