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

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

1. Level 0 Data –
   - Raw files (*.pkt) one per APID.
   - Only used for loading ESA data.

2. 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.

3. 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 Software Web Page

THEMIS Software

The THEMIS Data Analysis Software Suite consists of IDL routines which read data in CDF format, as well as other less refined data sets. IDL routines can be used to download, open, analyze, and plot Level 1 (L1) and Level 2 (L2) data quantities. They can also be used to transform L1 data into L2 data. L1 data is raw, uncalibrated data in CDF format. L2 data is calibrated in physical units. These IDL routines were derived from those used by the Cluster, Wind, Polar, and FAST missions. In addition to command line invoked IDL routines, the software provides a graphical user interface for opening, analyzing, and plotting data. This interface was designed to facilitate use of the most useful IDL routines.

To begin:
1. Download the latest release of the software.
   You can download the Quick Reference Guide directly from this website as a DWP or PDF.
   You can download the User's Guide directly from this website as a DOC or PDF.
2. After downloading a version of the software and the user's guide, open up the users guide and follow the instructions provided.
3. You may also find the HTML Docs for the latest released version of the Software. You can also browse the IDL source.

Future Releases:
1. You can receive emails notifying you of New Software Releases by Registering on the THEMIS Science Support Distribution List.
2. Download not yet released future Software. Please note this Software may not yet be fully tested and is not supported by the THEMIS Science Support Team.

IDL Gaepack DWP!
To use the Tsyganenko Model extension to the THEMIS software you need to Download and install the interface between Tsyganenko's Fortran code and IDL. This interface was developed and provided for THEMIS as a courtesy by H.ope North. Installation instructions can be found here.

For comments, observations, problems or questions about data access, software or web site content please contact the THEMIS Science Support Team.

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)
- 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

Installing/Configuring TDAS

• **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](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 THEMIS 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

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>thm_load_asi</td>
<td>All-Sky Imager</td>
<td>*</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>thm_load_ask</td>
<td>All-Sky Keogram</td>
<td>*</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>thm_load_efi</td>
<td>Electric Fields Instrument Waveforms</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>thm_load_esa</td>
<td>ElectoStatic Analyzer</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thm_load_esa_pkt</td>
<td>ElectoStatic Analyzer</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thm_load_fbk</td>
<td>Fields Filter Bank</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_fft</td>
<td>On-Board Fields Fast Fourier Transform</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_fgm</td>
<td>Flux Gate Magnetometer Waveforms</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_fit</td>
<td>On-Board Fields Spin-Fit</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_gmag</td>
<td>Ground Magnetometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>thm_load_hsk</td>
<td>Housekeeping</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>thm_load_mom</td>
<td>On-Board Particle Moments</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_scm</td>
<td>Search Coil Magnetometer Waveforms</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_sst</td>
<td>Solid State Telescope</td>
<td>*</td>
<td>(-)</td>
<td>*</td>
</tr>
<tr>
<td>thm_load_state</td>
<td>Orbit and Attitude</td>
<td></td>
<td>V3</td>
<td></td>
</tr>
<tr>
<td>thm_load_pseudoae</td>
<td>THEMIS gmag Derived AE-Index</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>thm_load_slp</td>
<td>Solar Lunar Position, Attitude, Velocity</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>thm_load_smode</td>
<td>Spacecraft Mode</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>thm_load_trg</td>
<td>Spaceraft Trigger</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thm_load_bau</td>
<td>BAU Housekeeping</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
(-) data reduction and analysis routines available: see crib sheet
Crib Sheets for Loading, Processing and Plotting

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

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

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

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'
```
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 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=24*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

XY field line/probe position plot

The diagram shows a XY plot with field lines and probe positions. The axes are labeled X and Y, with a range from -15 to 15 on both axes. The plot includes several lines and markers indicating probe positions.
Trace / Orbit Plots – XZ Plot

XZ field line/probe position 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
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 Ion/Electron Velocity Slices.
THEMIS Data Analysis Software
Graphical User Interface
The GUI is the quickest and easiest way to learn TDAS functionality.

To run the gui, type: `idl > thm_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
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
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)
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
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
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