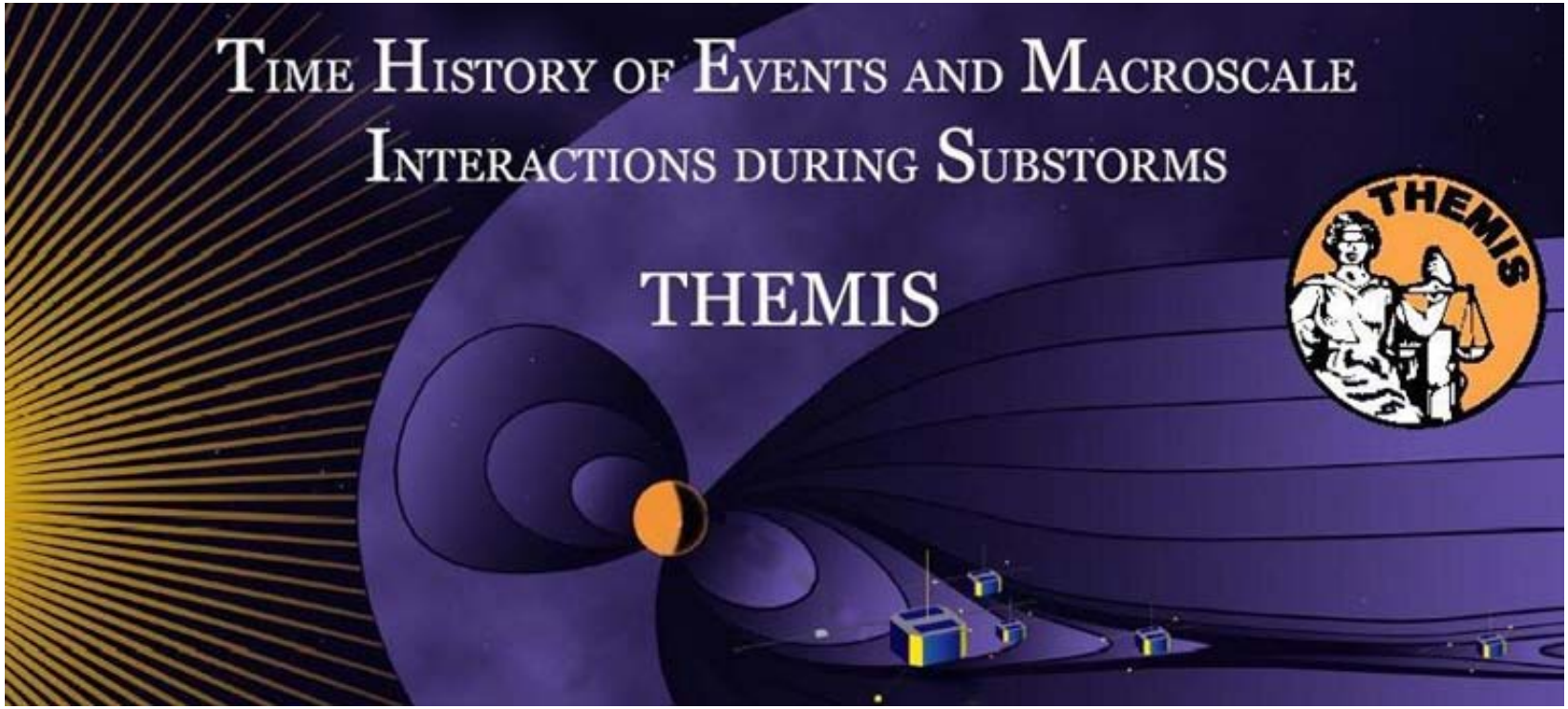

THEMIS Data Analysis Software – v6.0

RBSP SWG

Oct 21, 2011

THEMIS Data Analysis Software

Organization	Contributors
UC Berkeley	D Larson, H Frey, J Bonnell, J McFadden, A Keiling J McTiernan, J Lewis
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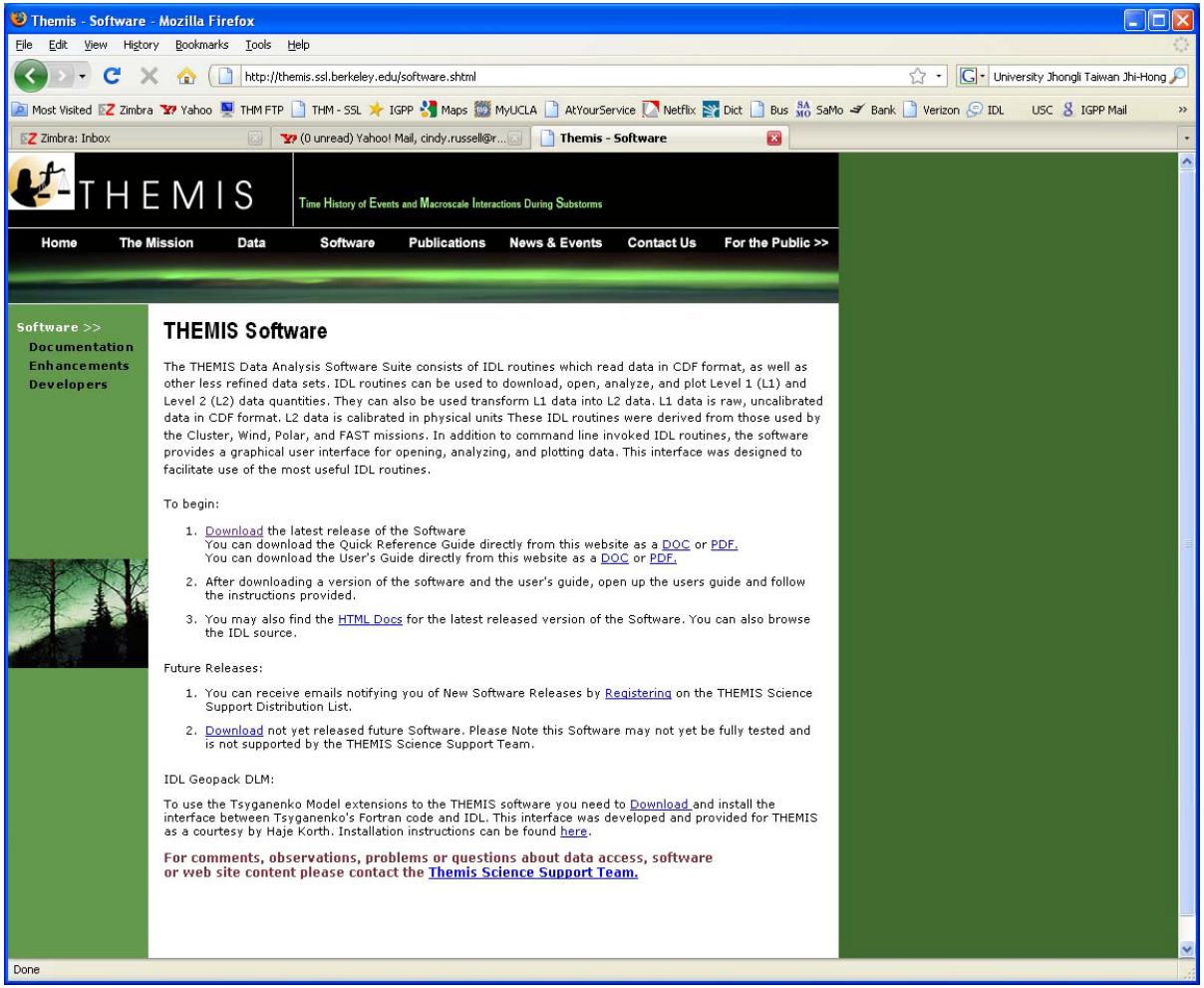
Software Objectives

- THEMIS Data Analysis Software (TDAS) Objectives
  - Powerful, Flexible Command Line Interface
  - GUI provides easy access to data, analysis tools, and graphics
  - Facilitates creation of publication quality plots
  - GUI design based on Windows
- IDL based (library of routines –but no main program!).
- Code is free and available to everyone
- Functionally separates routines by tasks into :
  - Reading, Manipulating, Plotting
- Platform independent. Works on:
  - Solaris, Linux, Windows, Vista, Mac OS X
- Easily ported to new missions
  - ACE
  - GOES
  - Wind
  - ERG-EFW
  - IUGONET
  - MMS

THEMIS Software Web Page

http://themis.ssl.berkeley.edu



THEMIS_Science_Support@ssl.berkeley.edu

Coordinate Transforms

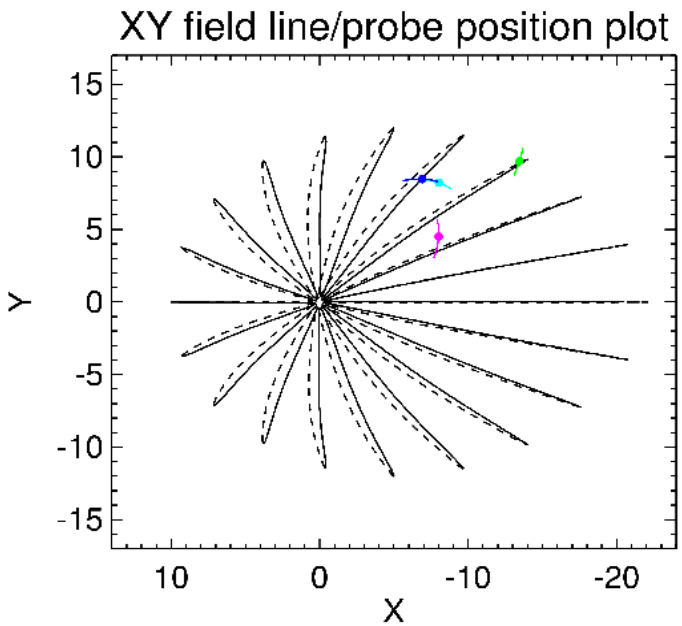
- Geophysical Coordinate Systems supported by TDAS
  - SPG Spinning Probe Geometric
  - SSL Spinning SunSensor L-vectorZ
  - DSL Despun SunSensor L-vectorZ
  - GEI Geocentric Equatorial Inertial
  - GSE Geocentric Solar Ecliptic
  - GSM Geocentric Solar Magnetospheric
  - SM Solar Magnetic
  - GEO Geographic Coordinate System
  - SSE Selenocentric Coordinate System
  - SEL Selenographic Coordinate System

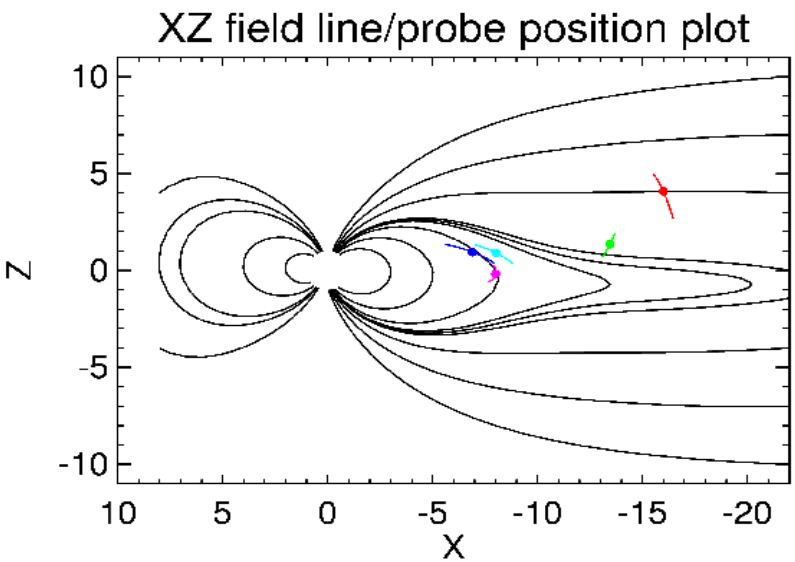
- Analytical Coordinate Systems supported by TDAS
  - tvector_rotate
  - fac_matrix_make
  - thm_fac_matrix_make
  - minvar_matrix_make
  - enp_matrix_make
  - rxy_matrix_make
  - sse_matrix_make
  - gsm2lmn

Magnetic Fields Model

- Tsyganenko Model Routines (IDL_GEOPACK)
  - (t)trace2iono
  - (t)trace2equator
  - (t)t89
  - (t)t96
  - (t)t01
  - (t)t04s

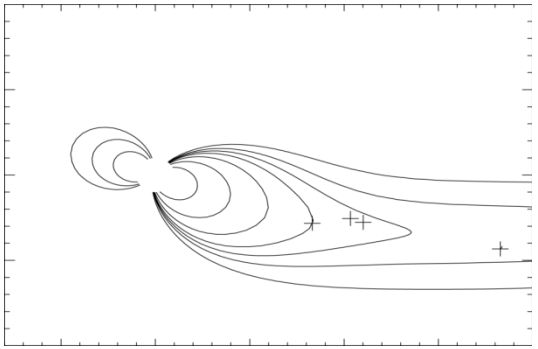
Trace / Orbit Plots



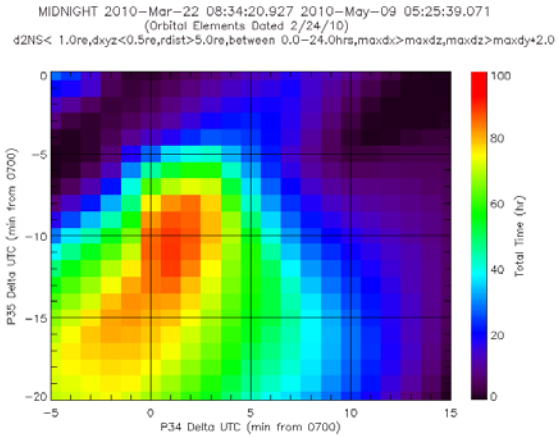


Plotting Routines

- Plotting routines using tplot variables
  - tplot
  - tplotxy
  - plotxy
  - plotxyz
  - tplot_names
  - tlimit
  - get_data
  - store_data



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



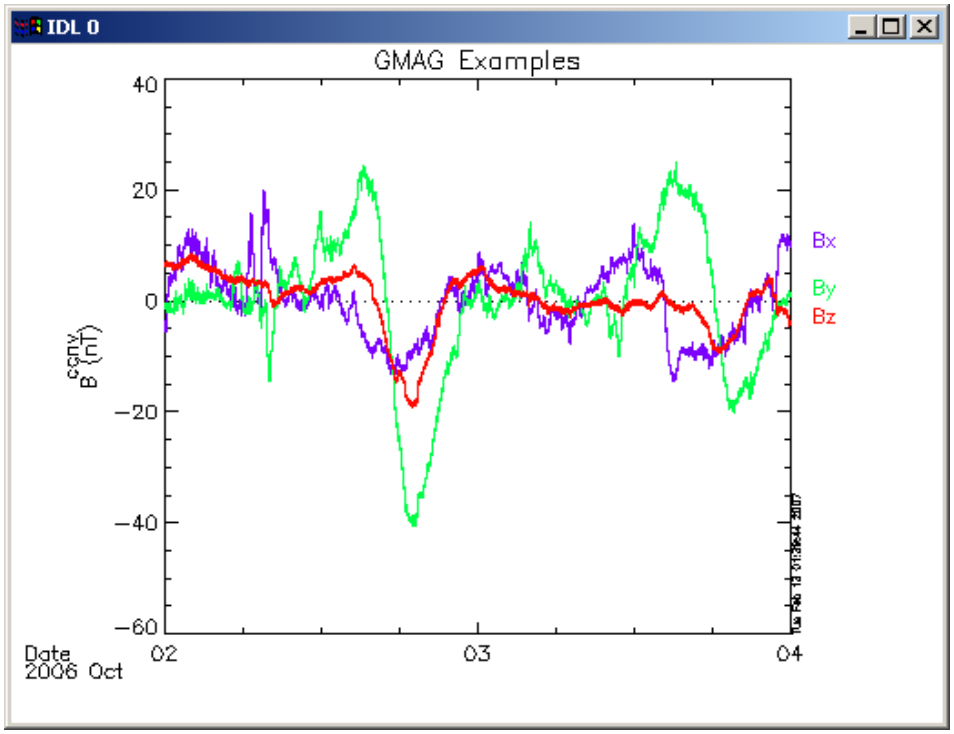
plotxyz can be used to plot 3 dimensional isotropic data, with any axis. (Not restricted to time-series.)

NOTE 1: Crib sheets are available for tplot and other plotting and analysis tools

NOTE 2: Functionality of TDAS routines are controlled by the use of keywords. The keywords available for each routine can be found in the header of the source code.

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'

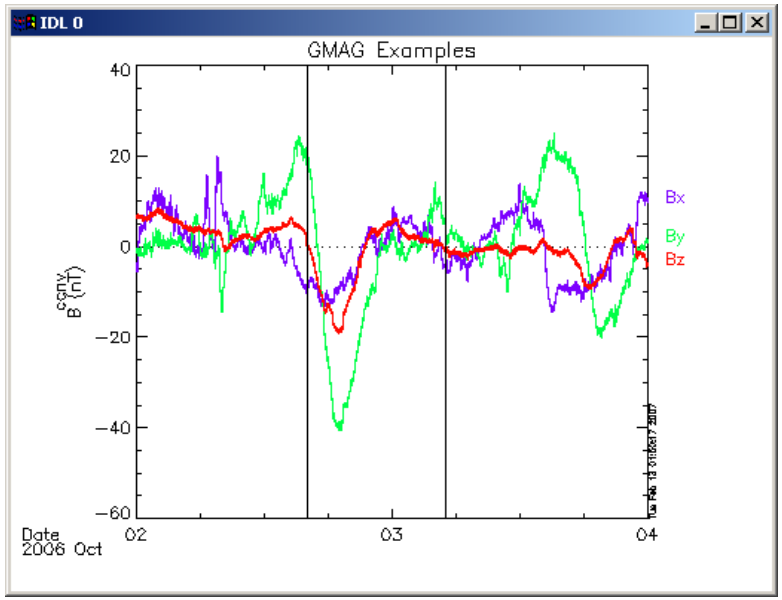


Wavelet Transform

- To perform a wavelet transform on an area of interest

; define area of interest

idl > **tr** = ['2007-07-23/09:00','2007-07-23/16']



; split the 3d vector into components

idl > **split_vec**, ' thg_mag_ccnv'

; compute transform of one component

idl > **wav_data**, 'thg_mag_ccnv_x', /kol, $

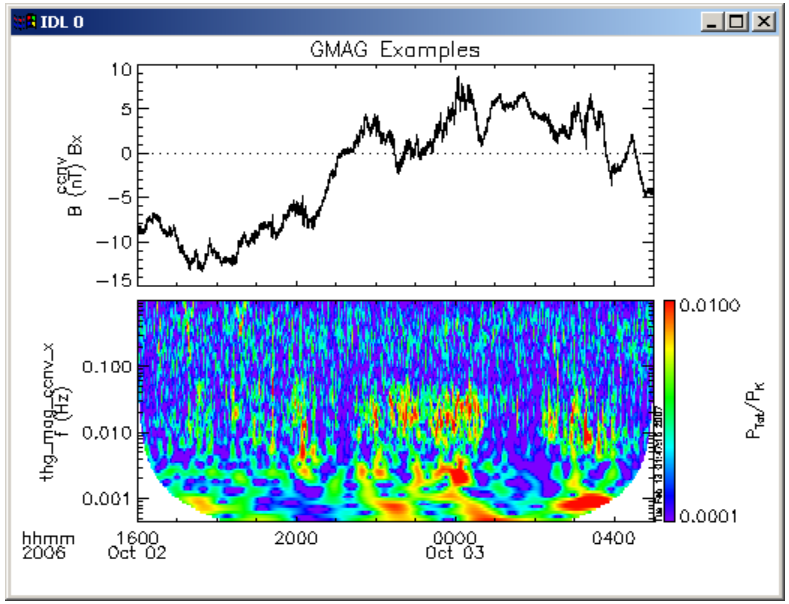
trange=tr, maxpoints = 24l*3600*2

; set color limits (log scale)

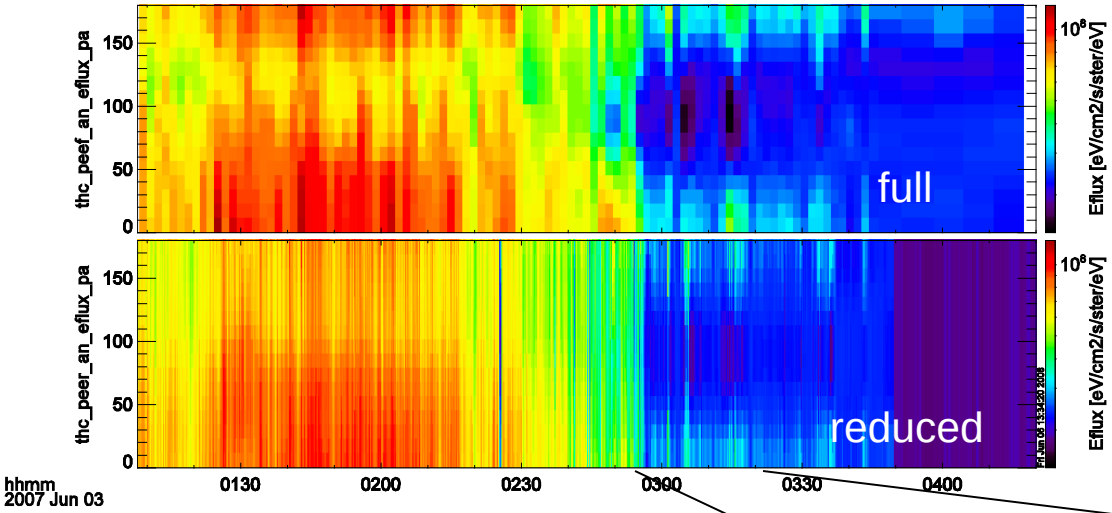
idl > **zlim**, '*pow', .0001, .01, 1

; and plot it.

idl > **tplot**, '*ccnv_x*' , trange=tr

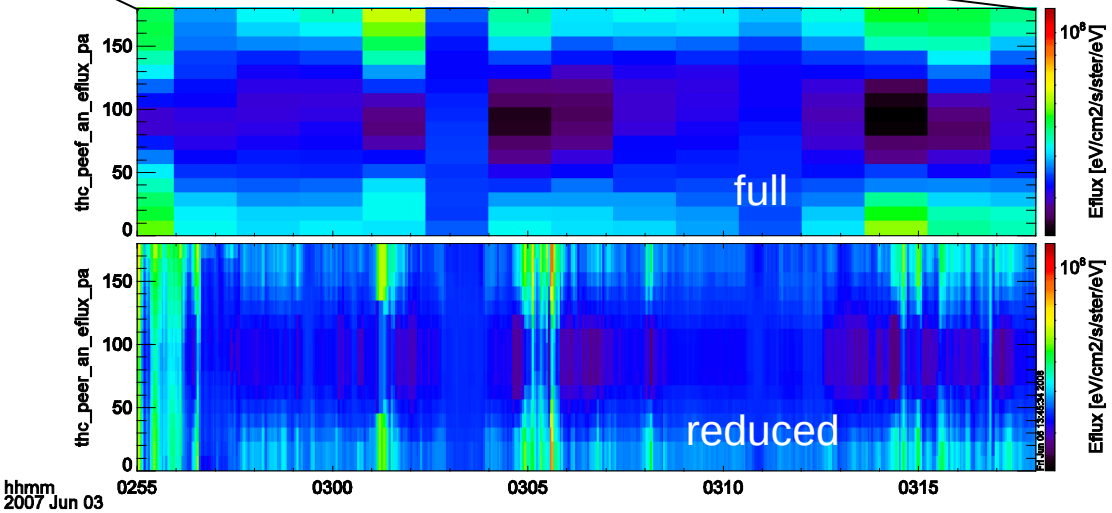


Plotting Angular Spectra

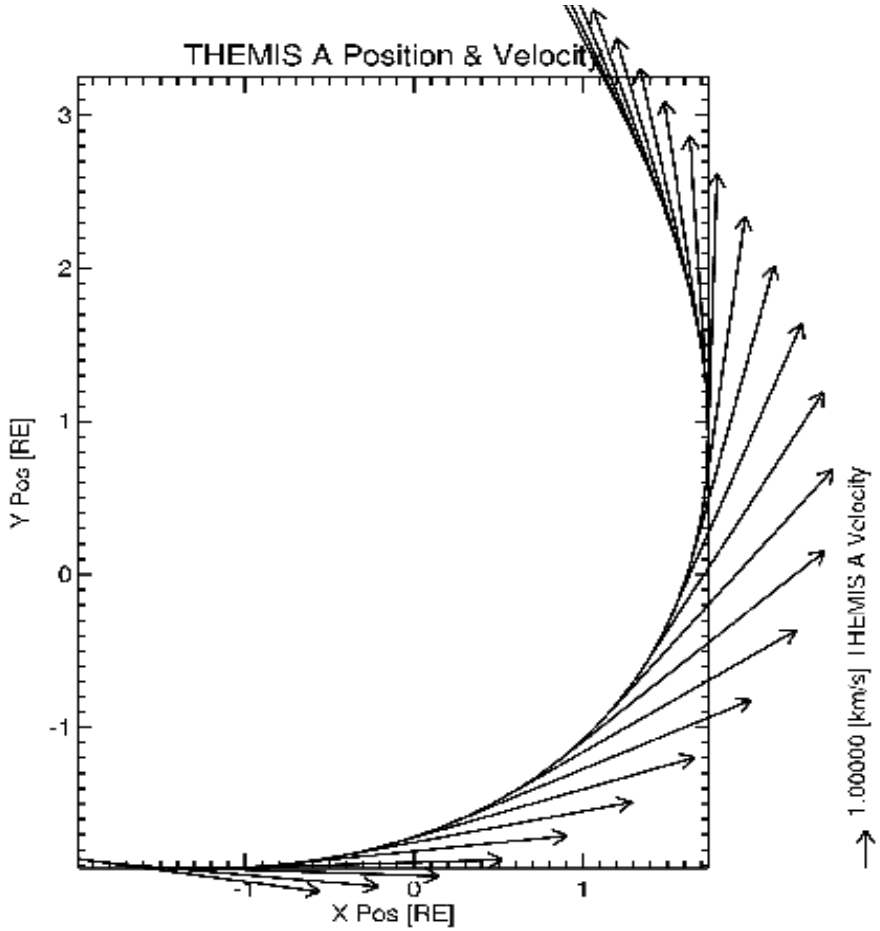


Pitch angle spectra for full and reduced mode electron ESA data. Plotted using tplot.

```
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
```

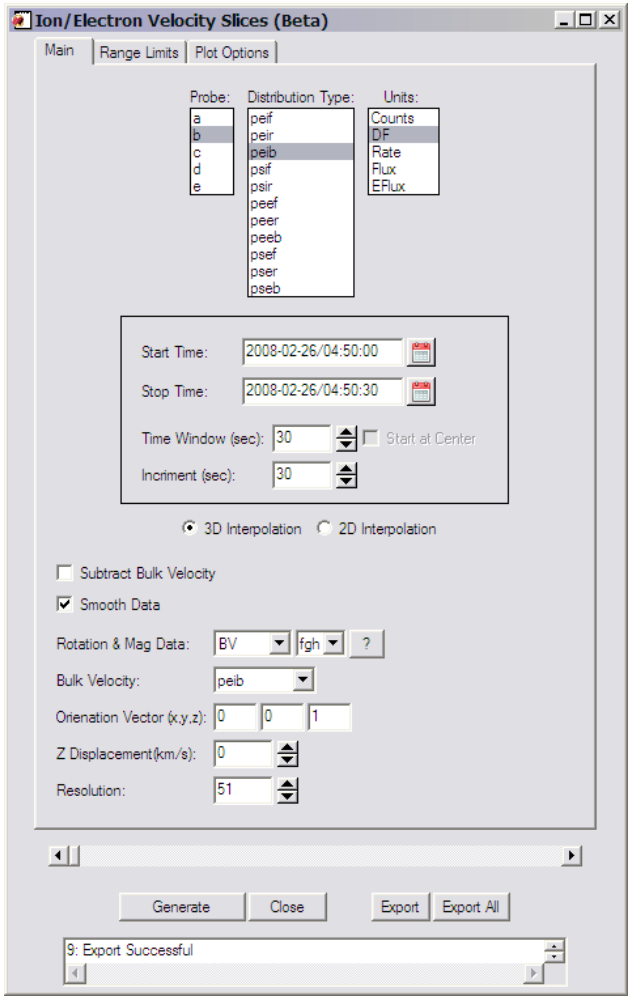


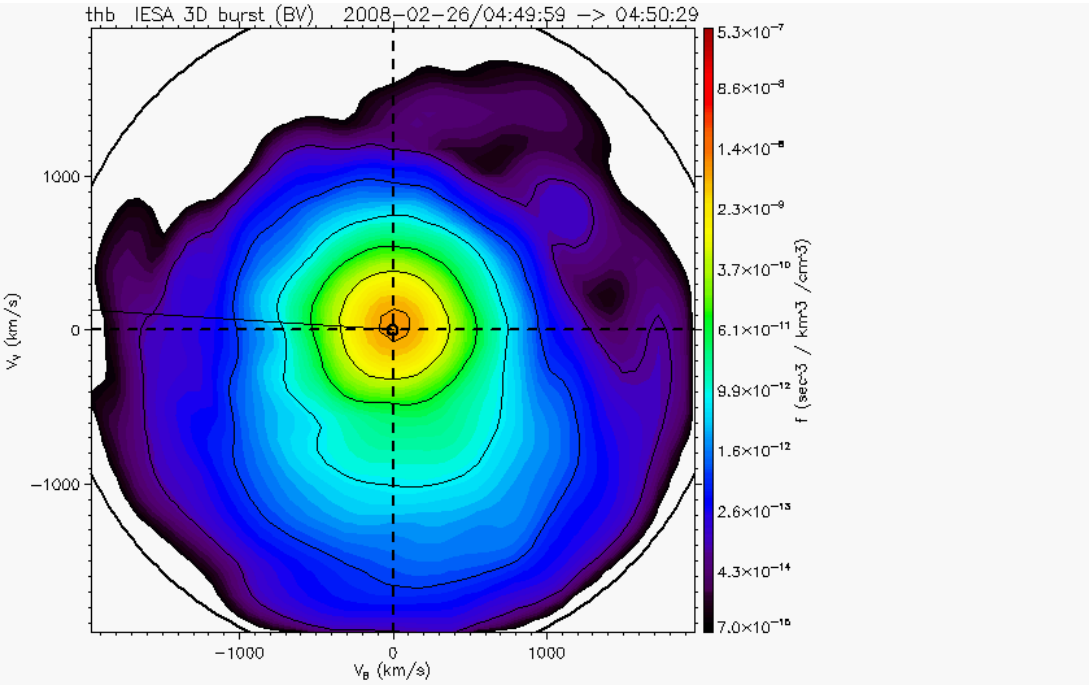
Plotxyvec – Position/Velocity Plot



Ion Electron Velocity Slices(Beta)

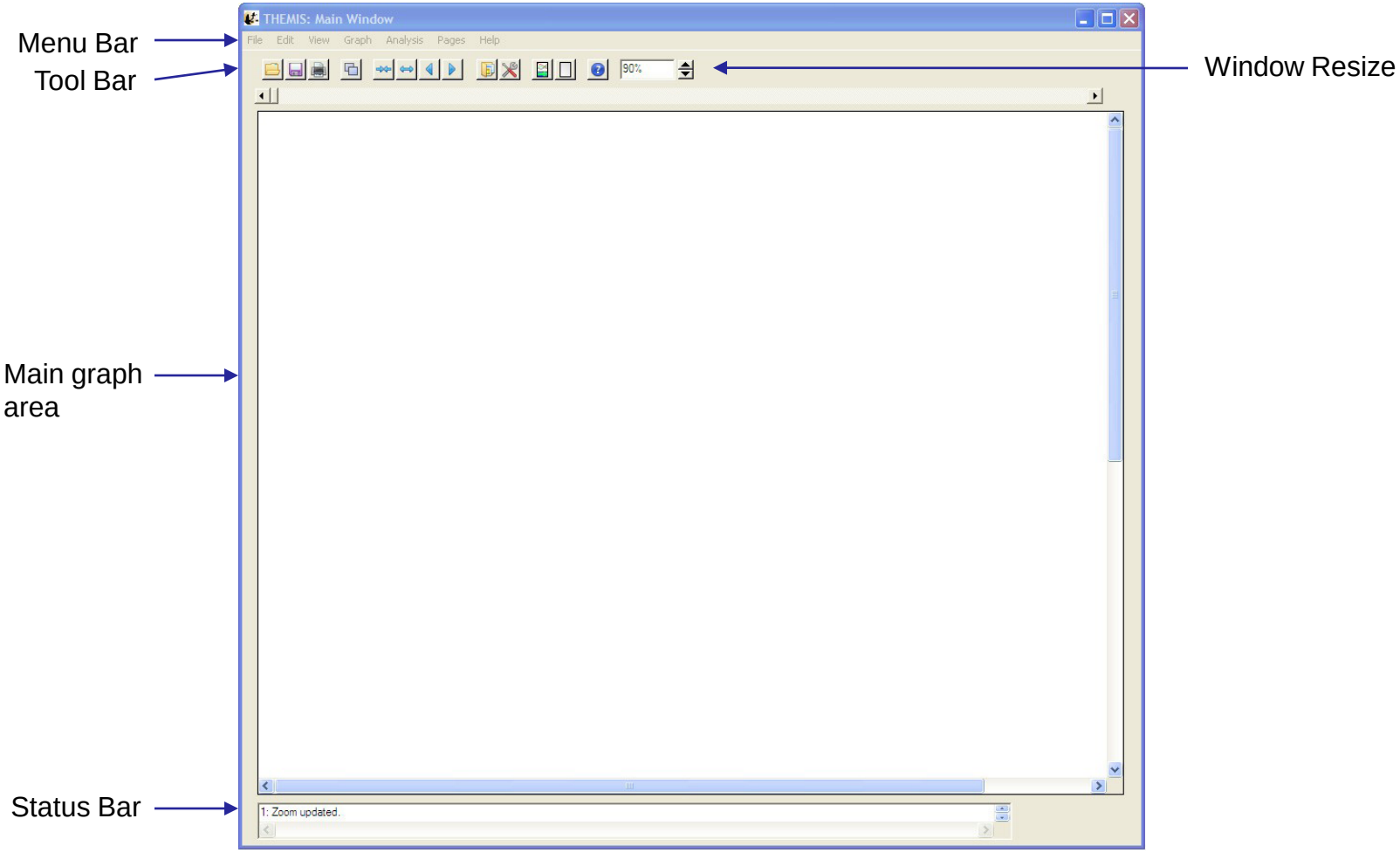
Beta support for Slices of 3d particle Velocity distributions are supported in the bleeding edge. Code can be started by typing: thm_ui_slice2d or can be accessed from the GUI by selecting Analysis->Velocity Slices





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

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

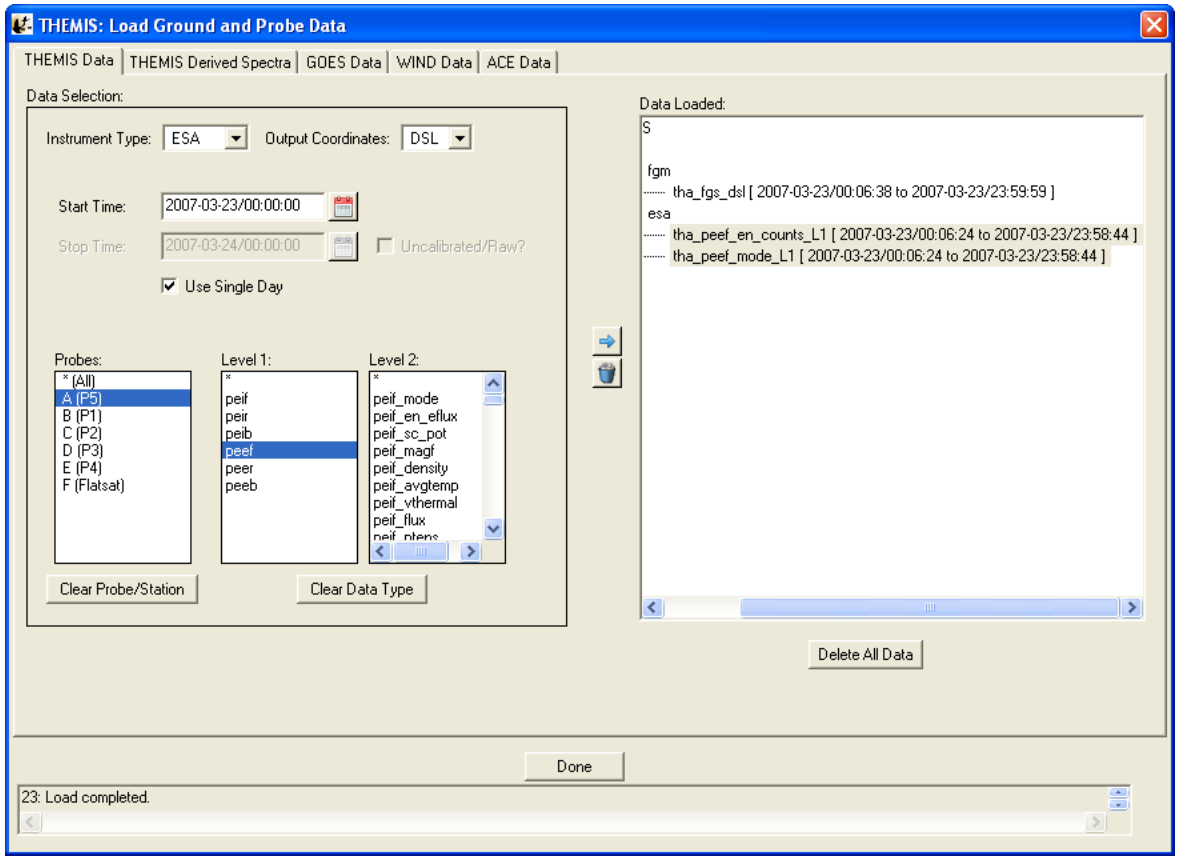
For Example:

<u>To Load Data:</u>

Select Load Data under the File menu

Select Instrument Type: fgm, Level2: fgs_dsl, Click Right arrow button

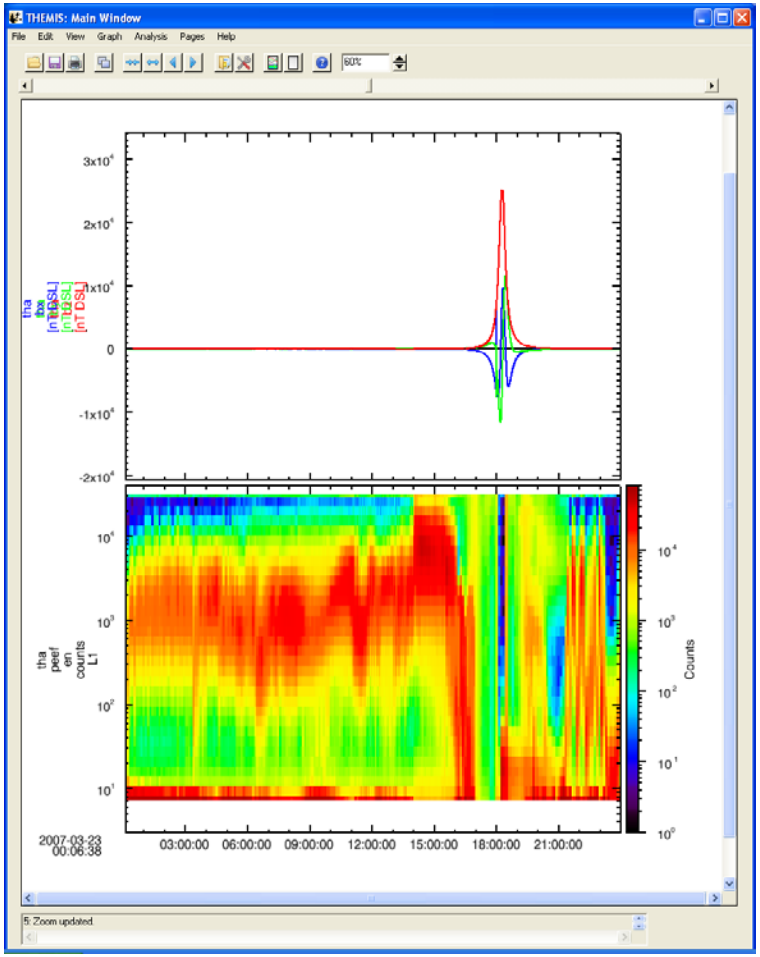
Select Instrument Type: esa, Level1: peef, Click Right arrow button



Plotting Data - GUI

With a few clicks of the button the user can load, analyze and plot data
For Example:

<u>To Plot Data:</u>
Select Plot/Layout Options… under the Graph menu
Select tha_fgs_dsl, Click Line button
Click Panels Add button, Select tha_fgl_dsl
Click Panels Add button, Select tha_peef_en_counts_L1



Summary

- THEMIS Data Analysis Software (TDAS) Objectives
  - Powerful, Flexible Command Line and Graphical User Interfaces
- Code is available to everyone
- Easily tailored for use by other Missions
  - Existing interfaces to ACE, GOES, and WIND science data
  - Used by other missions (ERG-EFW, MMS, IUGONET)
- Platform independent. Works on:
  - Solaris, Linux, Windows, Vista, Mac OS X
- TDAS Version 6.0 was released Spring 2011.
- All released software subjected to rigorous Quality Assurance
  - Comprehensive Command line scripts and GUI suites
- Extensive documentation available
  - TDAS Quick Reference Guide (up to date)
  - TDAS User's Guide (updated with major releases)
  - TDAS Developer's Guide (new release end of October)
  - Documentation can be found at:

  ftp://apollo.ssl.berkeley.edu/pub/THEMIS/3GroundSystems/3.2Science Operations/Science Operations Documents/

THEMIS Data Analysis Software
Back-up Slides

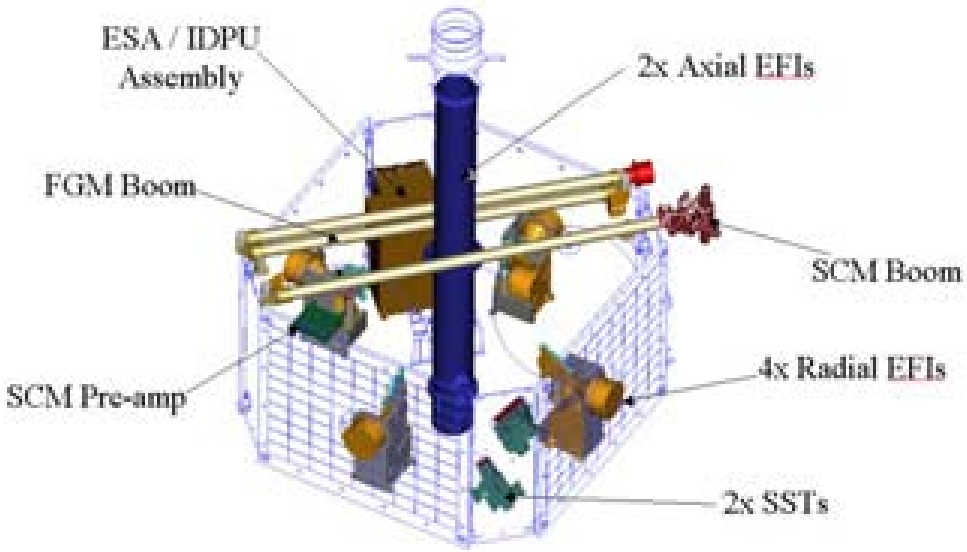
Space Based Instruments

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 Universit 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

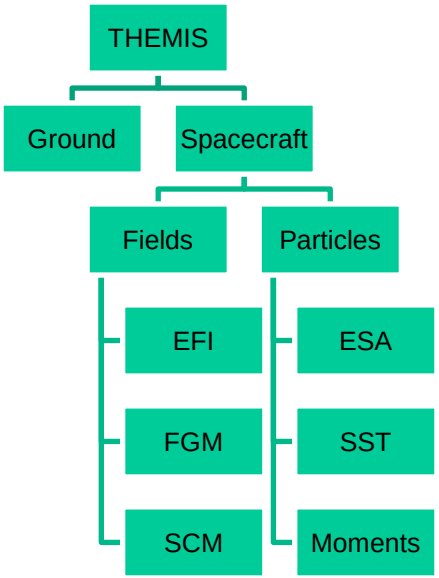
TDAS V6.0

- 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

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/**

Installing/Configuring TDAS

- 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

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/

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