THEMIS MAGNETOPAUSE CROSSING DATABASE
Version 1.1
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GENERAL DESCRIPTION

1. The database

The database covers time intervals when individual THEMIS probes were within 4 R_E of the nominal magnetopause, as determined from their orbits and the Sibeck magnetopause model for typical solar wind conditions (p = 2 nPa, Bz = 0 nT). Every such a continuous time interval constitutes for us an event of the probe proximity to magnetopause. This is an event database which does not provide continuous time coverage. Each event is described by a pair of survey plots covering the full event time interval and a set of one-hour plots offering spin-period (3s) time resolution data. Corresponding digital data are grouped in a folder labeled by the event time interval.

2. Data processing

We use Level 1 data downloaded from the UC Berkeley THEMIS web site http://themis.ssl.berkeley.edu at the moment of plot production (the date is given on the plots). We determine the cutoff potential for the ESA instrument employing a procedure described elsewhere [1]. We use the cutoff potential to salvage plasma moments by removing photoelectrons when directly measured spacecraft potentials are unavailable or questionable. We calibrate the Level 1 data with the help of TDAS routines and previously determined cutoff potentials, which we use as the spacecraft potential.

Each THEMIS probe provides several data streams for each physical variable. Our code evaluates the time coverage provided by these data streams and takes the one with the best coverage as the major data stream. Then it evaluates whether or not the remaining data streams can patch gaps in the time coverage of the major data stream (we do not intersperse data because the calibration process is usually different for different streams). A flag file tracking the data sources is created. Merged data are stored in the subfolder DataMerged.

Merged vector data and derived quantities are transformed into the Boundary-Normal Coordinates (BNC, called also LMN). BNC are defined with respect to the nominal magnetopause according to Sibeck's model [2]. Transformed data are stored in the subfolder DataBNC.

Before graphing, we remove outlier points and linear interpolate to fill data gaps onto a regular time grid. Fourier transforms are performed on data within a 30-minute long Hanning window whose center steps forward one minute at a time.

3. Database use

One survey plot and several one-hour plots cover each spacecraft magnetopause event displayed on GIFWALK. Full-resolution plots (up to the probe spin period of 3 seconds) are presented for downloading in the form of the raster graphics (gzipped postscript). Slightly reduced resolution plots can be found in the corresponding Adobe Acrobat (pdf) files. Finally, graphics in GIF format are available for quick viewing and search through SPDF GIFWALK GUI (http://cdaweb.gsfc.nasa.gov/cgi-bin/gif_walk).

We recommend the following approach:
1. Use a web browser to open the GIFWALK window at http://cdaweb.gsfc.nasa.gov/cgi-bin/gif_walk.
2. Select "MP Crossing Survey Plots" for one of THEMIS probes (a-e).
3. Browse the survey plots for events of interest or enter the date you seek.
4. Note the time of the event.
5. Select "MP Crossing 1-Hour Detailed Plots" for your probe from the pull-down menu.
6. Browse the one-hour plots for the hour of your interest (the jump to one-hour plots will never result in an offset of more than 12 hours from your target hour). The hour is specified in the plot header and on the time axis.
7. Download one or more high-resolution copies of the plot that interests you by clicking on the FTP links.
8. Download the data files that cover the event as a whole from the "MP Crossing Survey Plots" page for the THEMIS probes of interest.

4. Software requirements

You need to have a web browser, decompressing software for gzip format (example: WinRAR for Windows or gzip on UNIX/Linux) and a postscript viewer (example: GSview), or Adobe Acrobat Reader. Data folders contain a universal data reader for IDL. It can be easily translated to FORTRAN90/95 or C, if necessary.

5. Plot layout

Every event for each probe is covered by one two-page survey plot and several two-page one-hour plots posted for quick viewing on the SPDF GIFWALK. The high-resolution counterparts of these plots contain each page separately. We call them "Velocity" and "Fields" pages.

5.1. Survey plot

Velocity survey page

In the top row, there are three graphs:

- Radial projection of the spacecraft's footprint on Earth. The track runs from right to left. Red segments indicate when the spacecraft lies inside the nominal magnetopause, while blue segments indicate intervals when the spacecraft lies beyond the magnetopause. Start and end times are printed near the ends of the track.
- Color codes indicating the various data streams available for each sensor (ESA, FGM, EFI). Stream abbreviations are explained in this and other THEMIS documents (in particular, see pull-down menu "Data/Data Description" on THEMIS web site http://themis.ssl.berkeley.edu).
- The probe's trajectory in GSM coordinates during the event as viewed from the negative Z axis (below the ecliptic plane). Probe traces the trajectory segment clockwise. The GSM Z coordinate is color-coded for trajectory, and the green Earth in the center marks Z=0. The black arc is the nominal magnetopause position along the radial vector passing through the probe trajectory.

Next comes the header with the probe name and date of observations.

It is followed by the ion ESA spectrogram covering energies from 2 to 25000 eV. The horizontal color bar at the top codes the data stream used for plotting. As the data merging system may introduce some rectangular patches into the spectrogram, the full information about data sources can be found in the flag file supplied with data. This color bar refers only to the top part of the spectrogram. It usually indicates the main data stream. The spectrogram is normalized to the maximum value of the flux observed during the event. This maximum value is listed on the RHS of the plot. Absolute values of the flux at any moment may be calculated by multiplying this value by the relative intensity displayed on the plot.

Next we consider the pitch angle (PA) distributions of typical magnetospheric (12-21 keV) and magnetosheath (300-800 eV) ions. Each PA distribution is normalized to the instantaneous peak flux. The absolute maximum of the flux during the event can be found on the right hand side of the panel.[1] We use the PEIF data stream for PA distributions on the survey panel because it is continuous in time. Its coarse time resolution (up to few minutes) poses no problems for the survey plot.

The next panel displays the ion density N_i (black) and the ion temperatures parallel T_{par} (red) and perpendicular T_{per} (green) to the magnetic field. Units are cm^{-3} and keV, respectively. Here and on the other graphs, separate scales are given on the left and right for different quantities. The color of the scale matches the color of the trace. Colored horizontal bars identify the data streams: the top bar is for density, while the bottom bar is for temperature.

As we have independent measurements of electric and magnetic fields, we plot both drift velocities $\mathbf{V} = \mathbf{E}\mathrm{x}\mathbf{B}/B^2$ over those calculated from the ion moments. We use blue for the former and red for the latter in the next three graphs. The velocity components have been transformed into the boundary-normal coordinates (see below). The scales for the two sets of velocities differ to permit users to see similarities and differences.

The final three plots show the results from moving Fourier transforms applied to the velocity moments in the 30 min Hanning-framed windows. At every moment, Fourier transform provides spectral densities, which are independent from the velocity magnitude. (The sum of spectral densities over frequencies is equal to 1 at any moment.) The frequency displayed runs from 2 to 50 mHz. Displayed spectral densities are normalized to the maximal value for the graph.

UT time is displayed at the bottom of the panel together with the GSM coordinates of the probe (X, Y, Z – from top to bottom).

Fields survey page

The top four panels of the survey fields plots show the ESA electron data – the electron spectrogram covering the range from 2 to 32000 eV, the pitch angle distributions for two energy ranges: magnetospheric (15-26 keV) and magnetosheath (70-110 eV), and the electron density/temperature graphs The format is similar to that used to display the ion data on the Velocity page.

Next we display the components and total magnitudes of the electric E (in mV/m) and magnetic B (in nT) fields. Scalar quantities are displayed in **black**, vector quantities are given in LMN coordinates with respect to the nominal magnetopause. L-components are **green**, M-components – **blue**, and N-components **red**.

N is normal to the nominal magnetopause,
L points northward in the plane of the magnetopause, and
M completes the triad, pointing dawnward.

[1] In contrast to the energy spectrogram, this value cannot be used to find absolute intensities at any moment because of the adopted normalization scheme (normalization each moment provides for the best display of the angular dependence).

The next panel presents the B_n component separately. The final four panels present moving Fourier transforms of the LMN components of magnetic field and of its absolute magnitude. As on the Velocities page, the Fourier transform is performed in 30 min Hanning-framed windows and is normalized to give the spectral density. For plotting, it is normalized to the maximal value for the graph. The frequency displayed runs from 2 to 50 mHz.

5.2 One-hour Panels

The layout of the one-hour pages is similar to that for the corresponding survey pages with a few exceptions.

Velocity page

We use the PEIR data stream for the PA distributions on the one-hour panel because of its high time resolution (about 3 sec). However, in slow survey mode, the PEIR data stream does not carry angular information about fluxes, which makes the related data unreliable. When angular information is absent, the PA plots display red homogeneous strips, which should serve as a warning label against the use of high time resolution ground-processed data. It is beneficial to compare PEIR and PEIF data in this case (usually, we do not display PEIF data because of their poor time resolution).

In the slow survey mode T_{par} is set to be equal to T_{per}, so their traces look like a single brown line. They can be erroneous due to problems distinguishing flow speed from temperature.

UT time is displayed at the bottom of the panel together with the GSM coordinates of the probe (X, Y, Z – from left to right).

Fields page

The aforementioned problems with PA distributions and temperatures also apply to the electrons when the spacecraft is in slow survey mode.

We display the components and absolute values of the electric E (in mV/m) on one graph, and do the same for the magnetic B (in nT) field. Scalar quantities are displayed in **black**, vector quantities are given in LMN coordinates with respect to the nominal magnetopause. L-components are **green**, M-components – **blue**, and N-components are **red**.

N is normal to the nominal magnetopause,
L points northward in the plane of the magnetopause, and
M completes the triad, pointing dawnward.

Then we show a combination graph for B_l and B_m, with separate scales on the left and right. This allows us to show their variation in greater detail. The next panel displays B_n and |B| in a similar manner. The one-hour fields page concludes with panels depicting the Fourier transforms of the three magnetic field components and the total magnetic field strength, just like the survey page.

6. References

1. V. Kondratovich and D. Sibeck. Simple approach to salvaging THEMIS ESA moments prior to boom deployment. First Joint THEMIS-Cluster Workshop, Durham, NH, 2008. Also posted on THEMIS wiki pages, http://themis.sr.unh.edu.

2. Sibeck D.G., Lopez R.E. and Roelof E.C., Solar wind control of the magnetopause shape, location and motion, J. Geophys. Res., 96, 5489-5495, 1991.

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Known Problems and Caveats

1. Maneuvers. The maneuver flag is not reflected in the plotting so far. Please refer to THEMIS maneuver schedule. Maneuvers may affect the validity or quality of the data. General information about maneuvers can be found on THEMIS web site http://themis.ssl.berkeley.edu/news.shtml . Maneuver flag can be obtained the same way as other THEMIS data (from the above site or SPDF).

2. EFI data availability. Electric field data are available only after electric boom deployment and testing (which lasted about one month after deployment). Deployment dates differ for each probe:
- Probe A: January 8-15, 2008
- Probe B: November 8-15, 2007
- Probe C: May 8-15, 2007
- Probe D: June 8-15, 2007
- Probe E: June 8-15, 2007

We do not display electric field or quantities derived from the electric field before these dates.

3. EFI data quality. We compare drift $\mathbf{V} = \mathbf{E}\mathrm{x}\mathbf{B}/B^2$ and moment velocities on the Velocities pages. Numerous discrepancies indicate that the mainstream (best time coverage) electric field data from the EFI sensor displayed on the Fields page needs further refinement. Reliable electric field data can be produced manually for some time intervals. If you need reliable electric field data, please contact the EFI instrument lead.

4. S/c potential. Before electric field boom deployment, it was impossible to measure the probe electric potential directly. Therefore, it was impossible to eliminate spurious photoelectrons before calculating electron moments. We have developed and tested a procedure to salvage data with unknown (or inconsistent) spacecraft potentials. We routinely apply this procedure to THEMIS data provided on these pages and presented in these plots. The procedure involves identifying the potential that best removes photoelectrons and brings ion and electron densities into agreement over extended periods of time.

5. Best data. So far, our code selects the data streams to display on the basis of best time coverage. However, these data are not always of the best available quality due to noise levels and calibration issues. The algorithms for selection of the best quality data are under development and will be implemented as soon as possible.

6. Graphics. On graphic panels produced before February 12, 2009, the right scales on plots combining 2 graphs may be slightly off and shifted because of the IDL defaults, which were not properly restrained. Typically, discrepancies do not amount for more than 20% of the maximal value. The left scales and three-graph plots are not affected. The shape of the graphs is not distorted. Correct values can be checked on three-graph plots and in the data files accompanying the plots. We will reprocess such panels as soon as possible. All reprocessing is done backward in time – from recent events to past events. The panel creation date can be found at the panel header.

7. Missed events. Our routines request THEMIS data from UC Berkeley server at the time of calculations. In rare circumstances (about 1 in 200 events), received data is insufficient to start our processing. Our routine repeats the request and, if it is unsuccessful, moves to another event. The list of missed events is reprocessed once a half-year.