## THEMIS Data Analysis Software

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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
http://themis.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

**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.

`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.)
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

```idl
; 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
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.
The GUI is the quickest and easiest way to learn TDAS functionality. To run the gui type: **idl > thm_gui**
With a few clicks of the button the user can load, analyze and plot data.

For Example:

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

For Example:

To Plot Data:
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:
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:

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
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 University 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
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)
- 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
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 is large!
  – ~3GB/day for all probes (L1 data)

• Directory hierarchy keeps directory size manageable
  – Software performs automatic file retrieval.
  – Software maintains directory hierarchy.

• Behaviour of Automatic File Retrieval is configurable
  – ‘No Download’ mode for stand-alone operation.
  – ‘No Update’ mode to preserve local modifications.
  – Root directory determined automatically, is configurable.
  – Available configuration methods:
    – thm_ui_config IDL widget
    – Button on THEMIS GUI widget
    – Environment variables
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/](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,"thaDensity_log" = ln("tha_peer_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