ESS 261 Spring Quarter 2009

Coordinate Systems, Magnetospheric Models

Time Formats
Geophysical Coordinate Systems
Spinning and Despun Spacecraft Coordinate Systems
Magnetospheric Models
FORTRAN/IDL Access and Use of Models and Routines

References:
Russell, Geophysical Coordinate Transformations, Cosmic Electrodynamics, 1971.
Hapgood, Space Physics Coordinate Transformations: A users guide, PSS, 40, 711, 1992

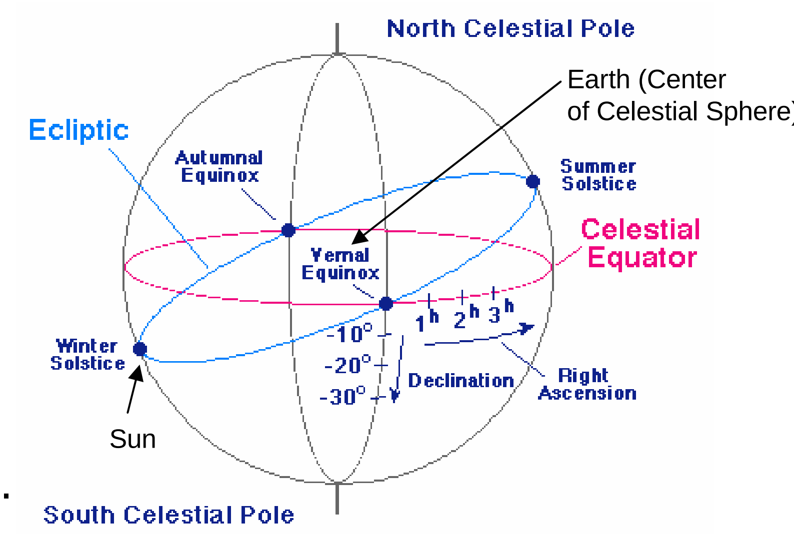
Lecture 3

Apr 13, 2009

Inertial Coordinates

- Celestial Coordinates
  - Z along north celestial pole (Polaris)
  - X along vernal equinox (the Earth-to-Sun line when night and day are equal in spring)

- Precession of Equinoxes
  - Celestial pole is ~1^o within Polaris
  - Celestial pole rocks because Moon/Sun torque Earth's budge resulting in precession of equinoxes by 50arcsec/year. Completes full revolution in 26,000 years
  - A few thousand years ago, vernal equinox was along Aries (Ram,♈) "First point in Aries".
  - Now vernal equinox moved through Pisces into Acquiarius (zodiacal "Age of the Acquarius").
  - The Autumnal equinox is towards Libra,♎.



- Right ascension, α, Declination δ

- Minutes seconds of right ascension, α
  - 1hr=15deg of α, 1min = 1/60hrs = 1/4deg, 1sec=1/60th of min=0.00416deg
  - Not to be confused with arcminutes (1/60 deg), arcseconds (1/3600 deg) of arc

TIME

- Precession of equinoxes causes a slow change in celestial coordinates of stars.
  - Time be considered to determine orientation and coordinate transformations from spacecraft to inertial coordinates.
- Celestial coordinates require date to define position of vernal equinox.
  - 1950 coordinates (the Vernal Equinox specified on Jan 1, 1950)
  - 2000 coordinates (Vernal Equinox on Jan 1, 2000)
    - J2000.0 coordinates is the above but specifies that it is measured in Julian Time
    - Julian Time is measured in fixed years of 365.25 days (1day=86400 SI seconds).
      - This is the average length of a year in the Julian Calendar
  - True of Date (TOD) coordinates (Vernal Equinox is floating with time)
    - Good to use for propagating coordinates as coordinate transformations are exact.
    - Computation of Earth pole precession is accounted for in propagators.
- Sidereal Time (Time it takes Earth to make complete revolution around stars)
  - 1 SD = 23hrs 56min 4sec (cannot be used as standard because stars have proper motion)
- True Solar Time (~24hrs but differs +/- 15min due to Earth's elliptical orbit, tilt)

TIME … continued

- Universal Time (UT). This is "Mean Solar Day" averaging out Earth's rotation
  - UT often referred to as GMT (Obsolete: Greenwich Mean Time) incorrectly
  - UT = 00:00 when Greenwich Meridian points at the Sun
- UTC (Coordinated Universal Time) is time based on atomic clock to follow UT
  - Combines atomic standard (precision) and convenience (adjusted to Earth rotation)
  - Adjustments result in removal of leap seconds to account for Earth spin rate changes
  - Synonymous to Zulu Time (Zulu comes from articulation of letter "Z" appended on the Greenwich Time transmitted from the British Naval Observatory in Greenwich, England)
  - Kept within +/- 0.5 seconds from UT by above adjustments.
- TDT = TT (Terrestrial Dynamic Time, renamed Terrestrial Time)
  - Is a uniform atomic time equals International Atomic Time (TAI) except for a constant
  - TDT = TAI + 32.184sec Offset is present to equate TDT with previously used ET
  - TT is TDT – just renamed – and replaced Ephemeris Time because ET was based on tropical year whereas atomic standard time was needed.
- JD (Julian Date) Number of days since Greenwich mean noon on Jan 1, 4713B.C.
  - New day advances at noon (no day change through night astronomical observations)
- MJD (Modified Julian Day) Defined as MJD=JD-2400000.5
  - MJD=0 on Nov 17, 1958 at 00:00 UT

Geophysical Coordinate Systems: Geocentric

System		Definition of axes
Geocentric equatorial inertial	GEI	X = First Point of Aries Z = Geographic North Pole
Geographic	GEO	X = Intersection of Greenwich meridian and geographic equator Z = Geographic North Pole
Geocentric solar ecliptic	GSE	X = Earth–Sun line Z = Ecliptic North Pole
Geocentric solar magnetospheric	GSM	X = Earth–Sun line Z = Projection of dipole axis on GSE YZ plane
Solar magnetic	SM	Y = Perpendicular to plane containing Earth–Sun line and dipole axis. Positive sense is opposite to Earth's orbital motion. Z = Dipole axis
Geomagnetic	MAG	Y = Intersection between geographic equator and the geographic meridian 90° East of the meridian containing the dipole axis. Z = Dipole axis

† Only two axes have to be defined; the third axis completes a right-handed Cartesian triad.

Hapgood, 1992

- EME2000 is the Earth Centered Inertial (ECI) system, which is GEI fixed on J2000
- Planetocentric (e.g., Moon)
  - SSE (Solar Selenocentric Ecliptic)

Hapgood, 1992

The transformations described in the following sections are presented as matrices, which are either a simple rotation matrix (a rotation of angle ζ about one of the principal axes) or are the products of simple rotation matrices. These simple matrices have only two degrees of freedom and so only two parameters are needed to specify the nine terms in the matrix. These two terms can be the rotation angle and the name of the rotation axis: X, Y or Z. Thus we can specify a simple rotation matrix as

$$\mathbf{E} = \langle \zeta, \text{axis} \rangle$$

e.g. $\langle \zeta, Z \rangle = \begin{bmatrix} \cos\zeta & \sin\zeta & 0 \\ -\sin\zeta & \cos\zeta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

and specify a product matrix as

$$\mathbf{T} = \mathbf{E}_1\mathbf{E}_2 = \langle \zeta_1, \text{axis}_1 \rangle * \langle \zeta_2, \text{axis}_2 \rangle.$$

Inversion is straightforward:

$$\mathbf{E}^{-1} = \langle -\zeta, \text{axis} \rangle$$

$$\mathbf{T}^{-1} = \mathbf{E}_2^{-1}\mathbf{E}_1^{-1} = \langle -\zeta_2, \text{axis}_2 \rangle * \langle -\zeta_1, \text{axis}_1 \rangle$$

Hapgood, 1992

4.1. *GEI to GEO*

$$\mathbf{T}_1 = \langle \theta, Z \rangle. \qquad (2)$$

This matrix corresponds to a rotation in the plane of the Earth's geographic equator from the First Point of Aries to the Greenwich meridian. The rotation angle θ is the Greenwich mean sidereal time. This can be calculated using the following formula (U.S. Naval Observatory, 1989):

$$\theta = 100.461 + 36000.770\ T_0 + 15.04107\ \mathrm{UT},$$

where

$$T_0 = \frac{\mathrm{MJD} - 51544.5}{36525.0}. \qquad (3)$$

Note that T_0 is the time in Julian centuries (36525 days) from 12:00 UT on 1 January 2000 (known as epoch 2000.0) to the previous midnight.

4.2. *GEI to GSE*

$$\mathbf{T}_2 = \langle \lambda_\odot, Z \rangle * \langle \varepsilon, X \rangle. \qquad (4)$$

These two matrices correspond to:

(1) rotation from the Earth's equator to the plane of the ecliptic;

(2) rotation in the plane of the ecliptic from the First Point of Aries to the Earth–Sun direction.

These two angles are calculated as follows (U.S. Naval Observatory, 1989). First ε, the obliquity of the ecliptic:

$$\varepsilon = 23.439 - 0.013\ T_0$$

and then $\lambda_\odot$, the Sun's ecliptic longitude:†

$$M = 357.528 + 35999.050\ T_0 + 0.04107\ \mathrm{UT}$$

$$\Lambda = 280.460 + 36000.772\ T_0 + 0.04107\ \mathrm{UT}$$

$$\lambda_\odot = \Lambda + (1.915 - 0.0048\ T_0) \sin M + 0.020 \sin 2M, \qquad (5)$$

where T_0 is defined in equation (3) above. Note that, strictly speaking, TDT should be used here in place of UT, but the difference of about a minute gives a difference of $\sim 0.0007°$ in $\lambda_\odot$.

Hapgood, 1992

4.3. *GSE to GSM*

$$\mathbf{T}_3 = \langle -\psi, X \rangle, \quad (6)$$

where ψ is the angle between the GSE Z axis and projection of the magnetic dipole axis on the GSE YZ plane (i.e. the GSM Z axis) measured positive for rotations towards the GSE Y axis. It can be calculated thus:

$$\psi = \arctan(y_e/z_e),$$

where ψ lies between $+90$ and $-90°$ and the values of y_e and z_e are obtained from:

$$\mathbf{Q}_e = \begin{bmatrix} x_e \\ y_e \\ z_e \end{bmatrix} \quad (7)$$

which is a unit vector describing the dipole axis direction in the GSE coordinate system.

4.4. *GSM to SM*

$$\mathbf{T}_4 = \langle -\mu, Y \rangle, \quad (10)$$

where μ is the dipole tilt angle, i.e. the angle between the GSM Z axis and the dipole axis. It is positive for the North dipole pole sunward of GSM Z. It is calculated using:

$$\mu = \arctan \frac{x_e}{\sqrt{y_e^2 + z_e^2}},$$

where x_e, y_e and z_e are defined in equation (7) and μ must lie between $+90$ and $-90°$.

- A simple way to go from one to another system is to combine the above rotations

	From		
To	GEI	GEO	GSE
GEI	1	T_1^{-1}	T_2^{-1}
GEO	T_1	1	$T_1T_2^{-1}$
GSE	T_2	$T_2T_1^{-1}$	1
GSM	T_3T_2	$T_3T_2T_1^{-1}$	T_3
SM	$T_4T_3T_2$	$T_4T_3T_2T_1^{-1}$	T_4T_3
MAG	T_5T_1	T_5	$T_5T_1T_2^{-1}$
	GSM	SM	MAG
GEI	$T_2^{-1}T_3^{-1}$	$T_2^{-1}T_3^{-1}T_4^{-1}$	$T_1^{-1}T_5^{-1}$
GEO	$T_1T_2^{-1}T_3^{-1}$	$T_1T_2^{-1}T_3^{-1}T_4^{-1}$	T_5^{-1}
GSE	T_3^{-1}	$T_3^{-1}T_4^{-1}$	$T_2T_1^{-1}T_5^{-1}$
GSM	1	T_4^{-1}	$T_3T_2T_1^{-1}T_5^{-1}$
SM	T_4	1	$T_4T_3T_2T_1^{-1}T_5^{-1}$
MAG	$T_5T_1T_2^{-1}T_3^{-1}$	$T_5T_1T_2^{-1}T_3^{-1}T_4^{-1}$	1

Hapgood, 1992

Geophysical Coordinate Systems: Heliocentric

System		Definition of axes
Heliocentric Aries ecliptic	HAE	X = First Point of Aries Z = Ecliptic North Pole
Heliocentric Earth ecliptic	HEE	X = Sun–Earth line Z = Ecliptic North Pole
Heliocentric Earth equatorial	HEEQ	X = Intersection between solar equator and solar central meridian as seen from Earth Z = North Pole of solar rotation axis

† Only two axes have to be defined; the third axis completes a right-handed Cartesian triad. The HAE and HEE systems are both sometimes known as heliocentric solar ecliptic or HSE. The HEEQ system is sometimes known as heliocentric solar or HS.

Hapgood, 1992

LAT/LON

- Geographic Lat/Lon
  - Simply transform from Cartesian GEO to Spherical coordinates
    - (Radius, Azimuth, Colatitude)
    - Longitude is Azimuth; Latitude is 90deg-colatitude
- Magnetic Local Time (MLT), Magnetic Longitude (MLON), Magnetic Latitude (MLAT)
  - Simply take GEO position, convert to SM (dipole), obtain Spherical coordinates
    - MLON=(Azimuth+180^o) mod 360^o; MLT is Azimuth/24; MLAT = 90^o-colatitude
- Footpoint MLT, MLAT/MLON
  - Take magnetic footpoint using a magnetic model, then convert to MLT, MLAT/MLON
- Dipole MLat/MLon: when using simple dipole for projection to ionosphere
  - Going from SM Radius, SM Lat/Lon to Dipole Magnetic Coordinates use:

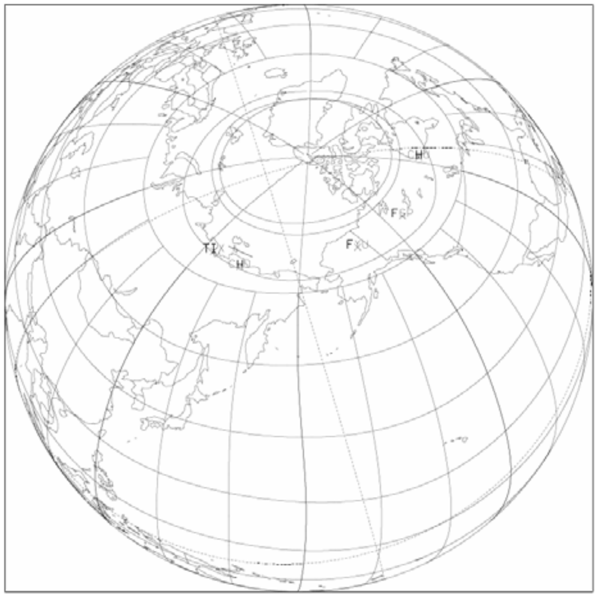
$$\frac{dr}{B_r} = \frac{r d\theta}{B_\theta} \Rightarrow \frac{dr}{r} = \frac{B_r}{B_\theta} d\theta = \frac{2\cos\theta}{\sin\theta} d\theta \Rightarrow r = r_o \sin^2\theta \Rightarrow \boxed{r = LR_E \sin^2\theta} \Rightarrow$$

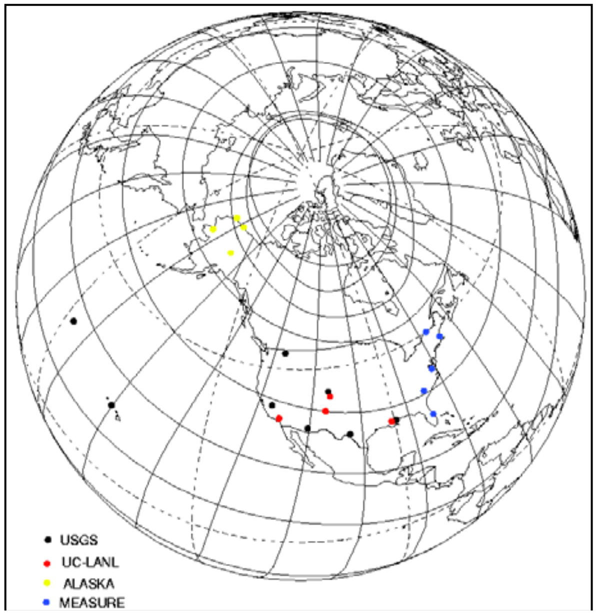
$$MLAT = a\sin(1/L)^{1/2}$$

$$\text{Recall}: \; B_r = \frac{M\mu_o}{2\pi}\frac{\cos\theta}{r^3} = -\frac{2B_0\cos\theta}{(r/R_E)^3} \qquad B_\theta = -\frac{M\mu_o}{4\pi}\frac{\sin\theta}{r^3} = -\frac{B_0\sin\theta}{(r/R_E)^3} \qquad B = B_0\frac{(1+3\cos^2\theta)^{1/2}}{(r/R_E)^3}$$

CGMLAT/LON

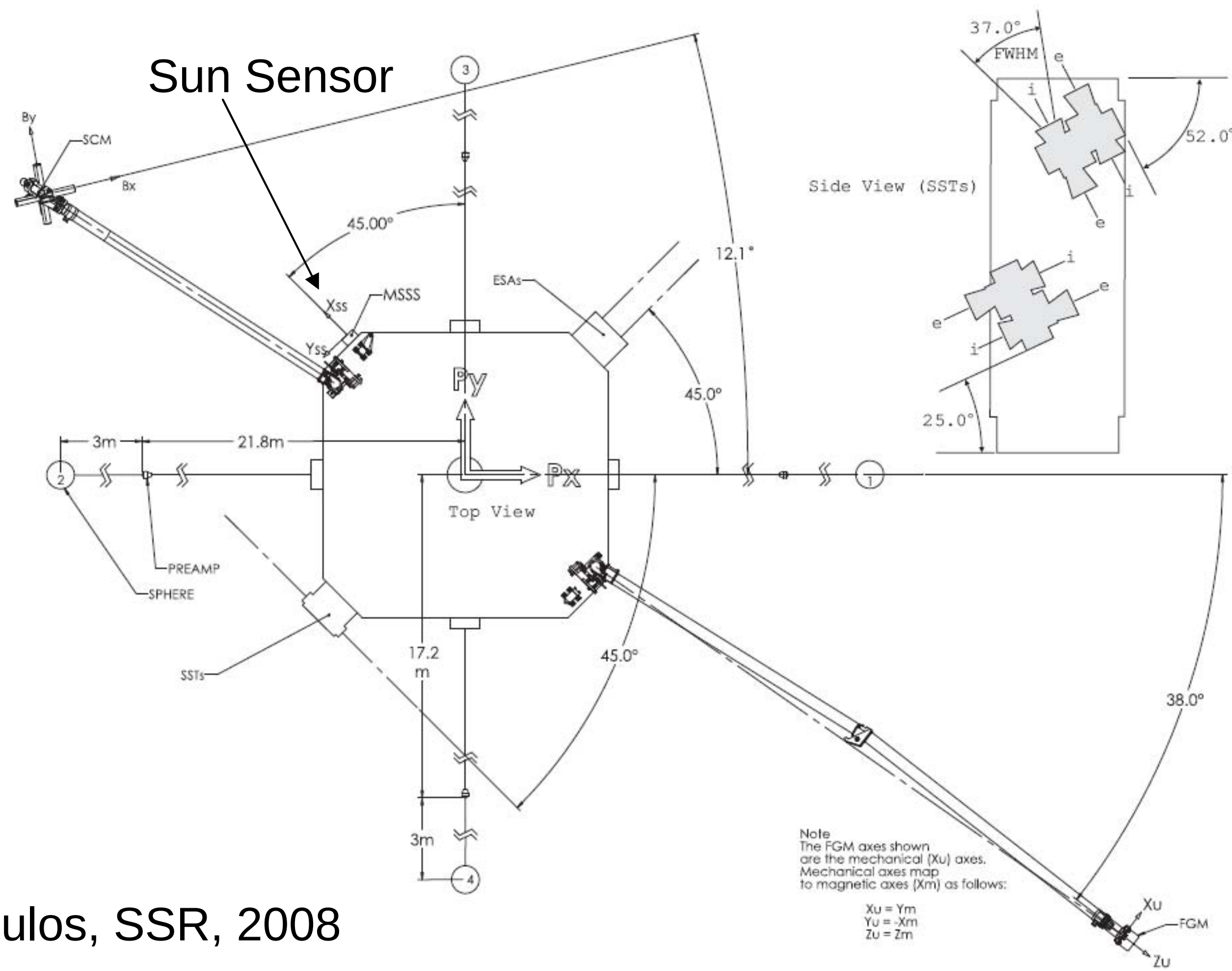
- Definition. "Corrected GeoMagnetic Coordinates are the Ionospheric MLAT/MLON coordinates of given point which projects on the equator, when using simple dipole, at the same location as a real field line starting from the point of interest."
  - Effectively, this corrects for distortion of dipole
  - A point's CGM coordinates order spatial relationships of phenomena at the equator.
  - Plotted on regular grid in CGM coordinates, phenomena dependent on equatorial processes are better organized (e.g., auroral arcs, cosmic noise absorption, polar cap).
- Recipe to obtain CGMLAT/LON
  - Map point to the equator using accurate field line model (specifically IGRF)
  - Obtain MLAT/MLON of that equatorial point
    - $L=r_{eq}/R_E$; GCMMLAT=$\sin^{-1}(1/L)$
    - Convert equatorial point to SM: CGMLON=SMLON





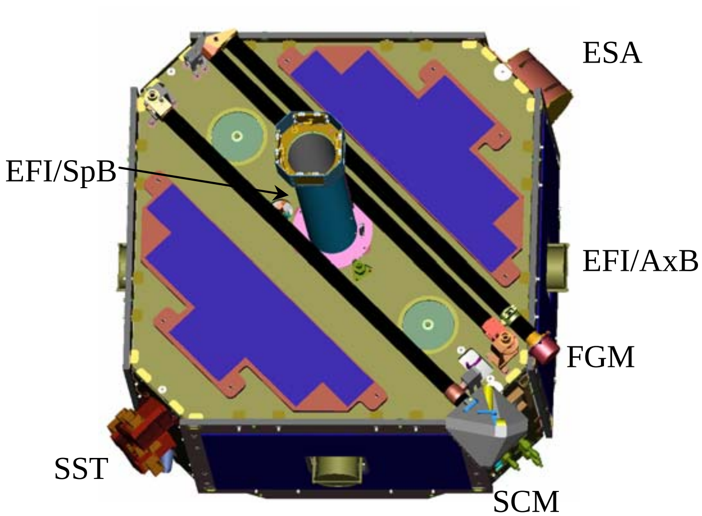
Spacecraft Coordinate Systems

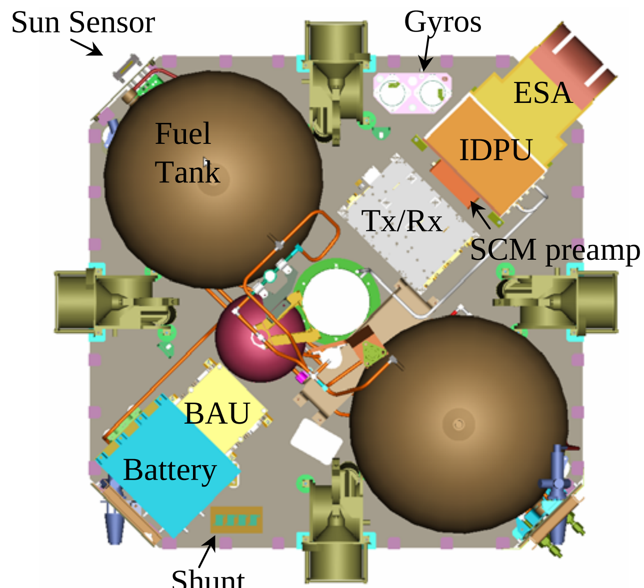
- Instrument Coordinates (spinning spacecraft)
  - These depend on individual instrument geometry and articulation.
    - E.g., FGM $X_mY_mZ_m$ instrument magnetic axes related to $X_uY_uZ_u$ instr. mechanical axes as shown
      - Mechanical and magnetic axes are orthogonal; calibrations applied to signals to correct for mechanical and electronics non-orthogonality.
    - E.g., ESA and SST naturally expressed in spacecraft body coordinates.

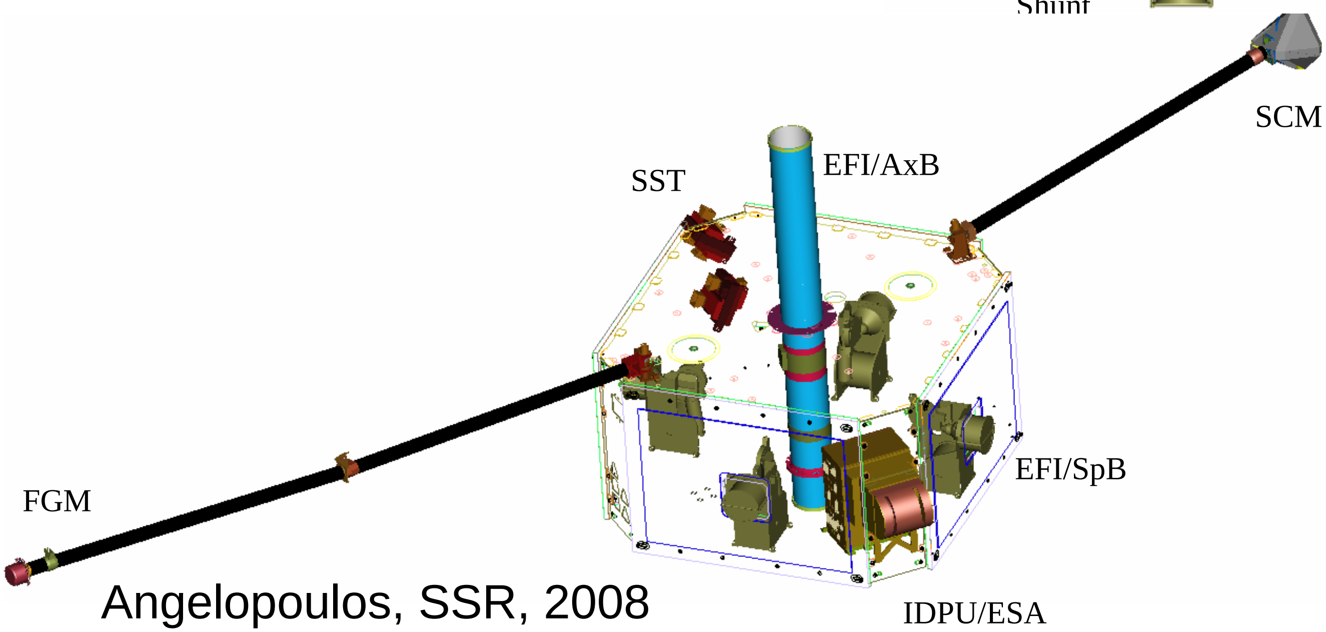


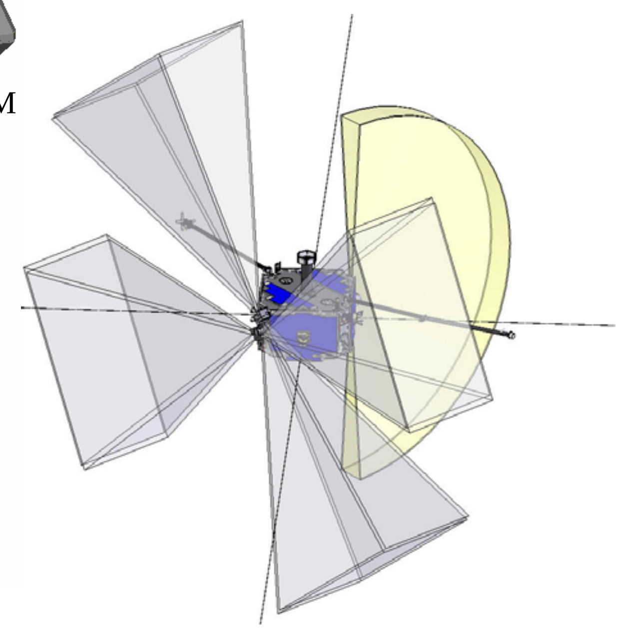
Angelopoulos, SSR, 2008

Spacecraft Coordinate Systems
… instrument locations, and field of views









Angelopoulos, SSR, 2008

Spacecraft Coordinate Systems … continued

- SPG (Spinning Probe Geometric)
  - Z_{SPG} is along probe geometric axis
  - X_{SPG} is along EFI Sphere #1
- SSL (Spinning Sun-sensor L-momentum vector)
  - X_{SSL} is along field of the Sun-sensor
  - Z_{SSL} is along the angular momentum vector L
    - THEMIS: During spin balance weights were placed at appropriate locations to ensure spin axis is along geometric axis. It was then verified that the maximum axis of inertia was <0.25^o away from the probe geometric axis
  - Y_{SSL} completes orthogonal system
    - THEMIS: Since Z_{SSL} is along Z_{SPG} the SSL system is derived from SPG by a 135^o rotation about Z.
- DSL (Despun, Sun-pointing L-momentum vector)
  - Z_{DSL} is identical to Z_{SS}
  - X_{DSL} - Z_{DSL} plane contains the Sun direction (X_{DSL} – positive towards the Sun)
  - Y_{DSL} completes the orthogonal system
    - Effectively Y_{DSL} is defined as Z_{DSL} x Sun_direction
    - THEMIS: DSL is obtained from SSL by rotation opposite to spin phase, by an angle that elapsed since the last Sun crossing by the Sun Sensor

Spacecraft Coordinate Systems … continued

- NOTE: on THEMIS, DSL is roughly along GSE system (within 8^o)
  - Specification in 2007-2009:
    - Inner probes: Spin axis ecliptic North: toward Sun by 8^o (+/-2^o) 2008/02/05 06:30 UT.
    - Outer probes: Spin axis ecliptic South: away from Sun by 8^o (+/-2^o) 2008/02/05 06:30 UT
  - Specification in 2010-2012:
    - Inner probes (THEMIS): Spin axis ecliptic North: toward Sun by 8^o (+/-2^o) 2010/05/01 03:30 UT.
    - Outer probes (ARTEMIS): Spin axis ecliptic South: any angle around 8^o (5^o - 15^o)

- From DSL (a common system in most missions) to GEI or GSE:
  - STEP#1: Knowing spacecraft spin axis attitude (in GEI or GSE coordinates), rotate to GEI
    - Then rotate to GSE or other systems
    - THEMIS: attitude file is STATE file (contains spin axis right ascension, declination in GEI coord's).
  - STEP#2: Go from Spacecraft-centered to Earth-centered coordinates
    - on Earth orbiting spacecraft this is a very small angle, $\arctan(r_A/1AU)$ and usually ignored.
    - On THEMIS/ARTEMIS angle is $<\arctan(60R_E/1AU) \sim 0.003^o$.

Magnetospheric Models

- Dipole system
  - Assumes Earth's field is a centered dipole
  - Usually planetary fields are expressed in terms of spherical harmonic expansion
    - Legendre polynomials (see Kivelson and Russell, 6.2.2 Generalized Planetary Magnetic Fields)
      - Coefficients of harmonic expansion of internal field into: $P_n^m(\cos\theta)\,(g_n^m \cos(m\varphi) + h_n^m \sin(m\varphi))$
    - Dipole Moment $M = R_E^3[\,(g_1^0)^2 + (g_1^1)^2 + (h_1^1)^2\,]^{1/2}$
    - Tilt = $\cos^{-1}(g_1^0/M)$

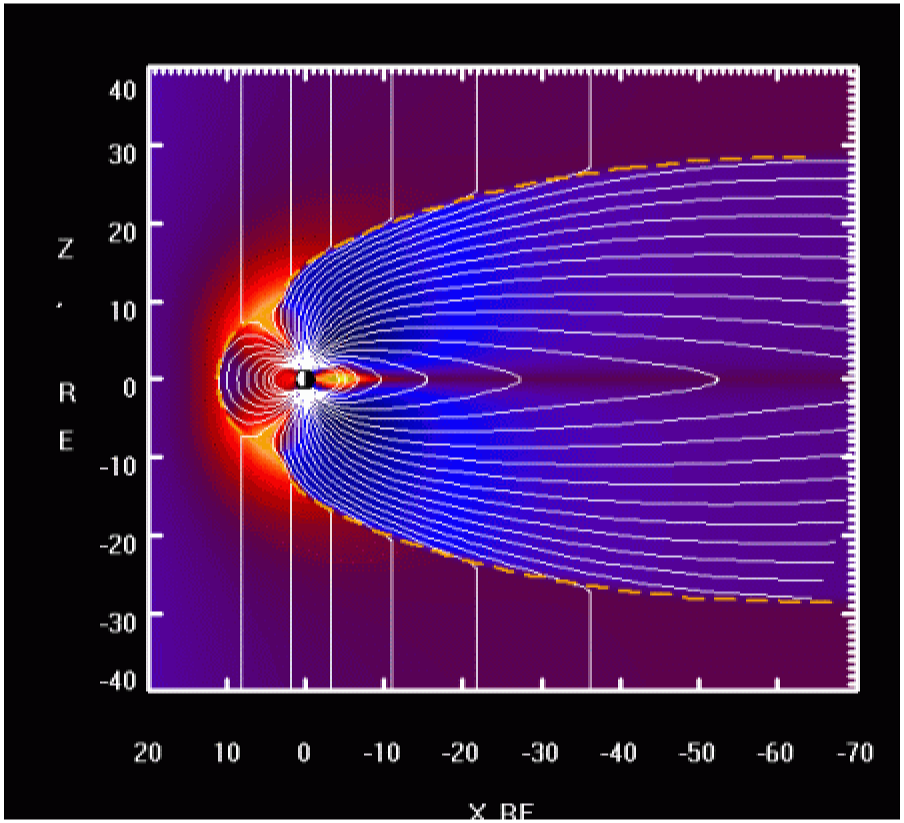
- IGRF International Geophysical Reference Field
  - Tabulates the coefficients up to N=10, a practical compromise adopted for producing well-determined main field models, while avoiding most of the contamination from crustal fields.
  - Released once per 5 years. Secular variations expressed as time rate of change of parameters.
  - Main field coefficients are rounded to the nearest nanotesla to reflect the limit of the resolution of the data.
  - ASCII files of the IGRF coefficients and computer programs for synthesizing field components are available from the World Data Centers
  - Available through THEMIS analysis tools by selecting T89 and kp<0.

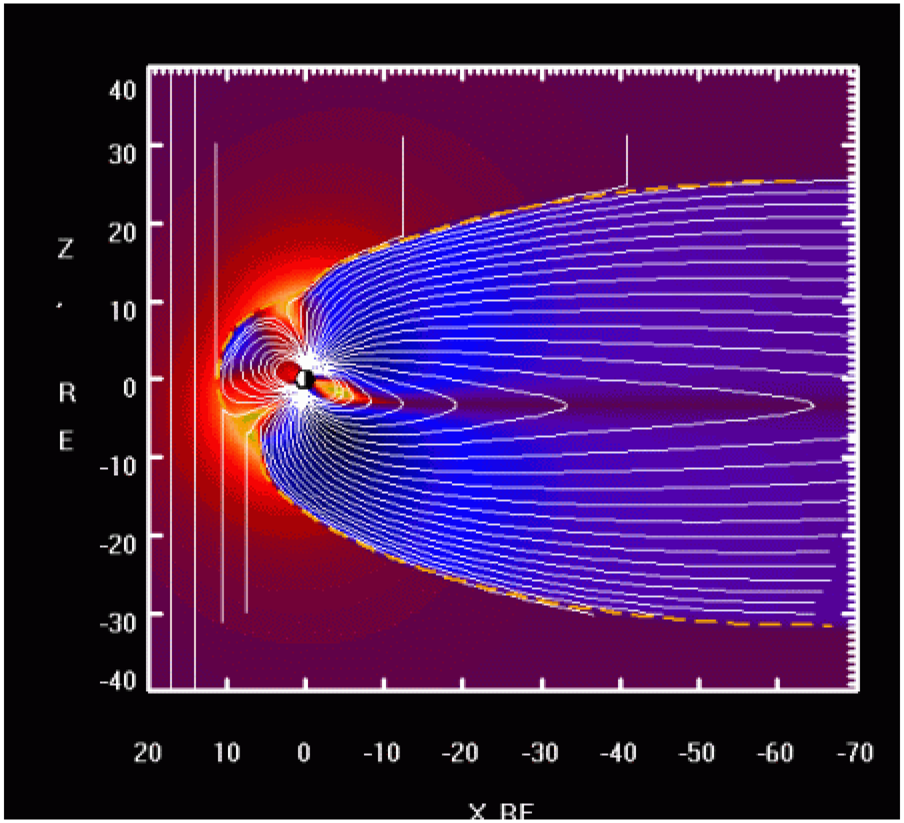
- Mapping:
  - Equation of a field line is: $\frac{dx}{B_x} = \frac{dy}{B_y} = \frac{dz}{B_z}$
  - Integrate as initial value problem with fixed step size (e.g., Tsyganenko routine TRACE)
  - Integrate using Runge-Kutta method with adaptive stepsize control (THEMIS routines)
    - See Numerical Recipies, Ch. 15 – Integration of ODEs.

Magnetospheric Models … continued

- Tsyganenko models
  - Use of internal (latest IGRF) plus modeled external fields
  - External field coefficients fit to magnetospheric data (ISEE, POLAR, Geotail, GOES…)
    - Ring current
    - Magnetotail current
    - Magnetopause current
    - (recent) Large scale field aligned currents (T96 an beyond)
    - (most recent) Substorm current wedge, plasma sheet inclination due to solar wind Vz
- T89:
  - External fields binned according to Kp (or AE as approximation of Kp), warped tail current
  - Has no magnetopause
  - Ends at X=-70Re unless extended explicitly by user
- T96:
  - Realistic magnetopause
  - Region 1 and Region 2 currents
  - IMF penetration across magnetopause boundary
  - Parametrized by Pdyn, Dst, and IMF By, Bz
- T02
  - Variable configuration of inner and near magnetosphere for IMF, ground disturbance
  - Partial ring current included
- TS05
  - Dynamical model of storm–time including 37 storms (1996-2000) using concurrent SW/IMF

Magnetospheric Models … accessibility





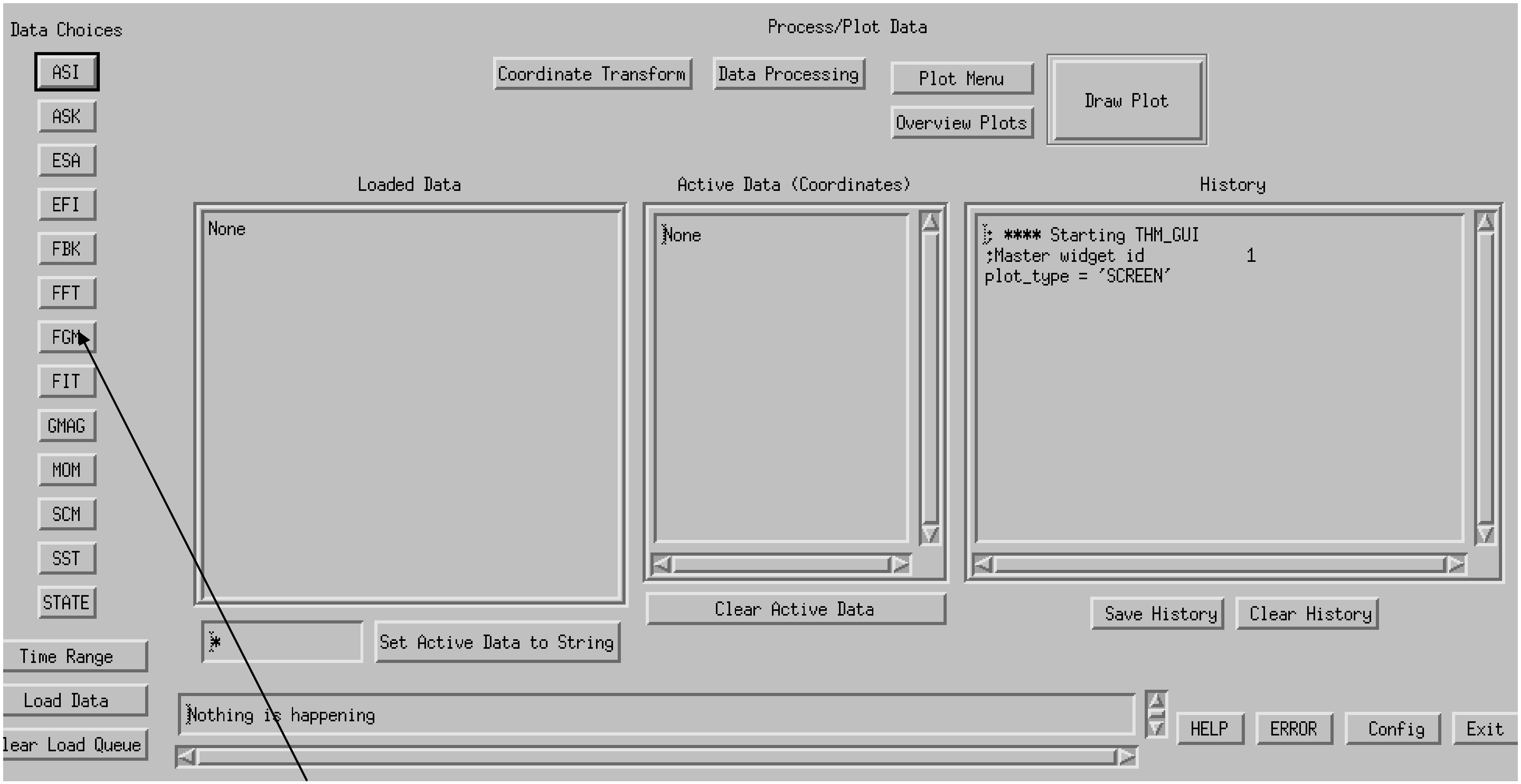
- Tsyganenko models
  - http://geo.phys.spbu.ru/~tsyganenko/modeling.html
  - LEFT: changes due to tilt angle
  - RIGHT: changes due to IMF Bz increase – Does not simulate substorms or reconnection.
  - EXAMPLES OF TRACING:
    - http://geo.phys.spbu.ru/~tsyganenko/Examples1_and_2.html
  - Available in Fortran from above site, or as dynamically linked executables thru THEMIS

THEMIS TRANSFORMATION ROUTINES

- Command Line:
  - thm_cotrans.pro (operates on tplot variables)
    - thm_load_state, /get_support
    - thm_cotrans, probe='a', datatype='fgl', out_suffix='_gsm';
    - ; ; or equivalently
    - thm_cotrans, 'tha_fgl', 'tha_fgl_gsm', out_coord='gsm'
    - ;
    - ; ; to transform all th?_fg?_dsl to th?_fg?_gsm
    - ;
    - ; thm_cotrans, 'th?_fg?', in_suffix='_dsl', out_suffix='_gsm'
    - ;
    - ; ; for arbitrary input variables, specify in_coord and probe:
    - ; thm_cotrans,'mydslvar1 mydslvar2 mydslvar3', $
    - ;   in_coord='dsl', probe='b c d', out_suff='_gse'
  - cotrans.pro (operates on arrays as well as tplot variables)
    - Choices:

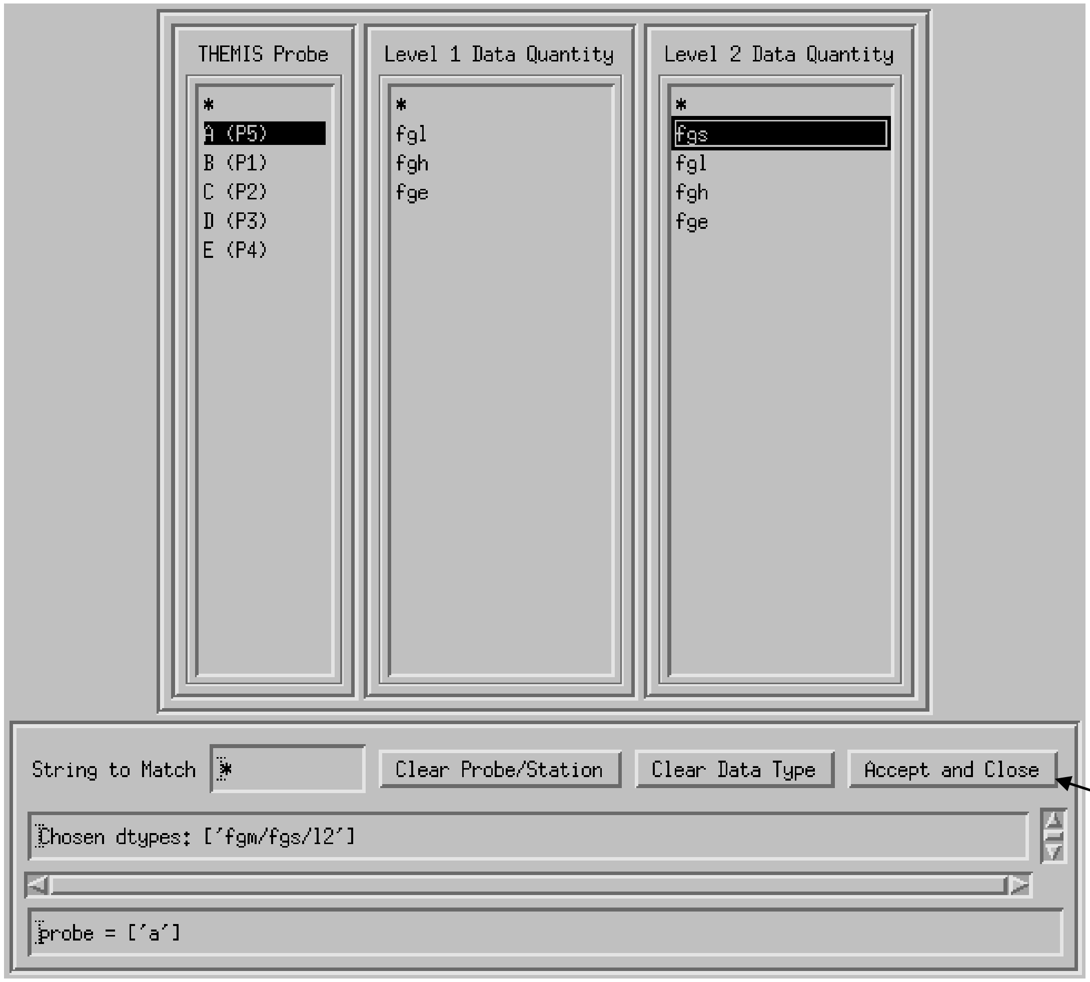
      GSM2GSE,GSE2GEI,GSE2GSM,GEI2GSE,GSM2SM,SM2GSM,GEI2GEO, GEO2GEI
    - cotrans,tha_fgl_gse_array,tha_fgl_gsm_array, tha_fgl_gse_time,/GSE2GSM
    - ; or
    - cotrans,'tha_fgl_gse','tha_fgl_gsm',/GSE2GSM
  - dsl2gse.pro (operates on arrays only)
    - dsl2gse,name_thx_xxx_in,name_thx_spinras,name_thx_spindec, name_thx_xxx_out,GSE2DSL=GSE2DSL

Choose Data to Load:



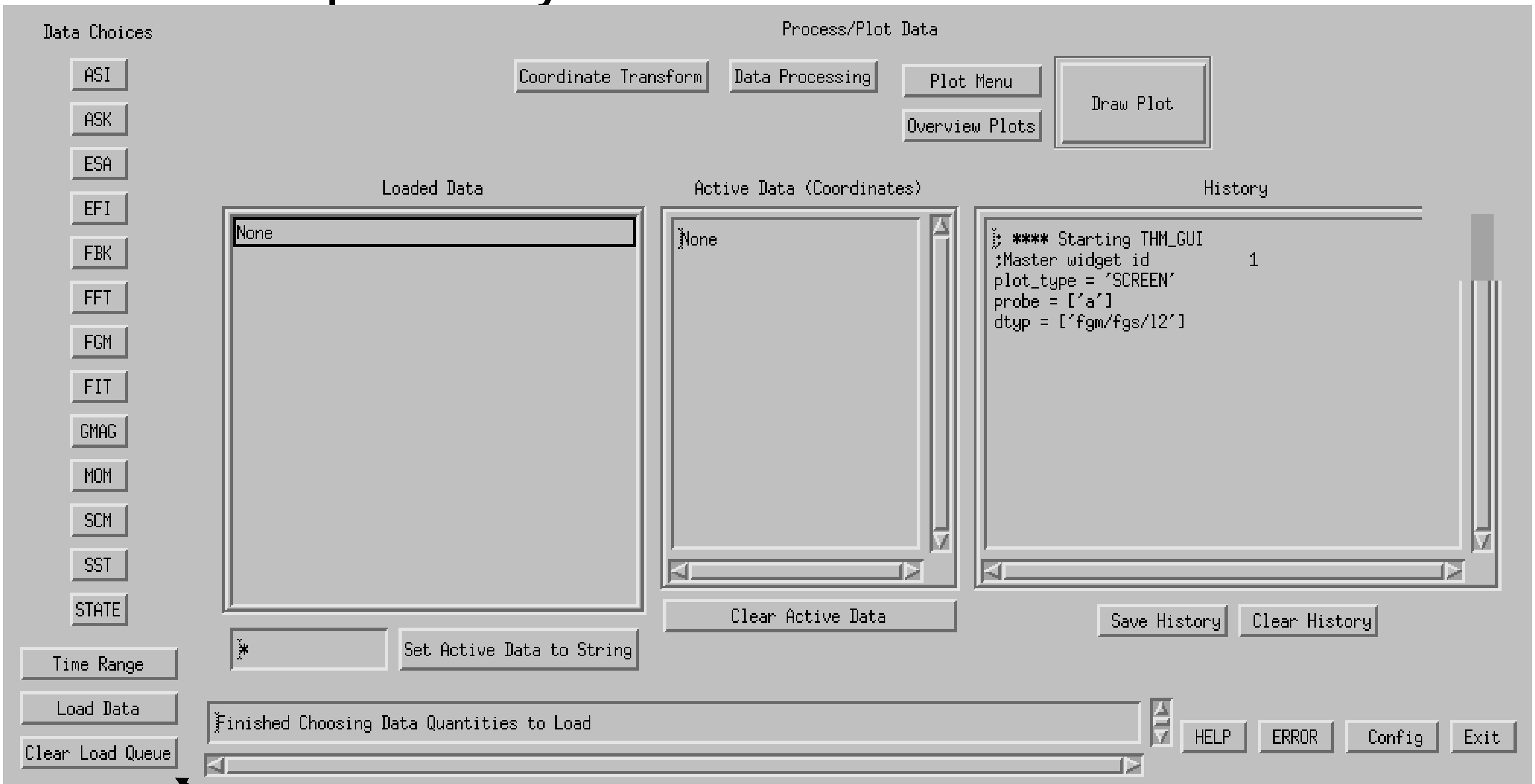
Click here for FGM data

Data choice window:



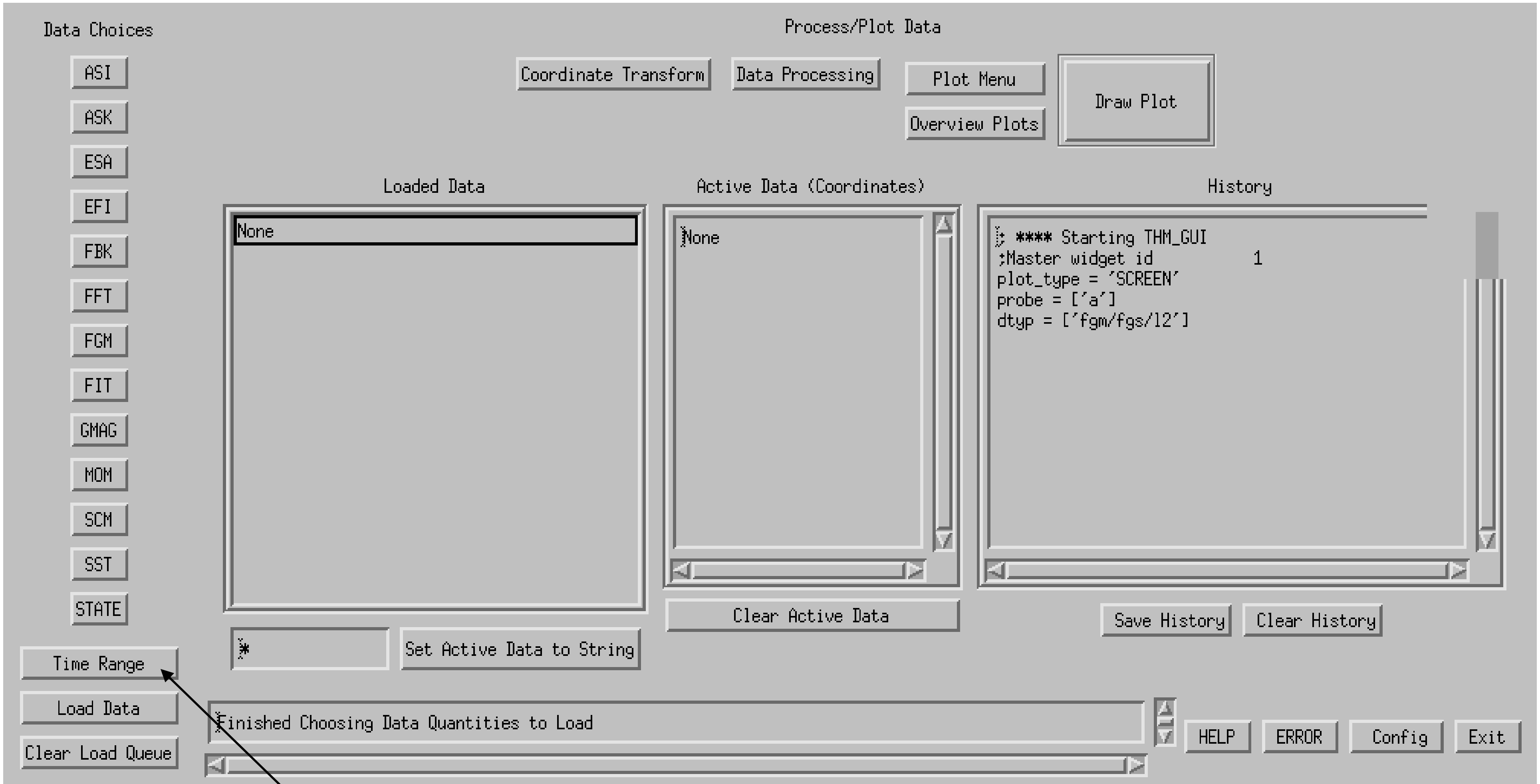
Nothing will happen until you click here

Choices show up in History Window:



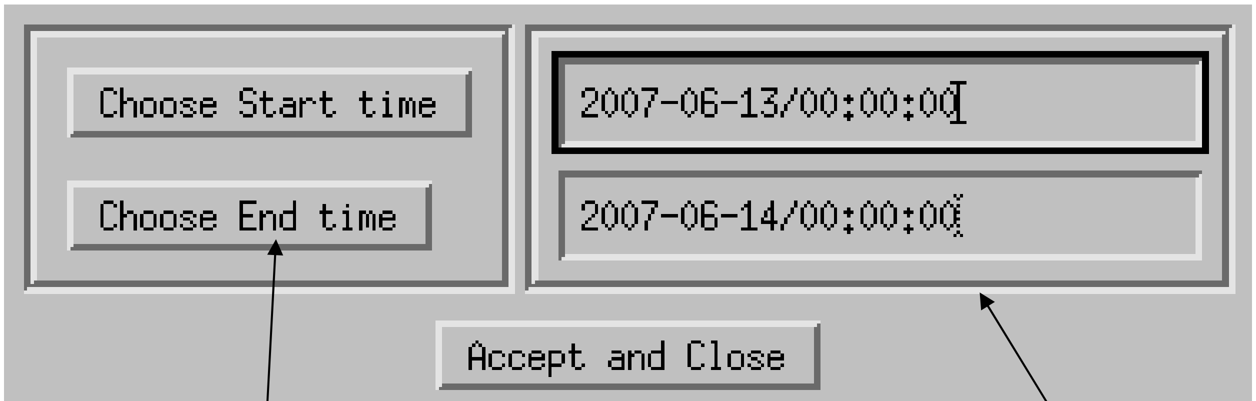
Click here to clear choices.

Nothing happens unless you choose a time range



Click Here to choose times.

Time Range Window:



You can type here.

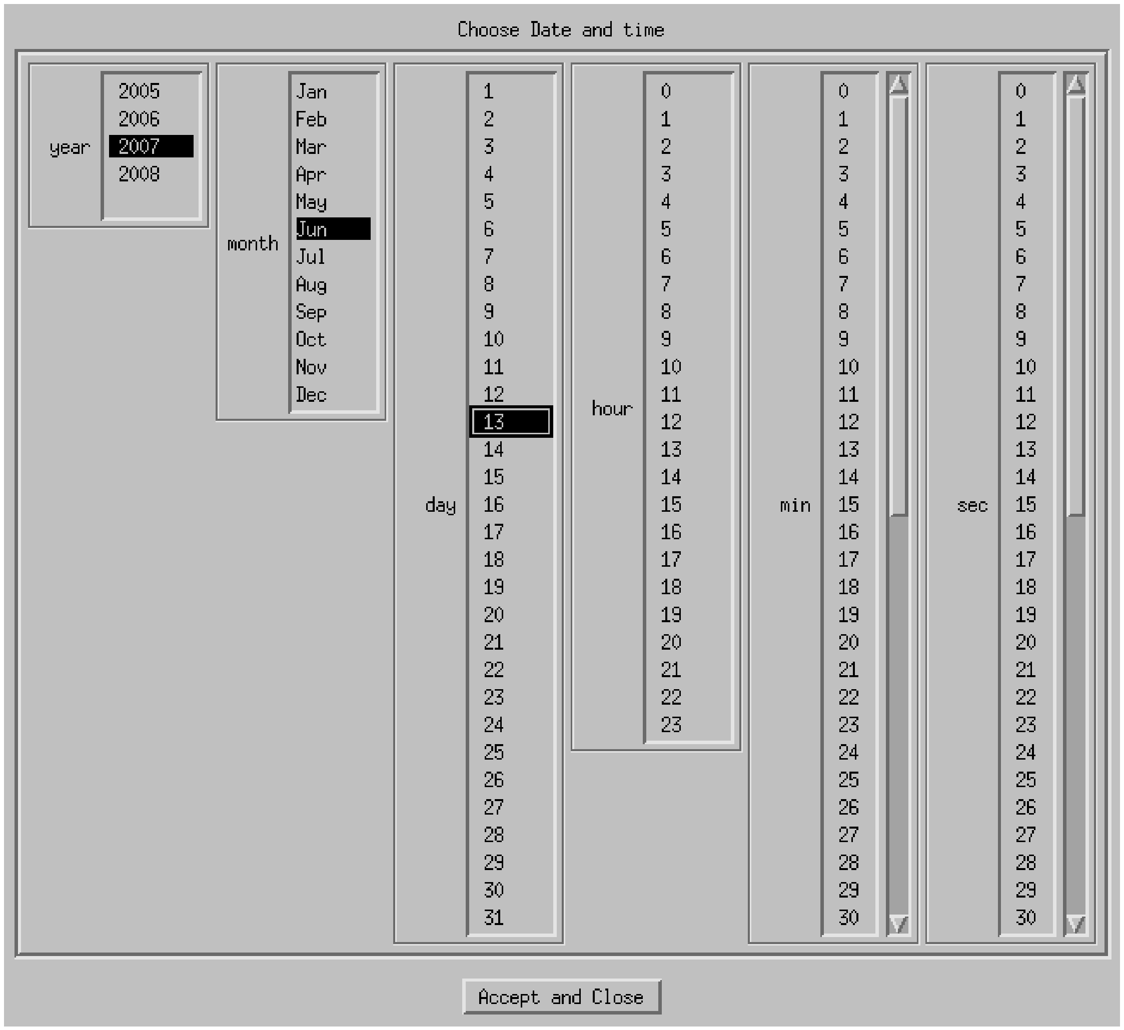
Initially times are set to

1970-01-01/00:00:00

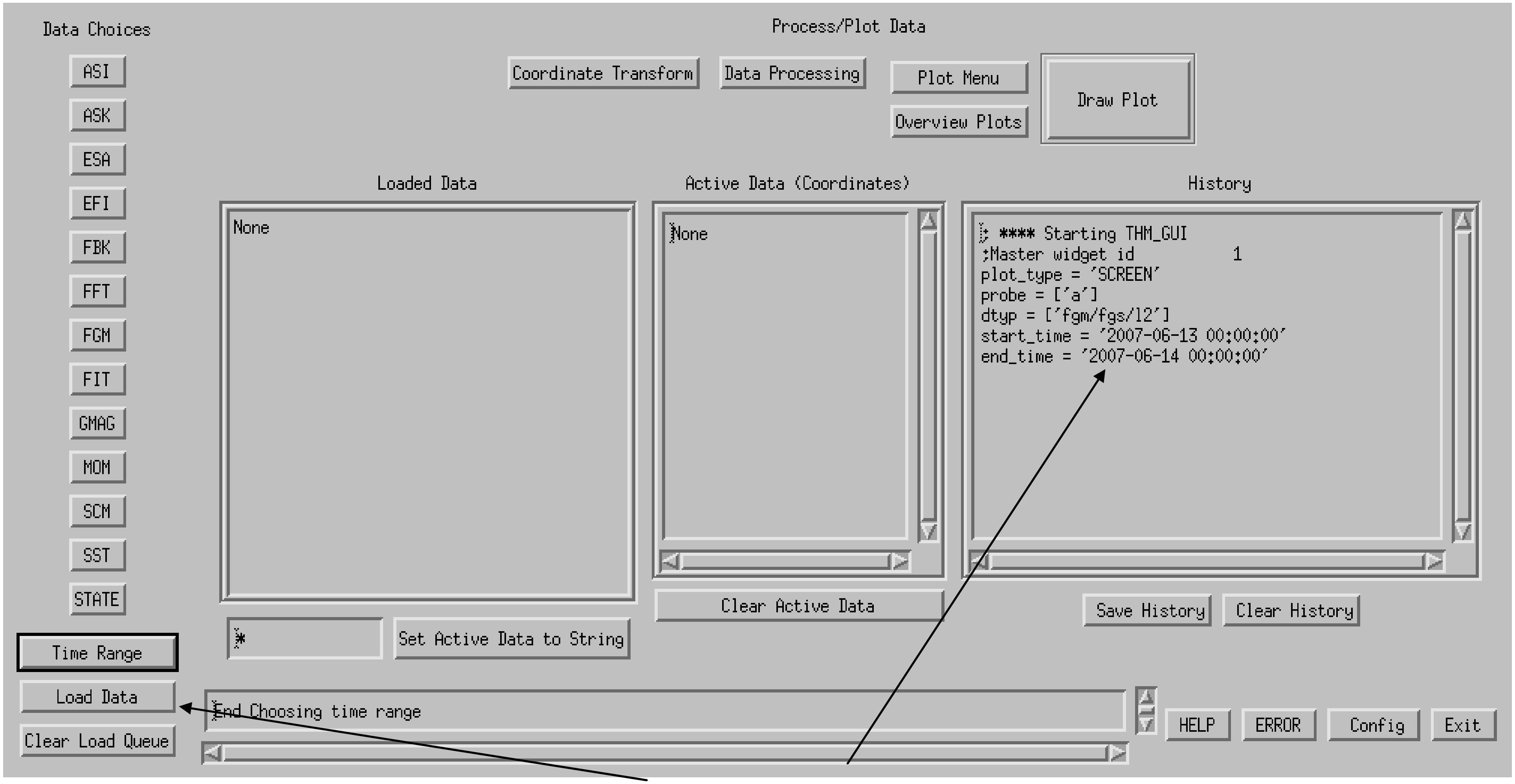
Times show up in history as you type.

Click here for a time selection widget

Time selection widget:

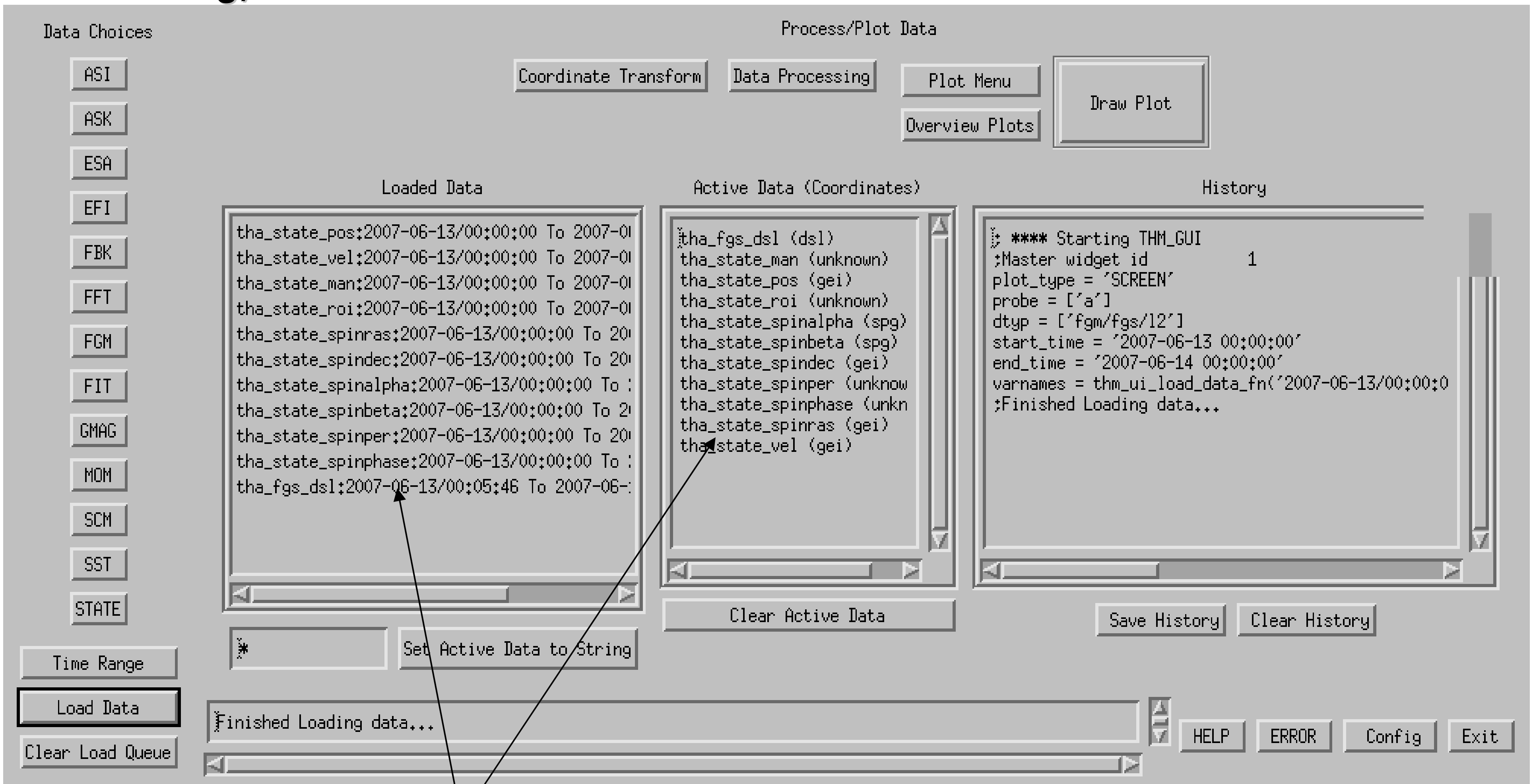


Selection shows up in the History:



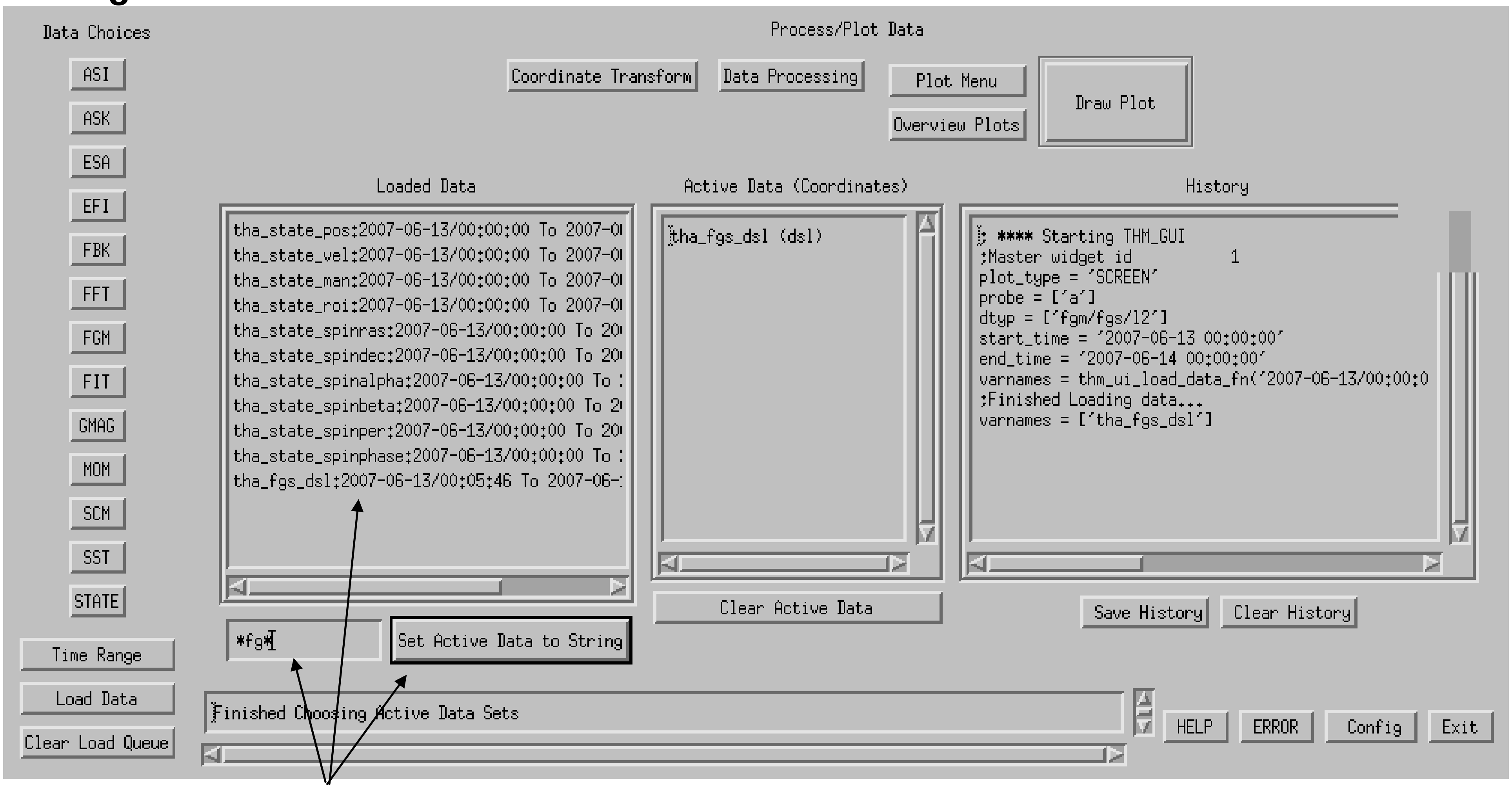
Now you can load data.

After loading, All data is “active”.



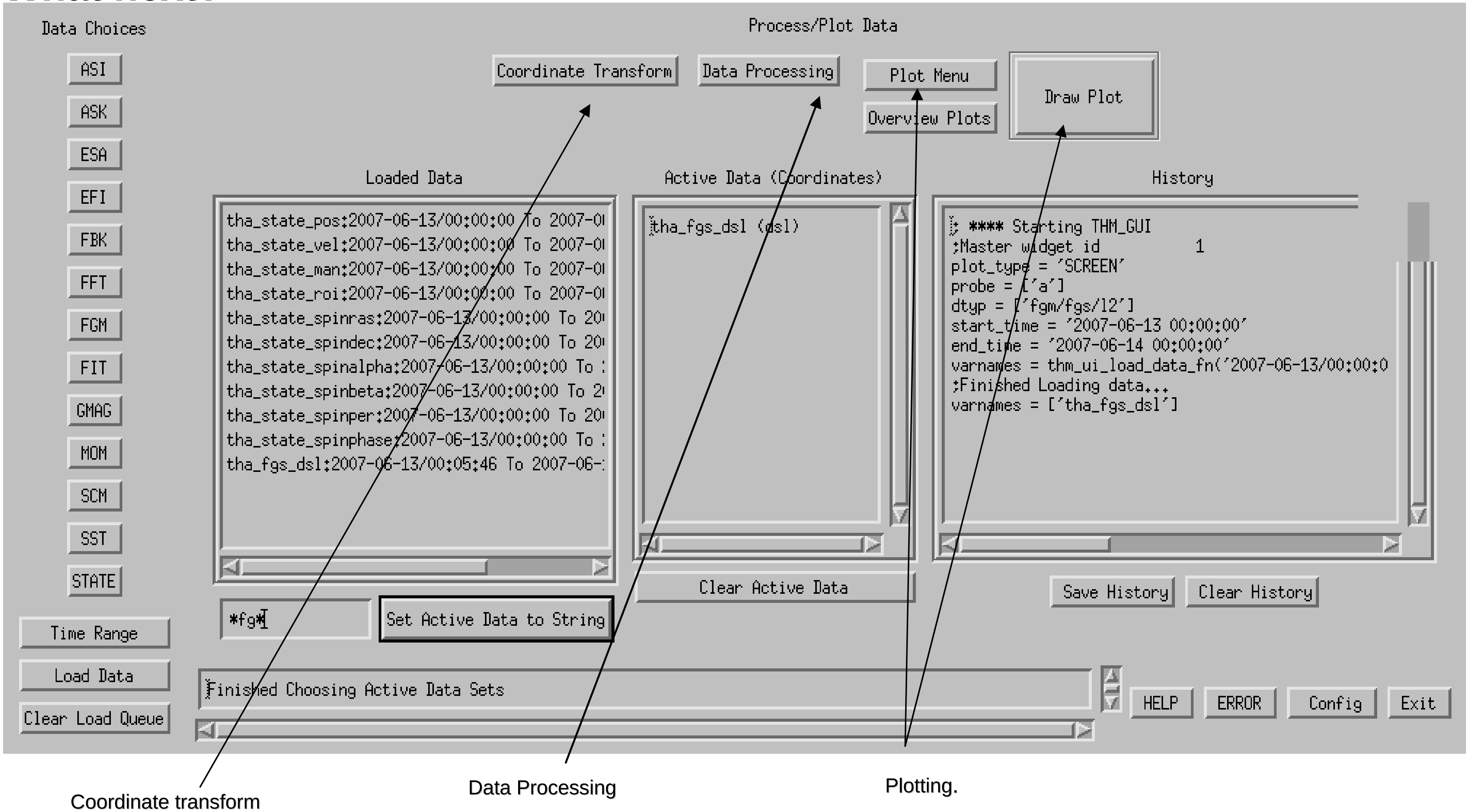
State data has been loaded automatically for FGM.

Setting Active Data:

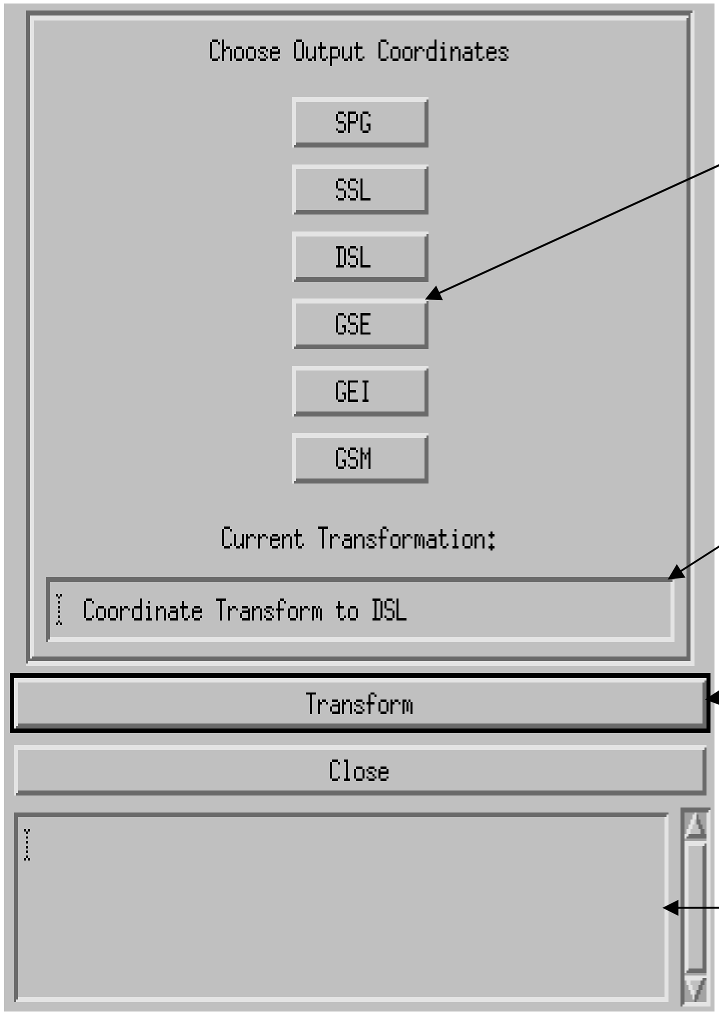


Type a string, or click to set data to “active”

What next?


Data Choices
ASI
ASK
ESA
EFI
FBK
FFT
FGM
FIT
GMAG
MOM
SCM
SST
STATE
Time Range
Load Data
Clear Load Queue
Process/Plot Data
Coordinate Transform
Data Processing
Plot Menu
Overview Plots
Draw Plot
Loaded Data
tha_state_pos:2007-06-13/00:00:00 To 2007-0
tha_state_vel:2007-06-13/00:00:00 To 2007-0
tha_state_man:2007-06-13/00:00:00 To 2007-0
tha_state_roi:2007-06-13/00:00:00 To 2007-0
tha_state_spinras:2007-06-13/00:00:00 To 20
tha_state_spindec:2007-06-13/00:00:00 To 20
tha_state_spinalpha:2007-06-13/00:00:00 To
tha_state_spinbeta:2007-06-13/00:00:00 To 2
tha_state_spinper:2007-06-13/00:00:00 To 20
tha_state_spinphase:2007-06-13/00:00:00 To
tha_fgs_dsl:2007-06-13/00:05:46 To 2007-06-
Active Data (Coordinates)
tha_fgs_dsl (dsl)
History
; **** Starting THM_GUI
;Master widget id 1
plot_type = 'SCREEN'
probe = ['a']
dtyp = ['fgm/fgs/l2']
start_time = '2007-06-13 00:00:00'
end_time = '2007-06-14 00:00:00'
varnames = thm_ui_load_data_fn('2007-06-13/00:00:0
;Finished Loading data...
varnames = ['tha_fgs_dsl']
fg
Set Active Data to String
Clear Active Data
Save History
Clear History
Finished Choosing Active Data Sets
HELP
ERROR
Config
Exit
Coordinate transform
Data Processing
Plotting.

Coordinate Transform:



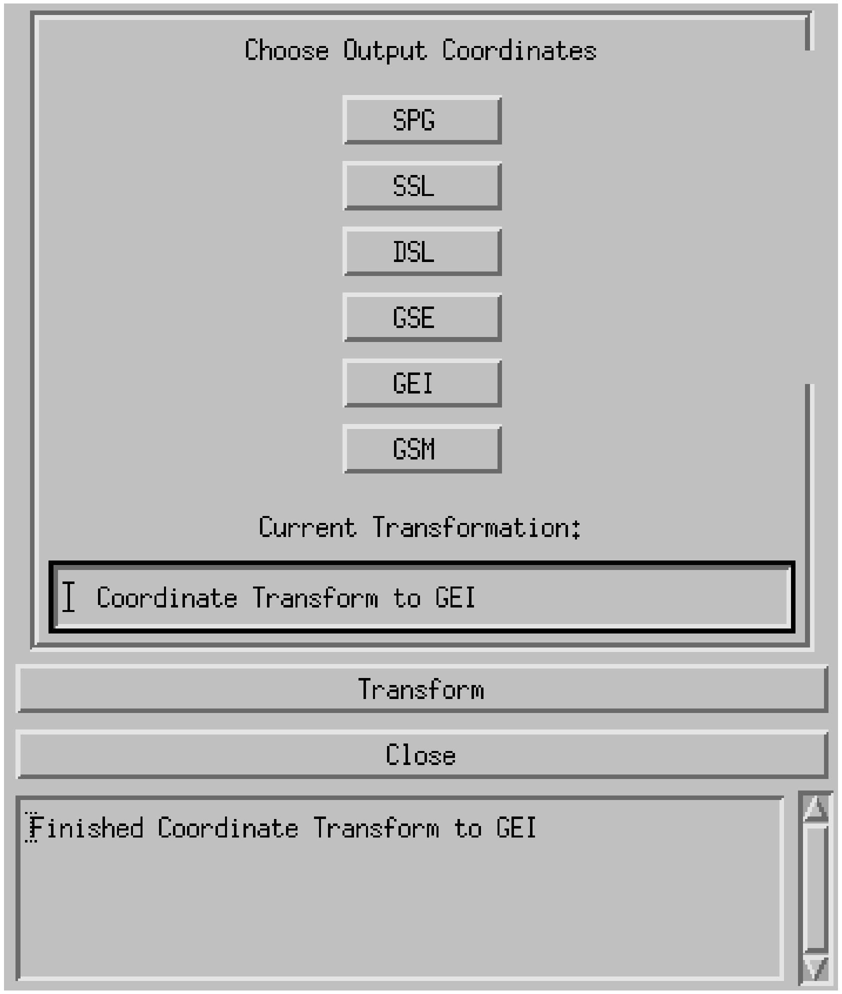
Click one of these to choose output coordinates.

Shows current transform

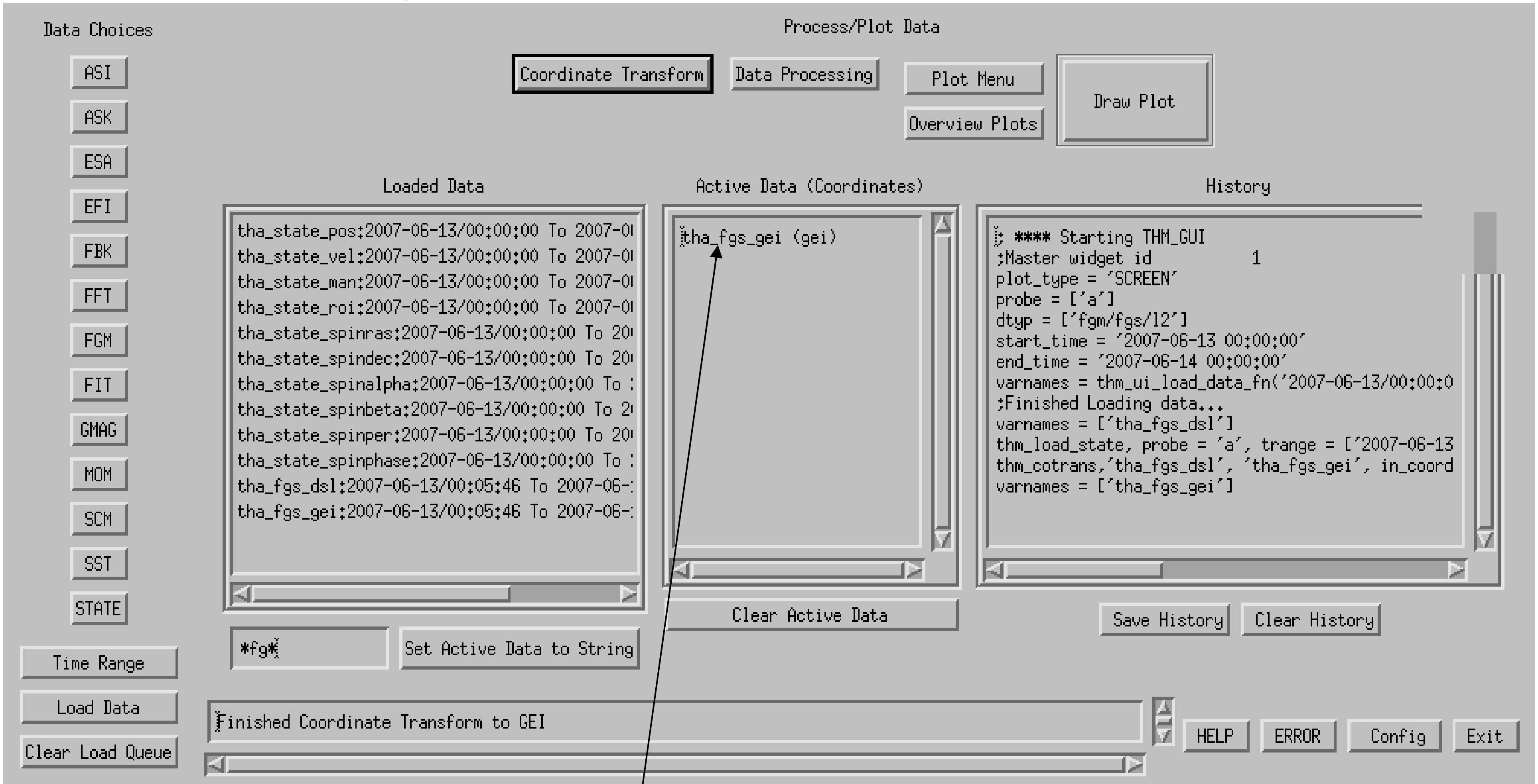
Click here to do the deed.

Message window: this will show warnings, errors, and progress.

Clicked on GEI, and Transform Button:

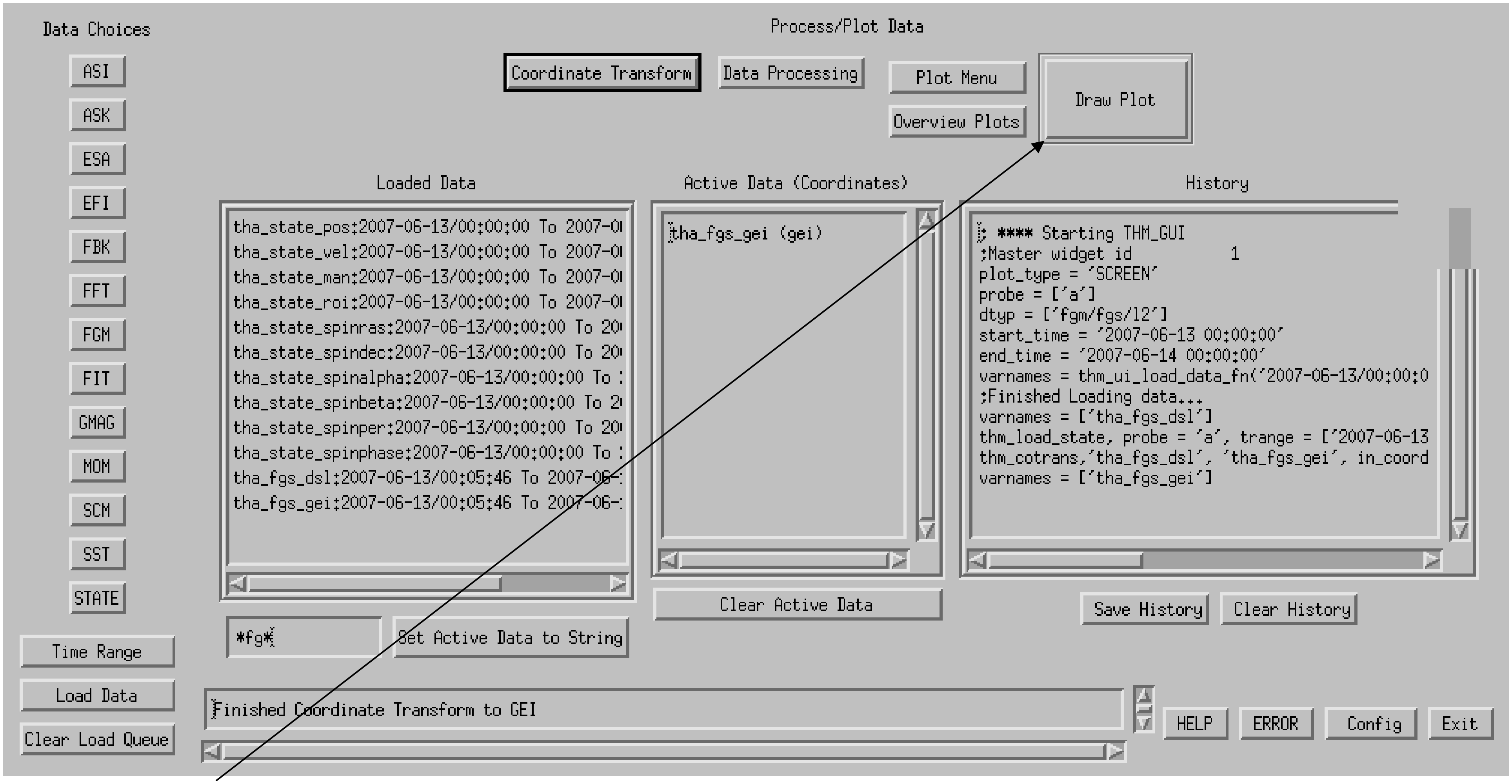


Back on the main widget:



New “active” data. Remember – only active data is processed.

Plotting:



Click the “Draw Plot” button. Active data is plotted.

THEMIS MODELS/MAPPING ROUTINES

- Command Line:
  - tt89_crib.pro (Available at: thm\external\IDL_GEOPACK\t89\tt89_crib.pro)
    - timespan, '2007-03-23'
    - ;load state data
    - thm_load_state, probe = 'b', coord = 'gsm'
    - ;calculate model field
    - tt89, 'thb_state_pos'
    - ;load fgm data for comparison
    - thm_load_fgm, probe = 'b', coord = 'gsm'
    - tplot_names
    - tplot, ['thb_state_pos_bt89', 'thb_fgs_gsm']
  - thm_crib_trace.pro (Available at: thm\themis\examples\thm_crib_trace.pro)
    - date = '2008-03-27/02:00:00' ;date to be plotted
    - hrs = 3 ;specifies the interval over which data will be loaded
    - sdate = time_double(date)-3600*hrs/2
    - edate = time_double(date)+3600*hrs/2
    - timespan,sdate,hrs,/hour
    - ;generate parameters for the tsyganenko model
    - model = 't89‘ & par = 2.0D ; use kp 2.0 for t89 model
    - ;generate points from which to trace for XZ projection
    - x = [-22,-22,-22,-22,-17,-12,-8,-5,-3,2,4,7,8,8] & y = replicate(0,14) & z = [10,7,4,0,replicate(0,9),4]
    - times = replicate(time_double(date),14)
    - … continued next page

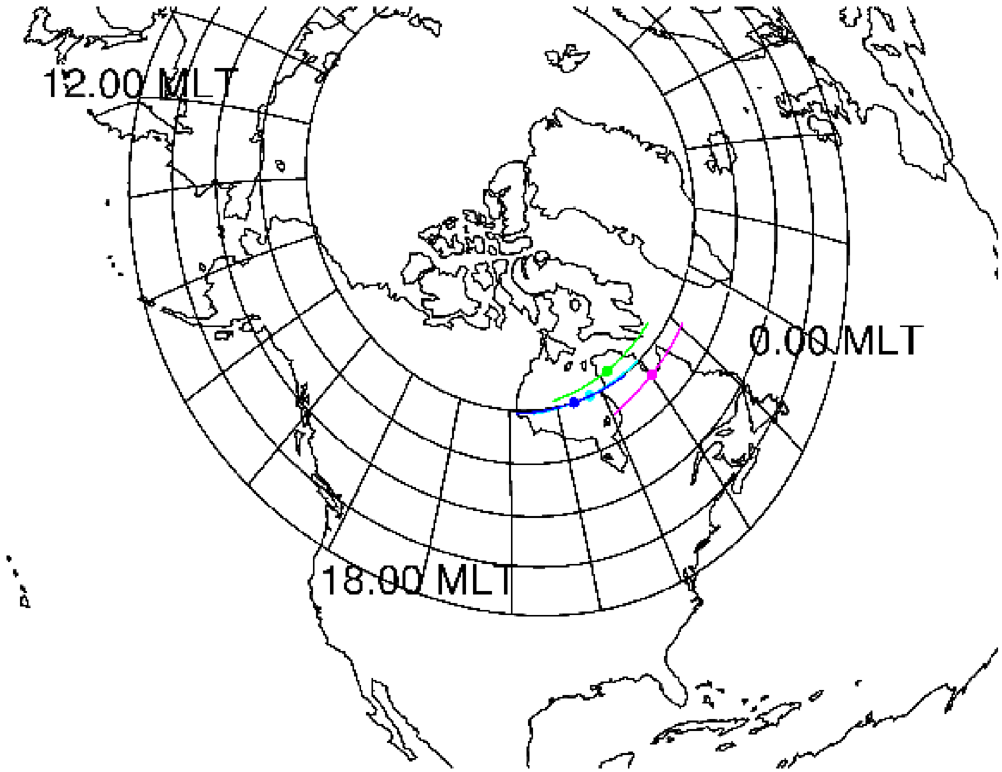
- Command Line:
  - thm_crib_trace.pro (Available at: thm\themis\examples\thm_crib_trace.pro)
    - … continued
    - trace_pts_north = [[x],[y],[z]] & trace_pts_south = [[x],[y],[-1*z]]
    - store_data,'trace_pts_north',data={x:times,y:trace_pts_north}
    - store_data,'trace_pts_south',data={x:times,y:trace_pts_south}
    - ;trace the field lines
    - ttrace2iono,'trace_pts_north',trace_var_name = 'trace_n', external_model=model,par=par,in_coord='gsm',out_coord='gsm'
    - ttrace2iono,'trace_pts_south',trace_var_name = 'trace_s', external_model=model,par=par,in_coord='gsm',out_coord='gsm', /south
    - window,xsize=800,ysize=600
    - xrange = [-22,10] ;x range of the xz plot
    - zrange = [-11,11] ;z range of the xz plot
    - ;generate the plot of field lines
    - tplotxy,'trace_n',versus='xrz',xrange=xrange,yrange=zrange,charsize=charsize,title="XZ field line/probe position plot",xthick=axisthick,ythick=axisthick,thick=linethick,charthick=charthick,ymargin=[.15,.1]
    - tplotxy,'trace_s',versus='xrz',xrange=xrange,yrange=zrange,/over,xthick=axisthick,ythick=axisthick,thick=linethick,charthick=charthick

Trace / Orbit Plots

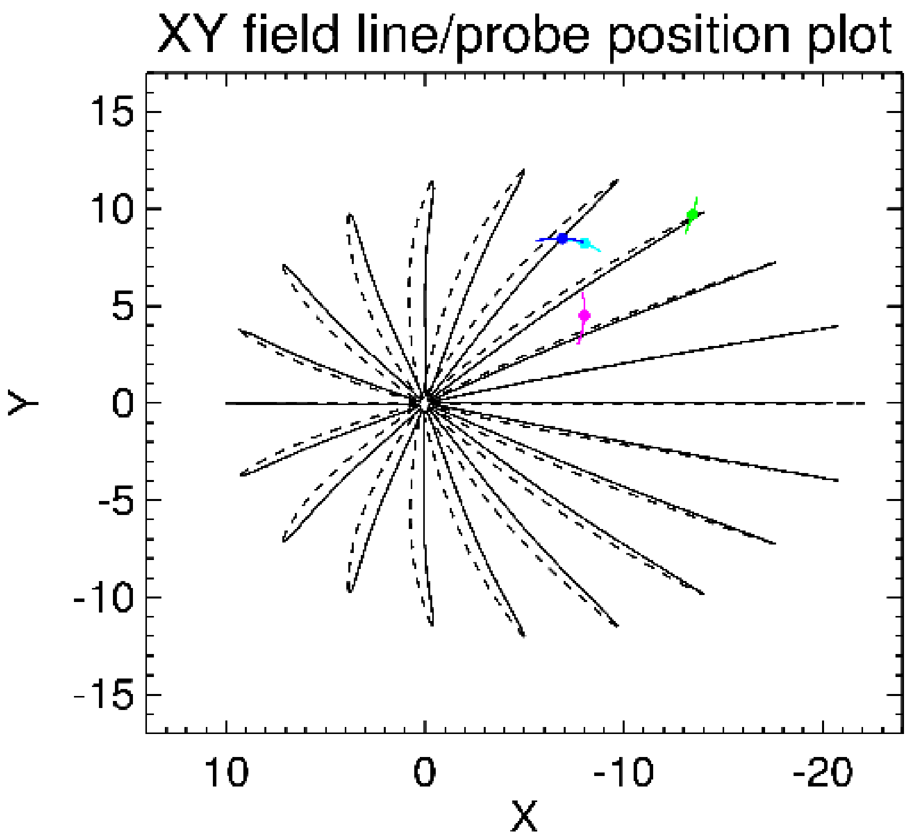
- New routines have been added to perform different 2d projections of 3d data. This particularly useful for plotting orbits and field lines.
- A Tsyganenko interface has been added to TDAS that allows us to calculate model field lines for T89,T96,T01,&T04 models. Field lines can also be Traced.
- Examples 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

Trace/Orbit Plots - AACGM/Iono Trace Plot



Trace / Orbit Plots – XY Plot



Trace / Orbit Plots – XZ Plot