Science Software – v5.00 Training

GEM – Snowmass, Colorado

June, 2009
<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda Item</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:30</td>
<td>Introduction</td>
<td>C. Goethel</td>
</tr>
<tr>
<td>10:35</td>
<td>THEMIS Web Site</td>
<td>C. Goethel</td>
</tr>
<tr>
<td>10:40</td>
<td>V5.00 Science Software/Data Status Report</td>
<td>C. Goethel</td>
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<tr>
<td>10:45</td>
<td>THEMIS Science Data Analysis Software</td>
<td>C. Goethel</td>
</tr>
<tr>
<td>11:10</td>
<td>Coordinate Transformation, Plotting, Mapping Tools, Mini-Language</td>
<td>P. Cruce</td>
</tr>
<tr>
<td>11:30</td>
<td>V5.00 THEMIS Graphical User Interface (GUI)</td>
<td>C. Goethel</td>
</tr>
<tr>
<td>12:15</td>
<td>THEMIS Ground Based Observatories (GBO)</td>
<td>P. Cruce</td>
</tr>
<tr>
<td>12:30</td>
<td>SPDF – CDAWeb</td>
<td>P. Cruce</td>
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</tbody>
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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

<table>
<thead>
<tr>
<th>Organization</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC Berkeley</td>
<td>D Larson, H Frey, J Bonnell, J McFadden, A Keiling</td>
</tr>
<tr>
<td></td>
<td>J McTiernan, J Lewis</td>
</tr>
<tr>
<td>UCLA</td>
<td>V Angelopoulos, P Cruce, B Kerr, C Goethel, M Feuerstein, K Ramer, H Schwarzl, A Flores</td>
</tr>
<tr>
<td>SP Systems</td>
<td>K Bromund</td>
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<tr>
<td>NASA/GSFC</td>
<td>V Kondratovich</td>
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<td>MPE</td>
<td>E Georgescu</td>
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<tr>
<td>TUBS</td>
<td>U Auster</td>
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<tr>
<td>CETP</td>
<td>P Robert, O LeContel</td>
</tr>
<tr>
<td>Calgary</td>
<td>B Jackel, E Donovan</td>
</tr>
</tbody>
</table>
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

- 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)
- 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
      ```
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 User’s Guide directly from this website or as PDF.
2. After downloading a version of the software and the user’s guide, open up the user’s guide and follow the instructions provided.
3. You may also find the HTML Doc 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. Consult the latest released future Software. Please note this software may not yet be fully tested and is not supported by the THEMIS Science Support Team.

IDL Source Code:

To use the Tytgatinsky Model extensions to the THEMIS software you need to Download and install the Interface between Tytgatinsky’s Fortran code and IDL. This interface was developed and provided for THEMIS as a courtesy by Haox. 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.
Installing/Configuring TDAS

• 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.
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 THEMIS GUI widget
    - Environment variables
## Primary Routines

### Load Routine Summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>L0</th>
<th>L1</th>
<th>L2</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>ElectroStatic Analyzer</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>thm_load_esa_pkt</td>
<td>ElectroStatic 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>
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<tr>
<td>thm_load_scm</td>
<td>Search Coil Magnetometer waveform</td>
<td>*</td>
<td>(*)</td>
<td></td>
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<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></td>
<td>v2</td>
</tr>
</tbody>
</table>

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

Crib Sheets for Loading, Processing and Plotting

thm_crib_asi          thm_crib_gmag
thm_crib_dproc        thm_crib_mom
thm_crib_efi          thm_crib_mva
thm_crib_esadata      thm_crib_overplot
thm_crib_esamoments   thm_crib_part_getspec
thm_crib_export       thm_crib_scm
thm_crib_fac          thm_crib_sst
thm_crib_fbk          thm_crib_state
thm_crib_fft          thm_crib_tplot
thm_crib_fgm          thm_crib_tplotxy
thm_crib_fit          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
- plot_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'
```
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=24I*3600*2

− Set color limits (log scale)
  » zlim,'*pow', .0001, .01, 1

− Plot it.
  » tplot,'*ccnv_x*', trange=tr
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.)
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

XY field line/probe position plot

![Graph showing XY field line/probe position plot.]
Trace / Orbit Plots – XZ Plot
Mini Language

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 A Position & Velocity

\[ Y \text{ Pos [RE]} \]
\[ X \text{ Pos [RE]} \]

1.00000 [km/s]  \quad \text{HEMIS A Velocity}

THEMIS Science Software Training
THEMIS software for GBO all-sky imager
Thm_crib_asi.pro
Harald U. Frey
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° magnetic Latitude and ~+12° 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

![Wavelet transform example graph](image)
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).
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.
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.