Science Software – v5.11 Training
Introduction

THEMIS Data Analysis Software

Plotting

Mini-Language

THEMIS Graphical User Interface (GUI)

SPDF – CDAWeb
# THEMIS Data Analysis Software

<table>
<thead>
<tr>
<th>Organization</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>
The main goal of the THEMIS (Time History of Events and Macroscale Interactions during Substorm) mission is understanding the nature of magnetospheric substorms.

THEMIS consists of

- Ground-based segment: the all-sky camera and magnetometer arrays at Northern America and Greenland;
- Space-based segment: five identical spacecraft whose apogees line up once every 4 days over the array of ground observatories.
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

![Image of THEMIS instrument setup](image-url)
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 main goal of the THEMIS software design is to provide researchers with tools to handle multiple missions, spacecraft, and instruments using the same interface. THEMIS software is free and available at the mission web site http://themis.ssl.berkeley.edu/software.shtml. The software is an IDL-based library of utilities:
- Platform independent – works on Windows, UNIX/Linux, MacOS
- Crib sheets also provided

Two interfaces are available:
- Graphical User Interface
- Command-line (based on TPLOT package).

Software enables users to:
- Download raw L1 and/or calibrated L2 data
- Data Analysis
- Ingestion of data from other missions
- Publication Quality Plots

Software distribution includes many functions written by community and is open for contributions.
Crib Sheets

- Crib sheets available for loading, processing and plotting THEMIS data
- Effective format for exchange of ideas
- Example:

  IDL>.run thm_crib_fgm

  thm_load_state, probe='a', /get_support_data
  thm_load_fgm, lev=1, probe=['a'], type='raw', suffix='_raw'
  thm_cal_fgm, probe=['a'], datatype='fg?', in_suffix='_raw', out_suffix='_ssl'
  tplot_options, 'title', 'THEMIS FGM Examples'
  tplot, ['tha_fgl_raw', 'tha_fgl_ssl']
Substorm Example

- Substorm event combining multi-instrument THEMIS data
Magnetopause Crossing – 2
The THEMIS data and software system provides familiar and standard interfaces to multiple missions and different science data sets.

Data is stored in the unified Common Data Format (CDF) in the distribution center and available via WWW.

THEMIS software is free, publicly available, platform independent, user friendly, and open for community contributions.

The system design philosophy is based on streamlining data and software distribution and exchange, thereby enhancing science productivity.
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 (LI) and Level 2 (LU) data quantities. They can also be used to transform LI data into LU data. LI data is raw, unformatted data in CDF format. LU 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 DOC 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 the user's guide and follow the instructions provided.
3. You may also find the HTML Data 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 is not yet fully tested and is not supported by the THEMIS Science Support Team.

To use the Tsyganenko Model extensions 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 Igor Korth. 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.
- Functionally separates the tasks into:
  - Reading
  - Manipulating
  - Plotting
- Platform independent. Works on:
  - Solaris
  - Linux
  - Windows, Vista
  - Mac OS X
• THEMIS (idl/themis/) – routines specific to THEMIS
• ssl_general (idl/ssl_general/) – general routines
• external (idl/external/) – external libraries
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 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`
Installing/Configuring TDAS

• Installation
  – Download and expand the latest TDAS release .zip file. The latest version is 5.11.
    http://themis.ssl.berkeley.edu/socware/tdas_5_11/tdas_5_11.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, 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 – 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 THEMES 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).
  - Datatype 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>
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<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_es</td>
<td>ElectoStatic Analyzer</td>
<td></td>
<td></td>
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<td>thm_load_es(pkt)</td>
<td>ElectoStatic Analyzer</td>
<td>*</td>
<td></td>
<td></td>
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<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>
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<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>
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<tr>
<td>thm_load_hsk</td>
<td>Housekeeping</td>
<td>*</td>
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<tr>
<td>thm_load_mom</td>
<td>On-Board Particle Moments</td>
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<td>thm_load_scm</td>
<td>Search Coil Magnetometer Waveforms</td>
<td>*</td>
<td>(*)</td>
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<td>thm_load_sst</td>
<td>Solid State Telescope</td>
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<td>thm_load_state</td>
<td>Orbit and Attitude</td>
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<td>V3</td>
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<td>thm_load_pseu</td>
<td>THEMIS gmag Derived AE-Index</td>
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<tr>
<td>thm_load_slp</td>
<td>Solar Lunar Position, Attitude, Velocity</td>
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<tr>
<td>thm_load_scmode</td>
<td>Spacecraft Mode</td>
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<tr>
<td>thm_load_trg</td>
<td>Spacecraft Trigger</td>
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<tr>
<td>thm_load_bau</td>
<td>BAU Housekeeping</td>
<td>*</td>
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**Notes:**

(*) calibration routine available but still under development
(-) data reduction and analysis routines available: see crib sheet
## Crib Sheets for Loading, Processing and Plotting

<table>
<thead>
<tr>
<th>thm_crib_asi</th>
<th>thm_crib_gmag</th>
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<tr>
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<td>thm_crib_part_getspec</td>
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<td>thm_crib_export</td>
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<td>thm_crib_fac</td>
<td>thm_crib_sst</td>
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<td>thm_crib_fbk</td>
<td>thm_crib_state</td>
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<td>thm_crib_fft</td>
<td>thm_crib_tplot</td>
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<tr>
<td>thm_crib_fgm</td>
<td>thm_crib_tplotxy</td>
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<tr>
<td>thm_crib_fit</td>
<td>thm_crib_twavpol</td>
</tr>
<tr>
<td></td>
<td>thm_map_examples</td>
</tr>
</tbody>
</table>

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.
  - 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
  - SSE Selenocentric 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
  - gsm2lhm

- **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=24l*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.

```plaintext
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.
Trace/Orbit Plots - AACGM/Iono Trace Plot
Trace / Orbit Plots – XY Plot

XY field line/probe position plot

X

Y

> 0

0

-5

-10

-15

10

0

-10

-20

15

10

5

0

-5

-10

-15

-20

THEMIS Science Software Training
SOFTWARE – 37
ESS265 Lecture 1
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: \texttt{calc,"tha\_pos\_re" = "tha\_state\_pos"/6374.4}’
  2: Natural log of total esa density:
    \texttt{calc,"tha\_density\_log" = ln("tha\_peir\_density"+"tha\_peer\_density"\texttt{\} )}
  3: Store tplot data in non-tplot idl variable: \texttt{calc,'var\_data = "tha\_efs"}
  4: Average Magnetic Pressure:
    \texttt{calc,'Pb\_avg = mean(0.01*total("tha\_fgs\_dsl"\texttt{\}^2,2)/25.132741)\texttt{\}’}

Additional examples can be found in themis/examples/thm_crib_calc.pro
Plotxyvec – Position/Velocity Plot
THEMIS Data Analysis Software
Graphical User Interface
THEMIS software for GBO all-sky imager
Thm_crib Asi.pro
Harald U. Frey
THEMIS GBO network

THEMIS Science Software Training

ESS265 Lecture 1
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 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
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
Pseudo-AE of network
Data and Orbits at SPDF

http://spdf.gsfc.nasa.gov
Level-2 Data from all 4 Instruments on all 5 Satellites

Ground Magnetometer Data from 42 stations (GBO, GEONS)

NEW: Keograms from 22 All-Sky-Imagers (ASI) going back to 2005.

All data updated daily (auto-ingest) from THEMIS data site.

GIF-Walk: pre-generated Magneto-pause Crossing Survey plots (David Sibeck, NASA GSFC)

http://cdaweb.gsfc.nasa.gov
CDAWeb - Other Data

Many data products of THEMIS interest: ACE, Cluster, Geotail, FAST, NOAA, GOES, LANL, Wind …

ITM data to study storm effects in ITM region: TIMED, ROCSAT, GPS (under development)
SSCweb TIPSOD

Orbits for most science satellites, updated regularly and often including predicts.

TIPSOD 4-D orbit viewer

Saved queries for typical THEMIS-related SSCweb runs (1-click access).

THEMIS Science Software Training

http://sscweb.gsfc.nasa.gov
Common Data Format- CDF

CDF Version 3.2.2 release, fixes memory leak and ReadOnly mode problems, and includes some changes for the tool programs.
CDF Patch for Matlab
CDF Patch for IDL 6+ (strongly recommended)
CDF's Java Network Launching Protocol latest development