Magnetic Field Models

- Magnetic Ephemeris calculations.
- Additional quantities to add.
- High resolution files.
- Problems with existing models.
- Field models for L4 processing?
- Recommendations

Magnetic Ephemeris Calculations

- The ECT team will provide magnetic ephemeris files to the rest of the RBSP teams (and anyone else who wants them).
- The Coordinates Committee (CooCoo) identified a minimal set of coords/quantities and we are currently computing all of those + some additional things.

  (See http://www.rbspect.lanl.gov/MagEphemDataFiles.php).
- 4 field models have been chosen: Two static – OP77, T89Kp2; and two dynamic – T89Dyn, T04sDyn.

MagEphem Quantities

Variable	Description	Units
Alpha	Pitch Angles	Degrees
PerigeeTimes	Perigee Times on this day	ISO8601 DateTime
PerigeePosGeod	Perigee Positions on this day in Geodetic Coords (lat/lon/alt).	Deg., Deg., km
ApogeeTimes	Apogee Times on this day.	ISO8601 DateTime
ApogeePosGeod	Apogee Positions on this day in Geodetic Coords (lat/lon/alt).	Deg., Deg., km
DateTime	The date and time in ISO 8601 compliant format.	ISO8601 DateTime
Date	The date. In YYYMMDD format.	
DOY	Ordinal Day of Year	Days
UTC	Universal Time (Coordinated). In decimal hours.	Hours
JulianDate	Julian Date. In decimal days.	Days
GpsTime	Number of SI seconds since 0h Jan 6, 1980 UTC.	Seconds

MagEphem Quantities

Variable	Description	Units
DipoleTiltAngle	Angle between Zgsm and Zsm (i.e. between Zgsm and dipole axis direction).	Degrees
Rgeo	Geocentric Geographic position vector of S/C.	Re
Rgeod_LatLon	Geodetic Geographic Latitude and Longitude of S/C.	Degrees
Rgeod_Height	Geodetic Geographic Height (Above WGS84 Ellipsoid) of S/C.	km
Rgsm	Geocentric Solar Magnetospheric position vector of S/C.	Re
Rsm	Geocentric Solar Magnetic position vector of S/C.	Re
Rgei	Geocentric Equatorial Inertial position vector of S/C.	Re
Rgse	Geocentric Solar Ecliptic position vector of S/C.	Re
CD_MLAT	Magnetic Latitude of S/C in Centerted Dipole Coordinates.	Degrees
CD_MLON	Magnetic Longitude of S/C Centerted Dipole Coordinates.	Degrees
CD_MLT	Magnetic Local Time of S/C in Centerted Dipole Coordinates.	Hours

MagEphem Quantities

Variable	Description	Units
CD_R	Radial distance of S/C from center of CDMAG coordinate system.	Re
ED_MLAT	Magnetic Latitude of S/C in Eccentric Dipole Coordinates.	Degrees
ED_MLON	Magnetic Longitude of S/C Eccentric Dipole Coordinates.	Degrees
ED_MLT	Magnetic Local Time of S/C in Eccentric Dipole Coordinates.	Hours
ED_R	Radial distance of S/C from center of EDMAG coordinate system.	Re
IntModel	Internal magnetic field model.	
ExtModel	External magnetic field model.	
Kp	Kp index value.	
Dst	Dst index value.	nT

MagEphem Quantities

Variable	Description	Units
Bsc_gsm	Magnetic field vector at S/C (in GSM coords).	nT
FieldLineType	Description of the type of field line the S/C is on., Can be one of 4 types: LGM_CLOSED - FL hits Earth at both ends. LGM_OPEN_N_LOBE - FL is an OPEN field line rooted in the Northern polar cap. LGM_OPEN_S_LOBE - FL is an OPEN field line rooted in the Southern polar cap. LGM_OPEN_IMF - FL does not hit Earth at eitrher end.	
S_sc_to_pfn	Distance between S/C and Northern Footpoint along field line.	Re
S_sc_to_pfs	Distance between S/C and Southern Footpoint along field line.	Re
S_pfs_to_Bmin	Distance between Southern Footpoint and Bmin point along field line.	Re
S_Bmin_to_sc	Distance between Bmin point and S/C along field line (positive if north of Bmin).	Re
S_total	Total Field Line length (along field line).	Re
d2B_ds2	Second derivative of |B| with respect to s (dist along FL) at minimum |B| point.	nT^2/Re^2
Sb0	Value of the 'Sb Integral' for equatorially mirroring particles (not generally zero).	Re
RadiusOfCurv	Field line radius of curvature at minimum |B| point.	Re

MagEphem Quantities

Variable	Description	Units
Pfn_geo	Location of Northern Footpoint (in GEO coords).	Re
Pfn_gsm	Location of Northern Footpoint (in GSM coords).	Re
Pfn_geod_LatLon	Geodetic Latitude and Longitude of Northern Footpoint.	Degrees
Pfn_geod_Height	Geodetic Height of Northern Footpoint.	km
Pfn_CD_MLAT	Magnetic Latitude of Northern Footpoint in Centerted Dipole Coordinates.	Degrees
Pfn_CD_MLON	Magnetic Longitude of Northern Footpoint Centerted Dipole Coordinates.	Degrees
Pfn_CD_MLT	Magnetic Local Time of Northern Footpoint in Centerted Dipole Coordinates.	Hours
Pfn_ED_MLAT	Magnetic Latitude of Northern Footpoint in Eccentric Dipole Coordinates.	Degrees
Pfn_ED_MLON	Magnetic Longitude of Northern Footpoint Eccentric Dipole Coordinates.	Degrees
Pfn_ED_MLT	Magnetic Local Time of Northern Footpoint in Eccentric Dipole Coordinates.	Hours

MagEphem Quantities

Variable	Description	Units
Bfn_geo	Magnetic field vector at Northern Footpoint (in GEO coords).	nT
Bfn_gsm	Magnetic field vector at Northern Footpoint (in GSM coords).	nT
Loss_Cone_Alpha_n	Value of Northern Loss Cone angle. asin(sqrt(Bsc/Bfn)).	Degrees
Pfs_geo	Location of Southern Footpoint (in GEO coords).	Re
Pfs_gsm	Location of Southern Footpoint (in GSM coords).	Re
Pfs_geod_LatLon	Geodetic Latitude and Longitude of Southern Footpoint.	Degrees
Pfs_geod_Height	Geodetic Height of Southern Footpoint.	km
Pfs_CD_MLAT	Magnetic Latitude of Southern Footpoint in Centerted Dipole Coordinates.	Degrees
Pfs_CD_MLON	Magnetic Longitude of Southern Footpoint Centerted Dipole Coordinates.	Degrees
Pfs_CD_MLT	Magnetic Local Time of Southern Footpoint in Centerted Dipole Coordinates.	Hours

MagEphem Quantities

Variable	Description	Units
Pfs_ED_MLAT	Magnetic Latitude of Southern Footpoint in Eccentric Dipole Coordinates.	Degrees
Pfs_ED_MLON	Magnetic Longitude of Southern Footpoint Eccentric Dipole Coordinates.	Degrees
Pfs_ED_MLT	Magnetic Local Time of Southern Footpoint in Eccentric Dipole Coordinates.	Hours
Bfs_geo	Magnetic field vector at Southern Footpoint (in GEO coords).	nT
Bfs_gsm	agnetic field vector at Southern Footpoint (in GSM coords).	nT
Loss_Cone_Alpha_s	Value of Southern Loss Cone angle. asin(sqrt(Bsc/Bfs)).	Degrees
Pmin_gsm	Location of minimum-|B| point (in GSM coords).	Re
Bmin_gsm	B-field at minimum-|B| point (in GSM coords).	nT
Lsimple	Geocentric distance to Bmin point for FL threading vehicle (i.e. |Pmin|).	Dimless
InvLat	Invariant latitude of vehicle computed from Lambda=acos(sqrt(1/Lsimple)).	Degrees

MagEphem Quantities

Variable	Description	Units
Lm_eq	McIlwain L of an eq. mirroring particle on same FL as vehicle (computed from L=Lm_eq, I=0, and Bm=|Bmin_gsm|, M=M_igrf).	Dimless
InvLat_eq	Invariant latitude of vehicle computed from Lambda=acos(sqrt(1.0/Lm_eq)).	Degrees
BoverBeq	Magntiude of Bsc over magnitude of Bmin.	Dimless
MlatFromBoverBeq	Dipole latitude where (B/Beq)_dipole == BoverBeq.	Degrees
M_used	The magnetic dipole moment that was used to convert magnetic flux to L*. In units of nT.	nT
M_ref	The fixed reference magnetic dipole moment for converting magnetic flux to L*. In units of nT.	nT
M_igrf	Time-dependant magnetic dipole moment (probably shouldn't be used for converting magnetic flux to L*, but it sometimes is). In units of nT.	nT
Lstar	Generalized Roederer L-shell value (also known as L*).	Dimless
L	McIlwain L-shell value.	Dimless
Bm	Magnetic field strength at mirror points for each pitch angle.	nT

MagEphem Quantities

Variable	Description	Units
I	Integral invariant for each pitch angle.	Re
K	Second Invariant (I*sqrt(Bm)) for each pitch angle.	Re G^0.5
Sb	Sb Integral for each pitch angle.	Re
Tb	Bounce period for 1 MeV electrons.	Seconds
Kappa	Kappa parameter for 1MeV electrons -- sqrt((Minimum Radius of Curvature)/Maximum gyroradius)) (see BÅ¼chner, J., and L. M. Zelenyi (1989), Regular and Chaotic Charged Particle Motion in Magnetotaillike Field Reversals, 1. Basic Theory of Trapped Motion, J. Geophys. Res., 94(A9), 11,821â€“11,842, doi:10.1029/JA094iA09p11821.	Dimless

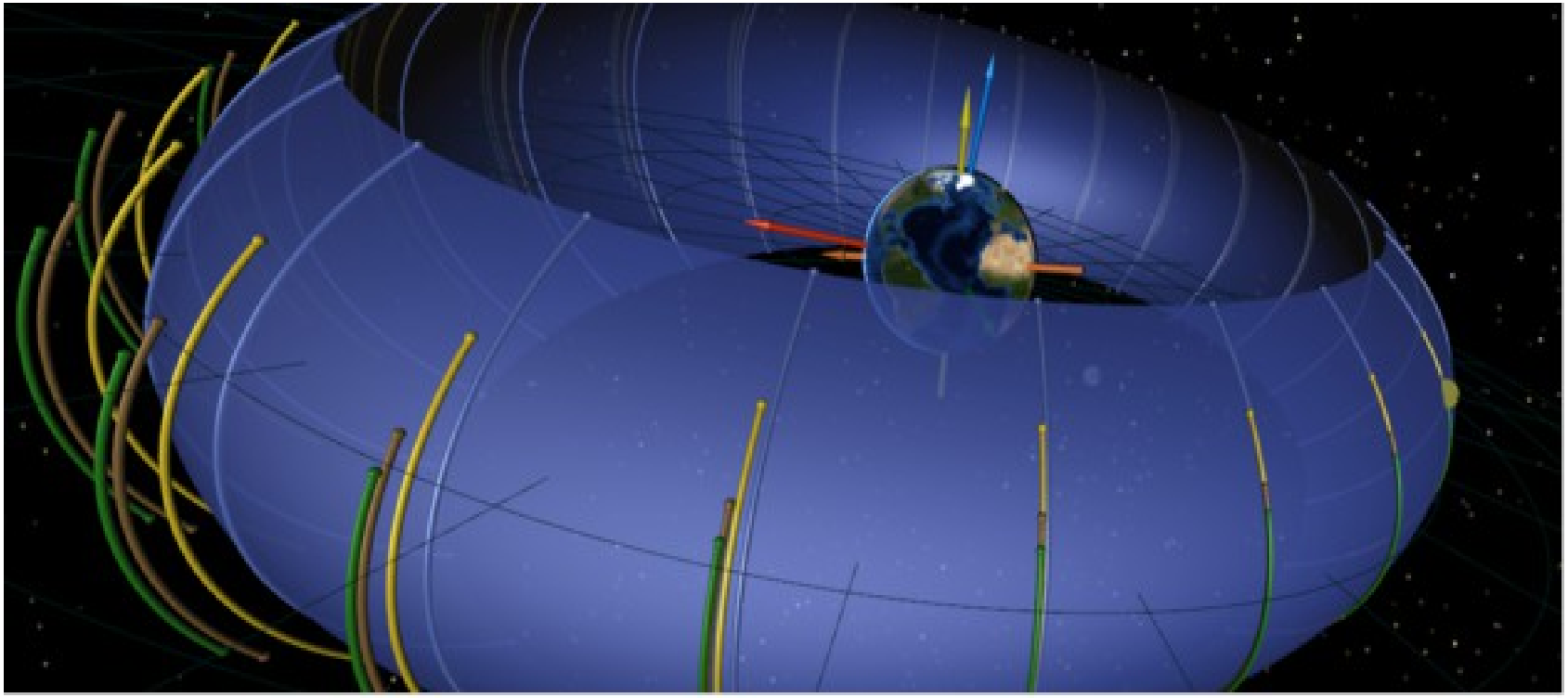
Possible additional quantities to add

- Drift periods for electrons/protons.
- Flag to indicate the type of drift shell (e.g. open, closed, shabansky).
- Other coordinate systems or quantities? Any requests?

High Resolution Files

- We dump binary files of the full drift shell calculations on demand. These include all field lines used to construct the shells as well as MLT-depndent quantities like I, K, Sb, mirror point locations, footpoint locations, Vgc (optional – based on gradient of I), etc.
- These can be visualized in an OpenGL application we have written at LANL.

ViewDriftShell Application



Problems with Existing Models

- Kp-dependent models (T89) are discontinuous!
- OP77 quiet has no dynamics at all. Limited domain of validity.
- TS04 is pretty slow.
- None of the statistical models can reproduce individuals events. (This is likely true of any of the newer models as well.)

Magnetic Fields for L4?

- What magnetic field should be used for conversion of Flux to PSD(mu,K) and E to Mu?
- The problem is that some of the quantities required for these operations (K, L*) require a global specification of B – and that is not available as a measurement.
- Using local B measurements to compute mu + model to get K, L*, etc. introduces inconsistencies at the outset because in general the model field will predict a different local B.
- Ideally, we should use a model that also agrees with local measurements (e.g. event-fitted). We have used T96mod before and it can even reproduce sawtooth behavior.
- Other models? MHD, RAM-SCB, models with tunable parameters + Kalman Filtering?

Recommendations

- If possible, use event-fitted empirical models. If we adopt this approach, there is minimal overhead in computing L*, etc. And we could distribute the time-dependent coefficients as a data-product for all to use. ECT has begun to explore this option. Data inputs would be: all available B-field measurements (GOES, LANL-GEO(?), THEMIS, RBSPA/B, Dst, etc.). The model could also be constrained to fit other things like location of open/closed boundary (i.e. mapping constraints), magnetopause location, absence of x-lines inside of GEO orbit , temporal smoothing, etc... More ambitious would be to also constrain the model to give PSD matching at GEO (during quiet-ish times?). Could also explicitly add current wedge and fit to magnetometer data as well. Etc.
- Data-enhanced physics based models (e.g. via Kalman filtering) could also be used for special events (e.g. DREAM/RAM-SCB). (We can accommodate B-fields defined on arbitrary meshes.)
- Other models?