What's new in TDAS?

- New code for particle product generation.
- Updated SST calibrations - better dead layer corrections
- Beta code to generate combined ESA & SST particle products.
- SST L2 CDFs planned to be available before TDAS 9.
- SPEDAS GUI API: ERG & IUGONET plugins
- Improved GUI support for loading geomagnetic and solar indices data
- Updated command line and GUI support for GOES 08-15 magnetometer, particle and Xray data
- Added support for loading netCDF files into tplot
- TDAS now serves data from over 125 ground based magnetometers
- New capability to download data sets from CDA web

This presentation can be found at:

http://themis.ssl.berkeley.edu/themisftp/3 Ground Systems/3.2 Science Operations/Science Operations Documents/Science Software Data Analysis Presentations/
## Acknowledgements

### THEMIS Data Analysis Software

<table>
<thead>
<tr>
<th>Organization</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Calgary</td>
<td>B Jackel, E Donovan</td>
</tr>
</tbody>
</table>
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 THEMIS and

- 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
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
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 Quick Start Guide on website
THEMIS Software Web Page

http://themis.ssl.berkeley.edu

THEMIS_Science_Support@ssl.berkeley.edu
• 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

• 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.
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
## Load Routine Summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Level 0 Raw</th>
<th>Level 1 Calibrated</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>
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<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>
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<tr>
<td>thm_load_fbk</td>
<td>Fields Filter Bank</td>
<td>*</td>
<td>*</td>
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<tr>
<td>thm_load.fft</td>
<td>On-Board Fields Fast Fourier Transform</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>thm_load_fgm</td>
<td>Flux Gate Magnetometer Waveforms</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>thm_load_fit</td>
<td>On-Board Fields Spin-Fit</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>thm_load_gmag</td>
<td>Ground Magnetometer</td>
<td>*</td>
<td></td>
<td></td>
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<tr>
<td>thm_load_hsk</td>
<td>Housekeeping</td>
<td>*</td>
<td>*</td>
<td></td>
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<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 Waveforms</td>
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<td>thm_load_sst</td>
<td>Solid State Telescope</td>
<td>*</td>
<td>(-)</td>
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<td>thm_load_state</td>
<td>Orbit and Attitude</td>
<td>V3</td>
<td></td>
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<tr>
<td>thm_load_pseudoae</td>
<td>THEMIS gmag Derived AE-Index</td>
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<tr>
<td>thm_load_sip</td>
<td>Solar Lunar Position, Attitude, Velocity</td>
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<td>*</td>
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<tr>
<td>thm_load_scmode</td>
<td>Spacecraft Mode</td>
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<td></td>
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<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
GUI has new capability to download data sets from CDAWeb

Interface to CDAWeb

- Mission Names
- Type of Instrument
- Datasets/Variables
- Time Widgets
- Path and File Name selection

CDAWeb Data Chooser

Dataset Selection:
- Mission Groups
- Instrument Types

Datasets/Variables:
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58
- RBSP Magnetometer HIRES: GSE, EMFISIS L3: 2012/09/08 00:00:05 - 2013/10/28 23:59:58

Start Time: 2013-09-23 00:00:00
Stop Time: 2013-09-24 00:00:00
Use Single Day
Local CDF directory: \data\cdfaweb
Prefix for plot variables: tdp
Crib Sheets for Loading, Processing and Plotting

• Cribs document command line features & show common usage.
• Currently 73 cribs in TDAS.

• Found in several locations:
  
  ssl_general/examples/ (tplot)
  themis/examples/basic (for major features & new users)
  themis/examples/advanced (obscure, technical, or experimental features)
  themis/examples/deprecated (old cribs, for documentation, may not run)

• Cribs can be executed or copy & pasted into the command line.
• Contain many comments to describe usage details.
• Many written by instrument PIs.
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*
• 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.
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
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`

  **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`
  - `enp_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`
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

\[
\text{Tr} = ['2006-10-2/16:00', '2006-10-3/05']
\]

Display timebar, tr

Split the 3-vector into components:

\[
\text{split_vec,'thg_mag_ccnv'}
\]

Compute transform of one component

\[
\text{wav_data,'thg_mag_ccnv_x',/kol$\text{tr}, \text{maxpoints=24*3600*2}}
\]

Set color limits (log scale)

\[
\text{zlim,'*pow', .0001,.01,1}
\]

Plot it.

\[
\text{tplot,'*ccnv_x*',trange=tr}
\]
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.)
Plotting Angular Spectra

Pitch angle spectra for full and reduced mode electron ESA data. Plotted using tplot.
See: thm_crib_part_products.pro

```
thm_part_products, $ ; new particle routine!
probe='c', $ ; select probe
trange=['07-06-03/01:08', $ ; select timerange
        '07-06-03/04:20'], $
data_type='peef, $ ; select data type
outputs='pa' ; select pitch angle spectra
```
Trace / Orbit Plots

- New routines have been added to perform different 2d projections of 3d data. This is 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 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/)
Trace/Orbit Plots - AACGM/Iono Trace Plot
Trace / Orbit Plots – XY Plot

XY field line/probe position plot

![XY field line/probe position plot diagram]
Trace / Orbit Plots – XZ Plot

XZ field line/probe position 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
The GUI can be started with `thm_ui_slice2d`; the crib sheet `thm_crib_part_slice2d` demonstrates command line usage.
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.
Plotting Data - GUI

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)
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 using 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 selected keograms
Zoom into interesting time
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

THEMIS—GBO ASI
2008–02–10/07:13:30
Mosaic with S/C footprint
From thumbnail 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