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**DEVELOPMENT OF A MAGNETOSPHERIC
SPECIFICATION MODEL**
Volume II: Appendices A, B, C, D, E

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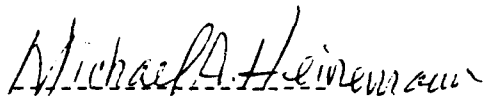
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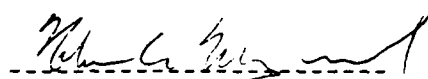


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This technical report has been reviewed and is approved for publication.

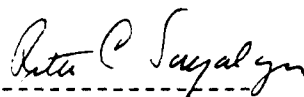


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<p>Rice University has developed a practical computer model that is capable of specifying electron and ion fluxes in the middle magnetosphere during geomagnetic storms. The model, called the Magnetospheric Specification Model (MSM), uses ground-based and satellite data from the Space Forecast Center-Environment Data Base to establish initial and boundary conditions and to determine input parameters for the magnetic and electric field models. These input values are updated every 15 minutes, and new output fluxes are computed for the same times. The primary function of the MSM is the specification of fluxes of 1-100 KeV electrons in the geostationary orbit region. However, it is also designed to specify a broad range of additional parameters for the global ionospheric-magnetospheric system, including fluxes of 1-50 KeV ions, auroral electron precipitation and ionospheric electric fields.</p>			
14. SUBJECT TERMS		15. NUMBER OF PAGES	
Electron fluxes	Spacecraft charging	Magnetic storms	414
Ion fluxes	Radiation belts	Proton fluxes	
Magnetosphere	Space radiation	Geomagnetic storms	
	Trapped radiation	Energetic particles	
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CONT OF BLOCK 13:

The model is accompanied by an application program that allows specification of fluxes at an arbitrary point in the magnetosphere within the modeling region. Consistent with its primary function, the MSM has been tested against spacecraft data for 2 substantial storms and has been shown to produce a good characterization of the enhancements of 40 KeV electron fluxes in the equatorial plane. The model never failed to predict high fluxes when they were observed, although it did predict high fluxes in some cases when they were not observed and it did fail to predict flux dropouts observed by the spacecraft. The MSM is ready for adaptation for use in an operational setting where the goal is real-time and retrospective specification of hazardous charged particle fluxes associated with geomagnetic storms.

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Appendix A

FUNCTIONAL DESCRIPTION

FUNCTIONAL DESCRIPTION - 1

Functional Description

2.2 Objectives. The Magnetospheric Specification Model was developed as a set of algorithms to be developed into a real-time program for use in the Space Forecast Center operated by the Air Weather Service of the U.S. Air Force. It is intended to help the Center personnel perform their mission of providing information, particularly during magnetospheric disturbances, to "customers" who operate spacecraft. The output of the model includes (but is not limited to):

- 1) Fluxes of electrons and ions in the inner plasma sheet and the geosynchronous orbit region.
- 2) Energy fluxes and characteristic energies of electrons precipitated into the auroral ionosphere.

2.4 Proposed Methods and Procedures.

The most sophisticated type of theoretical inner-magnetosphere/ionosphere model is exemplified by the Rice Convection Model (RCM). However, the Air Force requirement for near-real time data output and the relatively slow run-time of the RCM made it unsuitable for Air Force operational use. With these constraints in mind we dropped the self-consistent treatment and have separate ionospheric electric field and magnetospheric magnetic field models to trace particles in the magnetosphere equatorial plane (See attached flow chart). The magnetic field model provides the mapping between the two regions with the condition that the equatorward edge of the auroral zone in the ionosphere maps to the inner edge of the plasma sheet in the magnetospheric equatorial plane.

3.1 Specific Performance Requirements.

The output of the model includes fluxes of electrons and ions in the inner plasma sheet and the geosynchronous orbit region and energy fluxes and characteristic energies of the electrons and ions precipitated into the ionosphere. The throughput time will vary depending on the number and energy of particles traced, as well as the length of time for which the model is to be run.

3.2.1 Accuracy and Validity. The Magnetospheric Specification Model produces the most accurate and reliable specifications possible given the available input parameters and the state of magnetospheric science. The standard deviation of the model fluxes and available observed geosynchronous satellite data is output after each run.

3.2.2 Timing. Attached is a report on the throughput time on the IBM 3081 computer. All input data for the run will be acquired from the operational Environmental Database at the beginning of the run as shown on the MSM Control and Data Flow Diagram. All output data will be returned to the Environmental Database.

FUNCTIONAL DESCRIPTION - 2

3.2 Functional Area System Functions. The major components of the system are:

- MSMCON Main program - sets start, ending, and time steps for the run
- PPTCON Executive routine to control flow of Magnetospheric Specification Model
- EBCON Executive routine to control calculation of electric and magnetic field models
- PPTM Subroutine to trace particle trajectories from each grid point for each particle species back in time from time = TSTART to time = TSTOP

Attached is flow chart of each of the major components.

3.3 Inputs and Outputs.

Following is input within the program:

- ISTART(1) Start Year (last two digits)
- ISTART(2) Start Day (julian day). January 1 is day 1.
- ISTART(3) Start Time (seconds)
- IEND(1) End Year (last two digits)
- IEND(2) End Day (julian day) January 1 is day 1.
- IEND(2) End Time (seconds)
- IINC(1) Program time step increment (year)
- IINC(2) Program time step increment (day)
- IINC(3) Program time step increment (seconds)
- IRECEB For restart, record number of previously calculated electric and magnetic field output data to use as input for current run
- IRECPT For restart, record number of previously calculated particle-trace output data to use as input for current run

Following are the input files required, including those to be replaced by calls to the environmental data base:

- BOxxxxxx The magnetic field matrices needed for the model run.
- CLAPSE File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
- COORD File of values to set up the coordinate system.
- DST Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
- EFCOEF Coefficients from Heppner-Maynard model which are input to the electric field model.

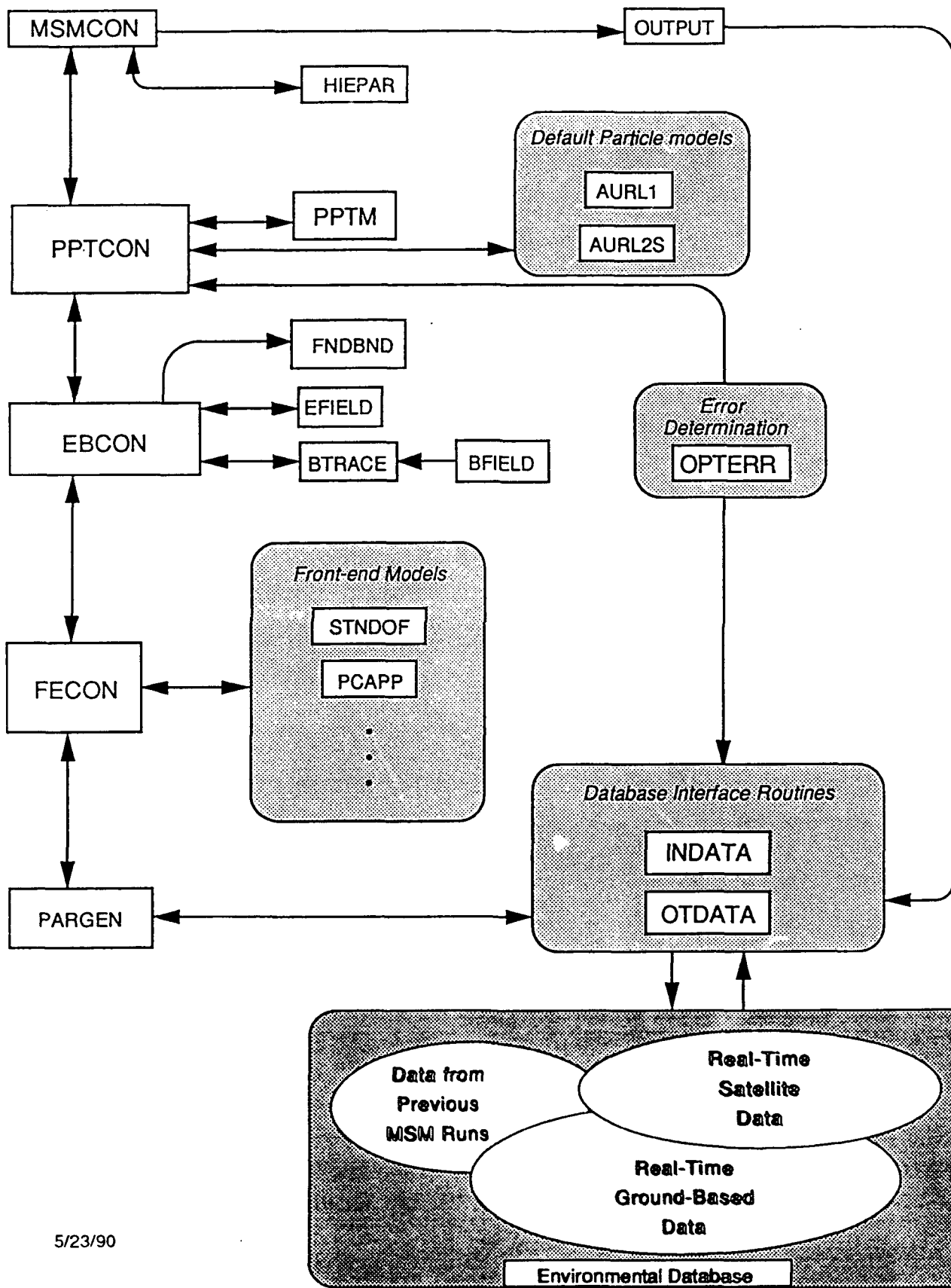
FUNCTIONAL DESCRIPTION - 3

ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

Following are the output files:

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts).
VNORTH	Northern hemisphere electric potential distribution (Volts).
VSOUTH	Southern hemisphere electric potential distribution (Volts).
VM	Flux tube volume ((Re/nT) ^{-2/3}).
BMIN	Equatorial magnetic field strength (nT).
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
BNDLOC	Location of outer boundary of detailed particle traces.
EFLUX	Precipitating energy flux array (ergs/cm ² -sec).
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec).
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV).
AUGPAR	Augmented data array for input values.
COLAT	Grid colatitude array (radians).
ALOCT	Grid local time array (radians eastward from noon).
FLUX	Flux values for all energy channels at all grid points

MSM Control & Data Flow Diagram



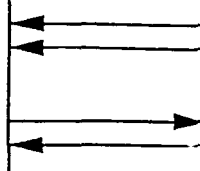
MSMCON

Main MSM control program

PARAMETER statement for array sizes
DIMENSION statements for all variables
Set starting and ending times
Perform major computations
Access high energy module
STOP

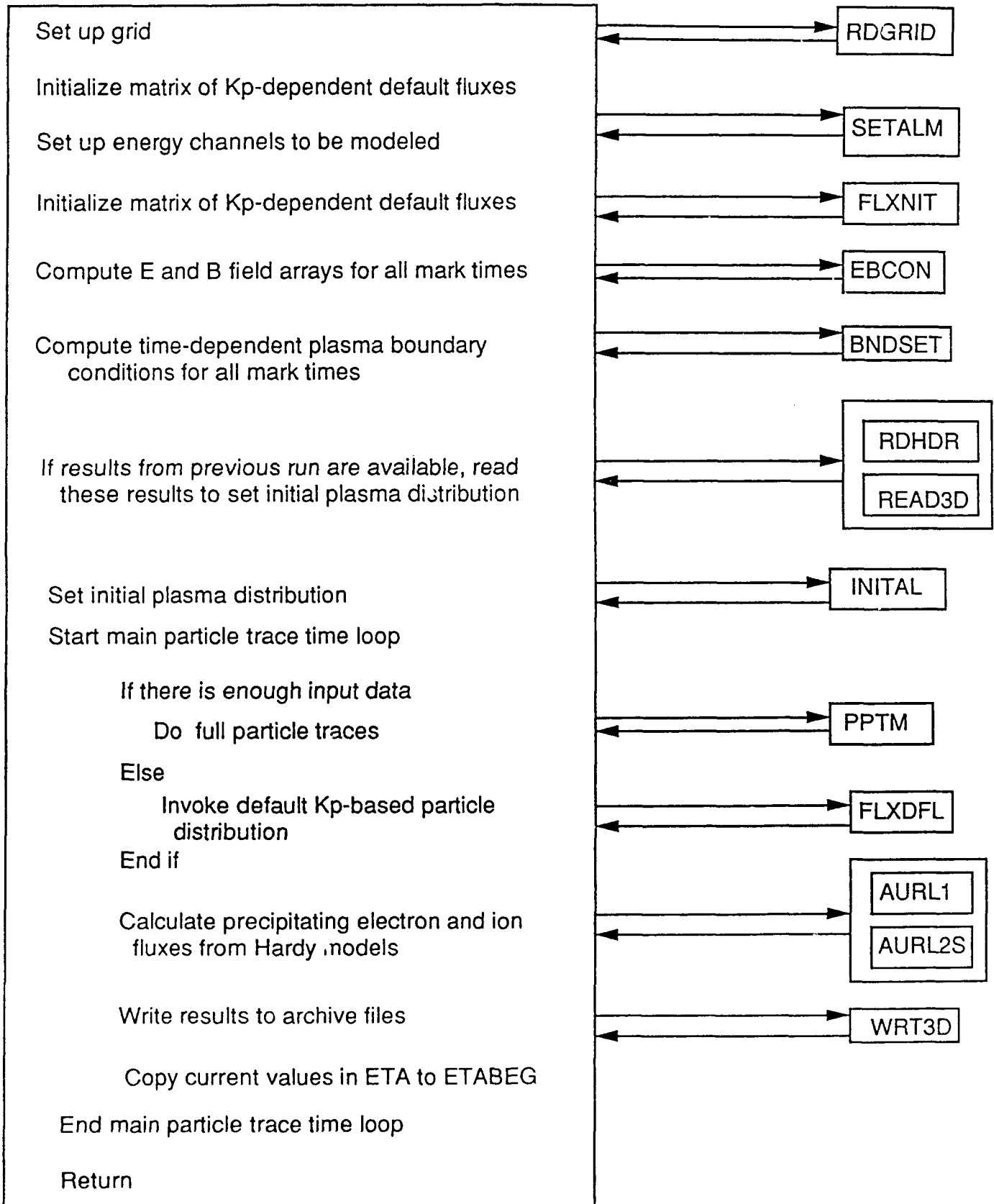
PPTCON

HIEPAR



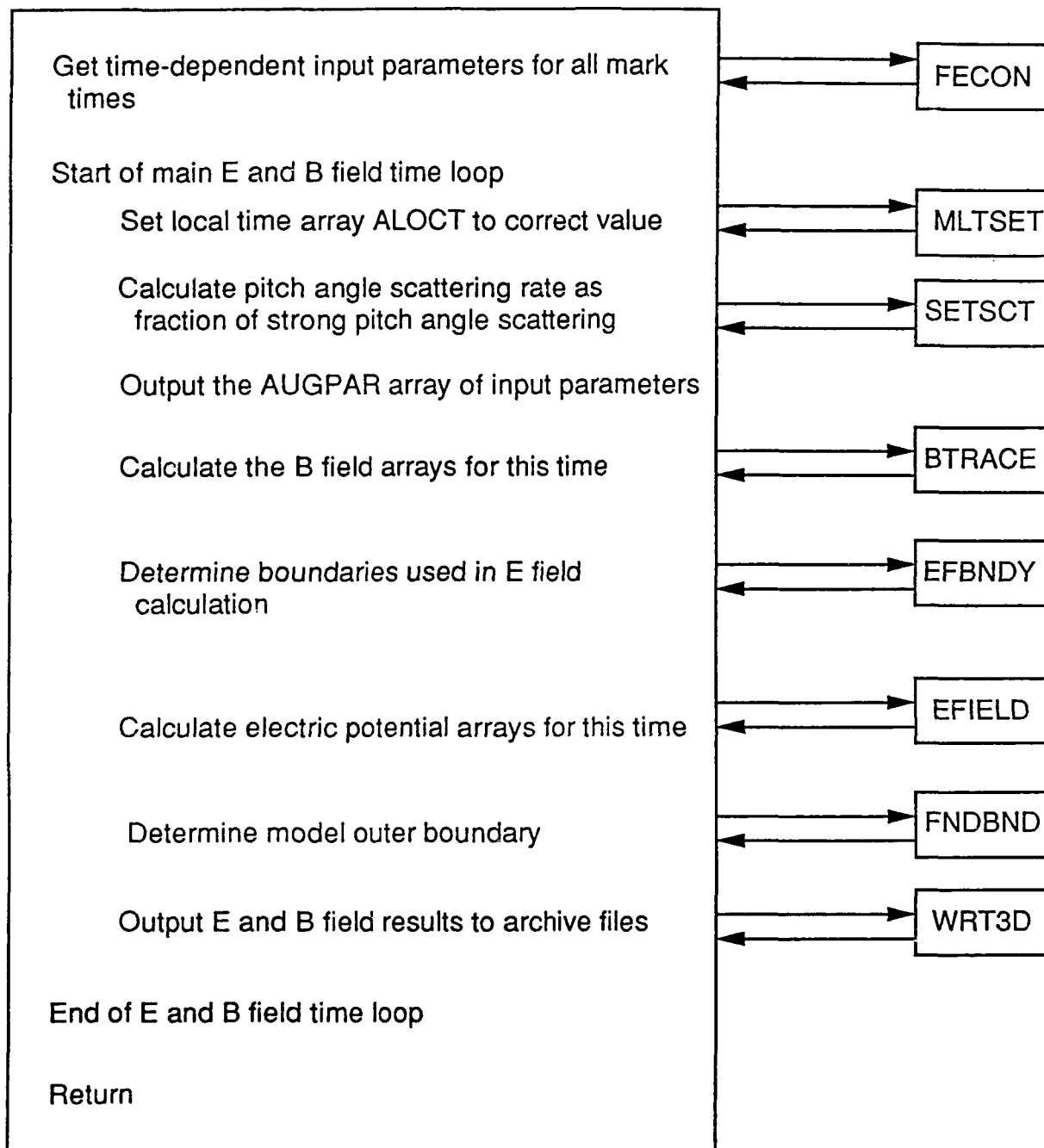
PPTCON

Subroutine that controls the major computations of the MSM.
This routine calls EBCON to construct E and B field matrices at
mark times and then proceeds to trace particle trajectories from
each grid point for each mark time.



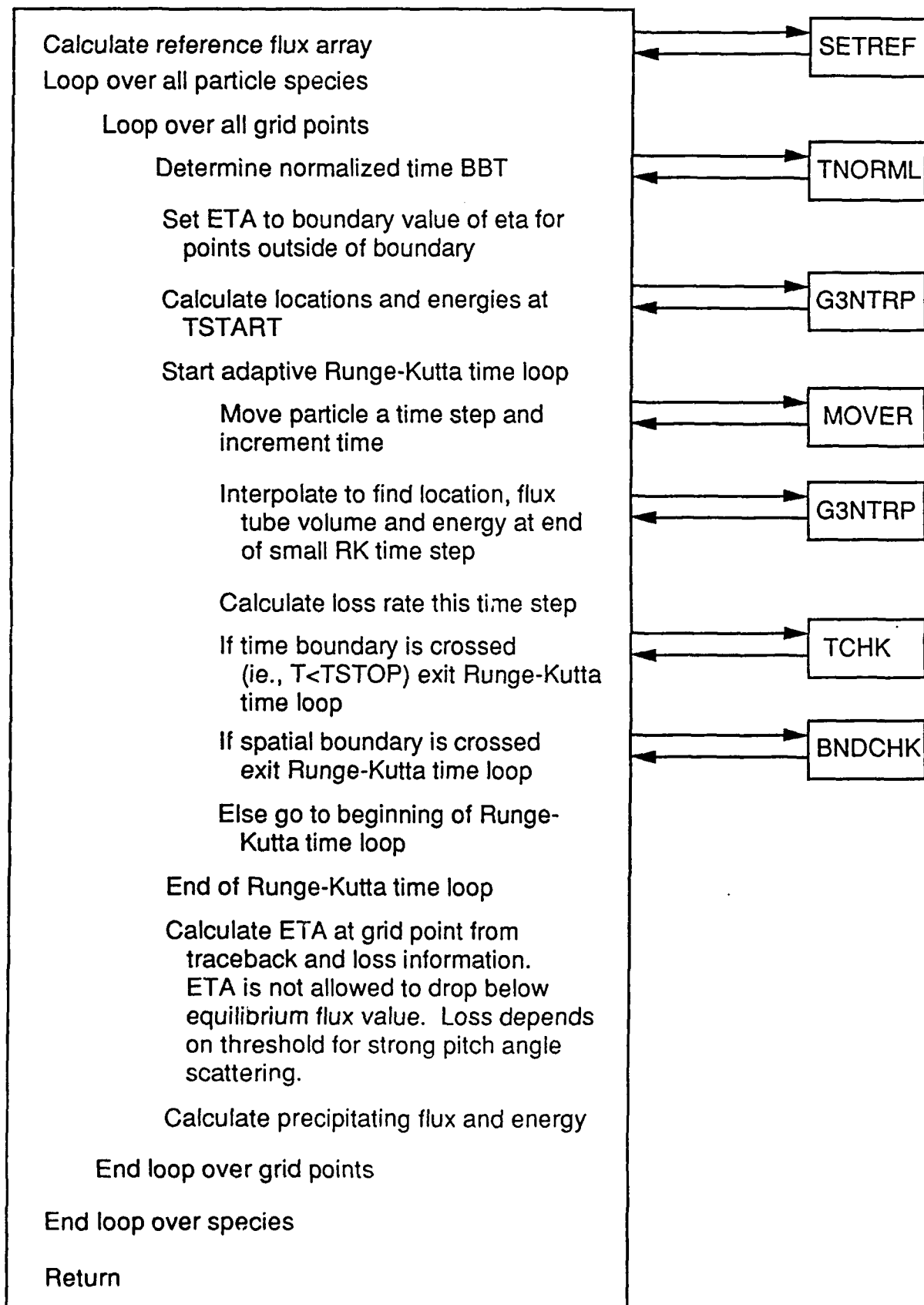
EBCON

Calculate E and B field arrays at grid points for mark times



PPTM

Subroutine to trace particle trajectories from each grid point for each particle species back in time one major time step from time = TSTART to time = TSTOP. (TSTART > TSTOP)



SYSTEM/SUBSYSTEM SPECIFICATION

System/Subsystem Specification

2.1 System/Subsystem Description. Attached is a flow chart of the major components of the Magnetospheric Specification Model. The major components of the model are MSMCON, PPTCON, EBCON, and PPTM.

2.2 System/Subsystem Functions.

MSMCON	Main program - sets start, ending, and time steps for the run
PPTCON	Executive routine to control flow of Magnetospheric Specification Model
EBCON	Executive routine to control calculation of electric and magnetic field models
PPTM	Subroutine to trace particle trajectories from each grid point for each particle species back in time from time = TSTART to time = TSTOP

2.2.1 Accuracy and Validity. The Magnetospheric Specification Model produces the most accurate and reliable specifications possible given the available input parameters and the state of magnetospheric science. The standard deviation of the model fluxes and available observed geosynchronous satellite data is output after each run.

2.2.2 Timing. Attached is a report on the throughput time on the IBM 3081 computer. All input data for the run will be acquired from the operational Environmental Database at the beginning of the run as shown on the MSM Control and Data Flow Diagram. All output data will be returned to the Environmental Database. No file interrogation takes place during the run.

4.3 System Data. The following files are necessary to restart the program:

BOxxxxxx	The magnetic field matrices needed for the model run.
COORD	File of values to set up the coordinate system.
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.

4.3.1 Inputs.

Following is input within the program:

ISTART(1)	Start Year (last two digits)
ISTART(2)	Start Day (julian day)
ISTART(3)	Start Time (seconds)
IEND(1)	End Year (last two digits)
IEND(2)	End Day (julian day)
IEND(2)	End Time (seconds)
IINC(1)	Program time increment (year)
IINC(2)	Program time increment (day)
IINC(3)	Program time increment (seconds)
IRECEB	For restart, record number of previously calculated electric and magnetic field output data to use as input for current run
IRECPT	For restart, record number of previously calculated particle-trace output data to use as input for current run

Following is the input files required, including those to be replaced by calls to the environmental data base:

BOxxxxxx	The magnetic field matrices needed for the model run.
CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
COORD	File of values to set up the coordinate system.
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).

SYSTEM/SUBSYSTEM SPECIFICATION - 3

SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

4.3.2 Outputs. The following files are output:

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VNORTH	Northern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VSOUTH	Southern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VM	Flux tube volume ((Re/nT) ^{-2/3}). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
BMIN	Equatorial magnetic field strength (nT). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
BNDLOC	Location of outer boundary of detailed particle traces. Output volume - number of longitudinal gridpoints × number of time steps × 4 (bytes)
EFLUX	Precipitating energy flux array (ergs/cm ² -sec). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × number of energy channels × 4 (bytes)
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons)

SYSTEM/SUBSYSTEM SPECIFICATION - 4

	(2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec).
EAVG	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 3 particle species × 4 (bytes) Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 3 particle species × 4 (bytes)
AUGPAR	Augmented data array for input values. Output volume - number of data elements × number of time steps × 4 (bytes)
COLAT	Grid colatitude array (radians). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
ALOCT	Grid local time array (radians eastward from noon). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
FLUX	Flux values for all energy channels at all grid points Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × number of energy channels × 4 (bytes)

4.3.3 Database/Data Bank. The attached chart lists the parameter inputs from the operational Environmental Database and a proposed data transfer method.

4.4 Software Unit Descriptions.

4.4.1 MSMCON - see attached flow chart.

PPTCON	Main control program for model
HIEPAR	High energy electron subroutine, currently a dummy routine pending computer code from Dan Baker, GSFC

4.4.2 PPTCON - see attached flow chart.

RDGRID	Subroutine to read grid system coordinates and calculate essential grid quantities
OUTP	Utility subroutine to print out array information
FLXNIT	Subroutine to calculate Kp-based particle number flux in units of particles/cm ² /s/sr/eV as function of R, energy and Kp
DTIME	Routine which returns current system time
EBCON	Executive routine to control calculation of electric and magnetic field models
EPREAD	Dummy routine to read satellite flux data - to be replaced by call to environmental data base when program is operational
SETALM	Subroutine to read the number of energy channels and their energies at geosynchronous orbit and calculate the energy invariant species needed to run the program

SYSTEM/SUBSYSTEM SPECIFICATION - 5

BNDSET	Subroutine to compute boundary plasma distribution
RDHDR	Subroutine to read the header record of the standard MSM disk file format
INITAL	Subroutine to compute initial plasma distribution
PPTM	Subroutine to trace particle trajectories from each grid point for each particle species back in time from time=TSTART to time=TSTOP
FLXDFL	Subroutine to calculate the energy-dependent ETA array from Kp and the location of the grid points by interpolating the empirical FLXMAT array - this routine is used as the MSM default model when full particle traces are not done
AURL1	Subroutine to determine default Hardy precipitating electron flux
AURL2S	Subroutine to determine default Hardy precipitating ion flux
PWRCAL	Subroutine to estimate precipitating electron energy flux poleward of the main MSM modeling region by comparing flux within modeling region with Hardy statistical values
WRT3D	Subroutine to write 3-d arrays into the standard MSM disk file format

4.4.3 EBCON - see attached flow chart.

FECON	Subroutine to obtain time-normalized observational values
MLTSET	Subroutine to calculate time dependent ALOCT of rotating grid points
SETSCT	Subroutine to set species dependent pitch angle scattering efficiency
BTRACE	Subroutine to calculate magnetic field models appropriate for geophysical conditions as specified by standoff distance, equatorward edge of the auroral zone, Dst, tail collapse, and tilt angle
EFBNDY	Subroutine to calculate latitudes and widths of electric field model boundaries 2 and 3
EFIELD	Subroutine to return values of the potential on the northern hemisphere grid (VNORTH), on the southern hemisphere grid (VSOUTH), and the average of the two hemispheres (V)
OUTP	Utility subroutine to print out array information
FNDBND	Subroutine to compute time dependent outer boundary location
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
VMLSET	Subroutine to calculate VMLOSS array
WRT3D	Subroutine to write 3-d arrays into the standard MSM disk file format

4.4.4 PPTM - see attached flow chart.

SETREF	Subroutine to set upper limit reference flux
OUTP	Utility routine to print our array information
TNORML	Utility function subprogram to calculate run-normalized time
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
WKRATE	Function subprogram to evaluate weak precipitation loss rate
MOVER	Subroutine to advance one particle location one time step using 4th-order Runge-Kutta algorithm with 5th order correction

SYSTEM/SUBSYSTEM SPECIFICATION - 6

MODFIX Subroutine to adjust BBJ to be between 2 and JDIM-1
TCHK Subroutine to check whether time boundary was crossed
BNDCHK Subroutine to determine whether particle has crossed boundary of calculation
FLXVAL Function subprogram to calculate Kp-dependent flux value a R=RR for particles
of energy ENRG and Kp=FKP by interpolating FLXMAT array

PARAMETER	NAME	UNITS	IO	Time Tag	Geo. Latitude	Geo. Longitude	Altitude	Mag. Local Time
KP	FKP	NONE	I	X				
Dst	DST	NANOTESLA	I	X				
C2	C2	NONE	I	X				
LOW LAT AURORAL BOUNDARY	DLATAZ	DEGREES	I	X			X	X
EQ. EDGE R1 CURRENTS	EDGER1	DEGREES	I	X			X	X
EQ. EDGE R2 CURRENTS	EDGER2	DEGREES	I	X			X	X
POLAR CAP POTENTIAL	PCP	KILOVOLTS	I	X				
POLAR CAP POTENTIAL PATTERN	XIPATT	NONE	I	X				
POLAR CAP BOUNDARY LATITUDE	PCBND	T.B.D.	I	X				
PRECIPITATION POWER INDEX	P	NONE	I	X				
GEO MAG X COMP.	GEOMGX	NANOTESLA	I	X				X
GEO MAG Y COMP.	GEOMGY	NANOTESLA	I	X				X
GEO MAG Z COMP.	GEOMGZ	NANOTESLA	I	X				X
GEO ELECTRON FLUX - CHANNEL(I)	EFLX(I)	ELEC/CM ² -S	I	X				X
GEO ION FLUX - CHANNEL(I)	GFLX(I)	IONS/CM ² -S	I	X				X
SOLAR WIND VELOCITY	SWVEL	KM/S	I	X	X	X	X	X
SOLAR WIND DENSITY	SWDEN	PROT/CM ³	I	X	X	X	X	X
IMF X COMPONENT	XIMFBX	NANOTESLA	I	X	X	X	X	X
IMF Y COMPONENT	XIMFBY	NANOTESLA	I	X	X	X	X	X
IMF Z COMPONENT	XIMFBZ	NANOTESLA	I	X	X	X	X	X

INPUT ONLY:

Data Transfer Method

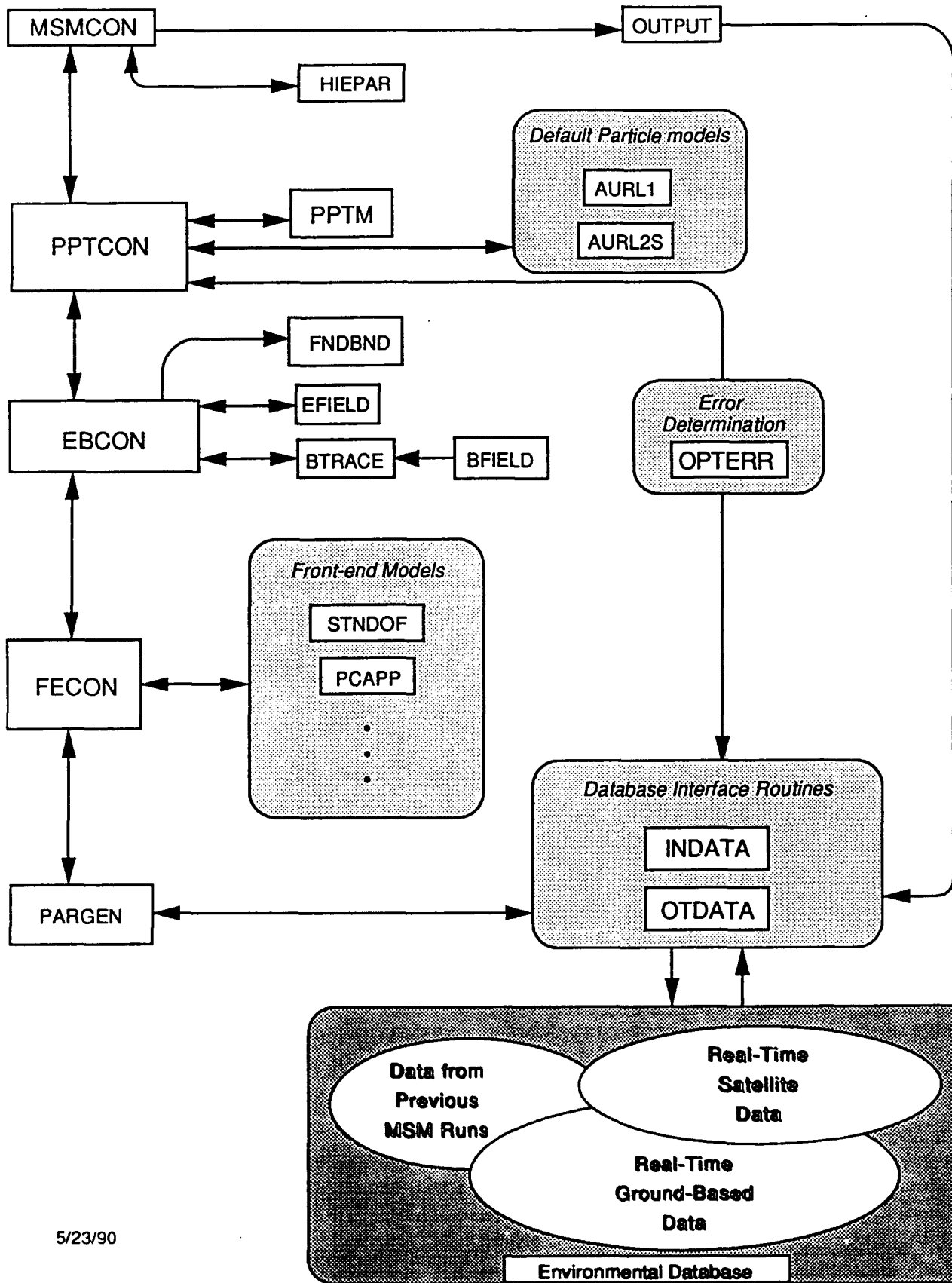
1. MSM will access the environmental database input data files by calling a subroutine, **INDATA**.
2. The call will be of the form:
CALL INDATA(parm-name, **STARTT**, **ENDT**, **NDIM**, **DARRY**, **NUMNUM**)
 Where:
parm-name is a valid parameter name from the MSM input parameter list.
STARTT is the starting time for this data request.
ENDT is the ending time for this data request.
NDIM is the horizontal dimension of **DARRY** and the maximum number of data points that may be returned.
DARRY is a two dimensional array to be retrieved from the database. The form of **DARRY** is shown on the next page. The size of **DARRY** will be **NDIM** by 7.
NUMNUM is the number of data values placed in **DARRY** by **INDATA**.
3. The system controller will periodically update the input data files.
4. Rice does not plan to write **INDATA**.
5. All parameters will be in single precision, floating point format.
6. Output data will be passed from MSM to the environmental database via a subroutine, **OTDATA**.
7. The call to **OTDATA** will be defined similarly to **INDATA**.
8. Rice does not plan to write **OTDATA**.

Format for DARRY

NDIM →

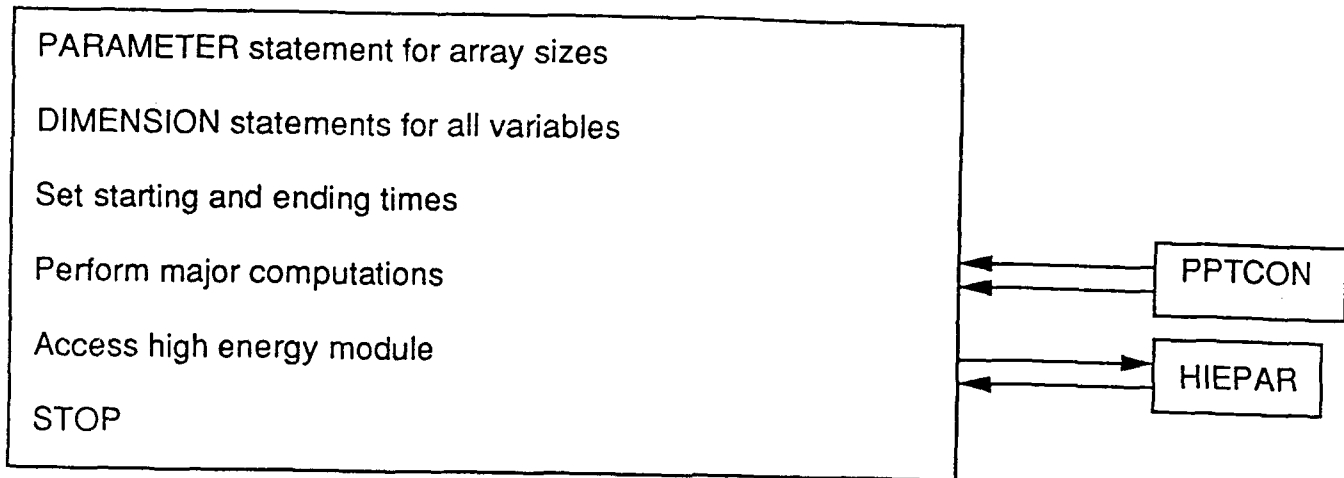
7 ↓	Data value at t1	Data value at t2	Data value at t3	Etc.
	Time tag at t1	Time tag at t2	Time tag at t3	
	Latitude	Latitude	Latitude	
	Longitude	Longitude	Longitude	
	Altitude	Altitude	Altitude	
	mag. local time	mag. local time	mag. local time	

MSM Control & Data Flow Diagram



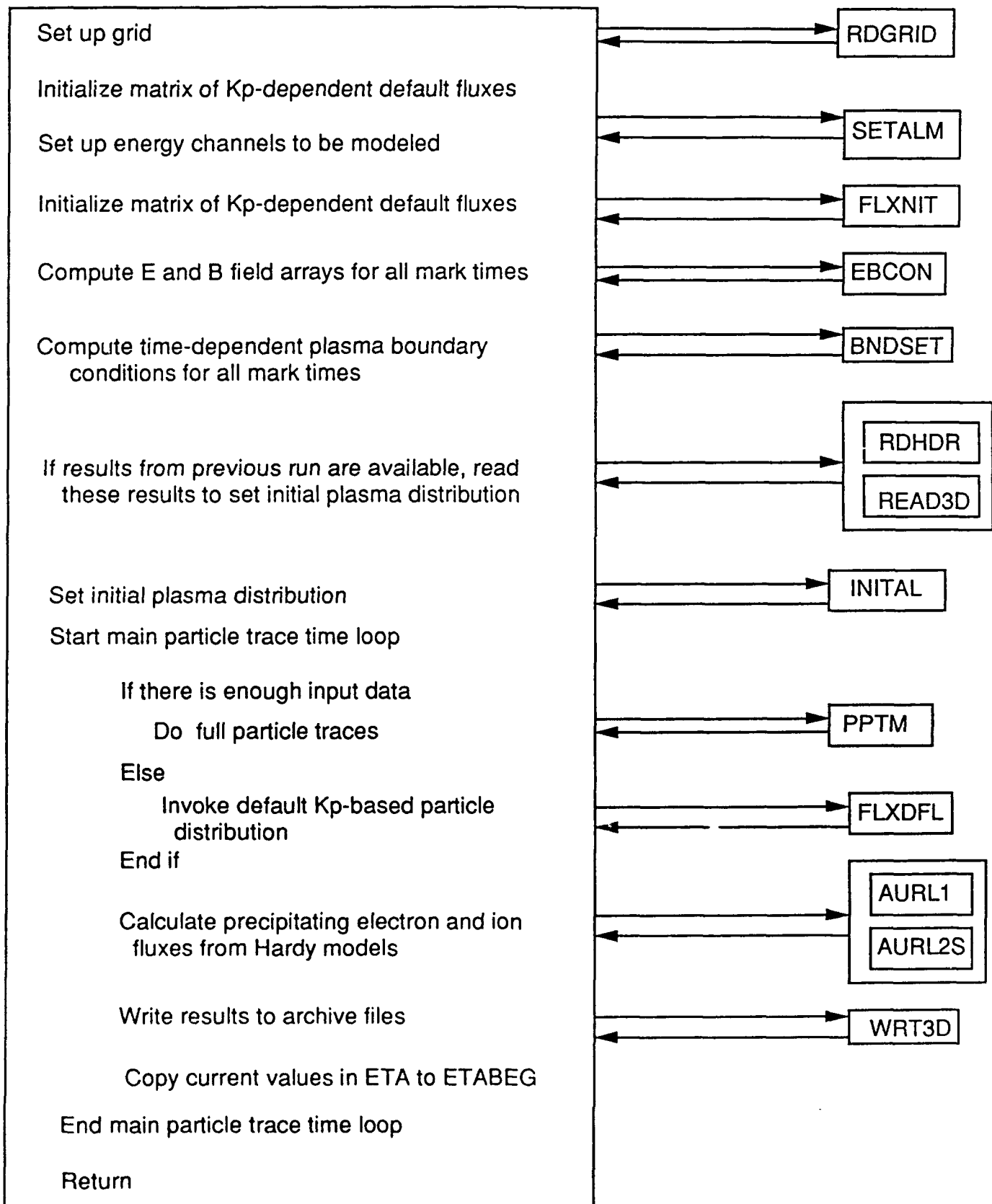
MSMCON

Main MSM control program



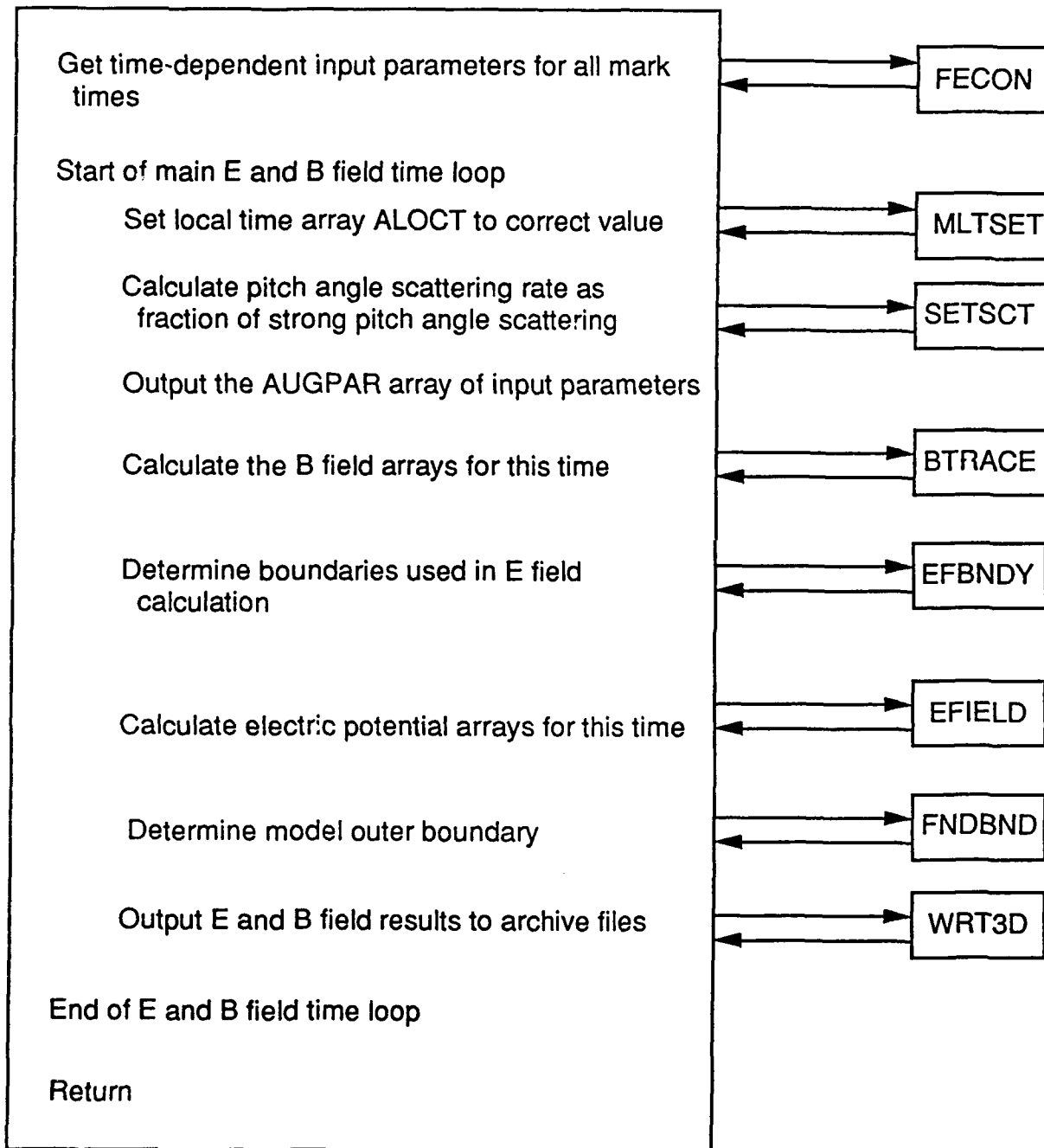
PPTCON

Subroutine that controls the major computations of the MSM.
This routine calls EBCON to construct E and B field matrices at
mark times and then proceeds to trace particle trajectories from
each grid point for each mark time.



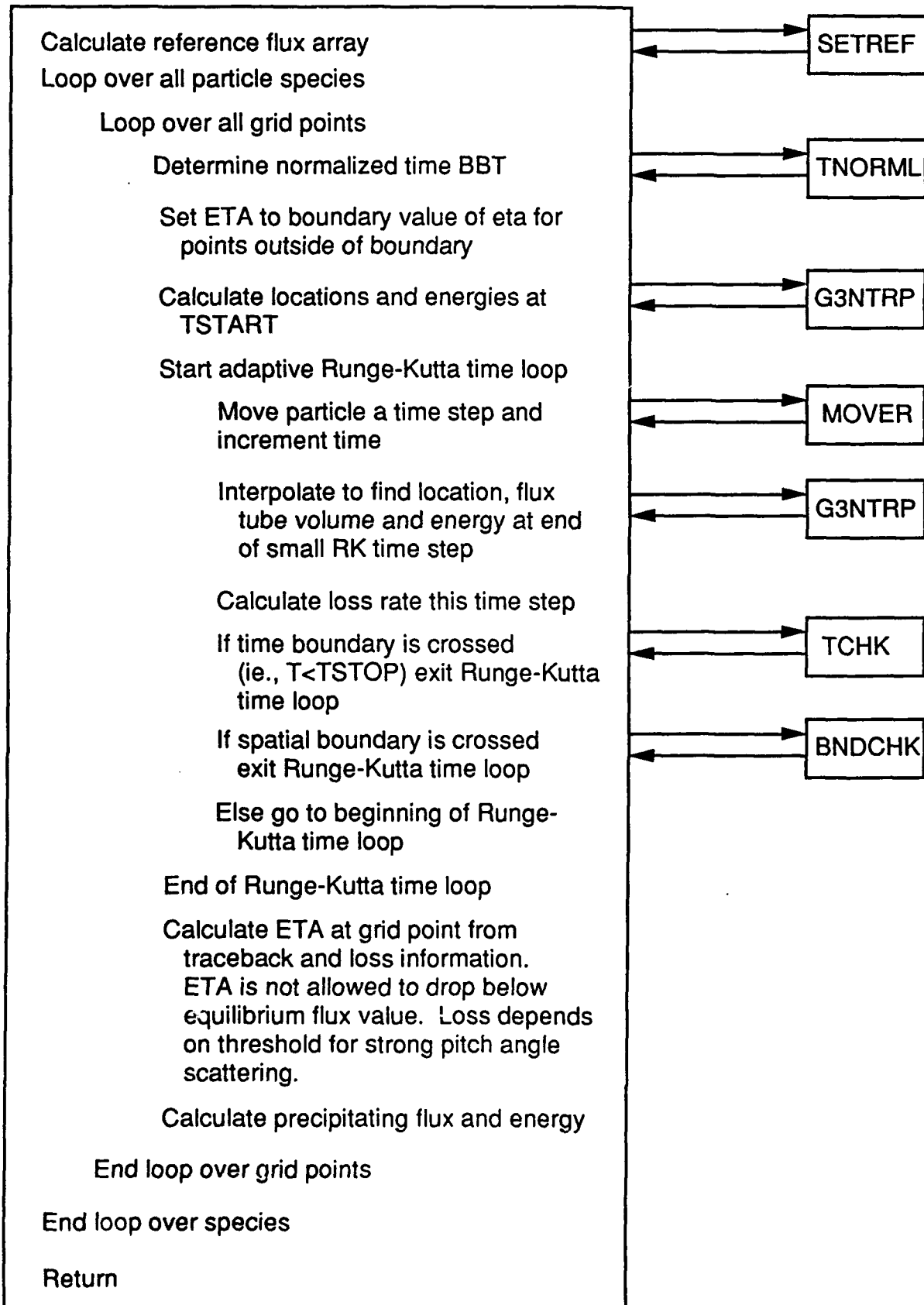
EBCON

Calculate E and B field arrays at grid points for mark times



PPTM

Subroutine to trace particle trajectories from each grid point for each particle species back in time one major time step from time = TSTART to time = TSTOP. (TSTART > TSTOP)



SOFTWARE UNIT SPECIFICATION

Software Unit Specification

2.2 Software Unit Functions. See the attached pages for the subroutine names, functions and calling environment.

2.2.1 Accuracy and Validity. The Magnetospheric Specification Model produces the most accurate and reliable specifications possible given the available input parameters and the state of magnetospheric science. The standard deviation of the model fluxes and available observed geosynchronous satellite data is output after each run.

2.2.2 Timing. Attached is a report on the throughput time on the IBM 3081 computer. All input data for the run will be acquired from the operational Environmental Database at the beginning of the run as shown on the MSM Control and Data Flow Diagram. All output data will be returned to the Environmental Database. No file interrogation takes place during the run.

4.3 Inputs.

Following is input within the program:

ISTART(1)	Start Year (last two digits)
ISTART(2)	Start Day (julian day)
ISTART(3)	Start Time (seconds)
IEND(1)	End Year (last two digits)
IEND(2)	End Day (julian day)
IEND(2)	End Time (seconds)
IINC(1)	Program time increment (year)
IINC(2)	Program time increment (day)
IINC(3)	Program time increment (seconds)
IRECEB	For restart, record number of previously calculated electric and magnetic field output data to use as input for current run
IRECPT	For restart, record number of previously calculated particle-trace output data to use as input for current run

Following is the input files required, including those to be replaced by calls to the environmental data base:

BOxxxxxx	The magnetic field matrices needed for the model run.
CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.

SOFTWARE UNIT SPECIFICATION - 2

COORD	File of values to set up the coordinate system.
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

4.3 Outputs. The following files are output:

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VNORTH	Northern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VSOUTH	Southern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VM	Flux tube volume ((Re/nT) ^{-2/3}). Output volume - number of latitudinal gridpoints × number of longitudinal

SOFTWARE UNIT SPECIFICATION - 3

BMIN	<p>gridpoints \times number of time steps \times 4 (bytes) Equatorial magnetic field strength (nT). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
XMIN	<p>gridpoints \times number of time steps \times 4 (bytes) GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
YMIN	<p>gridpoints \times number of time steps \times 4 (bytes) GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
ZMIN	<p>gridpoints \times number of time steps \times 4 (bytes) GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
BNDLOC	<p>gridpoints \times number of time steps \times 4 (bytes) Location of outer boundary of detailed particle traces. Output volume - number of longitudinal gridpoints \times number of time steps \times 4</p>
EFLUX	<p>(bytes) Precipitating energy flux array (ergs/cm²-sec). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
FLXSUM	<p>gridpoints \times number of time steps \times number of energy channels \times 4 (bytes) Total precipitation energy flux array (integrated over species for (1) electrons (2) H⁺ and (3) O⁺) (ergs/cm²-sec). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
EAVG	<p>gridpoints \times number of time steps \times 3 particle species \times 4 (bytes) Average precipitating electron energy for (1) electrons, (2) H⁺ and (3) O⁺ (eV). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
AUGPAR	<p>gridpoints \times number of time steps \times 3 particle species \times 4 (bytes) Augmented data array for input values. Output volume - number of data elements \times number of time steps \times 4 (bytes)</p>
COLAT	<p>Grid colatitude array (radians). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
ALOCT	<p>gridpoints \times number of time steps \times 4 (bytes) Grid local time array (radians eastward from noon). Output volume - number of latitudinal gridpoints \times number of longitudinal</p>
FLUX	<p>gridpoints \times number of time steps \times 4 (bytes) Flux values for all energy channels at all grid points</p>

SOFTWARE UNIT SPECIFICATION - 4

Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes)

MSM Routines by Function

Control Routines

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
MSMCON	Main program Sets start and ending times and time step for run.	not applicable	PPTCON HIEPAR
PPTCON	Executive routine to control flow of MSM. E and B field models are computed in EBCON; particle traces are done in PPTM.	MSMCON	RDGRID OUTP FLXNIT DTIME EBCON EPREAD SETALM BNDSET RDHDR INITAL PPTM FLXDFL AURL1 PWRCAL WRT3D
EBCON	Executive routine to control calculation of electric and magnetic field models.	PPTCON	FECON MLTSET SETSCT BTRACE EFBNDY EFIELD OUTP FNDBND G3NTRP VMLSET WRT3D
HIEPAR	Subroutine to give energetic particle results.	MSMCON	presently dummy

Magnetic Field Routines

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
BTRACE	Subroutine to calculate B field models appropriate for geophysical conditions as specified by FSTOFF, FEQEDG, FDST, FCLPSE, and FTILT.	EBCON	GETMAT RMVBESH BFGYRO
BFGYRO	Subroutine to rotate fixed grid B field arrays to match rotating coordinate system.	BTRACE	none
FNDBRK	Subroutine to find the proper B field array indices that bracket the magnetic field input parameters.	GETMAT	none
GETMAT	Subroutine to find the B field matrices needed for interpolation in order to represent current conditions.	BTRACE	MXINIT FNDBRK LOADBM ZEROBM OUTP
LOADBM	Subroutine to load individual B-matrices from the B-supermatrix into the work B-matrices.	GETMAT	none
MXINIT	Subroutine to initialize the array MEXIST to reflect the B-matrices that exist in the B-super matrix.	GETMAT	none
RMVBESH	Subroutine to extrapolate B-field matrices "into the bushes", ie., into extremely stretched or open regions.	BTRACE	none
ZEROBM	Subroutine to zero out an individual B matrix within the working B matrices. This is done when an individual matrix needed in the interpolation does not exist in the computed B-supermatrix.	GETMAT	none

Electric Field Routines

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
EFIELD	Subroutine to return values of the potential on the northern hemisphere grid (VNORTH), on the southern hemisphere grid (VSOUTH), and the average of the two hemispheres (V).	EBCON	EMODEL
AURORA	Returns potential at a specific location in auroral region.	EMODEL	none
EFBNDY	Subroutine to calculate latitudes and widths of efield bndys 2 and 3.	EBCON	EFLOC G3NTRP
EFLOC	Subroutine to find grid location (BI,BJ) of physical location (RVAL,XLT).	EFBNDY	PFIX
EMODEL	Returns the electric potential arrays VNORTH, VSOUTH, and V at all grid pts.	EFIELD	INPUT THET EPOT LOW AURORA REG1
EPOT	Using scaled Heppner-Maynard model returns potential at a specific pt.	EMODEL	none
FNDBND	Subroutine to compute time dependent outer boundary location.	EBCON	THET
INPUT	Get input needed for computation of Heppner-Maynard model.	EMODEL	none
LOW	Returns potential at a specific location in low latitude region.	EMODEL	none
REG1	Returns potential at a specific location in region 1.	EMODEL	none
THET	Function that gives eqn for an E field boundary ellipse in flat polar coordinates.	EMODEL FNDBND PWRCAL	none

Particle Trace Routines

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
PPTM	Subroutine to trace particle trajectories from each grid pt for each particle species back in time from time=TSTART to time=TSTOP.	PPTCON	SETREF OUTP TNORML G3NTRP WKRATE MOVER MODFIX TCHK BNDCHK FLXVAL
BNDCHK	Subroutine to determine whether particle has crossed bndy of calculation.	PPTM	TNORML
BNDSET	Subroutine to compute boundary plasma distribution.	PPTCON	none
CFACT	Function subprogram to compute correction factor based on equilibrium eta values.	not called	none
DVEFDI	Function subprogram to compute the I derivative of the effective potential at grid pt (I,J) at normalized time BT.	VLOCTY	none
DVEFDJ	Function subprogram to compute the J derivative of the effective potential at grid pt (I,J) at normalized time BT.	VLOCTY	none
FLXCAL	Subroutine to compute Kp-dependent flux at L=3,4,6,6, and 13 for electrons of given energy for a given Kp condition.	FLXNIT	none
FLXNIT	Subroutine to calculate Kp based particle number flux in units of particles/cm**2/s/sr/eV as function of r, energy, and Kp.	PPTCON	FLXCAL THRCAL
FLXVAL	Function subprogram to calculate Kp-dependent flux value at R=RR for particles of energy ENRG and KP=FKP by interpolating FLXMAT array.	PPTM BNDSET INITAL SETREF FLXDFL	G3NTRP

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
FLXTRP	Function subprogram to return LOG10 of empirical flux value interpolated between values at L=3,4,6.6, and 13 Re.	FLXNIT	none
INITAL	Subroutine to compute initial plasma distribution	PPTCON	FLXVAL
MOVER	Subroutine to advance one particle location one time step using 4th-order Runge-Kutta algorithm with 5th order correction.	PPTM	RK4
PWRCAL	Subroutine to estimate precipitating electron energy flux poleward of the main MSM modeling region by comparing flux within modeling region with Hardy statistical values.	PPTCON	THET
RK4	4th order Runge-Kutta routine	MOVER	VLOCTY
RLYONS	Function subprogram to evaluate Lyons-based weak loss rate.	WKRATE	none
SETALM	Subroutine to read the number of energy channels and their energies at geosynchronous orbit and calculate the energy invariant species needed to run the program.	PPTCON	none
SETREF	Subroutine to set upper limit reference flux.	PPTM	FLXVAL TNORML
SETSCT	Subroutine to set species dependent pitch angle scattering efficiency.	EBCON	none
TCHK	Subroutine to check whether time boundary was crossed.	PPTM	G3NTRP
THRCAL	Subroutine to calculate threshold flux at R=3, 4, 6.6, and 13 RE for KP=FKP and LOG(energy)=FNRGLG.	FLXNIT	none
VLOCTY	Subroutine to compute I and J components of particle velocity with energy invariant AALAM at location (BBI,BBJ) at normalized time BT.	RK4	G3NTRP

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
VMLSET	Subroutine to calculate VMLOSS array.	EBCON	none
WKRATE	Function subprogram to evaluate weak precipitation loss rate.	PPTM	RLYONS

Input and Output Data Handling

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
FECON	Subroutine to obtain time-normalized observational values.	EBCON	PARGEN
PARGEN	Subroutine to obtain values from the environmental data base and interpolate or extrapolate as appropriate to provide data at a normalized time.	FECON	INDATA DFLTVL SMOOTH DTXIPT DTNTRP TIMINC
DTNTRP	Subroutine to return interpolation values for the N data pairs of (XA(I),YA(I)), where I=1,NA.	PARGEN	none
DTXIPT	Subroutine to return interpolation values for XIPATT.	PARGEN	none
INDATA	Subroutine to read in data for the MSM during development and testing. This routine will be replaced in the operational MSM with an interface routine to the AWS environmental database.	PARGEN	none
OUTPUT	Subroutine to output MSM results to data base.	MSMCON	presently a dummy routine.
SMOOTH	Subroutine to check and extract data from DARRAY into XA and YA.	PARGEN	TCONV2
STNDOF	Subroutine to calculate the stand-off distance accordint to a formula from Alpbach (1979).	FECON	none

Default and Front-End Models

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
ADDHDY	Subroutine to calculate the Hardy model electron flux value for a given point.	AURL1	FSUM
AURL1	Subroutine to determine default Hardy precipitating electron flux.	PPTCON	FNDHDY ADDHDY
AURL2S	Subroutine to calculate the default Hardy precipitating ion model.	PPTCON	REGEN EFUN
CLPDFL	Subroutine to determine whether or not to use the collapsed tail version of the magnetic field model.	FECON	none
DSTDFL	Subroutine to calculate default (Kp driven) Dst value.	FECON	none
EFUN	Function subprogram used in evaluation of precipitating ion flux.	AURLS2	none
EQTDFL	Subroutine to calculate default (Kp driven) equatorward edge of auroral zone value.	FECON	none
FLXDFL	Subroutine to calculate the energy-dependent ETA array from Kp and the location of the grid pts by interpolating the empirical FLXMAT array. This routine is used as the MSM default model when full particle traces are not done.	PPTCON	FLXVAL
FNDHDY	Subroutine to find and read the pertinent Fourier coefficients for the Hardy electron model.	AURL1	none
FSUM	Function subprogram that determines the sum of a Fourier series for Hardy model.	ADDHDY	none
PATDFL	Subroutine to return polar-cap convection pattern type on the basis of measurements of IMF By and Bz components if direct measurements of pattern type from DMSP are not available.	FECON	none

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
PCPDFL	Subroutine to calculate default (Kp driven) cross-polar-cap potential value.	FECON	none
REGEN	Subroutine used in evaluation of Hardy model precipitating ion flux.	AURLS2	none
STNDFL	Subroutine to calculate the standoff distance. If solar wind velocity and density data are available, then Subroutine STNDOF does the actual calculation; otherwise, the default is Kp-based.	FECON	STNDOF
TILT	Subroutine to calculate the Earth's tilt angle. Tilt presently defaults to 0.	FECON	none

Utility Routines

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
BLOCK DATA	Sets index of data elements in the PARRAY and AUGPAR arrays. Sets I,J, and energy indices for locations and species to be traced.	Not applicable	Not applicable
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at pt (BI,BJ,BK).	EBCON PPTM TCHK VLOCTY EFBNDY FLXVAL PWRCAL	none
G3TRPA	Utility function subprogram to perform a general 3-d linear interpolation of an angular array.	PPTM	none
MLTSET	Subroutine to calculate time dependent ALOCT of rotating grid pts.	EBCON	none
MODFLX	Subroutine to adjust BBJ to be between 2 and JDIM-1.	PPTM VLOCTY	none
OUTP	Utility subroutine to print out array information.	Utility routine	none
PFIX	Subroutine to adjust modulus of periodic J coordinate.	EFLOC	none
RDGRID	Subroutine to read grid system coordinates and calculate essential grid quantities.	PPTCON	none
RDHDR	Subroutine to read the header record of the standard MSM disk file format.	PPTCON	none
READ3D	Subroutine to read a record from the standard MSM disk file format.	PPTCON	none
TCNV2	Function to take a start year, start decimal day, and current decimal day to produce a value that is the number of seconds from midnight of the start year and day.	SMOOTH	none

<i>Routine</i>	<i>Purpose</i>	<i>Called by</i>	<i>Calls</i>
TCONV3	Function to take a start year, start day, current year, current day, and current seconds of day to produce a value that is the number of seconds from midnight of the start year and day.	PARGEN	none
TIMINC	Subroutine to increment time for next E and B field record.	EBCON PARGEN FECON	none
TNORML	Utility function subprogram to calculate run-normalized time.	PPTM BNDCHK RK4 FNDLOC SETREF	none
WRT3D	Subroutine to write 3-d arrays into the standard MSM disk file format.	PPTCON EBCON	none

USERS MANUAL

Users Manual

2.5 System Performance. Some factors on which the system performance depends include:

1. Higher energy particles require more time to process. The particles move so rapidly that a smaller time step is required to move their position and the number of time steps required to move the particles on the grid is correspondingly higher.

2. The output files are updated every program time step. If the program is set to run for many time steps, the storage of these files could be a problem. The maximum number of time steps is set within the program to 50.

3. The maximum number of energy channels which can be run is set within the program to 30. The greater the number of channels selected, the longer the run time will be.

2.7 Database/Data Bank. During development the method of input and output is through disk files. These files will no longer be necessary when the Environmental Data Base interface is in place. Attached is a list of the input parameters and units. Also attached is the proposed data transfer method.

2.8 General Description of Inputs, Processing, Outputs.

a. Inputs -

The following parameters are set within the program:

IINC(1)	Program time step increment (year)
IINC(2)	Program time step increment (day)
IINC(3)	Program time increment (seconds)

Following are the input files required, including those to be replaced eventually by calls to the environmental data base:

* denotes the principal operator interfaces to the program

BOxxxxxx The magnetic field matrices needed for the model run.

CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
COORD	File of values to set up the coordinate system.
DKTABLE	Loss lifetimes for computing ion loss by charge exchange.
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete.
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN*	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete.
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.
MSMIN*	Specify start and stop times, a character list identifier, and sunspot number
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete.
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete.
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete.
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

b. Processing - After the data is gathered from the input files, it goes through Subroutine PARGEN which interpolates or extraplates data as appropriate to provide data a a normalized run-time. Subroutine FECON then calculates the physical parameters needed by the model for each run time label. When the Environmental Database interface is operational, output from the model will then return to the Environmental Data Base through Subroutine OUTPUT. (At present OUTPUT) is only a place-holding stub.) The MSM Control and Data Flow Diagram is attached.

c. Outputs. The following files are output:

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output for each time label.
VNORTH	Northern hemisphere electric potential distribution (Volts). Output for each time label.
VSOUTH	Southern hemisphere electric potential distribution (Volts). Output for each time label.
VM	Flux tube volume $((R_e/nT)^{-2\beta})$. Output for each time label
BMIN	Equatorial magnetic field strength (nT), Output for each time label
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
BNDLOC	Location of outer boundary of detailed particle traces. Output for each time label
EFLUX	Precipitation energy flux array (ergs/cm ² -sec). Output for each time label
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec). Output for each time label
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV). Output for each time label
AUGPAR	Augmented data array for input values. Output for each time label
COLAT	Grid colatitude array (radians). Output for each time label
ALOC	Grid local time array (radians eastward from noon). Output for each time label
FLUX	Flux values for all energy channels at all grid points. Output for each time label for each energy channel

3.2 Input Requirements.

Start and stop times are specified to the program through the 5 line MSMIN file as year (eg., 1988), day (eg., 112 for the 112 th day of the year), and time in seconds from the beginning of the start day (eg., 43200 for noon). For example, the following configuration of the MSMIN file will run the

MSM from 1800 on the 112th day of 1988 through 1830 on the same day. This is a fresh startup of the program (direct access record number is zero) and the sunspot number is 0.0.

1988 112 64800	'start year, start day, start time in seconds'
1988 112 66600	'end year, end day, end time in seconds'
0	'0 signifying new start'
'30 minute test run'	'up to 80 character run identification'
0.0	'sunspot number'

The time step increment is set in the program through the IINC vector.

IINC(1) = Increment Year
 IINC(2) = Increment Day
 IINC(3) = Increment Time (seconds)

If the run is to be a restarted using previous data, the direct access record number for restarting is also read from the MSMIN file. For example, the program is currently set up to run year 1988, day 112, hour 18 (64800 seconds) through year 1988, day 112, hour 1830 (66000 seconds) in 15 minute (900 second) increments. Since it is a new run the start record number is set to zero in MSMIN.

If after running this interval you want to restart the model at hour 1830 and continue through hour 20, the MSMIN input file would be:

```
1988 112 66600
1988 112 72000
3
'MSM run restart from 1830 on day 112'
0.0
```

The model would go back, pick up the original 5 records and continue the run from hour 19 to hour 20.

Input file ENCHAN controls how many and which energy channels are calculated. The file set up is:

```
Number of energy channels to be modeled (maximum 30, integer)
Particle type 1 (integer), Energy 1 (floating point)
Particle type 2 (integer), Energy 2 (floating point)
. . . . .
Particle type n (integer), Energy n (floating point)
```

The acceptable particle type input is:

- 1 electrons
- 2 H⁺
- 3 O⁺

The energy is at geosynchronous orbit in keV. The energies must be in ascending order, with particle types grouped together, which are checked within the program.

For example,

- 4
- 1 40
- 1 55
- 2 10
- 2 15

This is to model 4 energy channels, the first two are electrons of 40 and 55 keV at geosynchronous orbit. The second two are H⁺ ions of 10 and 15 keV energy at geosynchronous orbit.

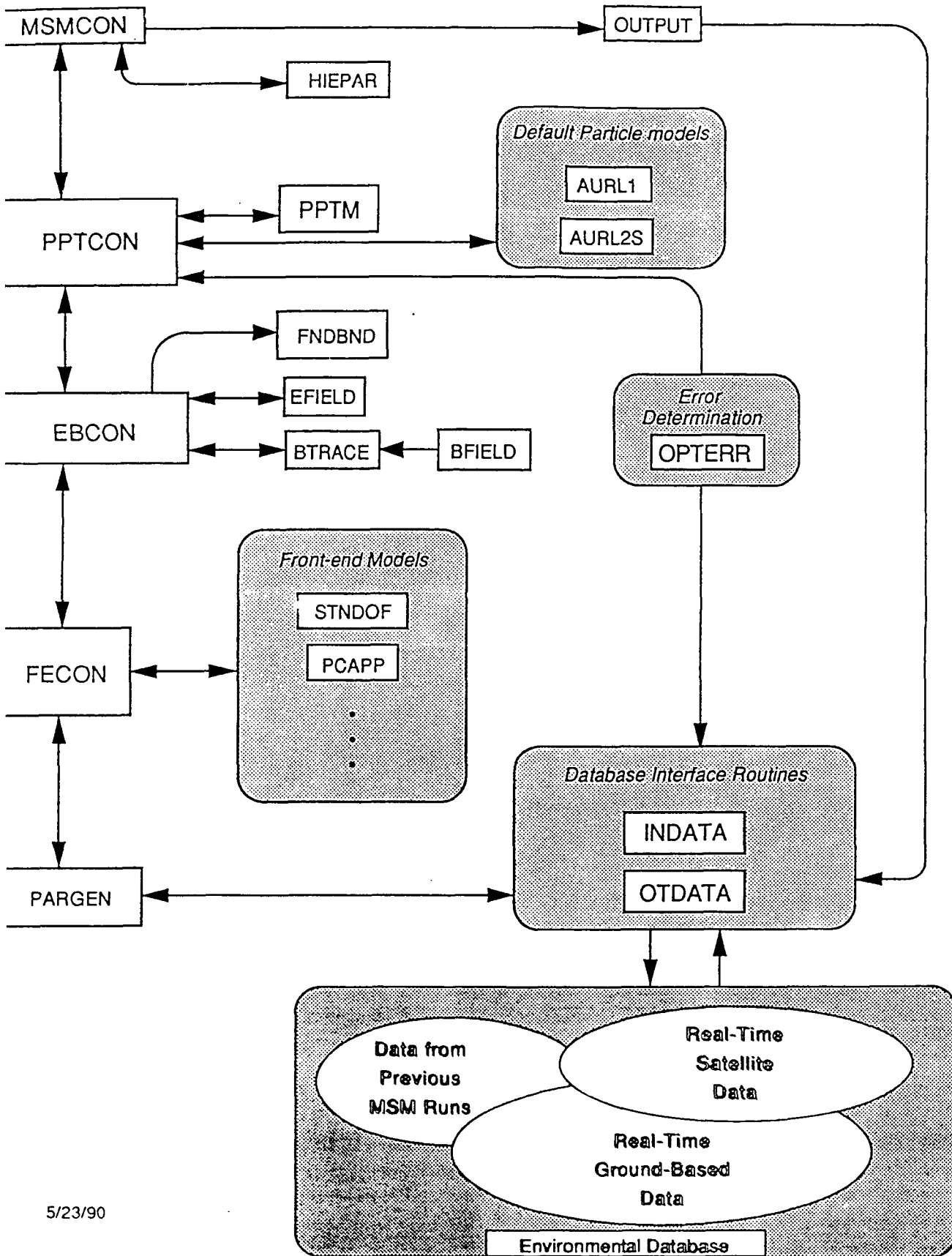
3.3 Output Requirements. The following files are output. When the Environmental Data Base is complete, these files will be stored there. The file of immediate use to forecasters is the FLUX data file which contains the particle flux information for the desired energy channels at all points on the model grid. The other data files will be needed for post-analysis of the event.

- V Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output for each time label.
- VNORTH Northern hemisphere electric potential distribution (Volts). Output for each time label.
- VSOUTH Southern hemisphere electric potential distribution (Volts). Output for each time label.
- VM Flux tube volume $((R_e/nT)^{-2/3})$. Output for each time label
- BMIN Equatorial magnetic field strength (nT), Output for each time label
- XMIN GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
- YMIN GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
- ZMIN GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output for each time label
- BNDLOC Location of outer boundary of detailed particle traces. Output for each time label
- EFLUX Precipitation energy flux array (ergs/cm²-sec). Output for each time label
- FLXSUM Total precipitation energy flux array (integrated over species for (1) electrons (2) H⁺ and (3) O⁺) (ergs/cm²-sec). Output for each time label
- EAVG Average precipitating electron energy for (1) electrons, (2) H⁺ and (3) O⁺(eV). Output for each time label

AUGPAR
COLAT
ALOC
FLUX

Augmented data array for input values. Output for each time label
Grid colatitude array (radians). Output for each time label
Grid local time array (radians eastward from noon). Output for each time label
Flux values for all energy channels at all grid points. Output for each time label
for each energy channel

MSM Control & Data Flow Diagram



PARAMETER	NAME	UNITS	IO	Time Tag	Geo. Latitude	Geo. Longitude	Altitude	Mag. Local Time
Kp	FKP	NONE	I	X				
Dst	DST	NANOTESLA	I	X				
C2	C2	NONE	I	X				
LOW LAT AURORAL BOUNDARY	DLATAZ	DEGREES	I	X			X	X
EQ. EDGE R1 CURRENTS	EDGER1	DEGREES	I	X			X	X
EQ. EDGE R2 CURRENTS	EDGER2	DEGREES	I	X			X	X
POLAR CAP POTENTIAL	PCP	KILOVOLTS	I	X				
POLAR CAP POTENTIAL PATTERN	XIPATT	NONE	I	X				
POLAR CAP BOUNDARY LATITUDE	PCBND	T.B.D.	I	X				
PRECIPITATION POWER INDEX	P	NONE	I	X				
GEO MAG X COMP.	GEOMGX	NANOTESLA	I	X				X
GEO MAG Y COMP.	GEOMGY	NANOTESLA	I	X				X
GEO MAG Z COMP.	GEOMGZ	NANOTESLA	I	X				X
GEO ELECTRON FLUX - CHANNEL(I)	EFLX(I)	ELEC/cm ² .s	I	X				X
GEO ION FLUX - CHANNEL(I)	GFLX(I)	IONS/cm ² .s	I	X				X
SOLAR WIND VELOCITY	SWVEL	KM/s	I	X	X	X	X	X
SOLAR WIND DENSITY	SWDEN	PROT/cm ³	I	X	X	X	X	X
IMF X COMPONENT	XIMFBX	NANOTESLA	I	X	X	X	X	X
IMF Y COMPONENT	XIMFBY	NANOTESLA	I	X	X	X	X	X
IMF Z COMPONENT	XIMFBZ	NANOTESLA	I	X	X	X	X	X

INPUT ONLY:

END USERS MANUAL

End Users Manual

2.1.2 Performance. Some factors on which the system performance depends include:

1. Higher energy particles require more time to process. The particles move so rapidly that a smaller time step is required to move their position and the number of time steps required to move the particles on the grid is correspondingly higher.
2. The output files are updated every program time step. If the program is set to run for many time steps, the storage of these files could be a problem. The maximum number of time steps is set within the program to 50.
3. The maximum number of energy channels which can be run is set within the program to 30. The greater the number of channels selected, the longer the run time will be.

COMPUTER OPERATION MANUAL

COMPUTER OPERATION MANUAL - 1

Computer Operation Manual

2.1 System Application. The Magnetospheric Specification Model was developed as a set of algorithms to be developed into a real-time program for use in the Space Forecast Center operated by the Air Weather Service of the U.S. Air Force. It is intended to help the Center personnel perform their mission of providing information, particularly during magnetospheric disturbances, to "customers" who operate spacecraft. The output of the model includes (but is not limited to):

- 1) Fluxes of electrons and ions in the inner plasma sheet and the geosynchronous orbit region.
- 2) Energy fluxes and characteristic energies of electrons precipitated into the auroral ionosphere.

2.4 Information Inventory.

2.4.1 Resource Inventory.

Following are the files accessed by the MSM, including those to be eventually replaced by calls to the environmental data base. Those required for a restart are so labelled.

Input data sets

* denotes principal mode of operator control of program

BOxxxxxx	The magnetic field matrices needed for the model run. Required for restart.
CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
COORD	File of values to set up the coordinate system. Required for restart.
DKTABLE	File of decay times for computing ion loss by charge exchange.
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model. Required for restart.
ENCHAN*	Input values for the number of energy channels, type and energy of particles to be traced. Required for restart.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete. Required for restart.
HARDY	Coefficients used by the Hardy precipitating electron model. Required for restart.
IONENG	Coefficients used as input for the ion precipitating model. Required for restart.

COMPUTER OPERATION MANUAL - 2

IONNUM	Coefficients used as input for the ion precipitating model. Required for restart.
MSMIN*	Primary input file to control run. Provides start and end times for run, a character string identifier for run, and sun spot number. Required for restart.
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

Output data sets

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VNORTH	Northern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VSOUTH	Southern hemisphere electric potential distribution (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VM	Flux tube volume $((Re/nT)^{-2/3})$. Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
BMIN	Equatorial magnetic field strength (nT). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).

COMPUTER OPERATION MANUAL - 3

ZMIN	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes) GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).
BNDLOC	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes) Location of outer boundary of detailed particle traces.
EFLUX	Output volume - number of longitudinal gridpoints \times number of time steps \times 4 (bytes) Precipitating energy flux array (ergs/cm ² -sec).
FLXSUM	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes) Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec).
EAVG	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes) Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV).
AUGPAR	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes) Augmented data array for input values.
COLAT	Output volume - number of data elements \times number of time steps \times 4 (bytes) Grid colatitude array (radians).
ALOCT	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes) Grid local time array (radians eastward from noon).
FLUX	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes) Flux values for all energy channels at all grid points. Needed for restart. Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes)

2.4.2 Report Inventory. A print file of arrays of different parameters is currently generated.

TEST PLAN

Test Plan

2. DEVELOPMENT ACTIVITY

2.1 Statement of Pretest Activity. During the development phase the model output was compared to observed data for 2 events - CDAW6 March 22, 1978 interval and April ~~22-24~~, 1988 interval.
21-23

2.2 Pretest Activity Results. Results of the CDAW6 interval are discussed in "Chapter IV - Testing the Model Using the CDAW6 Event" of B. Hausman's Masters Thesis (included as an appendix to this test plan.) MSM results are compared quantitatively with observations for the April ~~22-24~~, 1988 period in the Rice MSM final report.
21-23

3.1 System Description.

Start and stop times and start direct-access record number are provided in input file MSMIN.

Following are the input files required, including those to be replaced by calls to the environmental data base:

BOxxxxxx	The magnetic field matrices needed for the model run.
CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
COORD	File of values to set up the coordinate system.
DKTABLE	Decay times for computing charge-exchange loss of ions
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model.

PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.

Following are the output files:

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts).
VNORTH	Northern hemisphere electric potential distribution (Volts).
VSOUTH	Southern hemisphere electric potential distribution (Volts).
VM	Flux tube volume ((Re/nT) ^{-2/3}).
BMIN	Equatorial magnetic field strength (nT).
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re).
BNDLOC	Location of outer boundary of detailed particle traces.
EFLUX	Precipitating energy flux array (ergs/cm ² -sec).
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec).
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV).
AUGPAR	Augmented data array for input values.
COLAT	Grid colatitude array (radians).
ALOCT	Grid local time array (radians eastward from noon).
FLUX	Flux values for all energy channels at all grid points

4. TEST SPECIFICATION AND EVALUATION

4.1 Test Specification. The set of algorithms encoded as the MSM have been run and tested at Rice University. The results have been studied by comparing the model results with observed data. The version of the program code which was developed at Rice University gives the verified results. To validate the algorithms delivered to the Space Forecast Center, the output from the code run at Rice University will be compared with that run at the Space Forecast Center.

4.2 Test Methods and Constraints.

4.2.1 Test Conditions. The input data will come from Rice University.

4.4 Test Evaluation.

4.4.1 Test Data Criteria. Using the output data furnished from Rice University, the output from the code run at the Space Forecast Center should be the same.

IV. TESTING THE MODEL USING THE CDAW6 EVENT

A. General Description of Event

The Coordinated Data Analysis Workshop #6 (CDAW6) focused its effort on understanding the physical processes which control the flow of energy from the solar wind through the magnetosphere and the eventual release through magnetospheric substorms. The participants studied the first of 2 large substorms which occurred on March 22, 1979. Preceded by a day of quiet conditions both in the solar wind and the magnetosphere, a storm sudden commencement was observed at 0826UT followed by the onset of the expansive phase of the first substorm at 1054UT. The ready availability of a large data set and numerous papers (see Journal of Geophysical Research volume 90, February 1985 for most of them) made it a natural candidate for the preliminary testing of the model's capabilities.

Figure 4.1 is a summary of solar wind plasma parameters at IMP-8 (located slightly to the duskside of the bow shock) and the AE magnetic activity index published as Figure 2 in the overview paper by McPherron and Manka (1985). The major features of these data include:

- 1) An interplanetary shock arrives at IMP-8 at 0821:20UT, as indicated by an increase in solar wind density, velocity and magnetic field strength.
- 2) At 0826UT the shock arrives at the dayside of the earth compressing the magnetosphere causing a sudden storm commencement, which can be seen as a small spike in the AE index.
- 3) The magnetic field turns southward at IMP-8 at 1008UT which begins the stretching of the magnetotail and the growth phase of the first substorm.
- 4) The first substorm expansion onset at 1054UT produced auroral zone magnetic activity (as measured by the AE index) exceeding 1000 nT.

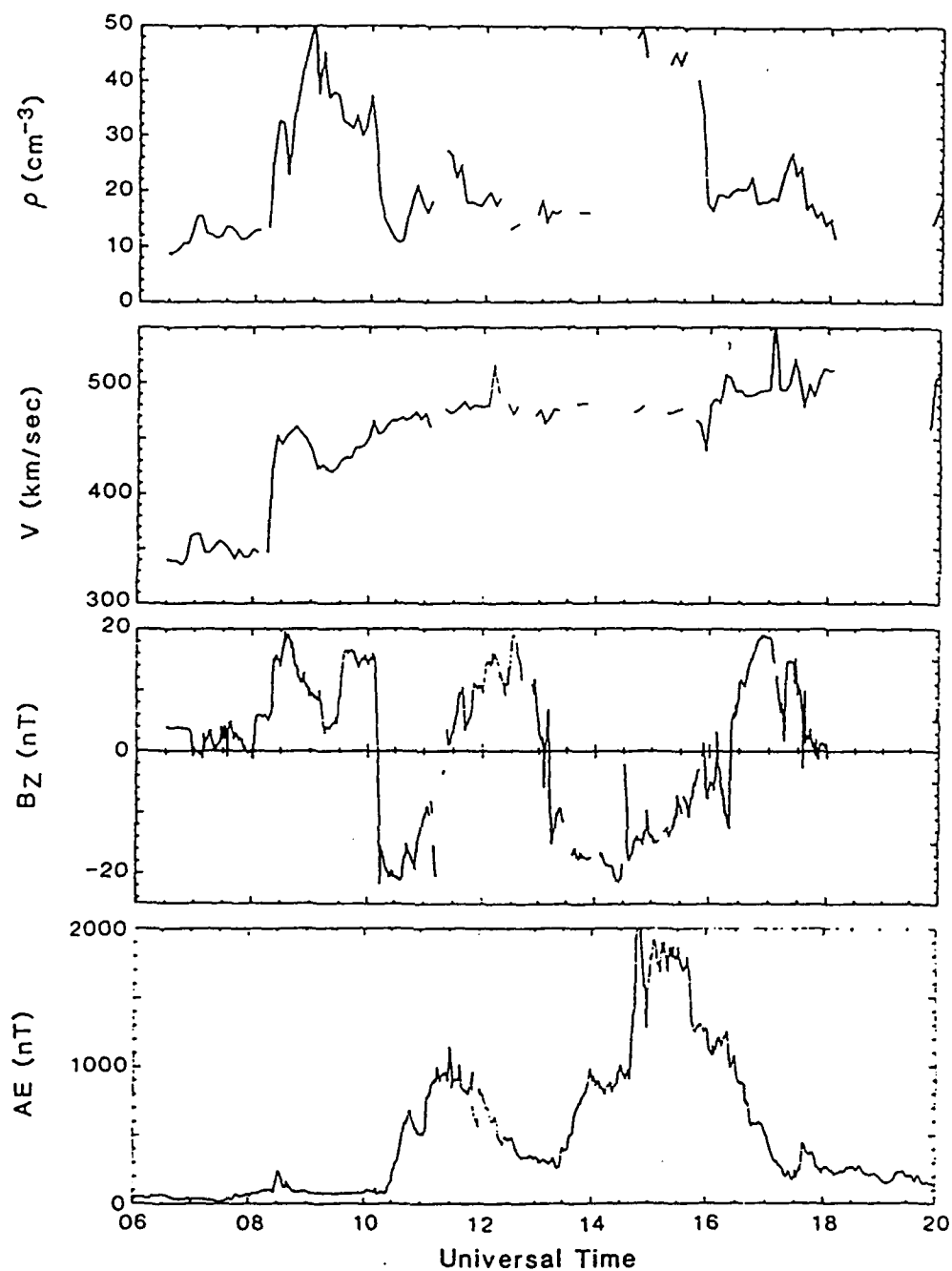


Figure 4.1 Summary of solar wind plasma parameters at IMP 8 on March 22, 1979. Top traces show 5-min averages of solar wind velocity and density. Middle trace shows 1-min values of the GSM Z component of the IMF at IMP 8. Bottom trace presents a 55-station AE index calculated at 1 min time resolution.

5) At 1122UT the IMF becomes northward at IMP-8, magnetic activity starts to decline and the recovery phase of the substorm begins.

B. Model Inputs

1. Magnetic Field Model

After studying the IMF data and Dst index, Dr. G.-H. Voigt subdivided the CDAW-6 interval into 17 time labels (Table 4.1) which represent different configurations of the magnetic field during the event. The magnetic field matrices were then pre-computed for each time. The inputs to the model are

STAND - the magnetopause standoff distance (R_e) from the solar wind data.

Dst - the standard index of ring current intensity (nT).

Aur.Eq.Bd. - the equatorward edge of the auroral zone at midnight (information on how this is done is in Section 2 - Electric Field Model Inputs).

Map(E) - the expected mapping from the Aur.Eq.Bd. (above) to the inner edge of the plasma sheet at local midnight in the equatorial plane of the magnetosphere (R_e). This was estimated using the work by Kivelson et al.(1979), Horowitz et al. (1986), and Gussenhoven et al. (1981) who have calculated K_p -based relationships between the inner edge of the plasma sheet and the equatorward edge of the auroral zone.

From these four observable parameters, Hilmer (1989) has devised a scheme to estimate the remaining input values necessary to run the model:

TILT - Dipole tilt angle (set to 0.0 for the CDAW-6 event).

HJNEAR - Strength of the cross-tail current sheet at the inner edge.

XNEAR - Location of the inner edge of the model plasma sheet at local midnight (R_e).

HJFRAC - Fraction of HJNEAR appearing at and beyond (XNEAR-100) R_e .

Current intensity is constant in the far tail.

LABEL = 1	6:00	UT	Pre-Storm Sudden Commencement
LABEL = 2	8:26	UT	Storm Sudden Commencement
LABEL = 3	10:00	UT	Same as LABEL 2 but little bit more stretch
LABEL = 4	10:20	UT	IMF turns southward
LABEL = 5	10:54 - EPS		Maximum stretch just before onset of first substorm
LABEL = 6	10:54 + EPS		Collapse right after onset of substorm
LABEL = 7	11:30	UT	End of phase "gradually back to normal"
LABEL = 8	12:06	UT	Nominal phase (i.e. nominal model)
LABEL = 9	12:43	UT	Nominal phase
LABEL = 10	13:10	UT	IMF turns southward
LABEL = 11	13:40	UT	Gradual stretching period
LABEL = 12	14:07	UT	Gradual stretching period
LABEL = 13	14:36 - EPS		Maximum stretch just before onset of second substorm
LABEL = 14	14:36 + EPS		Collapse right after onset of substorm
LABEL = 15	15:15	UT	Gradually back to normal after collapse
LABEL = 16	15:50	UT	Gradually back to normal
LABEL = 17	16:00	UT	Beginning of last nominal phase

Table 4.1 Critical time labels for CDAW-6 event.

DY - Scale length for changes in tail structure along the GSM y-axis (R_e). This applies to the westward tail current system.

DFIL - Plasma sheet thickness parameter.

BRN, BRP - Ring-current contributions (nT) at Earth's center from the westward and eastward components, respectively ($BRN < 0$, $BRP > 0$).

RN, RP - Characteristic radii of the westward and eastward ring-current components, respectively.

COLLAP - Fraction of the pre-collapse midnight cross-tail current remaining in the disturbed region (from the inner edge, XNEAR to XNEAR - DELXC). COLLAP = 1.0 means no collapse.

DELXC - The distance from the inner edge (R_e), along the x-axis, which is altered by the addition of eastward tail current. DELXC = 0.0 means no collapse.

DYC - Scale length for changes in tail structure along the GSM y-axis (R_e). Applies to the eastward disruption collapse current. DYC is always less than DY. DYC = 0.0 means no collapse.

Table 4.2 from Dr. R. Hilmer contains a list of these parameters for the CDAW-6 event. Also listed are three output parameters:

MAP(R) - The resulting midnight equatorial mapping distance (R_e).

RC Zero - Characteristic radius for the ring current (R_e). The ring current changes sign at this distance and is an implied particle pressure maximum.

Min-Loc - The minimum $|B|$ and its location in the equatorial plane at midnight.

2. Electric Field Model

The cross polar cap potential was calculated from the IMF data and the empirical formula suggested by Crooker et al. (1982) and presented by Reiff and Luhmann (1986)

$$\phi(\text{kV}) = 22 + 0.069 v_B Q1$$

where $Q1 = \alpha(\alpha - \cos \theta) (\alpha^2 + 1 - 2\alpha \cos \theta)^{-1/2}$ for $\cos \theta < \alpha$

	Label	UT	Comment	Stand	Dst	Aur.Eq.Bd.	Map(E)	Map(R)	RC Zero	Min-Loc
1	1	6:00	Pre-SSC	10.58	13.53	66.28	7.01	7.00	3.56	0.72 - 36
2	2	8:26	SSC	7.83	43.20	66.28	7.01	7.01	3.21	0.81 - 26
3	3	10:00	"	7.83	43.20	65.25	6.69	6.69	3.21	1.70 - 20
4	4	10:20	IMF South	8.93	32.56	64.72	6.53	6.52	3.20	1.24 - 20
5	5	10:54	Stretched	8.45	16.61	62.51	5.86	5.83	3.04	0.50 - 17
6	6	10:54+	Collapse	8.45	16.61	62.51			3.04	0.42 - 24
7	7	11:30	Nominal	8.10	-15.30	59.22	4.38	4.33	2.51	3.16 - 21
8	8	12:06	"	8.45	-24.41	58.82	4.24	4.23	2.41	3.21 - 21
9	9	12:43	"	8.77	-18.34	59.77	4.58	4.54	2.60	2.80 - 21
10	10	13:10	IMF South	8.71	-13.78	60.72	4.92	4.94	2.66	2.48 - 20
11	11	13:40		8.64	-9.22	60.73	4.92	4.90	2.64	2.44 - 20
12	12	14:07		8.61	-16.82	60.73	4.92	4.92	2.56	2.11 - 18
13	13	14:36	Stretched	7.58	-22.14	60.13	4.71	4.72	2.42	2.90 - 20
14	14	14:36+	Collapse	7.58	-22.14	60.13			2.42	1.09 - 26
15	15	15:15	Nominal	7.62	-39.61	59.80	4.59	4.58	2.24	2.57 - 22
16	16	15:50	"	7.68	-57.08	59.27	4.40	4.40	2.14	1.49 - 26
17	17	16:00	"	8.50	-60.88	59.14	4.35	4.35	2.14	1.40 - 26

	HJNEAR	XNEAR	HJFRAC	DY	DFIL	COLLAP	DELXC	DYC	BRN	BRP	RN	RP
1	4.3	-7.00	0.25	15.0	2.0	1.0	0.0	0.0	-105.0	117.2	3.2	2.1
2	8.3	-7.01	0.20	12.5	2.0	1.0	0.0	0.0	-50.0	75.9	4.0	1.6
3	12.0	-6.69	0.15	10.0	1.2	1.0	0.0	0.0	-50.0	75.9	4.0	1.6
4	12.7	-6.53	0.15	10.0	1.0	1.0	0.0	0.0	-50.0	72.0	4.0	1.6
5	17.5	-5.86	0.14	7.5	0.8	1.0	0.0	0.0	-230.0	221.6	2.9	2.1
6	17.5	-5.86	0.14	7.5	0.8	0.7	45.0	5.0	-230.0	221.6	2.9	2.1
7	15.0	-4.38	0.15	7.5	1.0	1.0	0.0	0.0	-400.0	354.5	2.7	2.1
8	15.0	-4.24	0.15	7.5	1.0	1.0	0.0	0.0	-490.0	437.1	2.6	2.1
9	15.0	-4.58	0.15	7.5	1.0	1.0	0.0	0.0	-390.0	345.8	2.7	2.1
10	15.0	-4.92	0.15	7.5	1.0	1.0	0.0	0.0	-380.0	340.4	2.7	2.1
11	15.0	-4.92	0.15	7.5	1.0	1.0	0.0	0.0	-540.0	504.9	2.6	2.2
12	17.0	-4.92	0.14	7.5	1.0	1.0	0.0	0.0	-500.0	466.4	2.5	2.1
13	17.0	-4.71	0.14	7.5	1.0	1.0	0.0	0.0	-570.0	522.9	2.5	2.1
14	17.0	-4.71	0.14	7.5	1.0	0.8	35.0	5.0	-570.0	522.9	2.5	2.1
15	15.0	-4.59	0.15	7.5	2.0	1.0	0.0	0.0	-840.0	774.3	2.4	2.1
16	11.0	-4.40	0.20	10.0	2.0	1.0	0.0	0.0	-700.0	615.9	2.5	2.1
17	11.0	-4.35	0.20	10.0	2.0	1.0	0.0	0.0	-680.0	597.9	2.5	2.1

Table 4.2 Input parameters for B-field model for CDAW-6 interval.

$$Q1 = 0$$

for $\cos \theta > \alpha$

$$\alpha = \min \left[\frac{(4B_T B_E)^{1/2}}{60 \text{ nT}}, 1 \right]$$

θ = polar angle of the IMF

B_T = projection of IMF on solar-magnetosphere y-z plane

B_E = magnetic field just inside magnetopause

The polar cap pattern type was also estimated from B_y and B_z IMF data for each time label using the criteria given in chapter 3. For the CDAW-6 interval, the equatorward edge of the diffuse aurora was based on electron data from DMSP, P78, and TIROS satellites.

Table 4.3 contains the input data calculated by Dr. R. A. Wolf and used during the interval for:

VPVC - cross-polar cap potential (kV).

IPATTV - polar cap pattern type.

EDGE - equatorward edge of auroral zone at midnight.

A(L) - radius of ellipse measured in x (sunward) direction.

B(L) - radius of ellipse measured in y (duskward) direction.

DX(L) - sunward displacement of coordinate system center from pole.

DY(L) - duskward displacement of coordinate system center from pole.

3. Boundary Plasma Condition

The invariant temperatures (λ_{kTe} , λ_{kTi}) were estimated from data from the ISEE-2 satellite, as shown in Figure 4.2 and published as Figure 1 in Paschmann et al. (1985). The satellite moved earthward from ~ 14.8 to ~ 13.0 Re geocentric distance at ~ 0200 local time from 1010-1200 UT. However, the published observations do not cover the entire

	1	2	3	4	5	6	7	8
1	Time	VPCV	IPATTV	EDGE	A(1)	A(2)	A(3)	B(1)
2	0 - 0826-e	24	4	66.25	15.47	16.81	21.88	15.67
3	0826+e	24	5	66.25	17.85	19.25	21.88	18.52
4	i000	24	5	65.35	18.75	20.48	22.63	18.63
5	1020	66	3	64.80	18.70	20.66	23.10	17.56
6	1054-e	137	3	62.80	20.88	22.89	24.78	19.05
7	1054+e	137	3	62.80	19.70	21.61	24.78	18.78
8	1130	130	3	59.00	20.94	22.72	27.97	20.12
9	1206	107	3	59.00	20.91	22.71	27.97	19.86
10	1243	88	3	59.90	20.77	22.61	27.21	19.39
11	1310	94	3	60.20	20.72	22.59	26.96	19.31
12	1340	135	3	60.85	20.61	22.47	26.42	19.25
13	1407	161	3	60.60	20.76	22.68	26.63	19.17
14	1436-e	156	3	60.10	21.34	23.15	27.05	20.64
15	1436+e	156	3	60.10	20.74	22.49	27.05	20.49
16	1515	144	2	59.80	20.99	22.71	27.30	20.75
17	1550	127	2	59.25	20.73	22.31	27.76	21.08
18	1600	122	2	59.25	20.33	22.02	27.76	20.19

	9	10	11	12	13	14	15	16
1	B(2)	B(3)	DX(1)	DX(2)	DX(3)	DY(1)	DY(2)	DY(3)
2	14.04	22.83	-1.00	-0.56	-1.87	-0.90	0.00	0.00
3	17.09	22.83	-1.19	-0.81	-1.87	-0.77	0.00	0.00
4	17.40	23.74	-1.54	-1.62	-2.02	-0.64	0.00	0.00
5	16.53	24.30	-1.73	-2.21	-2.10	-0.64	0.00	0.00
6	17.82	26.33	-1.96	-2.48	-2.42	-0.64	0.00	0.00
7	17.50	26.33	-1.36	-1.78	-2.42	-0.64	0.00	0.00
8	18.88	30.18	-1.08	-1.37	-3.03	-0.64	0.00	0.00
9	18.53	30.18	-1.10	-1.40	-3.03	-0.64	0.00	0.00
10	18.04	29.27	-1.27	-1.62	-2.89	-0.64	0.00	0.00
11	17.97	28.96	-1.35	-1.73	-2.84	-0.64	0.00	0.00
12	17.90	28.30	-1.35	-1.73	-2.74	-0.64	0.00	0.00
13	17.79	28.56	-1.56	-1.99	-2.78	-0.64	0.00	0.00
14	19.46	29.06	-1.20	-1.63	-2.86	-0.64	0.00	0.00
15	19.28	29.06	-0.89	-1.15	-2.86	-0.64	0.00	0.00
16	19.49	29.37	-0.68	-0.92	-2.90	-0.64	0.00	0.00
17	20.07	29.92	-0.31	-0.40	-2.99	-0.64	0.00	0.00
18	19.06	29.92	-0.48	-1.62	-2.99	-0.64	0.00	0.00

Table 4.3 Input parameters for E-field model for CDAW-6 interval.

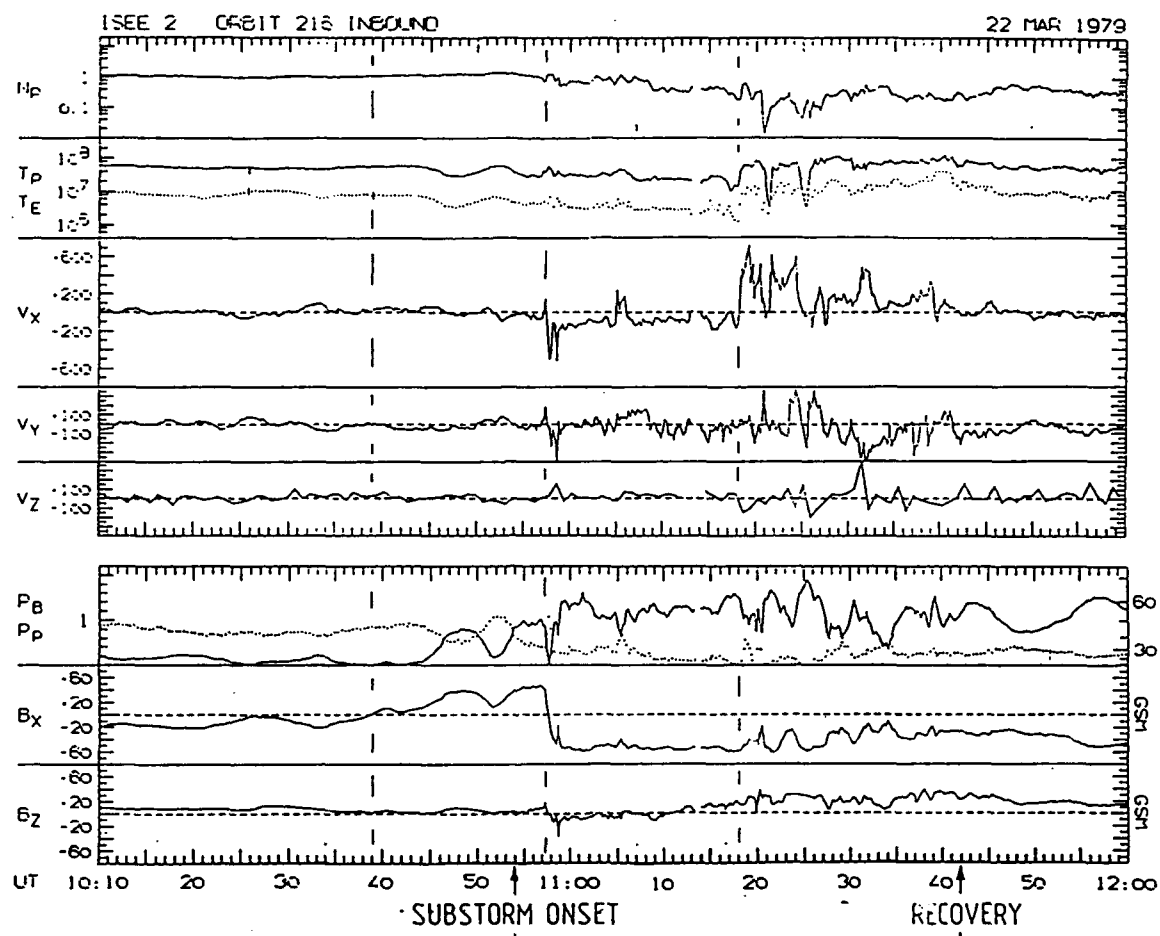


Figure 4.2 ISEE 2 plasma and magnetic field parameters for the time interval 1010-1200 UT on March 22, 1979. T_p and T_e are the ion and electron temperatures (degrees Kelvin).

time interval we want to model, so we have estimated the temperatures from the data and extrapolated to cover the rest of the event. The top of Table 4.4 shows the invariant temperatures calculated for the entire event. The headings are

Label - Time label of magnetic field model (See Table 4.1).

t_{figure} - Time of ISEE-2 data point used to calculate temperature.

r_{figure} - Radial distance of ISEE-2 (Re).

VM_{model} - Flux tube volume at r_{figure} from the magnetic field model.

T_i (°K) - Estimated ion temperature from ISEE-2 data.

T_e (°K) - Estimated electron temperature from ISEE-2 data.

λ_{kTi} - Calculated ion invariant temperature.

λ_{kTe} - Calculated electron invariant temperature.

$\langle |\lambda_i| \rangle$ - average value of ion energy invariant ($= 1.5 \times \lambda_{kTi}$).

$\langle |\lambda_e| \rangle$ - average value of electron energy invariant ($= 1.5 \times \lambda_{kTe}$).

The bottom figure shows the value of η_{tot} calculated from equation 3.24 in Chapter 3 at a distance of 20 Re and local midnight. The headings are

UT_{model} - the universal time of the model.

$B_{\text{lobe}}^2 / 8\pi(\text{model}(20\text{Re}))$ - lobe magnetic pressure at 20 Re and midnight.

$VM_{\text{model}}(20\text{Re})$ - flux tube volume at 20 Re and midnight.

η_{tot} - calculated total invariant density at 20 Re and midnight.

The initial invariant density for each energy channel is given by equation 3.31 in Chapter 3. A list of the energy channels (K), invariant energy (ALAM(K)), and boundary values at 20 Re and local midnight (ETAB(K)) is given in Table 4.5.

4. Initial Plasma Condition

The initial plasma condition is set using $K=32$, the highest electron energy that we model and it corresponds to $\sim 40\text{keV}$ at geosynchronous orbit. Using the 30-45 keV electron channel of the 1977-007 and 1976-059 spacecraft we estimated the average flux

Label	t _{figure}	r _{figure}	VM _{model}	T _i (*K)	T _e (*K)	λ_{kTi}	λ_{kTe}	$\langle \lambda_i \rangle$	$\langle \lambda_e \rangle$
1	10:26am	14.5	1.111	6.4×10^7	1.0×10^7	4960	775	7440	1162.5
2	10:26am	14.5	1.124	6.4×10^7	1.0×10^7	4908	767	7362	1150.5
3	10:26am	14.5	1.147	6.4×10^7	1.0×10^7	4810	752	7215	1128.
4	10:26am	14.5	1.121	6.4×10^7	1.0×10^7	4921	769	7381.5	1153.5
5	10:26am	14.5	1.453	6.4×10^7	1.0×10^7	3797	593	5695.5	889.5
6	10:26am	14.5	1.246	6.4×10^7	1.0×10^7	4428	692	6642	1038
7	11:50am	13.16	1.719	1.0×10^8	2.0×10^7	5015	1003	7522.5	1504.5
8	11:50am	13.16	1.730	1.0×10^8	2.0×10^7	4983	996	7474.5	1494
9	11:50am	13.16	1.649	1.0×10^8	2.0×10^7	5228	1045	7842	1567.5
10	10:26am	14.5	1.287	6.4×10^7	1.0×10^7	4287	670	6430.5	1005
11	10:26am	14.5	1.339	6.4×10^7	1.0×10^7	4120	644	6180	966
12	10:26am	14.5	1.316	6.4×10^7	1.0×10^7	4192	655	6288	982.5
13	10:26am	14.5	1.346	6.4×10^7	1.0×10^7	4099	640	6148.5	960
14	10:26am	14.5	1.296	6.4×10^7	1.0×10^7	4257	665	6385.5	997.5
15	11:50am	13.16	1.593	1.0×10^8	2.0×10^7	5412	1082	8118	1623
16	11:50am	13.16	1.642	1.0×10^8	2.0×10^7	5250	1050	7875	1575
17	11:50am	13.16	1.613	1.0×10^8	2.0×10^7	5345	1069	8017.5	1603.5

Label	UT _{model}	$B_{lobe}^2/8\pi(\text{model } (20R_E))$	VM _{model} (20R _E)	η_{tot}
1	0 - 0826-ε	8.049×10^{-10}	0.6049	1.966×10^{21}
2	0826+ε	20.019×10^{-10}	0.6050	4.940×10^{21}
3	1000	33.054×10^{-10}	0.7366	5.088×10^{21}
4	1020	35.461×10^{-10}	0.7335	5.393×10^{21}
5	1054-ε	65.914×10^{-10}	0.9300	7.178×10^{21}
6	1054+ε	34.808×10^{-10}	0.6462	8.075×10^{21}
7	1130	47.003×10^{-10}	0.8949	4.111×10^{21}
8	1206	49.956×10^{-10}	0.9148	3.912×10^{21}
9	1243	46.720×10^{-10}	0.8730	4.170×10^{21}
10	1310	46.792×10^{-10}	0.8709	5.137×10^{21}
11	1340	46.601×10^{-10}	0.8631	5.636×10^{21}
12	1407	55.492×10^{-10}	0.8923	6.069×10^{21}
13	1436-ε	56.765×10^{-10}	0.9280	5.757×10^{21}
14	1436+ε	43.138×10^{-10}	0.8166	5.799×10^{21}
15	1515	45.457×10^{-10}	0.7328	6.071×10^{21}
16	1550	31.912×10^{-10}	0.6988	4.948×10^{21}
17	1600	31.526×10^{-10}	0.6860	5.028×10^{21}

Table 4.4 Invariant temperature and total invariant density calculated from CDAW-6 interval.

<u>K</u>	<u>ALAM(K)</u>	<u>ETAB(K)</u>
1	374.80640	0.86136E+20
2	1202.52612	0.15263E+21
3	2146.50952	0.19207E+21
4	3223.09546	0.21585E+21
5	4450.89844	0.22572E+21
6	5851.17187	0.22246E+21
7	7448.13672	0.20738E+21
8	9269.42187	0.18272E+21
9	11346.53120	0.15164E+21
10	13715.41020	0.11792E+21
11	16417.03520	0.85332E+20
12	19498.16410	0.56979E+20
13	23012.07810	0.34758E+20
14	27019.57030	0.19146E+20
15	31589.98440	0.93944E+19
16	36802.38670	0.62709E+19
17	-58.56357	0.86136E+20
18	-187.89493	0.15263E+21
19	-335.39233	0.19207E+21
20	-503.60913	0.21585E+21
21	-695.45410	0.22572E+21
22	-914.24683	0.22246E+21
23	-1163.77295	0.20738E+21
24	-1448.34888	0.18272E+21
25	-1772.89771	0.15164E+21
26	-2143.03564	0.11792E+21
27	-2565.16455	0.85332E+20
28	-3046.59180	0.56979E+20
29	-3595.64160	0.34758E+20
30	-4221.81250	0.19146E+20
31	4935.93750	0.93945E+19
32	-5750.37891	0.62709E+19

Table 4.5 A list of the energy channels (K), invariant energy (ALAM(K)), and boundary values at 20 Re and local midnight (ETAB(K)).

to be $10^{1.48} \text{ cm}^{-2}\text{s}^{-1}\text{sr}^{-1}\text{eV}^{-1}$ (See Figure 4.3). The other parameters needed to solve equation 3.40 are:

ALAM(K) - energy invariant for energy K=32; $= -5750.4 (\text{Re}/nT)^{2/3}$

VM - magnetic flux tube volume at 6.6 Re on dawn/dusk meridian

$$= 6.82 (\text{Re}/nT)^{2/3}$$

$\lambda_{k\text{max}}$ - defined in equation 3.33a in Chapter 3

$$= -7451.8 \text{ eV} (\text{Re}/nT)^{2/3}$$

$\lambda_{k\text{min}}$ - defined in equation 3.32b in Chapter 3

$$= -5343.2 (\text{Re}/nT)^{2/3}$$

Solving for EETA(32), the invariant density at geosynchronous orbit is

$$\text{EETA}(32) = 1.666\text{E}17$$

The invariant density for K=32 at the back boundary is given in Table 4.4 as 0.6271E19.

The initial back boundary at local midnight at 15.87 Re. Solving equation 3.42 in Chapter 3 to get the power law coefficient:

$$\frac{\text{EETA}(\text{Geosynchronous})}{\text{EETA}(\text{Boundary})} = \frac{1.666\text{E}17}{0.627\text{E}19} = 0.0266 = \left[\frac{6.6 \text{ Re}}{15.87 \text{ Re}} \right]^p$$

$$p = 4.134$$

Previous runs have shown the 'Kivelson' effect is not important for 40 keV electrons at local midnight, and it is neglected for adjusting the η values. Solving equation 3.44 in Chapter 3, the revised density becomes

$$\eta_{\text{tot}}(r) = (1.966\text{E}21) \left[\frac{r}{15.87} \right]^{4.134}$$

The initial density values for entire grid are calculated using

$$\text{EETA}_{\text{initial}}(K,I,J) = \left[\frac{\eta_p(\text{midnight})}{1.966\text{E}21} \right] \left[\frac{r(I,J)}{15.87} \right]^{4.134}$$

where $\eta_p(\text{midnight})$ is the initial value for energy species K at midnight.

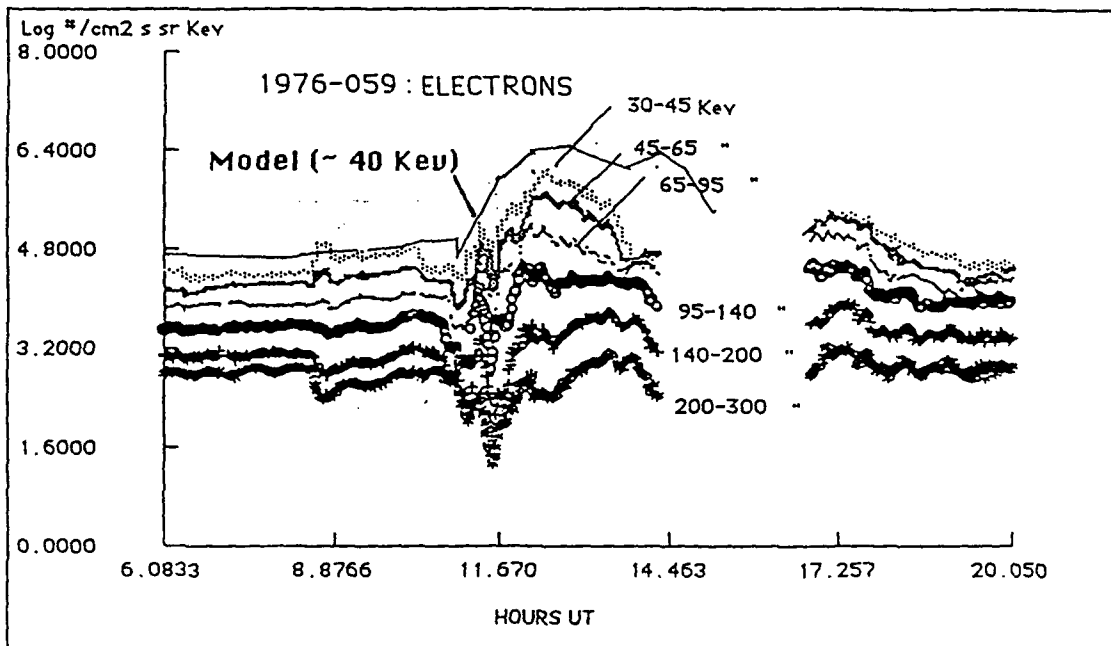
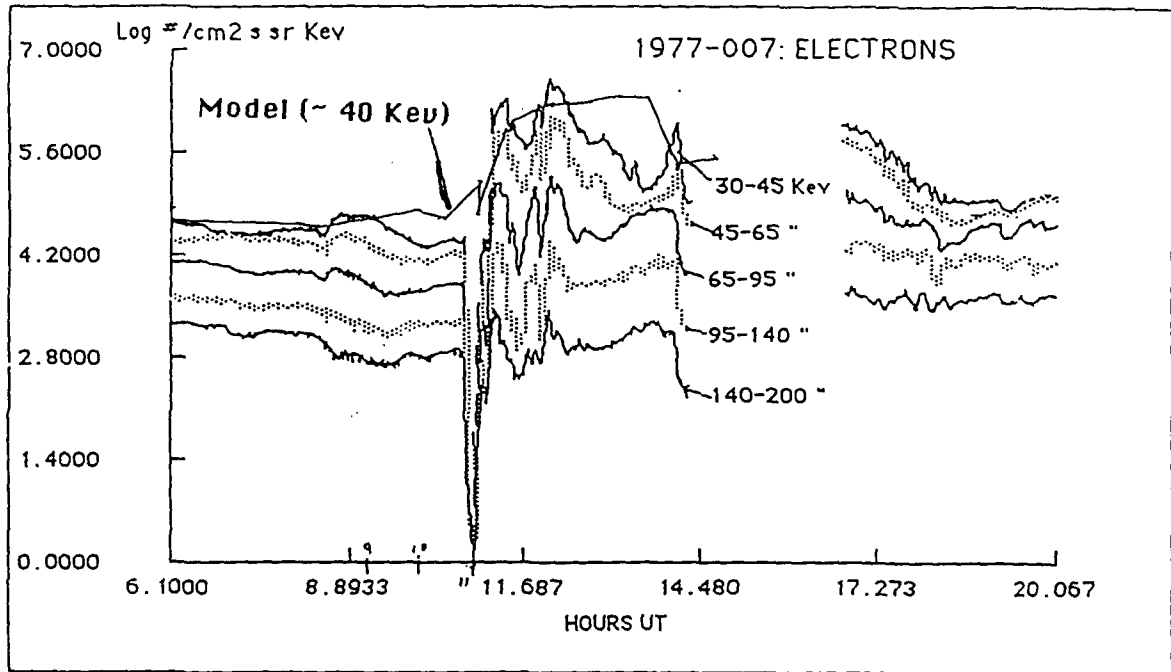


Figure 4.3 Calculated 40 keV geosynchronous electron flux values and 1977-077 and 1976-059 observed 40 keV electron flux values.

The plasma sheet depletion factor (f_{FP}) defined in equation 3.35 of Chapter 3 was set to 5 and was activated at the substorm onset at 10:54:01 UT.

C. Model Results

Figure 4.4 shows the time evolution of the invariant density (η) in the equatorial plane for our highest energy electrons (~ 40 keV at synchronous orbit). Figure 4.5 is a similar plot for "medium energy" ions (~ 40 keV at synchronous orbit); and Figure 4.6 represents low energy ions (~ 2.5 keV at synchronous orbit). The contours represent contours of constant η ; that is, constant numbers of particles per unit magnetic flux. The contours differ by a factor of $10^{0.2}$ in density level. In the plots, the sun is to the left. The outermost contour represents approximately the outer boundary of our calculations. Some physical features include

- 1) Collapse of the magnetic field causes the inner edge of the plasma sheet near local midnight to move earthward approximately 1 Re at the onset of the expansion phase of the first substorm at 1054UT.
- 2) Electrons drift eastward after the injection, with high densities reaching local noon at approximately 1200UT.
- 3) Medium energy ions drift westward from the midnight region, leading to high densities at local noon beginning about 1200UT.
- 4) Subsequently the afternoon inner edge moves gradually earthward.

The output from the model was compared with data available from the CDAW-6 interval, which included

- 1) Available data from geosynchronous orbit
 - a) 1-16 keV ions in the afternoon sector just after noon UT (GEOS-2)
 - b) 40 keV electrons around 0200 LT at 1100UT (1977-077)
 - c) 40 keV electrons around dawn at 1100UT (1976-056)
- 2) Low orbit data

$\lambda = 5750$ electrons (~ 40 keV at synchronous orbit)

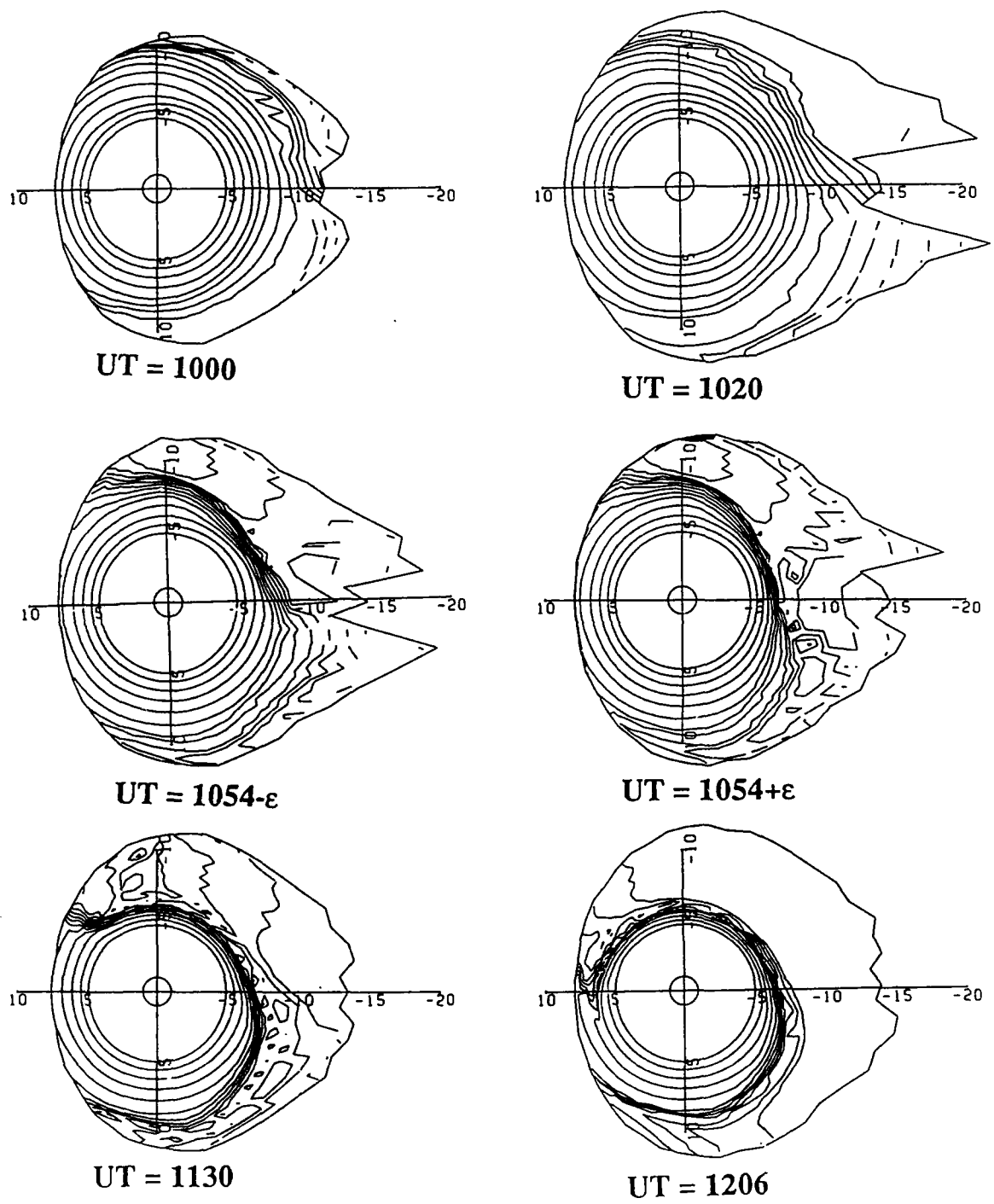


Figure 4.4 Time evolution of invariant density (η) in the equatorial plan for highest energy electrons (~ 40 keV at geosynchronous).

$\lambda = 5851$ ions (~ 40 keV at synchronous orbit)

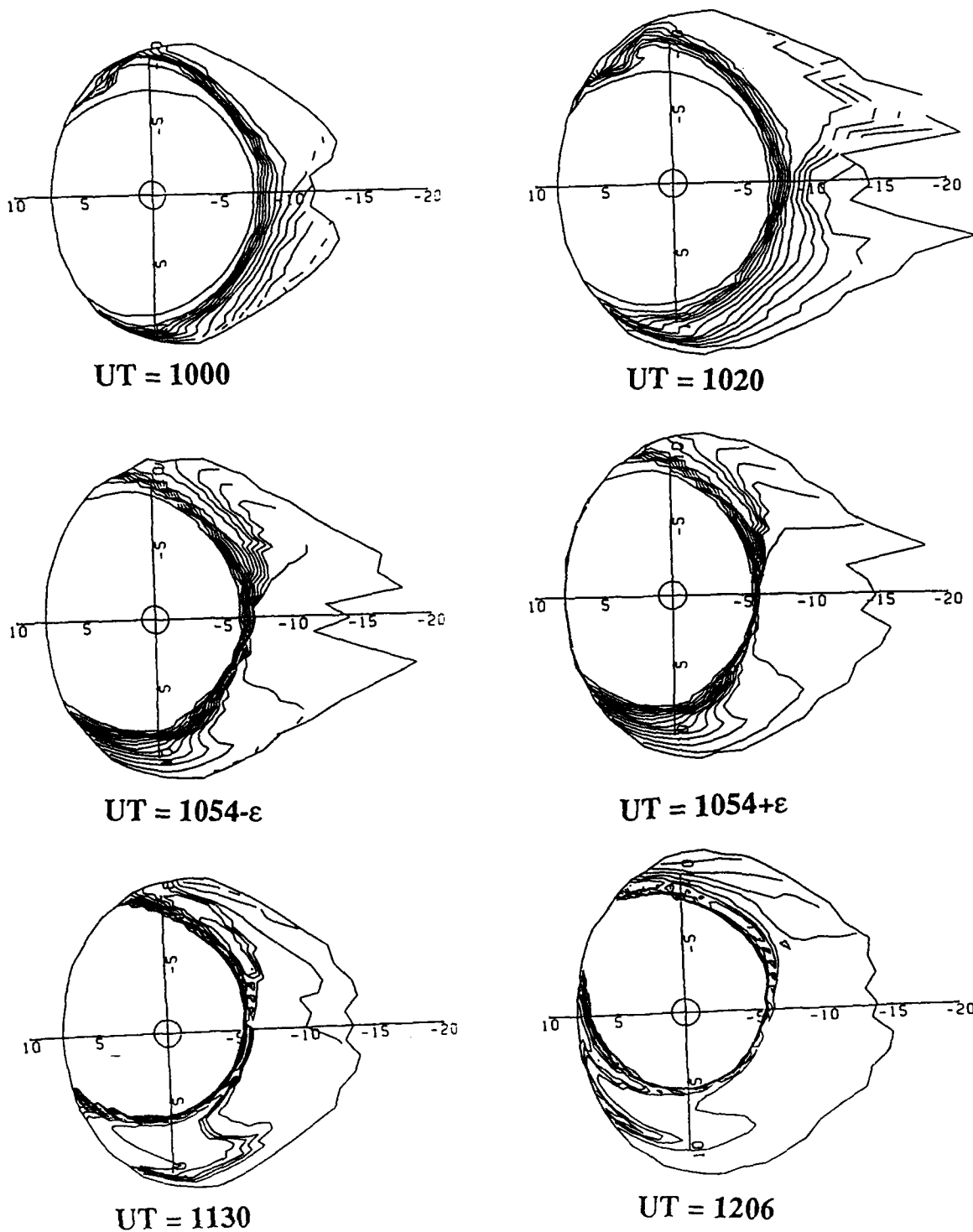


Figure 4.5 Time evolution of invariant density (η) in the equatorial plan for medium energy ions (~ 40 keV at geosynchronous).

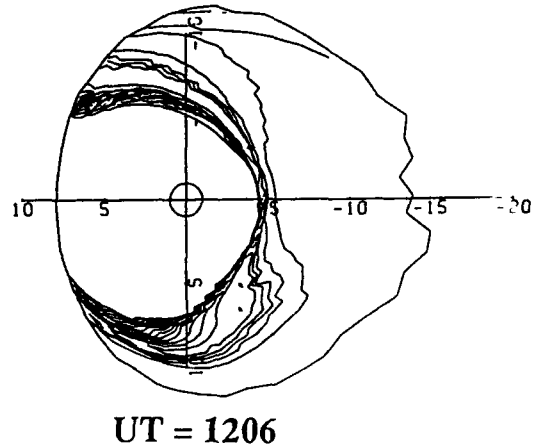
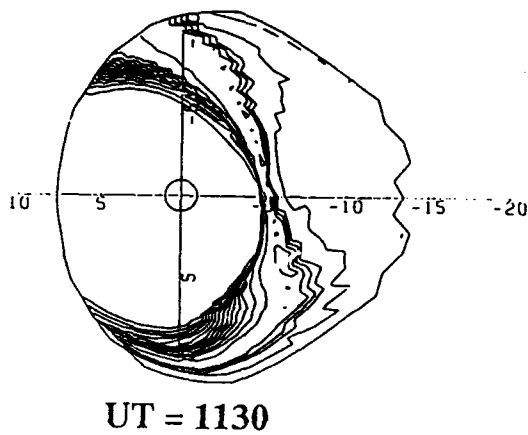
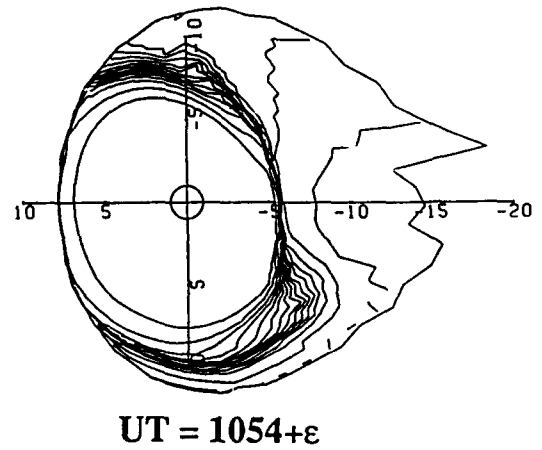
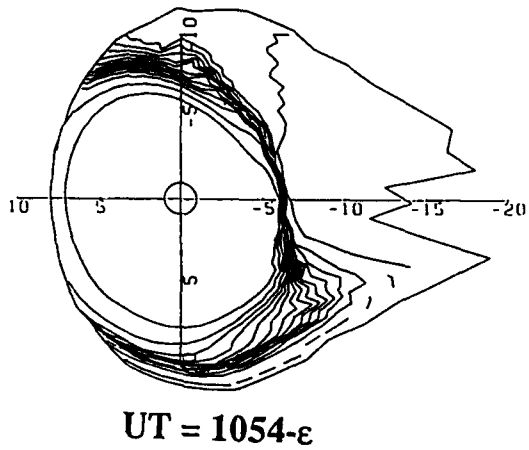
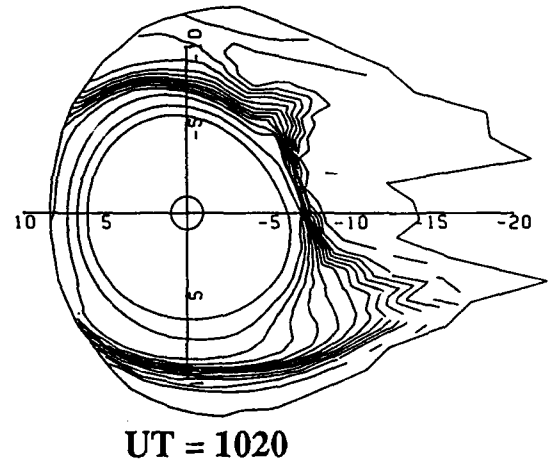
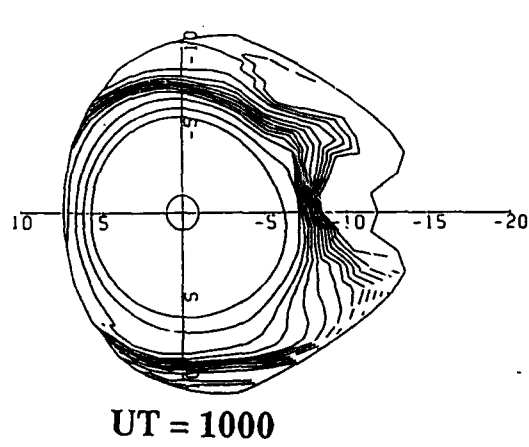


Figure 4.6 Time evolution of invariant density (η) in the equatorial plan for low energy ions (~ 2.5 keV at geosynchronous).

a) Precipitating electron flux from DMSP

Figure 4.3 shows the electron flux measured at the geosynchronous satellites and compares them with the highest electron energy channel ($K=32$) in the model which corresponds to approximately 40 keV at geosynchronous orbit. The arrival times of approximately 1100UT for 1977-077 and 1130UT for 1976-059 show good agreement. However, in both cases the fluxes are too high by a factor of 2.

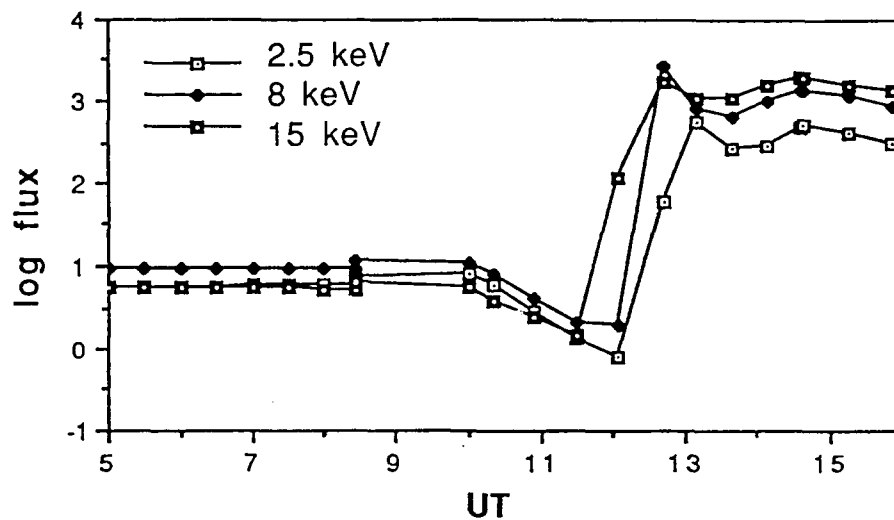
The ion energy channels for $K=1, 2,$ and 3 in the model correspond approximately to geosynchronous energies of 2.5 keV, 8.0 keV, and 15.0 keV respectively. A comparison of the model ion flux with the GEOS-2 data is shown on Figure 4.7. Again the arrival times and energy dispersion are in good agreement with the 15 keV ions arriving around 1200UT, 8.0 keV ions arriving around 1230UT, and the 2.5 keV ions arriving about 1330UT. The peak fluxes show the same general tendency to be high by about a factor of 2.

The graphs of the DMSP precipitating electron energy flux are given as Figures 4.8 and 4.9. The model values normalized to the data are represented by overlays. The model does not calculate precipitation in the region poleward of our main modeling region; that excluded region includes the polar cap and the higher-latitude part of the auroral zone so this is not included. The data shown in Figure 4.8 are for the pre-substorm period. In all three examples both the shape and the magnitude of the fluxes agree well with the satellite data. Figure 4.9 presents the results after the substorm onset and Figure 4.10 is the substorm recovery period. As with the geosynchronous fluxes, for both cases the magnitude is again too high by a factor of 2.

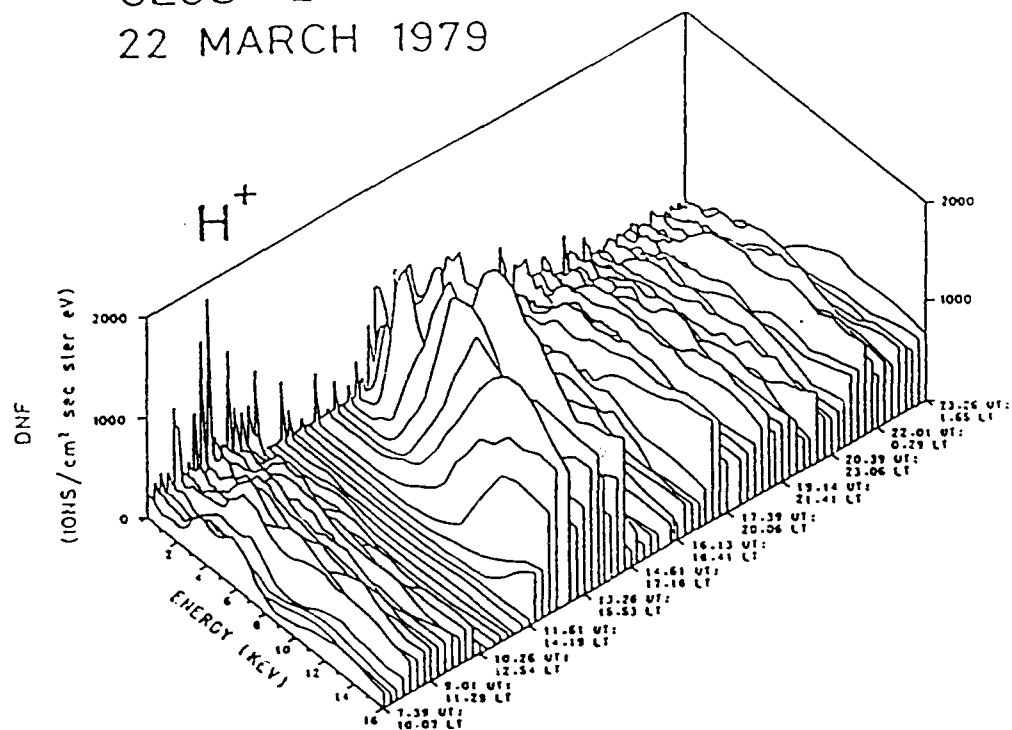
D. Interpretation and Implication

This model represents an attempted simulation of the inner-magnetosphere processes associated with magnetospheric substorms, including the magnetic field collapse at the onset of the substorm expansion phase and the subsequent injection of particles into

Ion Flux at GEOS 2



GEOS 2 ICE
22 MARCH 1979



After Stokholm, Amata, Balsiger, Candidi, Orsini, and Anderson, J.
Geophys. Res., 90, pp 1253-1261, 1985

Figure 4.7 Calculated ion flux values and GOES 2 observed ion flux values.

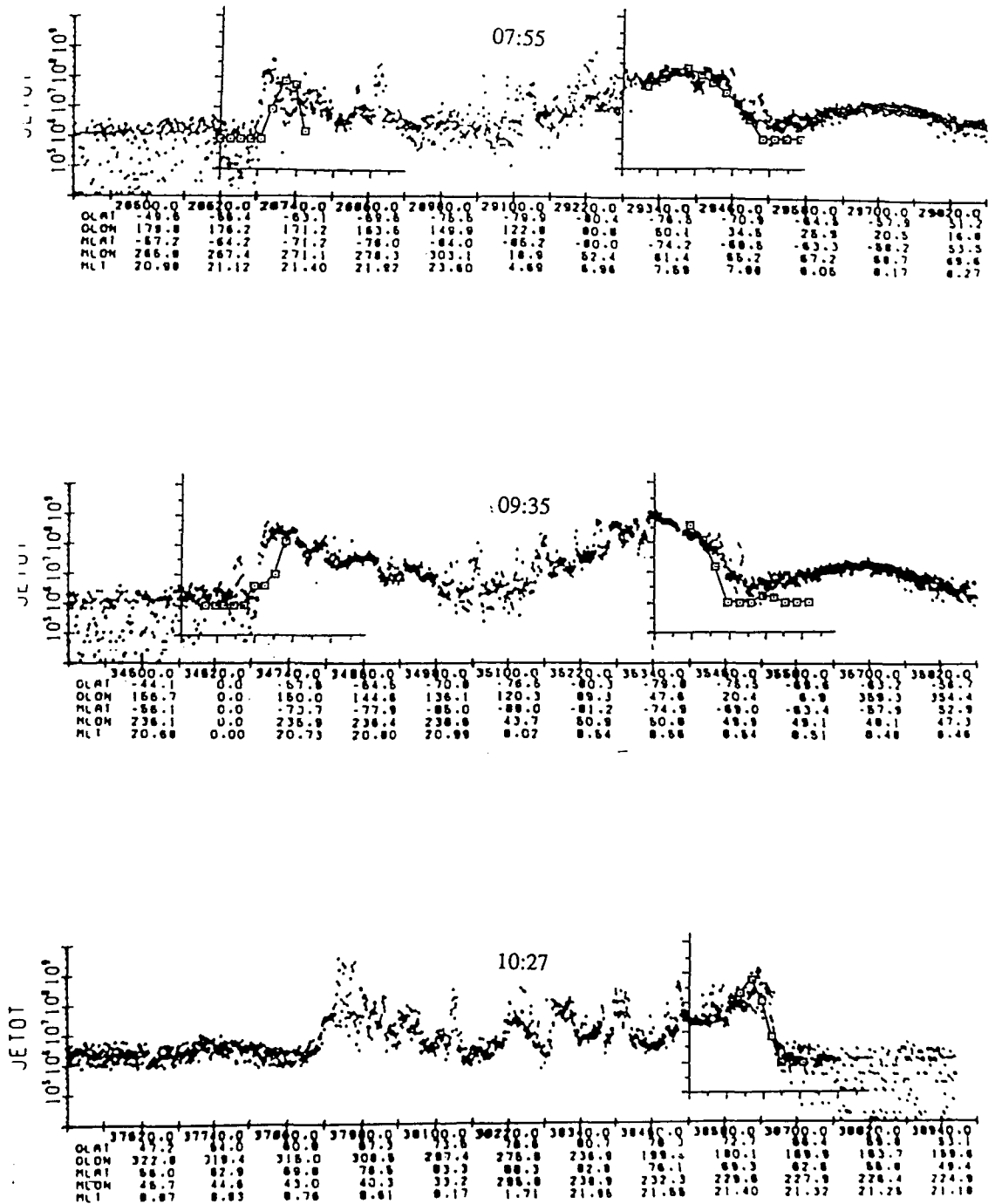


Figure 4.8 DMSP precipitating electron energy flux before substorm onset.

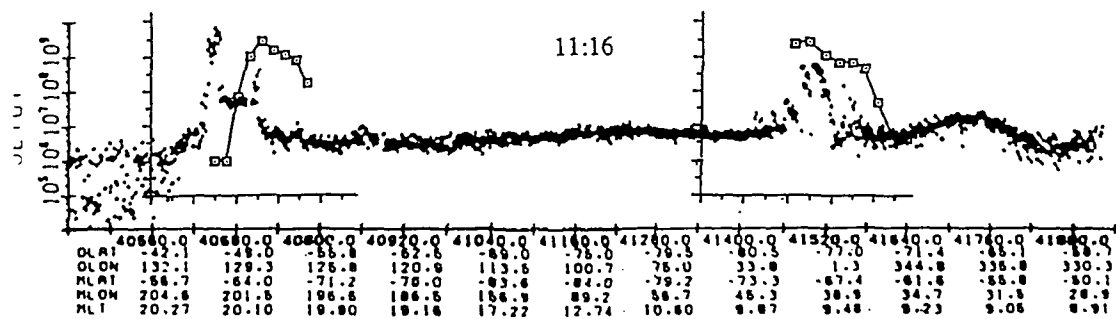


Figure 4.9 DMSP precipitating electron energy flux after substorm onset.

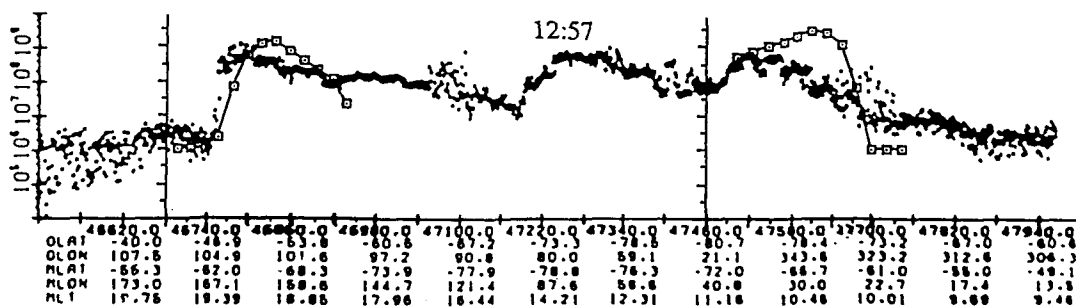
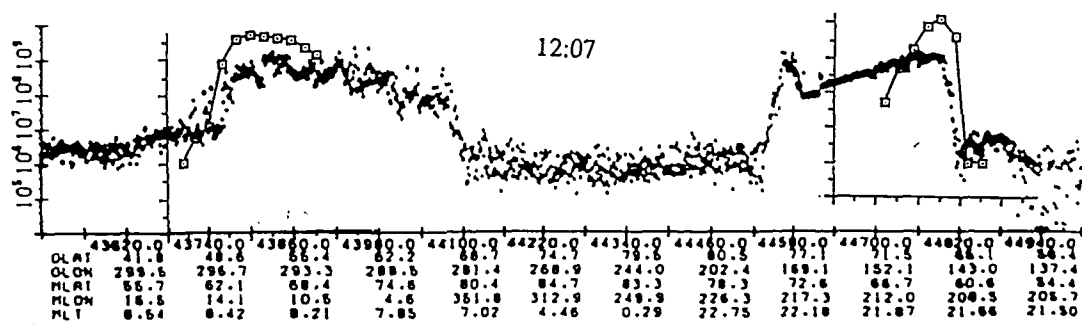


Figure 4.10 DMSP precipitating electron energy flux during substorm recovery period.

geosynchronous orbit. The arrival times of the electrons near dawn and the ions which have drifted to noon local time agree with the satellite data. However, assuming that middle plasma sheet flux tubes are convected adiabatically through the inner plasma sheet to synchronous orbit in a substorm with allowances for precipitation loss, the model results imply unrealistically high synchronous fluxes and unrealistically high precipitation rates. In addition, the modeled, geosynchronous 40 keV electron flux does not decrease during the recovery phase late in the event as the data shows. It may be that we are underestimating the pitch-angle scattering rate for these particles. The Hones (1979) substorm theory implies that a portion of the plasma on tail-plasma-sheet flux tubes escapes down the tail as a plasmoid. Therefore, for the initial model runs, we decreased the plasma sheet density by a factor of 2 at substorm onset. This still produced fluxes and precipitation too high by a factor of 5. The results presented here, from a later model run, assume a factor-of-5 depletion after substorm onset. The model predictions and observations agree to within a factor of 2 in flux levels and precipitation. The implication is that the substorm process must involve a powerful electron loss process in addition to precipitation, or the flux tubes which convect into geosynchronous orbit have previously been depleted.

TEST ANALYSIS REPORT

TEST ANALYSIS REPORT - 1

Test Analysis Report

2. TEST ANALYSIS

2.1 Test The set of algorithms encoded as the MSM have been run and tested at Rice University. The results have been studied by comparing the model results with observed data. The version of the program code which was developed at Rice University gives the verified results. To validate the algorithms delivered to the Space Forecast Center, the output from the code run at Rice University will be compared with that run at the Space Forecast Center.

2.1.3 Performance. Using the output data furnished from Rice University, the output from the code run at the Space Forecast Center should be the same.

3. SUMMARY AND CONCLUSIONS

3.1 Demonstrated Capability. This test verifies that the algorithms developed for the Air Weather Service at Rice University are running properly at the Space Forecast Center.

DATABASE SPECIFICATION

Database Specification

2.1 Database Identification.

AWS Environmental Database - Presently all the input data are on disk files, some of which will no longer be needed when the Environmental Data Base is operational. Attached is a listing of the input parameters needed to run the MSM and a proposed data transfer method.

MSM Database - Below is a list of the input files needed to restart the model.

BOxxxxxx	The magnetic field matrices needed for the model run.
COORD	File of values to set up the coordinate system.
DKTABLE	Decay times for computing charge-exchange loss of ions
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model. (km/sec)
MSMIN	Input start and stop times, start direct-access record number, and sunspot number

Following is a list of files output from the MSM.

V	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VNORTH	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VSOUTH	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VM	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
BMIN	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
XMIN	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)

DATABASE SPECIFICATION - 2

YMIN	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)
ZMIN	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)
BNDLOC	Output volume - number of longitudinal gridpoints \times number of time steps \times 4 (bytes)
EFLUX	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes)
FLXSUM	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes)
EAVG	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes)
AUGPAR	Output volume - number of data elements \times number of time steps \times 4 (bytes)
COLAT	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)
ALOCT	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)
FLUX	Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes)

2.3.1 Conceptual Model. The MSM will interrogate the Environmental Data Base at mark times for all physical parameters needed by the model. Attached is a copy of the MSM Control and Data Flow Diagram. Subroutine PARGEN within the MSM code will interpolate or extrapolate as necessary to adjust the data to the model time. Subroutine FECON then calculates the parameters needed within the program. The model is capable of running with no data except Kp. If Kp is missing, the program so states and stops.

Data from previous MSM runs is communicated through the direct-access record number read in file MSMIN. It specifies at which time label of the previous run to begin the current run. Zero means the start of a new run.

3.3.2 Content.

BOxxxxxx	The magnetic field matrices needed for the model run.
COORD	File of values to set up the coordinate system.

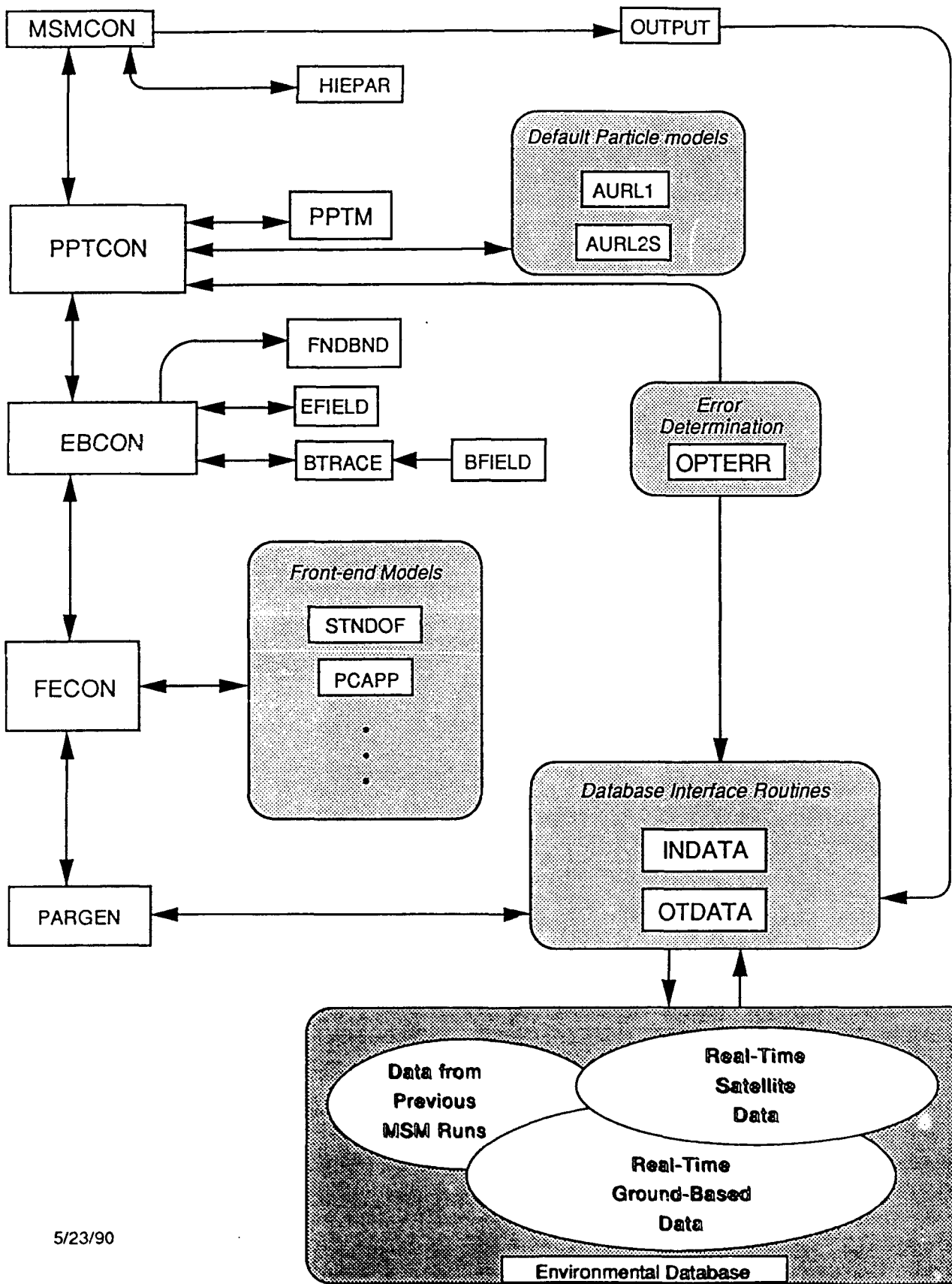
DATABASE SPECIFICATION - 3

EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate.
HARDY	Coefficients used by the Hardy precipitating electron model.
IONENG	Coefficients used as input for the ion precipitating model.
IONNUM	Coefficients used as input for the ion precipitating model. (km/sec)

Following is a list of files output from the MSM.

V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts).
VNORTH	Northern hemisphere electric potential distribution (Volts).
VSOUTH	Southern hemisphere electric potential distribution (Volts).
VM	Flux tube volume $((R_e/nT)^{-2/3})$.
BMIN	Equatorial magnetic field strength (nT).
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).
BNDLOC	Location of outer boundary of detailed particle traces.
EFLUX	Precipitating energy flux array (ergs/cm ² -sec).
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec).
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV).
AUGPAR	Augmented data array for input values.
COLAT	Grid colatitude array (radians).
ALOC	Grid local time array (radians eastward from noon).
FLUX	Flux values for all energy channels at all grid points

MSM Control & Data Flow Diagram



PARAMETER	NAME	UNITS	IO	Time Tag	Geo. Latitude	Geo. Longitude	Altitude	Mag. Local Time
KP	FKP	NONE	I	X				
Dst	DST	NANOTESLA	I	X				
C2	C2	NONE	I	X				
LOW LAT AURORAL BOUNDARY	DLATAZ	DEGREES	I	X			X	X
EQ. EDGE R1 CURRENTS	EDGER1	DEGREES	I	X			X	X
EQ. EDGE R2 CURRENTS	EDGER2	DEGREES	I	X			X	X
POLAR CAP POTENTIAL	PCP	KILOVOLTS	I	X				
POLAR CAP POTENTIAL PATTERN	XIPATT	NONE	I	X				
POLAR CAP BOUNDARY LATITUDE	PCBND	T.B.D.	I	X				
PRECIPITATION POWER INDEX	P	NONE	I	X				
GEO MAG X COMP.	GEOMGX	NANOTESLA	I	X				X
GEO MAG Y COMP.	GEOMGY	NANOTESLA	I	X				X
GEO MAG Z COMP.	GEOMGZ	NANOTESLA	I	X				X
GEO ELECTRON FLUX - CHANNEL(1)	EFLX(1)	ELEC/CM ² -s	I	X				X
GEO ION FLUX - CHANNEL(1)	GFLX(1)	IONS/CM ² -s	I	X				X
SOLAR WIND VELOCITY	SWVEL	KM/s	I	X	X	X	X	X
SOLAR WIND DENSITY	SWDEN	PROT/CM ³	I	X	X	X	X	X
IMF X COMPONENT	XIMFBX	NANOTESLA	I	X	X	X	X	X
IMF Y COMPONENT	XIMFBY	NANOTESLA	I	X	X	X	X	X
IMF Z COMPONENT	XIMFBZ	NANOTESLA	I	X	X	X	X	X

INPUT ONLY:

Data Transfer Method

1. MSM will access the environmental database input data files by calling a subroutine, **INDATA**.
2. The call will be of the form:
CALL INDATA(parm-name, **STARTT**, **ENDT**, **NDIM**, **DARRY**, **NUMNUM**)
 Where:
parm-name is a valid parameter name from the MSM input parameter list.
STARTT is the starting time for this data request.
ENDT is the ending time for this data request.
NDIM is the horizontal dimension of **DARRY** and the maximum number of data points that may be returned.
DARRY is a two dimensional array to be retrieved from the database. The form of **DARRY** is shown on the next page. The size of **DARRY** will be **NDIM** by 7.
NUMNUM is the number of data values placed in **DARRY** by **INDATA**.
3. The system controller will periodically update the input data files.
4. Rice does not plan to write **INDATA**.
5. All parameters will be in single precision, floating point format.
6. Output data will be passed from MSM to the environmental database via a subroutine, **OTDATA**.
7. The call to **OTDATA** will be defined similarly to **INDATA**.
8. Rice does not plan to write **OTDATA**.

Format for DARRY

NDIM →

7 ↓	Data value at t1	Data value at t2	Data value at t3	Etc.
	Time tag at t1	Time tag at t2	Time tag at t3	
	Latitude	Latitude	Latitude	
	Longitude	Longitude	Longitude	
	Altitude	Altitude	Altitude	
	mag. local time	mag. local time	mag. local time	

IMPLEMENTATION PROCEDURES

IMPLEMENTATION PROCEDURES - 1

Implementation Procedures

3.1.5 Detailed Procedures. Following are the files needed to run the MSM, including those to be replaced by calls to the environmental data base. Those required for a restart are so labelled.

BOxxxxxx	The magnetic field matrices needed for the model run. Required for restart.
CLAPSE	File containing values giving the collapse/no collapse state of the magnetosphere. To be replaced by call to AWS environmental data base, when complete.
COORD	File of values to set up the coordinate system. Required for restart.
DST	Dst values for the event. To be replaced by call to AWS environmental data base, when complete (nT).
DKTABLE	Decay times for computing charge-exchange loss of ions
EFCOEF	Coefficients from Heppner-Maynard model which are input to the electric field model. Required for restart.
ENCHAN	Input values for the number of energy channels, particle type and energy channels for the model to simulate. Required for restart.
EQEDGE	Values of the equatorward edge of the auroral oval at midnight used as input into the electric field model. To be replaced by call to AWS environmental data base, when complete (degrees).
FKP	Kp data for the event. To be replaced by call to AWS environmental data base, when complete. Required for restart.
HARDY	Coefficients used by the Hardy precipitating electron model. Required for restart.
IONENG	Coefficients used as input for the ion precipitating model. Required for restart.
IONNUM	Coefficients used as input for the ion precipitating model. Required for restart.
MSMIN	Input start and stop times, start direct-access record number, and sunspot number
PCP	Cross-polar cap potential values for event used as input to the electric field model. To be replaced by call to AWS environmental data base, when complete (kV).
SWDEN	Solar wind density values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (particles/cm ³)
SWVEL	Solar wind velocity values used to calculate the standoff distance for the event. To be replaced by call to AWS environmental data base, when complete. (km/sec)
XIPATT	Polar cap pattern type used as input to electric field model for the event. To be replaced by call to AWS environmental data base, when complete.
V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts). Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes)
VNORTH	Northern hemisphere electric potential distribution (Volts).

IMPLEMENTATION PROCEDURES - 2

VSOUTH	<p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p> <p>Southern hemisphere electric potential distribution (Volts).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
VM	<p>Flux tube volume $((R_e/nT)^{-2/3})$.</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
BMIN	<p>Equatorial magnetic field strength (nT).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
XMIN	<p>GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
YMIN	<p>GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
ZMIN	<p>GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
BNDLOC	<p>Location of outer boundary of detailed particle traces.</p> <p>Output volume - number of longitudinal gridpoints \times number of time steps \times 4 (bytes)</p>
EFLUX	<p>Precipitating energy flux array (ergs/cm²-sec).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times number of energy channels \times 4 (bytes)</p>
FLXSUM	<p>Total precipitation energy flux array (integrated over species for (1) electrons (2) H⁺ and (3) O⁺) (ergs/cm²-sec).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes)</p>
EAVG	<p>Average precipitating electron energy for (1) electrons, (2) H⁺ and (3) O⁺(eV).</p> <p>Output volume - number of latitudinal gridpoints \times number of longitudinal gridpoints \times number of time steps \times 3 particle species \times 4 (bytes)</p>
AUGPAR	<p>Augmented data array for input values.</p> <p>Output volume - number of data elements \times number of time steps \times 4 (bytes)</p>
COLAT	<p>Grid colatitude array (radians).</p>

IMPLEMENTATION PROCEDURES - 3

ALOCT	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes) Grid local time array (radians eastward from noon).
FLUX	Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × 4 (bytes) Flux values for all energy channels at all grid points Output volume - number of latitudinal gridpoints × number of longitudinal gridpoints × number of time steps × number of energy channels × 4 (bytes)

4.1.2 Detailed Procedures. To run the MSM:

Start and stop times are specified to the program through the 5 line MSMIN file. Following is an example of MSMIN for the fresh startup of the program.

```
1988 112 64800      'start year, start day, start time (seconds)'  
1988 112 66600      ' end year, end day, end time (seconds)'  
0                  'direct-access record number 0 means new start'  
'30 minute test run' 'up to 80 character run identification'  
0.0                'sunspot number=0.'
```

The MSMIN configuration given above would run the MSM for a 30 minute period from 1800 hours on day 112 of 1988 to 1830 on the same day. The sunspot number is zero.

To restart the MSM from 1830 (direct-access record number 3) and run until 2000 UT, the following MSMIN file would be used:

```
1988 112 66600  
1988 112 72000  
3  
'MSM restart from 1830 on day 112'  
0.0
```

Input file ENCHAN controls how many and which energy channels are calculated. The file set up is:

```
Number of energy channels to be modeled (maximum 30,integer)  
Particle type 1 (integer), Energy 1 (floating point)  
Particle type 2 (integer), Energy 2 (floating point)  
.....  
Particle type n (integer), Energy n (floating point)
```

The acceptable particle type input is:

IMPLEMENTATION PROCEDURES - 4

1	electrons
2	H ⁺
3	O ⁺

The energy is at geosynchronous orbit in keV. The energies must be in ascending order, with particle types grouped together, which are checked within the program.

For example,

4	
1	40
1	55
2	10
2	15

This is to model 4 energy channels, the first two are electrons of 40 and 55 keV at geosynchronous orbit. The second two are H⁺ ions of 10 and 15 keV energy at geosynchronous orbit.

MAINTENANCE MANUAL

Maintenance Manual

2.1 System Application. The Magnetospheric Specification Model was developed as a set of algorithms to be incorporated into a real-time program for use in the U.S. Air Force Air Weather Service Space Forecast Center. It is intended to help Space Forecast Center personnel perform their mission of providing information, particularly during magnetospheric disturbances, to "customers" who operate spacecraft. The output of the model includes (but is not limited to):

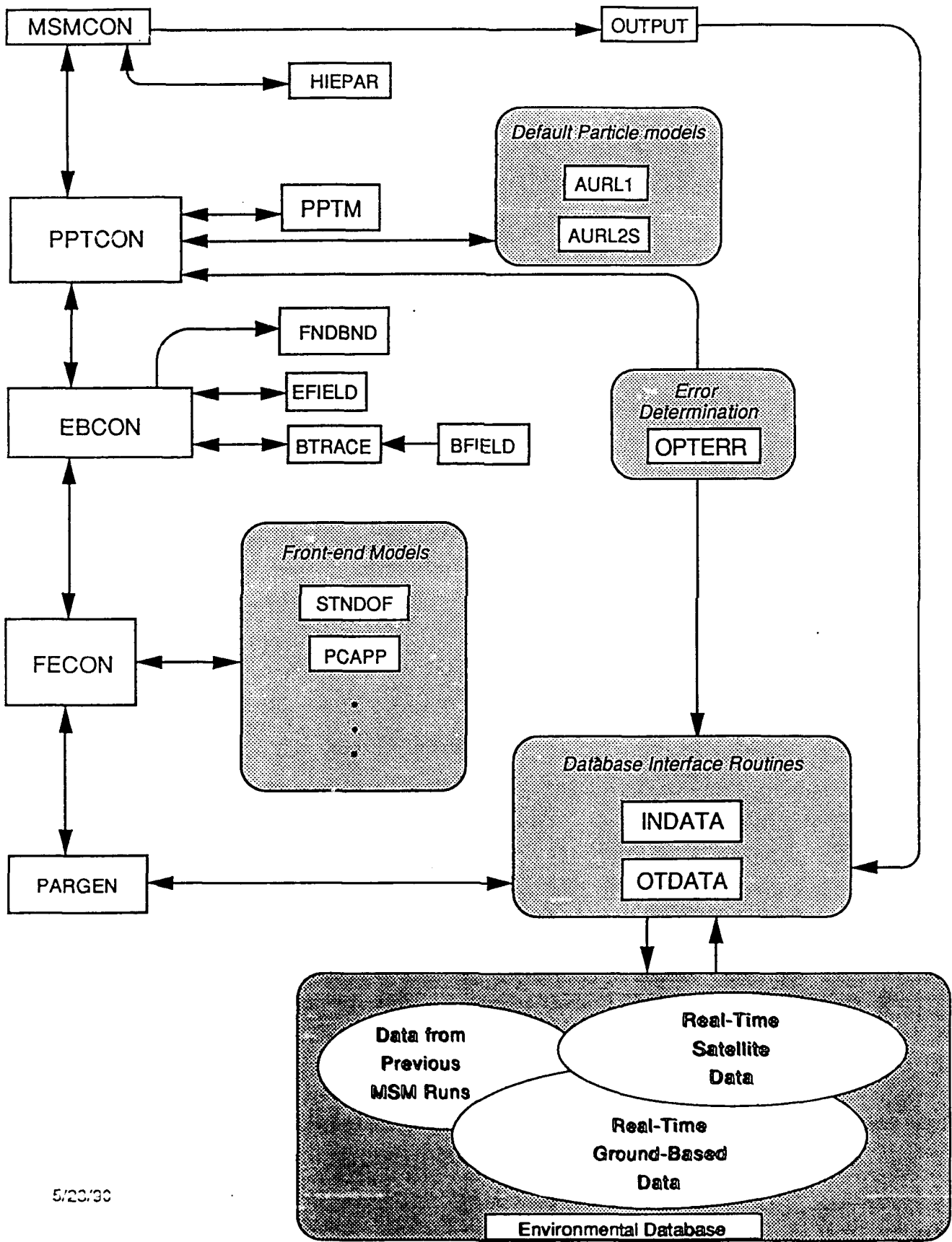
- 1) Fluxes of electrons and ions in the inner plasma sheet and the geosynchronous orbit region.
- 2) Energy fluxes and characteristic energies of electrons precipitated into the auroral ionosphere.

2.2 System Organization. The model uses separate ionospheric electric-field and magnetospheric magnetic field models to trace particle trajectories in the magnetosphere equatorial plane. The following flowchart shows the major components of the model and how they are related.

4.1 Conventions. None.

5.1.1 Description. See following pages.

MSM Control & Data Flow Diagram



MSMCON

a. Functions - The MSM control program MSMCON provides dimensioning of the arrays used throughout the program, and the initial, end and increments of time information for all other subroutines of the program. It also accesses the high energy particle tracing routines.

b. Input

ISTART(1) Start Year (last two digits)
 ISTART(2) Start Day (julian day) January 1 is day 1.
 ISTART(3) Start Time (seconds)
 IEND(1) End Year (last two digits)
 IEND(2) End Day (julian day) January 1 is day 1.
 IEND(2) End Time (seconds)
 IINC(1) Program time step increment (year)
 IINC(2) Program time step increment (day)
 IINC(3) Program time step increment (seconds)
 IRECEB For restart, record number of previously calculated electric and magnetic field output data to use as input for current run
 IRECPT For restart, record number of previously calculated particle-trace output data to use as input for current run

c. Processing - following is a list of subroutines called and their major function:

PPTCON Main control program for model
 HIEPAR High energy electron subroutine, currently a dummy routine pending computer code from sources outside Rice University.
 OUTPUT Output routine to interface with Space Forecast Center Environmental Database. Currently a dummy routine.

See the flowchart on the following page for the logic flow of the subroutine.

Global parameters for the run are set in this routine and are as follows:

LATDIM, Number of latitudinal grid lines (aliased as IDIM in some routines)
 LTDIM Number of local time (longitude) grid lines (aliased as JDIM in some routines)
 IEDIM Number of invariant energy species traced by the program
 ITMDIM Maximum number of major time steps per run of the program
 NAUGEL Number of elements in the augmented input array
 IRDIM Number of R values for which the empirical flux array, FLXMAT, is calculated
 NRGDIM Number of preset energy values for which FLXMAT is calculated
 KPDIM Number of KP values for which FLXMAT is calculated
 KPPLUS Kp dimension of the augmented FLXMAT array (KKPLUS = KPDIM + 2)

ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
IRDK	R dimension of DKTIME array
INRGDK	Energy dimension of DKTIME array
ISOLDK	Sun spot number dimension of DKTIME array
IONDK	Number of ion species in DKTIME array

d. Output. None. All output is currently handled by other subroutines.

PPTCON

a. *Functions* - main control program for the electric and magnetic field models and the running of the particle trace algorithm.

b. Input -

ISTART	Start year, day, and time (sec)
IINC	Major time step increment (year, day, time)
IEND	Ending year, day, and time (sec)
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
IEDIM	Number of particle species to be traced
ITMDIM	Maximum number of major time steps for this run
IRDK	R dimension of DKTIME array
INRGDK	Energy dimension of DKTIME array
ISOLDK	Sun spot number dimension of DKTIME array
IONDK	Number of ion species in DKTIME array
IRDIM	R dimension of FLXMAT arrays
NRGDIM	Energy dimension of FLXMAT arrays
KPDIM	KP dimension of FLXMAT arrays
KPPLUS	Kp dimension of the augmented FLXMAT array (KKPLUS = KPDIM + 2)
ISPDIM	Plasma mass species dimension

c. Processing - following is a list of subroutines called and their major function:

RDGRID	Subroutine to read grid system coordinates and calculate essential grid quantities
OUTP	Utility subroutine to print out array information
FLXNIT	Subroutine to calculate Kp-based particle number flux in units of particles/cm ² /s/sr/eV as function of R, energy and Kp
DTIME	Routine which returns current system time
EBCON	Executive routine to control calculation of electric and magnetic field models
EPREAD	Dummy routine to read satellite flux data - to be replaced by call to environmental data base when program is operational
SETALM	Subroutine to read the number of energy channels and their energies at geosynchronous orbit and calculate the energy invariant species needed to run the program
BNDSET	Subroutine to compute boundary plasma distribution
RDHDR	Subroutine to read the header record of the standard MSM disk file format
INITAL	Subroutine to compute initial plasma distribution
PPTM	Subroutine to trace particle trajectories from each grid point for each particle species back in time from time=TSTART to time=TSTOP

FLXDFL	Subroutine to calculate the energy-dependent ETA array from Kp and the location of the grid points by interpolating the empirical FLXMAT array - this routine is used as the MSM default model when full particle traces are not done
AURL1	Subroutine to determine default Hardy precipitating electron flux
AURL2S	Subroutine to determine default Hardy precipitating ion flux
PWRCAL	Subroutine to estimate precipitating electron energy flux poleward of the main MSM modeling region by comparing flux within modeling region with Hardy statistical values
WRT3D	Subroutine to write 3-d arrays into the standard MSM disk file format
READ3D	Subroutine to read 3-d arrays from the standard MSM disk file format
RDVEC	Subroutine to read header vector from standard MSM disk file format
WRTVEC	Subroutine to write header vector from standard MSM disk file format
OPTERR	Subroutine to calculate standard deviation and error of the model flux and available observed geosynchronous satellite data

See the following flow-chart for the logical structure of the subroutine.

d. Output -

FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated ($\log_{10}(\text{eV})$)
FLXKP	KP values for which FLXMAT arrays are calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values ($\log_{10}(\#/\text{cm}^2\text{-s-ster-eV})$)
THRMAT	Array of empirical fluxes as function of R, energy, and KP for use as threshold fluxes. ($\log_{10}(\#/\text{cm}^2\text{-s-ster-eV})$)
CHID	Character header string (up to 80 characters)
ID	Integer header vector ID(1) = Year ID(2) = Day ID(3) = Hours ID(4) = Minutes ID(5) = Seconds ID(6) = Presently unused ID(7) = Presently unused ID(8) = First dimension of output array ID(9) = Second dimension of output array ID(10) = Third dimension of output array ID(11) = Time index L ID(12) - ID(20) = Presently unused
RID	Real header vector RID(1) = TIMTAG (seconds) RID(2) = KP RID(3) = Polar cap potential drop (kV)

	RID(4) = Time derivative of location of low-latitude edge of auroral precipitation (degrees/hour)
	RID(5) - RID(20) = Presently unused
SCTFRC	Assumed pitch angle scattering efficiency
IFLAV	Chemical species identifier
	1 means electrons
	2 means H ⁺ ions
	3 means O ⁺ ions
BNDMAX	Maximum I value of model boundary along each local time grid line during the duration of this run.
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
TETA	Colatitude of I grid lines (radians)
PHI	Non-rotated hour angle of J grid lines (radians)
BIR	Radial component of ionospheric magnetic field (nT)
SINI	SIN(Magnetic field inclination angle)
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
COLAT	Grid colatitude array (radians)
ALOCT	Grid local time array (radians eastward from noon)
V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts)
VNORTH	Northern hemisphere electric potential distribution (Volts)
VSOUTH	Southern hemisphere electric potential distribution (Volts)
ASOUTH	Southern hemisphere radius of ellipse measured in x (sunward) direction
BSOUTH	Southern hemisphere radius of ellipse measured in y (duskward) direction
DXS	Southern hemisphere radius of ellipse measured in y (duskward) direction
DYS	Southern hemisphere radius of ellipse measured in y (duskward) direction
ANORTH	Northern hemisphere radius of ellipse measured in x (sunward) direction
BNORTH	Northern hemisphere radius of ellipse measured in y (duskward) direction
DXN	Northern hemisphere radius of ellipse measured in y (duskward) direction
DYN	Northern hemisphere radius of ellipse measured in y (duskward) direction
VM	Flux tube volume ((Re/nT) ^{-2/3})
VMLOSS	Geometric factor used in calculating precipitation loss
BMIN	Equatorial magnetic field strength (nT)
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
ALAM	Energy invariant vector (eV(Re/nT) ^{2/3})
ETABEG	Initial flux tube content distribution each time step (weber ⁻¹)
ETABND	Boundary flux tube content distribution (weber ⁻¹)
FLXBND	Flux at boundary (cm ² second) ⁻¹
BNDLOC	Location of outer boundary of detailed particle traces
ETA	Flux tube content array (weber ⁻¹)

FLUX	Flux (cm ² second) ⁻¹
EFLUX	Precipitation energy flux array (ergs/cm ² -sec)
FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec)
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV)
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
ALMDEL	Width of energy invariant channels
NAUGEL	Dimension of input arrays
AUGPAR	Augmented data array for input values
MODE	Logical variable telling which input parameters we have values for
RPP	Nominal radius of plasmapause defined as dipole mappine of equatorward edge of auroral zone to magnetospheric equatorial plane (Re)
THRSH	Vector giving full-traceback/default flux information
ERSHFT	Vector of error values
DKTIME	Array giving charge exchange decay times (seconds) for an array of radial distances, energies, sunspot numbers, and species

EBCON

a. Functions - EBCON calls routines to calculate the electric and magnetic field at our grid points for all time labels for this run.

b. Input -

ISTART	Start year, day, and time (sec)
IINC	Major time step increment (year, day, time)
IEND	Ending year, day, and time (sec)
COLAT	Grid colatitude array (radians)
ALOCT	Grid local time array (radians eastward from noon)
LATDIM	Number of latitudinal grid lines (aliased as IDIM in some routines)
LTDIM	Number of local time (longitude) grid lines (aliased as JDIM in some routines)
ITMDIM	Maximum number of major time steps per run of the program
IEDIM	Number of invariant energy species traced by the program
NAUGEL	Number of elements in the augmented input array
CHID	Character header string (up to 80 characters)
BIR	Radial component of ionospheric magnetic field (nT)
SINI	SIN(Magnetic field inclination angle)
IEMAX	Maximum number of energy channels
TETA	Colatitude of I grid lines (radians)

c. Processing - following are the subroutines called and their major function:

FECON	Subroutine to obtain time-normalized observational values
MLTSET	Subroutine to calculate time dependent ALOCT of rotating grid points
SETSCT	Subroutine to set species dependent pitch angle scattering efficiency
BTRACE	Subroutine to calculate magnetic field models appropriate for geophysical conditions as specified by standoff distance, equatorward edge of the auroral zone, Dst, tail collapse, and tilt angle
EFBNDY	Subroutine to calculate latitudes and widths of electric field model boundaries 2 and 3
EFIELD	Subroutine to return values of the potential on the northern hemisphere grid (VNORTH), on the southern hemisphere grid (VSOUTH), and the average of the two hemispheres (V)
OUTP	Utility subroutine to print out array information
FNDBND	Subroutine to compute time dependent outer boundary location
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
VMLSET	Subroutine to calculate VMLOSS array
WRT3D	Subroutine to write 3-d arrays into the standard MSM disk file format

d. Outputs -

ID	Integer header vector ID(1) = Year ID(2) = Day ID(3) = Hours ID(4) = Minutes ID(5) = Seconds ID(6) = Presently unused ID(7) = Presently unused ID(8) = First dimension of output array ID(9) = Second dimension of output array ID(10) = Third dimension of output array ID(11) = Time index L ID(12) - ID(20) = Presently unused
RID	Real header vector RID(1) = TIMTAG (seconds) RID(2) = KP RID(3) = Polar cap potential drop (kV) RID(4) = Time derivative of location of low-latitude edge of auroral precipitation (degrees/hour) RID(5) - RID(20) = Presently unused
VM	Flux tube volume (weber ⁻¹)
BMIN	Equatorial magnetic field strength (nT)
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
ZMIN	GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
V	Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts)
VNORTH	Northern hemisphere electric potential distribution (Volts)
VSOUTH	Southern hemisphere electric potential distribution (Volts)
ASOUTH	Southern hemisphere radius of ellipse measured in x (sunward) direction
BSOUTH	Southern hemisphere radius of ellipse measured in y (duskward) direction
DXS	Southern hemisphere radius of ellipse measured in y (duskward) direction
DYS	Southern hemisphere radius of ellipse measured in y (duskward) direction
ANORTH	Northern hemisphere radius of ellipse measured in x (sunward) direction
BNORTH	Northern hemisphere radius of ellipse measured in y (duskward) direction
DXN	Northern hemisphere radius of ellipse measured in y (duskward) direction
DYN	Northern hemisphere radius of ellipse measured in y (duskward) direction
BNDLOC	Location of outer boundary of detailed particle traces
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
ITMMAX	Maximum number of time labels

R Array giving radial distance of grid pts in magnetospheric equatorial plane (R_e)
P Array giving hour angle (measured eastward from noon in radians) of grid pts
 in equatorial plane
VMLOSS Geometric factor used in calculating precipitation loss
SCTFRC Assumed pitch angle scattering efficiency
AUGPAR Augmented data array for input values
MODE Logical variable telling which input parameters we have values for
RPP Nominal radius of plasmopause defined as dipole mapping of equatorward edge
 of auroral zone to magnetospheric equatorial plane (R_e)

BLOCK DATA

- a. Functions - Block data containing the index of data elements and connections between the logical unit number and names. Sets I, J, and energy indices for locations and species to be traced.
- b. Input - none.
- c. Processing - No other subroutines are called.

The block data contains the data element assignments (for example for the AUGPAR vector) and connects the logical unit number to the name within the program.

- d. Output - the following assignments are made:

Elements in the input data array

1	Year
2	Day
3	Seconds of day
4	Minute
5	Seconds
6	Kp
7	Dst (nT)
8	Equatorward edge of auroral zone at midnight (degrees)
9	Low latitude boundary of auroral zone (degrees)
10	Equatorward edge of Region 2 currents (degrees)
11	Currently unused
12	Bx component of interplanetary magnetic field (nT)
13	By component of interplanetary magnetic field (nT)
14	Bz component of interplanetary magnetic field (nT)
15	Magnetotail collapse parameter
16	X component of geosynchronous magnetic field data (nT)
17	Y component of geosynchronous magnetic field data (nT)
18	Z component of geosynchronous magnetic field data (nT)
19	Currently unused
20	Currently unused
21	Solar wind velocity (km/sec)
22	Solar wind density (prot/cm ³)
23	Tilt angle (degrees)
24	Standoff distance (Re)
25	Cross polar cap potential drop (kV)
26	Electric field pattern type
27	Time rate of change of Dst (nT/hour)

28 Time rate of change of the equatorward edge of the auroral oval at midnight (degrees/hour)

Elements in the logical unit assignment:

- 9 LUERR - Error output
- 13 LUPPT - Not currently used
- 14 LUCORD - Coordinate data
- 15 LUPRNT - Output to printer
- 16 LUIDAT - Not currently used
- 17 LUHDYE - Coefficients to calculate electron precipitating energy and number flux in default model
- 20 LUDK - charge exchange decay parameter file
- 21 LUETAB - ETABND file (boundary flux tube content distribution)
- 22 LUEBEG - ETABEG file (initial flux tube content distribution each time step)
- 23 LUSHFT - error correction factor file
- 24 LUPION - Not currently used
- 25 LUEAVG - EAVG file (average precipitating electron energy for (1) electrons, (2) H⁺ and (3) O⁺)
- 26 LUFLSM - FLXSUM file (total precipitation energy flux array (integrated over species for (1) electrons, (2) H⁺ and (3) O⁺))
- 27 LUFLX - FLUX file (particle flux array)
- 28 LUEFLX - EFLUX file (precipitation energy flux array)
- 35 LUEFLD - V file (electric potential distribution on grid (average of VNORTH and VSOUTH))
- 36 LUBFLD - VM file (flux tube volume)
- 37 LUBMIN - BMIN file (equatorial magnetic field strength (nT))
- 38 LUXMIN - XMIN file (GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane)
- 39 LUYMIN - YMIN file (GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane)
- 40 LUZMIN - ZMIN file (GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane)
- 41 LUALOC - ALOCT file (grid local time array (radians eastward from noon))
- 42 LUCOLT - COLAT file (grid colatitude array (radians))
- 43 LUBNDL - BNDLOC file (location of outer boundary of detailed particle traces)
- 44 LUPDAT - AUGPAR vector (augmented data array for input values)
- 45 LUVN - VNORTH file (northern hemisphere electric potential distribution)
- 46 LUVS - VSOUTH file (southern hemisphere electric potential distribution)
- 47 LIONEG - Coefficients to calculate ion precipitating energy flux in default model
- 48 LIONNO - Coefficients to calculate ion number flux in default model
- 49 LUENCH - File used to input number and range of energy channels to model

Other assignments made:

IBEG	Starting I value, currently set to 1
ISTOP	Ending I value, currently set to 53
JBEG	Starting J value, currently set to 3
JSTOP	Ending J value, currently set to 50
IEBEG	Starting energy value index, currently set to 1

EMODEL

a. Functions - This subroutine specifies the electric potential at each grid point in the modelling region for the northern hemisphere, southern hemisphere and the average of both hemispheres.

b. Inputs

IPATT	Polar cap pattern type (from Heppner-Maynard empirical model)
PCP	Cross polar cap potential (Volts)
DEQDT	Time rate of change of the latitude of the equatorward edge of the auroral zone at midnight (degrees/hour)
A	Radius of ellipse measured in X(sunward) direction
B	Radius of ellipse measured in Y(duskward) direction
DX	Sunward displacement of coordinate system center from pole
DY	Duskward displacement of coordinate system center from pole
COLAT	Grid colatitude array (radians)
ALOCT	Grid local time array (radians eastward from noon)
MODE	Not currently used
LATDIM	Number of latitudinal grid lines
LTDIM	Number of local time (longitude) grid lines
JWRAP	Number of points of overlap in J (longitude) direction
ICNTRL	= 1 means different formulas are used in regions 1, 2, 3, = 2 means Heppner-Maynard formula is used for all latitudes , but scaled to externally specified cross polar cap potential drop and ellipse parameters = -1 means Heppner-Maynard formula is used for all latitudes, unscaled. = -2 should not be used. It is the form used by the Rice Convection Model
ITOP	= 1 means the ellipse parameters A, B, DX, and DY for the polar cap boundary are computed internally in the subroutine. This is the normal mode for the MSM.

c. Processing - following is a list of the subroutines called and their major function:

INPUT	Get input needed for computation of Heppner-Maynard model
THET	Function that gives equation for the electric field boundary ellipse in flat polar coordinates
EPOT	Using scaled Heppner-Maynard model returns potential at a specific point
LOW	Returns potential at a specific location in low latitude region
AURORA	Returns potential at a specific location in auroral region
REG1	Returns potential at a specific location in Region 1

A concise description of the electric field model and its components is given in Section 2.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

V Electric potential disbritution on grid (Volts)

EPOT

a. Functions - This subroutine uses the scaled Heppner-Maynard model to return the electric potential at a specific point.

b. Input -

COEF	Coefficients from digitization of Heppner-Maynard electric field model
TLAT	Colatitude of point on boundary to be calculated (radians)
TLON	Magnetic local time of point on boundary to be calculated (radians)
NTAPE	Unit number from which to read Heppner-Maynard coefficients
IPATT	Heppner-Maynard pattern type
NNMAX	Number of coefficients to use in calculation
A	Radius of ellipse measured in x (sunward) direction
B	Radius of ellipse measured in y (duskward) direction
DX	Radius of ellipse measured in y (duskward) direction
DY	Radius of ellipse measured in y (duskward) direction
XCO	Electric field model coefficients
AHM	Radius of ellipse measured in x (sunward) direction from Heppner-Maynard Model
BHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
DXHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
DYHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
VMIN	Computed electric potential minimum from Heppner-Maynard Model
VMAX	Computed electric potential maximum from Heppner-Maynard Model
PCP	Cross-polar-cap potential drop
ICNTRL	= 1 means different formulas are used in regions 1, 2, 3, = 2 means Heppner-Maynard formula is used for all latitudes , but scaled to externally specified cross polar cap potential drop and ellipse parameters = -1 means Heppner-Maynard formula is used for all latitudes, unscaled. = -2 should not be used. It is the form used by the Rice Convection Model

c. Processing - A concise description of the electric field model and its components is given in Section 2.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

VALUE	Electric potential at point on boundary a (Volts)
-------	---

LOW

a. Functions - This subroutine returns the electric potential at a specification location in the low latitude region of the electric field model.

b. Input -

COL	Colatitude of point on boundary to be calculated (radians)
ALO	Magnetic local time of point on boundary to be calculated (radians)
DEQDT	Time rate of change of equatorward edge of auroral zone (degrees/hour)
AEQEDG	Radius of ellipse 3 measured in x (sunward) direction
DXEQEG	Offset of ellipse 3 in x direction
VBAR	Average potential at low latitudes
G	Weighting factor

c. Processing - A concise description of the electric field model and its components is given in Section 2.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

VLOW	Electric potential of a point in low latitude region (Volts)
------	--

AURORA

a. Functions - This subroutine returns the electric potential at a specific location in the auroral zone region of the electric field model.

b. Input -

COL	Colatitude of point on boundary to be calculated (radians)
ALO	Magnetic local time of point on boundary to be calculated (radians)
VBAZ	Auroral-zone contribution to the potential at boundary b
TB	Location of boundary b for specific local time
TC	Location of boundary c for specific local time
J	Local time index
JMAX	Maximum number of points in J direction
JWRAP	Number of points of overlap in J direction

c. Processing - A concise description of the electric field model and its components is given in Section 2.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

VAZ	Electric potential for a point in the auroral zone (Volts)
-----	--

REG1

a. Functions - This subroutine returns the electric potential for a specific point in Region 1 of the electric field model.

b. Input -

COL	Colatitude of point on boundary to be calculated (radians)
AL	Magnetic local time of point on boundary to be calculated (radians)
TA	Location of boundary a for specific local time
TB	Location of boundary b for specific local time
VAA	Electric potential for point on boundary a
VBB	Electric potential for point on boundary b
DVAA	Derivative of electric potential for point on boundary a
DVBB	Derivative of electric potential for point on boundary b

c. Processing - A concise description of the electric field model and its components is given in Section 2.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

V1	Electric potential for a point in Region 1 (Volts)
----	--

THET

a. Function - This function subprogram gives the equation for an electric field boundary ellipse in flat polar coordinates.

b. Input -

AA	Radius of ellipse measured in X(sunward) direction
BB	Radius of ellipse measured in Y(duskward) direction
XC	Sunward displacement of coordinate system center from pole
YC	Duskward displacement of coordinate system center from pole
PHI	Magnetic local time

c. Processing - This function gives the solution to the equation for an ellipse in flat polar coordinates. It specifies colatitude as a function of local time.

d. Output -

THET	Colatitude of input ellipse parameters and local time
------	---

INPUT

a. Function - This subroutine reads in the necessary input for the computation of the Heppner-Maynard electric field model.

b. Input -

NTAPE Unit number from which to read Heppner-Maynard coefficients

c. Processing - This subroutine reads from logical unit NTAPE the coefficients necessary for the Heppner-Maynard electric field model.

d. Output -

COEF	Coefficients from digitization of Heppner-Maynard electric field model
IPATT	Polar cap pattern type (from Heppner-Maynard empirical model)
XCO	E field coefficients
AHM	Radius of ellipse measured in x (sunward) direction from Heppner-Maynard Model
BHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
DXHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
DYHM	Radius of ellipse measured in y (duskward) direction from Heppner-Maynard Model
VMIN	Computed electric potential minimum from Heppner-Maynard Model
VMAX	Computed electric potential maximum from Heppner-Maynard Model

BTRACE

a. Functions - Subroutine to calculate magnetic field models for appropriate geophysical conditions as specified by the standoff distance, equatorward edge of the auroral zone, Dst, tail collapse parameter, and tilt angle. Calculates the output on the MSM spatial grid by interpolating between pre-computed magnetic field models.

b. Input -

LATDIM	Number of latitudinal grid lines
LTDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program
L	Current temporal grid index
FSTOFF	Standoff distance (Re)
FEQEDG	Equatorward edge of aurora (degrees)
FDST	Dst (nT)
FCLPSE	Collapse parameter
FTILT	Tilt angle (degrees)
ALOCT	Local time hour angle (measured east from noon)
TETA	Colatitude of I grid lines (radians)

c. Processing - following are the subroutines called and their major functions:

GETMAT	Subroutine to find the magnetic field matrices needed for interpolation in order to represent current conditions
RMVBSH	Subroutine to extrapolate magnetic field matrices into extremely stretched or open regions
BFGYRO	Subroutine to rotate fixed grid magnetic field arrays to match rotating coordinate system

This subroutine determines which of the pre-computed magnetic field matrices are needed to match the geophysical conditions specified. After the matrices are retrieved and stored into a work array (WORK(LATDIM,LTDIM,2,2,2,2)) they are interpolated using a multilinear interpolation scheme given by Press et al. in Numerical Recipes, Cambridge University Press, 1987, pp 95-97. The arrays are then rotated so that they have the same local time orientation as the main program.

d. Output -

VM	Flux tube volume $((Re/nT)^{-2/3})$
BMIN	Equatorial magnetic field strength (nT)
XMIN	GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
YMIN	GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)

ZMIN GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (R_e)
R Array giving radial distance of grid pts in magnetospheric equatorial plane (R_e)
P Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane

BFGYRO

a. Functions - Subroutine to rotate fixed grid magnetic field arrays to match the rotating grid system of the main program.

b. Inputs -

LATDIM	Number of latitudinal grid lines
LTDIM	Number of local time (longitude) grid lines
ARRAY	Unrotated magnetic field values called sequentially for the following quantities: VM - Flux tube volume $((Re/nT)^{-2/3})$ BMIN - Equatorial magnetic field strength (nT) XMIN - GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re) YMIN - GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re) ZMIN - GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
WORK	Internal working array
ALOCT	Local time hour angle (measured east from noon)

c. Processing - No other subroutines are called.

This routine uses a linear interpolation scheme to determine how much the magnetic field matrices should be rotated (F). It applies this factor to the input matrices so that the magnetic local time of the magnetic field matrices and the main program agree.

d. Output -

ARRAY	Rotated magnetic field values for the following quantities: VM - Flux tube volume $((Re/nT)^{-2/3})$ BMIN - Equatorial magnetic field strength (nT) XMIN - GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re) YMIN - GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re) ZMIN - GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)
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PPTM

a. Functions - This subroutine traces particle trajectories from each grid point for each particle species back in time from time=TSTART to time=TSTOP.

b. Inputs

TSTART	Time at which to begin particle traceback (seconds)
TSTOP	Time at which to end particle traceback (seconds)
DTNOM	Nominal time step to begin traces. DTNOM < 0 to trace back in time. PPTM will adjust time step as needed
SCTFRC	Assumed pitch angle scattering efficiency
IFLAV	Chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions
BNDMAX	Maximum I value of model boundary along each local time grid line during the duration of this run.
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
BIR	Radial component of ionospheric magnetic field (nT)
ITMMAX	Number of temporal grid points used
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
IEDIM	Number of invariant energy species traced by the program
ITMDIM	Maximum number of major time steps per run of the program
IRDIM	Number of R values for which the empirical flux array, FLXMAT, is calculated
NRGDIM	Number of preset energy values for which FLXMAT is calculated
KPDIM	Number of KP values for which FLXMAT is calculated
KPPLUS	KP dimension of augmented FLXMAT array (KPPLUS=KPDIM+2)
ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated (log ₁₀ (eV))
FLXKP	KP values for which FLXMAT arrays are calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values (log ₁₀ (#/cm ² -s-ster-eV))
THRMAT	Array of empirical fluxes as function of R, energy, and KP for use as threshold fluxes. (log ₁₀ (#/cm ² -s-ster-eV))
TIMTAG	Vector giving times at which E and B parameters are calculated
ALAM	Energy invariant vector (eV(Re/nT) ^{2/3})
ALMDEL	Width of energy invariant channels
VM	Flux tube volume ((Re/nT) ^{-2/3})
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane

VMLOSS	Geometric factor used in calculating precipitation loss
V	Electric potential distribution on grid (Volts)
ETABEG	Initial flux tube content distribution each time step (weber ⁻¹)
ETABND	Boundary flux tube content distribution (weber ⁻¹)
BNDLOC	Location of outer boundary of detailed particle traces
LL	Current temporal grid index
RPP	Nominal radius of plasmapause defined as dipole mapping of equatorward edge of auroral zone to magnetospheric equatorial plane (Re)
FKP	Current Kp value
IEMAX	Number of energy channels in use
THRSH	Vector giving full-traceback/default flux information
TSHENG	Threshold value to switch from full-traceback to default models - current set at > 100 keV electrons
TSHING	Threshold value to switch to default models for ions - currently set at 50 keV
IRDK	R dimension of DKTIME array
INRGDK	Energy dimension of DKTIME array
ISOLDK	Sun spot number dimension of DKTIME array
IONDK	Number of ion species in DKTIME array
DKTIME	Array giving charge exchange decay times (seconds) for an array of radial distances, energies, sunspot numbers, and species

c. Processing - following are the subroutines called and their major function

SETREF	Subroutine to set upper limit reference flux
OUTP	Utility routine to print our array information
TNORML	Utility function subprogram to calculate run-normalized time
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
WKRATE	Function subprogram to evaluate weak precipitation loss rate
MOVER	Subroutine to advance one particle location one time step using 4th-order Runge-Kutta algorithm with 5th order correction
MODFIX	Subroutine to adjust BBJ to be between 2 and JDIM-1
TCHK	Subroutine to check whether time boundary was crossed
BNDCHK	Subroutine to determine whether particle has crossed boundary of calculation
FLXVAL	Function subprogram to calculate Kp-dependent flux value a R=RR for particles of energy ENRG and Kp=FKP by interpolating FLXMAT array

See the following flow chart for the logic of the subroutine.

d. Output

ETA	Flux tube content array (weber ⁻¹)
-----	--

EFLUX Precipitation energy flux array (ergs/cm²-sec)
FLXSUM Total precipitation energy flux array (integrated over species for (1) electrons
 (2) H⁺ and (3) O⁺) (ergs/cm²-sec)
EAVG Average precipitating electron energy for (1) electrons, (2) H⁺ and (3) O⁺(eV)

BNDCHK

a. Functions - This subroutine determines whether a particle has crossed the spatial boundary of the model calculation.

b. Input -

T	Time
IE	Energy channel
BBI	I location at end of time step
BBJ	J location at end of time step
BIOLD	I location at beginning of time step
BJOLD	J location at beginning of time step
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
ETABND	Boundary flux tube content distribution (weber ⁻¹)
BNDMAX	Maximum I value of model boundary along each local time grid line during the duration of this run.
BNDLOC	Location of outer boundary of detailed particle traces
JDIM	Number of local time (longitude) grid lines
IEDIM	Number of invariant energy species traced by the program
ITMDIM	Maximum number of major time steps per run of the program
ITMMAX	Number of temporal grid points used
JWRAP	Number of points of overlap in J direction

c. Processing - following are the subroutines called and their major function:

 TNORML Utility function subprogram to calculate run-normalized time

Using BNDMAX, the I value of the boundary, the time-normalized I (BBI) and J (BBJ) input values are compared to see if the particle has passed out of the outer boundary of the calculation region. If the particle has passed the boundary, the ETA value at that point on the boundary is calculated and returned.

d. Output -

ETANIL	If boundary is crossed, ETANIL is the value of ETA at the boundary crossing point (weber ⁻¹)
IEXIT	If the boundary is crossed, IEXIT = 2

DVEFDI

a. Function - Function subprogram to compute the I derivative of the effective potential at grid point (I,J) at normalized time BT.

b. Input -

I	I coordinate of the grid point
J	J coordinate of the grid point
BT	Normalized time
AALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
V	Electric potential distribution on grid (Volts)
VM	Flux tube volume ($(Re/nT)^{-2/3}$)
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - No other subroutines are called.

Standard central-difference formula is used to differentiate the effective potential (potential energy - kinetic energy) in the I direction.

d. Output -

DVEFDI Derivative of effective potential at point (I,J,BT)

DVEFDJ

a. Function - Function subprogram to compute the J derivative of the effective potential at grid point (I,J) at normalized time BT.

b. Input -

I	I coordinate of the grid point
J	J coordinate of the grid point
BT	Normalized time
AALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
V	Electric potential distribution on grid (Volts)
VM	Flux tube volume ($(Re/nT)^{-2/3}$)
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - No other subroutines are called.

Standard central-difference formula is used to differentiate the effective potential (potential energy - kinetic energy) in the J direction.

d. Output -

DVEFDJ Derivative of effective potential at point (I,J,BT)

G3NTRP

a. Functions - Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)

b. Input -

A	Array to be interpolated
IMAX	I dimension of array A
JMAX	J dimension of array A
KMAX	K dimension of array A
BI	Floating point value to interpolate in I dimension
BJ	Floating point value to interpolate in J dimension
BK	Floating point value to interpolate in K dimension

c. Processing - No other subroutines are called.

This subroutine uses the standard linear interpolation technique to interpolate an array in 3 dimensions.

d. Output -

G3NTRP	Interpolated point from array A
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MODFIX

a. Functions - Subroutine to adjust J value to be within array bounds.

b. Input -

BBJ	J value to be adjusted
JDIM	J dimension of array
JWRAP	Number of points of overlap in J direction

c. Processing - No other subroutines are called.

The subroutine tests to see if the value is within the array bounds and adjusts the value if it is not.

d. Output -

BBJ	Adjusted J value
-----	------------------

MOVER

a. Functions - Subroutine to advance one particle location one time step using 4th-order Runge-Kutta algorithm with 5th order correction.

b. Input -

T	Time parameter
DTTRY	Time step to try < 0 = moves particles back in time > 0 = moves particles forward in time
BIOLD	Current I location of particle
BJOLD	Current J location of particle
EPS	Accuracy parameter
BBISCL	I error scaling parameter
BBJSCL	J error scaling parameter
AALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
V	Electric potential distribution on grid (Volts)
VM	Flux tube volume ($(Re/nT)^{-2/3}$)
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
BIR	Radial component of ionospheric magnetic field (nT)
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - following are the subroutines called and their major functions:

RK4 4th order Runge-Kutta routine

This routine is based on the discussion in Numerical Recipes, Press et al, on pages 550-560 in the chapter on integration of ordinary differential equations.

d. Output -

BBI	Updated I location of particle
BBJ	Updated J location of particle
DTUSED	Time step actually used
DTNEXT	Estimated next stepsize

RK4

a. Functions - This subroutine integrates an ordinary differential equation using a 4th order Runge-Kutta scheme.

b. Inputs -

T	Time parameter
DT	Time step < 0 = moves particles back in time > 0 = moves particles forward in time
BBIIN	Current I location of particle
BBJIN	Current J location of particle
AALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
V	Electric potential distribution on grid (Volts)
VM	Flux tube volume ($(Re/nT)^{-2/3}$)
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
BIR	Radial component of ionospheric magnetic field (nT)
IDIM	Number of latitudinal grid lines
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - following are the subroutines called and their major function:

VLOCTY	Subroutine to compute I and J components of particle velocity with energy invariant AALAM at location (BI,BJ) at normalized time BT
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This algorithm comes from Abramowitz, Milton and Stegun, Irene A., 1964, Handbook of Mathematical Function, National Bureau of Standards, 1970, p. 896, section 25.5.10. It is also referenced in Numerical Recipes by Press et al.

d. Output

BBIOUT	Computed I location at end of time step
BBJOUT	Computed J location at end of time step

TCHK

a. Functions - This subroutine checks whether a particle has crossed a time boundary for this time step.

b. Input -

T	Time
TSTOP	Time at which to end particle traceback
DTNOM	Nominal time step to begin traces
BBI	I location of particle
BBJ	J location of particle
IEUSE	Energy index of particle
ETABEG	Initial flux tube content distribution each time step (weber ⁻¹)
IDIM	Number of latitudinal grid lines
JDIM	Number of local time (longitude) grid lines
IEDIM	Number of invariant energy species traced by the program

c. Processing - following are the subroutines called and major functions:

G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
--------	--

If time boundary is crossed, the ETA at the location (BBI,BBJ) is interpolated.

d. Output -

ETANIL	ETABEG value at location (BBI,BBJ) at time T for energy species IEUSE if particle has crossed time boundary (weber ⁻¹)
IEEXIT	= 1 if particle has crossed time boundary

TNORML

a. Functions - Utility function subprogram to calculate run-normalized time.

b. Input -

TT	Time (seconds)
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
ITMMAX	Number of temporal grid points used

c. Processing - No other subroutines are called.

Using the run times given in TIMTAG, the time is located. Using standard linear interpolation, the correction factor is calculated.

d. Output -

TNORML Non-integer time index corresponding to time TT

VLOCTY

a. Functions - This subroutine computes the I and J components of particle velocity for a particle with energy invariant AALAM at location (BBI,BBJ) at normalized time BT.

b. Input -

BBI	I location of particle
BBJJ	J location of particle
BT	Normalized time
AALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
BIR	Radial component of ionospheric magnetic field (nT)
V	Electric potential distribution on grid (Volts)
VM	Flux tube volume ($(Re/nT)^{-2/3}$)
IDIM	Number of latitudinal grid lines
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - following are the subroutines called and major functions:

G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
--------	--

This subroutine computes the I and J components of the particle's ExB drift.

d. Output -

DBIDT	I velocity of particle (I units/sec)
DBJDT	J velocity of particle (J units/sec)

RDGRID

a. Functions - Subroutine to read grid system coordinates and calculate essential grid quantities.

b. Input - Read from input file 'COORD'

ID	Eight character identifier
OFFSET	Offset of center of coordinate system from magnetic pole, currently zero
DLAM	Latitudinal grid spacing constant
DPSI	Local time grid spacing constant
RI	Radius of earth + ionosphere (km)
RE	Radius of earth (km)
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
TETA	Colatitude of I grid lines (radians)
PHI	Non-rotated hour angle of J grid lines (radians)

c. Processing - No other subroutine are called.

d. Additional outputs -

BIR	Radial component of ionospheric magnetic field (nT)
SINI	SIN(Magnetic field inclination angle)
COLAT	Grid colatitude array (radians)

MLTSET

a. Functions - This subroutine calculates the time dependent magnetic local time of rotating grid points.

b. Input -

ISEC	Time from start of run (seconds)
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines

c. Processing - No other subroutines are called.

The subroutine calculates the change in the hour angle of the J grid lines (DPHI) and the time rate of change of the hour angle of the J grid lines (DPHIDT) to compute the time dependent magnetic local time grid

d. Output -

ALOCT	Time dependent magnetic local time grid
-------	---

VMLSET

a. Functions - This subroutine sets up the time-dependent VMLOSS array

b. Input -

ITMCUR	Current time label
VM	Flux tube volume $((R_e/nT)^{-2/3})$
BIR	Radial component of ionospheric magnetic field (nT)
SINI	SIN(Magnetic field inclination angle)
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. Processing - No other subroutines are called.

d. Output -

VMLOSS	Geometric factor used in calculating precipitation loss
--------	---

FNDBND

a. **Functions** - This subroutine computes the time dependent outer model boundary location.

b. **Input** -

ITMCUR	Current time label
COLAT	Grid colatitude array (radians)
ALOCT	Time dependent magnetic local time grid (radians eastward from noon)
A2	Radius of ellipse 2 measured in x (sunward) direction
B2	Radius of ellipse 2 measured in y (duskward) direction
DX2	Offset of ellipse 2 measured in y (duskward) direction
DY2	Offset of ellipse 2 measured in y (duskward) direction
IDIM	Number of latitudinal grid lines)
JDIM	Number of local time (longitude) grid lines
ITMDIM	Maximum number of major time steps per run of the program

c. **Processing** - following are the subroutines called and their major function:

THET	Function that gives the equation for an electric field boundary ellipse in flat polar coordinates
-------------	---

For each J (longitudinal) value, the location of the outer boundary is calculated. Then the colatitude array (COLAT) is searched to find the pair of I values that encompass the boundary. The location is then linearly interpolated and placed in the array BNDLOC.

d. **Output** -

BNDLOC	Location of outer boundary of detailed particle traces
---------------	--

OUTP

a. Functions - This is utility subroutine to print out array information.

b. Input -

R	Array to be output
ISIZE	I dimension of R array
JSIZE	J dimension of R array
IBEG	Initial I value to be output
IEND	Final I value to be output
IINC	I value increment for output
JBEG	Initial J value to be output
JEND	Final J value to be output
JINC	J value increment for output
XSCALE	= 0.0 scale is calculated by subroutine to give best display. All elements or array are divided by scale before being output ≠ 0.0 scale is set by user
TITLE	Character string that identifies the array being output
NTP	Output unit number
NCOL	Number of columns of output device (usually either 80 or 132)

c. Processing - No other subroutines are called.

This subroutine takes any 2-dimensional array and formats the output.

d. Output - The array is output to the device NTP.

AURL1 (also FNDHDY, ADDHDY, FSUM)

a. Function - These subroutines determine the default Hardy precipitating electron flux.

b. Input -

FKP	Current Kp value
COLAT	Grid colatitude array (radians)
ALOCT	Time dependent magnetic local time grid (radians)
LATDIM	Number of latitudinal grid lines)
LTDIM	Number of local time (longitude) grid lines

c. Processing - following are the subprograms called and their major function:

FNDHDY	Subroutine to find and read the pertinent Fourier coefficients for the Hardy electron model
ADDHDY	Subroutine to calculate the Hardy model electron flux value for a given point
FSUM	Function subprogram to determine sum of a Fourier series

These subroutines were supplied by Dr. David Hardy at the Air Force Geophysics Laboratory, Bedford, Mass.

d. Output -

AEFLUX	The integral electron energy flux (ergs/cm ² -sec)
AEMEAN	The average energy (eV)

WRT3D

a. Functions - This subroutine writes 3-d arrays to disk in the standard MSM disk file format.

b. Input -

LUN	Logical unit number on which to write file
IRECMX	Logical record number at which to write data
ID	Integer header vector
	ID(1) = Year
	ID(2) = Day
	ID(3) = Hours
	ID(4) = Minutes
	ID(5) = Seconds
	ID(6) = Presently unused
	ID(7) = Presently unused
	ID(8) = First dimension of output array
	ID(9) = Second dimension of output array
	ID(10) = Third dimension of output array
	ID(11) = Time index L
	ID(12) - ID(20) = Presently unused
RID	Real header vector
	RID(1) = TIMTAG (seconds)
	RID(2) = KP
	RID(3) = Polar cap potential drop (kV)
	RID(4) = Time derivative of location of low-latitude edge of auroral precipitation. (degrees/hour)
	RID(5) - RID(20) = Presently unused
CHID	Character header string (up to 80 characters)
ARRAY	3-d array to be written
IDIM	I dimension of ARRAY
JDIM	J dimension of ARRAY
KDIM	K dimension of ARRAY
ITMDIM	Maximum number of major time steps for this run

c. Processing - No other subroutines are called.

This routine takes the desired array, opens the appropriate file, writes the array to the file starting with the specified logical record number, and closes the file.

d. Output - The array is written to unit number LUN.

RDHDR

a. Functions - This subroutine reads the header record of the standard MSM disk file

b. Input -

LUN	Logical unit number on which to write file
FILNAM	Character string containing file name
IRECMX	Record number to begin read function
IDIM	I dimension
JDIM	J dimension
ITMDIM	Maximum number of major time steps for this run

c. Processing - No other subroutines are called.

This routine opens the appropriate file, reads the header information of the file starting with the specified record number, and closes the file.

d. Output -

ID	Integer header vector ID(1) = Year ID(2) = Day ID(3) = Hours ID(4) = Minutes ID(5) = Seconds ID(6) = Presently unused ID(7) = Presently unused ID(8) = First dimension of output array ID(9) = Second dimension of output array ID(10) = Third dimension of output array ID(11) = Time index L ID(12) - ID(20) = Presently unused
RID	Real header vector RID(1) = TIMTAG (seconds) RID(2) = KP RID(3) = Polar cap potential drop (kV) RID(4) = Time derivative of location of low-latitude edge of auroral precipitation (degrees/hour) RID(5) - RID(20) = Presently unused
CHID	Character header string (up to 80 characters)

READ3D

a. Function - This subroutine reads a record from the standard MSM disk file.

b. Input -

LUN	Logical unit number from which to read file
FILNAM	Character string containing file name
LREC	Logical record number to read direct access data set
IDIM	1st dimension of ARRAY
JDIM	2nd dimension of ARRAY
KDIM	3rd dimension of ARRAY
ITMDIM	Maximum number of major time steps for this run

c. Processing - No other subroutines are called.

This routine opens the appropriate file, reads the array from the file starting with the specified record number, and closes the file.

d. Output -

ID	Integer header vector ID(1) = Year ID(2) = Day ID(3) = Hours ID(4) = Minutes ID(5) = Seconds ID(6) = Presently unused ID(7) = Presently unused ID(8) = First dimension of output array ID(9) = Second dimension of output array ID(10) = Third dimension of output array ID(11) = Time index L ID(12) - ID(20) = Presently unused
RID	Real header vector RID(1) = TIMTAG (seconds) RID(2) = KP RID(3) = Polar cap potential drop (kV) RID(4) = Time derivative of location of low-latitude edge of auroral precipitation (degrees/hour) RID(5) - RID(20) = Presently unused
CHID	Character header string (up to 80 characters)
ARRAY	3-d array to be read

SETALM

a. Functions - This subroutine reads the number of energy channels and their energies at geosynchronous orbit and calculates the energy invariant species corresponding to these energies.

b. Input - Read from file 'ENCHAN'

IFLAV	Chemical species identifier
	1 means electrons
	2 means H ⁺ ions
	3 means O ⁺ ions
ENCHNL	Energy channel at geosynchronous orbit (eV)

c. Processing - No other subroutines are called.

The input data must be in eV with energy increasing within each chemical species. The parameter VM6 is the typical value for (flux tube volume)^{-2/3} at geosynchronous orbit.

d. Output -

ALAM	Energy invariant vector (eV(Re/nT) ^{2/3})
IEMAX	Maximum number of energy channels
IEDIM	Number of invariant energy species traced by the program
IFLAV	Chemical species identifier
	1 means electrons
	2 means H ⁺ ions
	3 means O ⁺ ions
ALMDEL	Width of energy invariant channels

BNDSET

a. Functions - This subroutine computes the boundary plasma distribution.

b. input -

LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
IEDIM	Number of particle species to be traced
ITMDIM	Maximum number of major time steps for this run
ITMMAX	Actual number of time steps for this run
IRDIM	R dimension of FLXMAT arrays
NRGDIM	Energy dimension of FLXMAT arrays
KPDIM	KP dimension of FLXMAT arrays
KPPLUS	Augmented KP dimension (=KPDIM+2)
ISPDIM	Plasma mass species dimension
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated (log ₁₀ (eV))
FLXKP	KP values for which FLXMAT arrays are calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values (log ₁₀ (#/cm ² -s-ster-eV))
NAUGEL	Number of elements in the augmented input array
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
BNDLOC	Location of outer boundary of detailed particle traces
IFLAV	Chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions
AUGPAR	Augmented data array for input values
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
VM	(Flux tube volume) ^{-2/3} ((Re/nT) ^{-2/3})
ETA	Flux tube content array (weber ⁻¹)
ALAM	Energy invariant vector (eV(Re/nT) ^{2/3})
ALMDEL	Width of energy invariant channels
IEMAX	Maximum number of energy channels

c. Processing - No other subroutines are called.

The background for this subroutine is contained in Section 2.5.5 of Contract #F19628-87-0001 Final Report.

d. Output

ETABND Boundary flux tube content distribution (weber⁻¹)
FLXBND Flux values at boundary (cm² sec)⁻¹

SETSCT

a. Functions - Subroutine to set species-dependent pitch angle scattering efficiency.

b. Input -

L	Time label
ISEC	Time (seconds)
IEDIM	Number of particle species to be traced
LTDIM	Number of local time (longitudinal) grid spaces
ITMDIM	Maximum number of major time steps for this run
LATDIM	Number of latitudinal grid spaces
FKP	Kp value for current time
ALAM	Energy invariant vector ($eV(Re/nT)^{2/3}$)
ALOCT	Grid local time array (radians eastward from noon)
IEMAX	Maximum number of energy channels

c. Processing - No other subroutines are called.

This subroutine sets the species-dependent pitch angle scattering efficiency. The rationale for this subroutine is discussed in Section 2.6.3 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

SCTFRC	Assumed pitch angle scattering efficiency
--------	---

PFIX

a. Functions - This subroutine adjusts the modulus of a periodic J coordinate.

b. Input -

P1	Hour angle measured eastward from noon (radians)
P2	Hour angle array at position J (radians)
P3	Hour angle array at position J+1 (radians)

c. Processing - No other subroutines are called.

This subroutine adjusts the modulus of the periodic input parameters to match P1 so that they can be used to interpolate data.

d. Output -

P4	Adjusted hour angle array at position J (radians) (corresponds to P2)
P5	Adjusted hour angle array at position J+1 (radians) (corresponds to P3)

INITAL

a. Functions - This subroutine computes the initial plasma distribution.

b. Input -

LL	Time label
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
IEDIM	Number of particle species to be traced
ITMDIM	Maximum number of major time steps for this run
IRDIM	R dimension of FLXMAT arrays
NRGDIM	Energy dimension of FLXMAT arrays
KPDIM	KP dimension of FLXMAT arrays
ISPDIM	Plasma mass species dimension
FLXR	R values at which FLXMAT arrays are calculated (R_e)
FLXNRG	Energy values for which FLXMAT arrays are calculated ($\log_{10}(\text{eV})$)
FLXKP	KP values for which FLXMAT arrays are calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values ($\log_{10}(\#/\text{cm}^2\text{-s-ster-eV})$)
BNDLOC	Location of outer boundary of detailed particle traces
IFLAV	Chemical species identifier 1 means electrons 2 means H^+ ions 3 means O^+ ions
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (R_e)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
VM	$(\text{Flux tube volume})^{-2/3} ((R_e/nT)^{-2/3})$
ETA	Flux tube content array (weber^{-1})
ALAM	Energy invariant vector ($\text{eV}(R_e/nT)^{2/3}$)
ALMDEL	Width of energy invariant channels
FKP	Kp at present time step
IEMAX	Maximum number of energy channels
AZERO	Statistical model weighting parameter
BZERO	Old results weighting parameter
CZERO	Traceback weighting parameter

c. Processing - following are the subroutines called and their major functions:

FLXVAL Function subprogram to calculate Kp-dependent flux value a $R=RR$ for particles of energy ENRG and $Kp=FKP$ by interpolating FLXMAT array

This subroutine can compute the initial plasma distribution based on a combination of empirical (Kp-based) data and results from previous runs. In practice, previous run results are used, if

available, and the empirical model is used otherwise. The rationale for this subroutine is discussed in Section 2.5.4 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

ETABEG Initial flux tube content distribution each time step (weber⁻¹)

TIMINC

a. Function - This subroutine increments the time for the next electric and magnetic field record.

b. Input -

ITIME	Current time (year, day, seconds)
IINC	Increment time (year,day,seconds)

c. Processing - No other subroutines are called.

This subroutine increments the time and checks that it is within bounds.

d. Output -

ITMNEW	Time for next record (year,day,seconds)
--------	---

SETREF

a. Functions - This subroutine sets an upper limit reference flux.

b. Input -

LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
IEDIM	Number of particle species to be traced
ITMDIM	Maximum number of major time steps for this run
IRDIM	R dimension of FLXMAT arrays
NRGDIM	Energy dimension of FLXMAT arrays
KPDIM	KP dimension of FLXMAT arrays
ISPDIM	Plasma mass species dimension
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated ($\log_{10}(\text{eV})$)
FLXKP	KP values for which FLXMAT arrays are calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values ($\log_{10}(\#/ \text{cm}^2\text{-s-ster-eV})$)
BNDLOC	Location of outer boundary of detailed particle traces
IFLAV	Chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
VM	Flux tube volume $((\text{Re}/nT)^{-2/3})$
ETA	Flux tube content array (weber ⁻¹)
ALAM	Energy invariant vector ($\text{eV}(\text{Re}/nT)^{2/3}$)
ALMDEL	Width of energy invariant channels
IEMAX	Maximum number of energy channels
TIMTAG	Vector giving times at which E and B parameters are calculated (seconds)
TVAL	Current time (seconds)
ITMMAX	Maximum number of time labels

c. Processing - following are the subroutines called and their major functions:

TNORML	Utility function subprogram to calculate run-normalized time
FLXVAL	Function subprogram to calculate Kp-dependent flux value at $R=RR$ for particles of energy ENRG and $Kp=FKP$ by interpolating FLXMAT array

The rationale for this subroutine is discussed in Section 2.5.6 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

FLXREF Upper limit to reference flux ($\log_{10}(\#/cm^2\text{-s-ster-eV})$)

EFLOC

a. Functions - This subroutine finds the grid location (BI,BJ) of physical location (RVAL,XLT).

b. Input -

RVAL	Radial distance (Re)
XLT	Hour angle measured eastward from noon (radians)
LL	Time index
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
ITMDIM	Maximum number of major time steps for this run
ALOCT	Grid local time array (radians eastward from noon)
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)

c. Processing - following are the subroutines called and their major functions:

PFIX	Subroutine to adjust modulus of periodic J coordinate
------	---

This subroutine locate a point within a grid square and then linearly interpolates in I and J to give the non-integer locations.

d. Output -

BI	Non-integer I location of (RVAL,XLT)
BJ	Non-integer J location of (RVAL,XLT)

EFBNDY

a. Functions - This subroutine calculates the latitudes and widths of the electric field boundarys 2 and 3.

b. Input -

LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
ITMDIM	Maximum number of major time steps for this run
LL	Time label
EQEDG	Equatorward edge of auroral oval (degrees)
STDOFF	Standoff distance (Re)
VDROP	Cross-polar cap potential drop
ALOCT	Grid local time array (radians eastward from noon)
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
COLAT	Grid colatitude array (radians)

c. Processing - following are the subroutines called and their major functions.

EFLOC	Subroutine to find grid location (BI,BJ) of physical location (RVAL,XLT)
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)

The rationale for this subroutine is discussed in Section 2.4.2 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

A	Radius of ellipse measured in x (sunward) direction
B	Radius of ellipse measured in y (duskward) direction
DX	Offset of ellipse in x(duskward) direction
DY	Offset of ellipse in y (duskward) direction

FECON

a. Functions - This subroutine obtains the time-normalized observational values.

b. Input -

ISTART	Start time (year,day, seconds)
IINC	Increment time (year,day,seconds)
IEND	Stop time (year,day,seconds)
ITMDIM	Maximum number of major time steps per run of the program
NAUGEL	Number of elements in the augmented input array
ITMMAX	Number of time labels used
TIMTAG	Vector giving times at which E and B parameters are calculated

c. Processing - following are the subroutines called and their major functions:

PARGEN	Subroutine to obtain values from the environmental data base and interpolate or extrapolate as appropriate to provide data at a normalized time
TIMINC	Subroutine to increment time for next electric- and magnetic field record
TILT	Subroutine to calculate the Earth's tilt angle
DSTDFL	Subroutine to calculate default (Kp driven) Dst value
EQTDFL	Subroutine to calculate default (Kp driven) equatorward edge of auroral zone value
STNDFL	Subroutine to calculate the standoff distance
PCPDFL	Subroutine to calculate default (Kp driven) cross-polar-cap potential value
PATDFL	Subroutine to return polar-cap convection pattern typ
CLPDFL	Subroutine to determine whether or not to use the collapsed tail version of the magnetic field model

This subroutine calls Subroutine PARGEN to obtain time-normalized observational data that is then used to calculate other values needed by the electric field and magnetic field routines.

d. Output -

AUGPAR	Augmented data array for input values
MODE	Logical vector which gives whether each variable comes from actual data or a front end model.

PARGEN

a. Functions - Subroutine to obtain values from the environmental data base and interpolate or extrapolate as appropriate to provide data at a normalized time.

b. Input -

ISTART	Start time (year,day, seconds)
IINC	Increment time (year,day,seconds)
IEND	Stop time (year,day,seconds)
ITMDIM	Maximum number of major time steps per run of the program
NAUGEL	Number of elements in the augmented input array
ITMMAX	Maximum number of time labels
TIMTAG	Vector giving times at which E and B parameters are calculated
NELTS	Number of elements in output data array

c. Processing - following are the subroutines called and their major functions:

INDATA	Subroutine to read in data for the MSM during development and testing.
SMOOTH	Subroutine to extract data from input array.
DTXIPT	Subroutine to return interpolated polar cap patterns
DTNTRP	Subroutine to return interpolated data values
TIMINC	Subroutine to increment time for next electric and magnetic field record

This subroutine retrieves observational data from the environmental data base and interpolates as necessary to have input data for the entire run. Mode is set to TRUE if there exists data for the run within the time constraints of array IGAP. If the gap in the data is too long, MODE is set false and the KP-based default models are used to compute the input data needed.

d. Output -

PARRAY	Data array of interpolated data values
MODE	Logical variable telling which input parameters we have values for

INDATA

a. Functions - Subroutine to read in data for the MSM during development and testing.

b. Input -

PARAM	File name to read input data from (character)
STARTT	Start time (year,day,seconds)
ENDT	End time (year,day,seconds)
NDIM	Maximum number of data points to read

c. Processing - No other routines are called.

This routine opens a data file and reads the observation data. This routine will be replaced in the operational MSM with an interface routine to the AWS environmental data base.

d. Output -

DARRY	Array containing observational data
NUMNUM	Number of data points read

GETMAT

a. Functions - Subroutine to find the magnetic field matrices needed for interpolation in order to represent current geophysical conditions.

b. Input -

IWANT	Different magnetic field parameters = 1 - XMIN (GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 2 - YMIN (GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 3 - ZMIN (GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 4 - BMIN (Equatorial magnetic field strength (nT)) = 5 - VM (Flux tube volume (weber ⁻¹))
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
BFPAR	Array containing geophysical parameters to use to find magnetic field matrices 1 = Standoff distance (Re) 2 = Tilt angle (degrees) 3 = Equatorward edge of auroral oval (degrees) 4 = Dst (nT) 5 = Collapse parameter

c. Processing - following are the subroutines called and their major functions:

FNDBRK	Subroutine to find the proper magnetic field indices that bracket the magnetic field input parameters
LOADBM	Subroutine to load individual magnetic field matrices from the magnetic field super matrix into the work magnetic field matrices
ZEROBM	Subroutine to zero out an individual magnetic field matrix within the working magnetic field matrices
OUTP	Utility subroutine to print out array information

d. Output -

WORK	Internal working array
BFLIM	Indices of magnetic field models read
BFEXST	Array of logical variables of which magnetic field model matrices exist

FNDBRK

a. Functions - Subroutine to find the magnetic field array indices that bracket the magnetic field input parameters.

b. Input -

PARVAL	Magnetic field geophysical parameter
PVALS	Array of magnetic field parameters
IPDIM	Dimension of PVALS

c. Processing - No other subroutines are called.

This routine finds the indices of the values in array PVAL that bracket the input geophysical parameter.

d. Output -

MIN	Lower array bound index
MAX	Upper array bound index

MEXIST

a. Functions - Logical function that checks to see if a particular B-matrix exists in the B supermatrix

b. Input -

MSTND	Number of standoff parameters, currently set to 5
MTILT	Number of tilt angle parameters, currently set to 5
MINED	Number of auroral equatorward edge parameters, currently set to 16
MDST	Number of Dst parameters, currently set to 8
MSTCH	Number of tail collapse parameters, currently set to 2

c. Processing - No other subroutines are called.

This function uses the FORTRAN "INQUIRE" command to check for the existence of needed B-field arrays/

d. Output -

MEXIST true if B field arrays exist, false otherwise

ZEROBM

a. Functions - Subroutine to zero out an individual magnetic field matrix within the working magnetic field matrices if the matrix does not exist in the supermatrix.

b. Input -

LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
I,J,K,L,M	Indices of working magnetic field matrices
WORK	Working magnetic field matrix

c. Processing - No other subroutines are called.

So that the program does not crash if a magnetic field matrix does not exist, it is zeroed out. The printout within the program prints that no magnetic field matrix existed for those geophysical conditions.

d. Output -

WORK	Zeroed out working magnetic field matrix
------	--

LOADBM

a. Processing - Subroutine to load individual magnetic field matrices from the magnetic field super-matrix into the work magnetic field matrices.

c. Input -

IWANT	5 different magnetic field parameters = 1 - XMIN (GSM X location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 2 - YMIN (GSM Y location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 3 - ZMIN (GSM Z location of where field line going through grid pt crosses the equatorial (B-field minimum) plane (Re)) = 4 - BMIN (Equatorial magnetic field strength (nT)) = 5 - VM ((Flux tube volume) ^{-2/3} ((Re/nT) ^{-2/3}))
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
I,J,K,L,M	Indices of working magnetic field matrices
BFNDX	Array containing the indices of the magnetic field matrices to load for geophysical conditions of standoff distance, tilt angle, equatorward edge of the auroral oval, Dst, and tail collapse index

c. Processing - No other subroutines are called.

This subroutine loads individual magnetic field matrices from the offline magnetic field super-matrix into the work magnetic field matrices. A check is made to verify that the correct matrix has been retrieved. If this check fails the program will stop.

d. Output -

Work	Magnetic field matrix work array
------	----------------------------------

TCONV2

a. Functions - Function to take a start year, start decimal day, and current decimal day to produce a value that is the number of seconds from midnight of the start year and day.

b. Input -

YR	Current year
DD	Current day
STRTYR	Start year
STRTDD	Start day

c. Processing - No other subroutines are called.

d. Output -

TCONV2 Seconds from midnight of start day

TCONV3

a. Functions - Function to take a start year, start day, current year, current day, and current seconds of day to produce a value that is the number of seconds from midnight of the start year and day.

b. Input -

ITIME	Current time (year,day,seconds)
ISTART	Start time (year,day,seconds)

c. Processing - No other subroutines are called.

d. Output -

TCONV3	Seconds from the start year and day
--------	-------------------------------------

SMOOTH

a. Functions - Subroutine to extract and interpolate data from observational data into a usable form for the MSM.

b. Input -

DARRY	Array containing input observational data
NDIM	Maximum number of data points in DARRY
NUMNUM	Number of data points in DARRY
STARTY	Start year
STARTD	Start day

c. Processing - following are the subroutines called and their major functions:

TCONV2	Function to take a start year, start decimal day, and current decimal day to produce a value that is the number of seconds from midnight of the start year and day.
--------	---

This subroutine extracts the data relevant to the total run time.

d. Output -

NA	Total number of data points found
XA	Time (seconds)
YA	Data point
IERR	Error code
	= 0 no errors detected
	= -1 error in data

DTNTRP

a. Functions - Subroutine to return interpolated data.

b. Input -

X	Time (seconds)
NA	Number of data points
XA	Time array of observational data (seconds)
YA	Array of observed data

c. Processing - No other subroutines are called.

This subroutine takes the given time, finds the bracketing time in the XA array and linearly interpolates the observational data. It also does the differential DY/DX.

d. Output -

Y	Interpolated observational data
DYDX	Differential DY/DX
DELTA	The difference between the given time and the time of the observational data
IERR	Error code
	= 0 no problems in interpolation
	= -1 error detected

STNDOF

a. Functions - Subroutine to calculate the standoff distance from solar wind velocity and density data.

b. Input -

VELOC	Solar wind velocity data (km/sec)
DENS	Solar wind density data (cm ⁻³)

c. Processing - No other subroutines are called.

This is based on the analytic calculation of Alpbach (1979).

d. Output -

STAND	Standoff distance (Re)
-------	------------------------

FLXNIT

a. Functions - Subroutine to calculate Kp based particle number flux as function of R, energy and Kp.

b. Input -

IRDIM	Number of R values for which the empirical flux array, FLXMAT, is calculated
NRGDIM	Number of preset energy values for which FLXMAT is calculated
KPDIM	Number of KP values for which FLXMAT is calculated
ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated (log ₁₀ (eV))
FLXKP	KP values for which FLXMAT arrays are calculated

c. Processing - following are the subroutines called and their major functions:

FLXCAL	Subroutine to compute Kp-dependent flux at L=3, 4, 6.6, and 13 for electrons of given energy for a given Kp condition
THRCAL	Subroutine to calculate threshold flux at R=3, 4, 6.6, and 13 Re for given Kp and energy

This subroutine sets up the threshold and default fluxes for the program run.

d. Output -

FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values (log ₁₀ (#/cm ² -s-ster-eV))
THRMAT	Array of empirical fluxes as function of R, energy, and KP for use as threshold fluxes. (log ₁₀ (#/cm ² -s-ster-eV))

FLXCAL

a. Functions - Subroutine to compute Kp-dependent flux at L=3, 4, 6.6 and 13 for different species of given energy for a given Kp condition.

b. Input -

KPDIM	Number of KP values for which FLXMAT is calculated
ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
FNRGLG	One energy value for which FLXMAT arrays are calculated (log ₁₀ (eV))
FLKP	One KP value for which FLXMAT arrays are calculated
ISPP	Chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions

c. Processing - No other subroutines are called.

The rationale for this subroutine is discussed in Section 2.5 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

FLX3	Flux at L=3 (#/cm ² -sec-ster-eV) for given energy for given Kp
FLX4	Flux at L=4 (#/cm ² -sec-ster-eV) for given energy for given Kp
FLX6	Flux at L=6 (#/cm ² -sec-ster-eV) for given energy for given Kp
FLX13	Flux at L=13 (#/cm ² -sec-ster-eV) for given energy for given Kp

FLXTRP

a. Functions - Function subprogram to return Log_{10} of empirical flux value interpolated between values at L=3, 4, 6.6, and 13.

b. Input -

RLOG	Log_{10} of radial distance to be interpolated
FLX3	Flux at L=3 ($\#/\text{cm}^2\text{-sec-ster-eV}$) for given energy for given Kp
FLX4	Flux at L=4 ($\#/\text{cm}^2\text{-sec-ster-eV}$) for given energy for given Kp
FLX6	Flux at L=6 ($\#/\text{cm}^2\text{-sec-ster-eV}$) for given energy for given Kp
FLX13	Flux at L=13 ($\#/\text{cm}^2\text{-sec-ster-eV}$) for given energy for given Kp

c. Processing - No other subroutines are called.

d. Output -

FLXTRP	Flux value interpolated in radial distance
--------	--

FLXVAL

a. Functions - Function subprogram to calculate Kp-dependent flux value for particles at a given radial distance, energy, and Kp conditions by interpolating the FLXMAT array.

b. Input -

ISP	Vector of chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions
FKP	Kp for current time
RR	Radial distance of particle (Re)
PP	Hour angle (measured eastward from noon in radians) in equatorial plane
ENRG	Energy (eV)
IRDIM	Number of R values for which the empirical flux array, FLXMAT, is calculated
NRGDIM	Number of preset energy values for which FLXMAT is calculated
KPDIM	Number of KP values for which FLXMAT is calculated
ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated (log ₁₀ (eV))
FLXKP	KP values for which FLXMAT arrays are calculated

c. Processing - following are the subroutines called and their major functions:

G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
--------	--

This subroutine performs a general 3-d interpolation in radial distance, Kp, and energy.

d. Output -

FLXVAL	Interpolated flux
--------	-------------------

EFIELD

a. Functions - Subroutine to return values of the potential on the northern hemisphere grid, southern hemisphere grid, and the average of the two hemispheres.

b. Input -

KPATT	Polar cap pattern type = 0 $B_z > 0$ = 1 $B_z < 0$ with stronger flow on dawn side of polar cap = 2 $B_z < 0$ with symmetric flow in polar cap = 3 $B_z < 0$ with stronger flow on dusk side of polar cap
PCP	Cross polar cap potential drop (kV)
DEQDT	Time rate of change of the equatorward edge of the auroral zone (degrees/hour)
ASOUTH	Southern hemisphere radius of ellipse measured in x (sunward) direction
BSOUTH	Southern hemisphere radius of ellipse measured in y (duskward) direction
DXS	Southern hemisphere offset of ellipse measured in x (sunward) direction
DYS	Southern hemisphere offset of ellipse measured in y (duskward) direction
ANORTH	Northern hemisphere radius of ellipse measured in x (sunward) direction
BNORTH	Northern hemisphere radius of ellipse measured in y (duskward) direction
DXN	Northern hemisphere offset of ellipse measured in x (sunward) direction
DYN	Northern hemisphere offset of ellipse measured in y (duskward) direction
COLAT	Grid colatitude array (radians)
ALOCI	Grid local time array (radians eastward from noon)
MODE	Logical variable telling which input parameters we have values for
LATLIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
JWRAP	Number of points of overlap in J direction
ITMCUR	Current time label
ITMDIM	Maximum number of major time steps per run of the program
ICNTRL	= 1 means different formulas are used in regions 1, 2, 3, = 2 means Heppner-Maynard formula is used for all latitudes, but scaled to externally specified cross polar cap potential drop and ellipse parameters

ITOP = -1 means Heppner-Maynard formula is used for all latitudes, unscaled.
 = -2 should not be used. It is the form used by the Rice Convection Model
 = 1 means the ellipse parameters A, B, DX, and DY for the polar cap boundary are computed internally in the subroutine. This is the normal mode for the MSM.

c. Processing - following are the subroutines called and their major functions:

EMODEL Returns the electric potential arrays on the northern hemisphere grid, southern hemisphere grid, and the average of the two hemispheres

The major function of this subroutine is to translate the KPATT pattern types given by the University of Texas, Dallas to the internally used IPATT pattern types of the Heppner-Maynard empirical model. It also keeps track of which hemisphere is being modelled and averages the output from the two hemispheres.

d. Output -

V Electric potential distribution on grid (average of VNORTH and VSOUTH) (Volts)
 VNORTH Northern hemisphere electric potential distribution (Volts)
 VSOUTH Southern hemisphere electric potential distribution (Volts)

PWRCAL

a. Functions - Subroutine to estimate precipitating electron energy flux poleward of the main MSM modeling region by comparing flux within the modeling region with AFGL statistical values.

b. Input -

LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
ISPDIM	Number of plasma mass species (electrons, H ⁺ , O ⁺ , etc.)
ITMCUR	Current time label
ITMDIM	Maximum number of major time steps per run of the program
FKP	Kp for current time
COLAT	Grid colatitude array (radians)
ALOCT	Grid local time array (radians eastward from noon)
ALPHA	Latitudinal grid spacing vector
BETA	Longitudinal grid spacing vector
BNDLOC	Location of outer boundary of detailed particle traces
A	Radius of ellipse measured in x (sunward) direction
B	Radius of ellipse measured in y (duskward) direction
DX	Offset of ellipse measured in x (sunward) direction
DY	Radius of ellipse measured in y (duskward) direction

c. Processing - following are the subroutines called and their major functions:

THET	Function that gives equation for and electric field boundary ellipse in flat polar coordinates
------	--

The rationale for this subroutine is discussed in Section 2.6.5.2 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

FLXSUM	Total precipitation energy flux array (integrated over species for (1) electrons (2) H ⁺ and (3) O ⁺) (ergs/cm ² -sec)
EAVG	Average precipitating electron energy for (1) electrons, (2) H ⁺ and (3) O ⁺ (eV)

WKRATE

a. Functions - Function subroutine to evaluate weak precipitation loss rate.

b. Input -

RMID	R value at point where function is to be evaluated (Re)
RPPMID	Estimate of plasmopause radius at midnight local time(Re)
PMID	Local time hour angle in equatorial plane (radians from local noon)
ENRG	Particle energy (eV)

c. Processing - following are the subroutines called and their major functions:

RLYONS Function to evaluate Lyons-based weak loss rate

The rationale for this subroutine is discussed in Section 2.6.3 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

WKRATE Estimate of weak precipitation loss rate

RLYONS

a. Functions - Function to evaluate Lyons-based weak loss rate.

b. Input -

RMD	R value at point where function is to be evaluated (Re)
ENRG	Particle energy (eV)

c. Processing - No other subroutines are called.

The rationale for this subroutine is discussed in Section 2.6.3 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

RLYONS Estimate of weak precipitation loss rate from L. Lyons formula

G3TRPA

a. Functions - Utility function subprogram to perform a general 3-d linear interpolation of an angular array A(I,J,K) at point (BI,BJ,BK)

b. Input -

A	Array to be interpolated
IMAX	I dimension of array A
JMAX	J dimension of array A
KMAX	K dimension of array A
BI	Floating point value to interpolate in I dimension
BJ	Floating point value to interpolate in J dimension
BK	Floating point value to interpolate in K dimension

c. Processing - No other subroutines are called.

This subroutine uses the standard linear interpolation technique to interpolate an angular array in 3 dimensions.

d. Output -

G3TRPA Interpolated point from array A

THRCAL

a. Functions - Subroutine to calculate threshold flux at R=3, 4, 6.6, and 13 Re for given Kp value and energy.

b. Input -

FNRGLG	One energy value for which FLXMAT arrays are calculated (log ₁₀ (eV))
FKP	One KP value for which FLXMAT arrays are calculated
NRGNDX	Energy calculation index
KPNDX	Kp calculation index
IRDIM	Number of R values for which the empirical flux array, FLXMAT, is calculated
NRGDIM	Number of preset energy values for which FLXMAT is calculated
KPDIM	Number of KP values for which FLXMAT is calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values (log ₁₀ (#/cm ² -s-ster-eV))

c. Processing - No other subroutines are called.

The rationale for this subroutine is discussed in Section 2.5.8 of the Final Report for Contract #F19628-87-K-0001.

d. Output -

THR	Value for threshold flux (particles/cm ² -s-ster-eV)
-----	---

FIXDFL

a. Functions - Subroutine to calculate the energy-dependent ETA array from Kp and the location of the grid points by interpolating the empirical FLXMAT array.

b. Input -

ITM	Current time label
FKP	Current Kp
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (Re)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
VM	Flux tube volume $((Re/nT)^{2/3})$
ALAM	Energy invariant vector $(eV(Re/nT)^{2/3})$
IRDIM	Number of R values for which the empirical flux array, FLXMAT, is calculated
NRGDIM	Number of preset energy values for which FLXMAT is calculated
KPDIM	Number of KP values for which FLXMAT is calculated
FLXMAT	Array of empirical fluxes as function of R, energy, and KP for use in calculating initial and boundary flux values ($\log_{10}(\#/cm^2-s-ster-eV)$)
FLXR	R values at which FLXMAT arrays are calculated (Re)
FLXNRG	Energy values for which FLXMAT arrays are calculated ($\log_{10}(eV)$)
FLXKP	KP values for which FLXMAT arrays are calculated
ALMDEL	Width of energy invariant channels
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
ITMDIM	Maximum number of major time steps per run of the program
BNDLOC	Location of outer boundary of detailed particle traces
IEMAX	Maximum number of energy channels
IEDIM	Number of invariant energy species traced by the program
IFLAV	Chemical species identifier 1 means electrons 2 means H ⁺ ions 3 means O ⁺ ions
IEBEG	Beginning energy index
IEEND	Ending energy index

c. Processing - following are the subroutines called and their major functions:

FLXVAL	Function subprogram to calculate Kp-dependent flux value at given radial distance, energy and Kp by interpolating FLXMAT array.
--------	---

This routine is used as the MSM default model when full particle traces are done. The subroutine interpolates the FLXMAT arrays for the given energies for all grid points.

d. Output -

ETA	Flux tube content array (weber ⁻¹)
EFLUX	Precipitation energy flux array (ergs/cm ² -sec)

RMVBESH

a. Functions - Subroutine to extrapolate magnetic field matrices into extremely stretched or open regions.

b. Input -

WORK	Working magnetic field matrix
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces

c. Processing - No other subroutines are called.

To prepare the magnetic field matrices for interpolation, previously assigned 'very large numbers' to signify that the magnetic field extended beyond 50 Re are removed. The subroutine looks for the closest value in local time (J) and linearly interpolates for the latitudinal (I) grid points.

d. Output -

WORK	Revised working magnetic field matrix
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DSTDFL

a. Functions - Subroutine to calculate default (Kp-driven) Dst value

b. Input -

MODE	Logical variable telling which input parameters we have values for
AUGPAR	Augmented data array for input values
NAUGEL	Number of elements in the augmented input array
ITMDIM	Maximum number of major time steps per run of the program
ITM	<i>Current time label</i>
ITMMAX	Maximum number of time labels
TIMTAG	Vector giving times at which E and B parameters are calculated

c. Processing - following are the subroutines called and their major functions:

DTNTRP Subroutine to return interpolated data values

The subroutine uses the Kp value in the AUGPAR array for the given time and calculates Dst. This value is then put into the AUGPAR array. Subroutine DTNTRP is called to give the DY/DX value also needed in AUGPAR.

d. Output -

AUGPAR Augmented data array for input values

EQTDFL

a. Function - Subroutine to calculate default (Kp-driven) equatorward edge of the auroral oval value.

b. Input -

MODE	Logical variable telling which input parameters we have values for
AUGPAR	Augmented data array for input values
NAUGEL	Number of elements in the augmented input array
ITMDIM	Maximum number of major time steps per run of the program
ITM	Current time label
ITMMAX	Maximum number of time labels
TIMTAG	Vector giving times at which E and B parameters are calculated

c. Processing - following are the subroutines called and their major functions:

DTNTRP Subroutine to return interpolated data values

The subroutine uses the Kp value in the AUGPAR array for the given time and calculates the location of the equatorward edge of the auroral oval. The algorithm is given in a JGR paper by Gussenhoven et al. (1983). This value is then put into the AUGPAR array. Subroutine DTNTRP is called to give the DY/DX value also needed in AUGPAR.

d. Output -

AUGPAR Augmented data array for input values

PDPDFL

a. Functions - Subroutine to calculate default (Kp-driven) cross-polar-cap potential value.

b. Input -

MODE	Logical variable telling which input parameters we have values for
XKP	Current KP value

c. Processing - No other subroutines are called.

This subroutine uses the algorithms of Reiff et al to calculate the cross-polar-cap potential from given Kp.

d. Output -

PCP	Cross-polar cap potential (kV)
-----	--------------------------------

PATDFL

a. Functions - Subroutine to return polar cap convection pattern type of the basis of the measurements of the B_y and B_z components of the interplanetary magnetic field.

b. Input -

MODE Logical variable telling which input parameters we have values for
MODEBY Logical variable telling if we have B_y data
MODEBZ Logical variable telling if we have B_z data

c. Processing - No other subroutines are called.

This subroutine determines the pattern type using interplanetary magnetic field data:

Polar cap pattern type
= 0 $B_z > 0$
= 1 $B_z < 0$ with stronger flow on dawn side of polar cap
= 2 $B_z < 0$ with symmetric flow in polar cap
= 3 $B_z < 0$ with stronger flow on dusk side of polar cap

If no data is available, pattern #2 is the default.

d. Output -

IPATT Polar cap pattern type

CLPDFL

a. Functions - Subroutine to determine whether or not to use the collapsed tail version of the magnetic field model.

b. Input -

MODE Logical variable telling which input parameters we have values for

c. Processing - No other subroutines are called.

If mode is false, no value has been returned from the environmental data base and the default value is set to 1 (no collapse).

d. Output -

CLAPSE Value of magnetotail collapse parameter

STNDFL

a. Functions - Subroutine to calculate the standoff distance.

b. Input -

MODE	Logical variable telling which input parameters we have values for
MODVEL	Logical variable telling if we have solar wind velocity data
MODDEN	Logical variable telling if we have solar wind density data
SWVEL	Value of solar wind velocity data
SWDEN	Value of solar wind density data
XKP	Current Kp value

c. Processing - following are the subroutines called and their major functions:

STNDOF	Subroutine to calculate the standoff distance according to a formula published by Alpbach (1979)
--------	--

If solar wind velocity and density data are available Subroutine STNDOF does the actual calculation. Otherwise the default is a Kp-based formula.

d. Output -

STAND	Standoff distance (Re)
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TILT

a. Functions - Subroutine to calculate the earth's tilt angle.

b. Input -

DAY	Day of year
YEAR	Year

c. Processing - No other subroutines are called.

This subroutine currently sets the tilt angle at 0.0.

d. Output -

XTILT	Tilt angle
-------	------------

AURL2S

a. Function - This subroutine determines the default Hardy precipitating ion flux.

b. Input -

FKP	Current Kp value
COLAT	Grid colatitude array (radians)
ALOCT	Time dependent magnetic local time grid
LATDIM	Number of latitudinal grid lines)
LTDIM	Number of local time (longitude) grid lines

c. Processing - following are the subroutines called and their major function:

REGEN	Subroutine used in evaluation of precipitatin ion fluxes
EFUN	Subroutine used in evaluation of precipitatin ion fluxes

These set of subroutines were developed by Dr. David Hardy at the Air Force Geophysics Laboratory, Bedford, Mass.

d. Output -

AEFLUX	The integral ion energy flux (ergs/cm ² -sec)
AEMEAN	The average energy (eV)

OPTERR

a. Functions - Subroutine to calculate the error and standard deviation between the MSM flux and observational geosynchronous satellite data.

b. Input -

FLUX	Particle flux array ($\text{cm}^2 \text{s}^{-1}$)
VM	$(\text{Flux tube volume})^{-2/3} ((R_e/nT)^{-2/3})$
LATDIM	Number of latitudinal grid spaces
LTDIM	Number of local time (longitudinal) grid spaces
IEDIM	Maximum number of energy channels
IEMAX	Number of invariant energy species traced by the program
ALAM	Energy invariant vector ($\text{eV}(R_e/nT)^{2/3}$)
ALMDEL	Width of energy invariant channels
THRSH	Threshold energy beyond which particles are not traced and empirical data are used
ITMDIM	Maximum number of major time steps per run of the program
IFLAV	Chemical species identifier 1 means electrons 2 means H^+ ions 3 means O^+ ions
ISTART	Start time (year,day,seconds)
IEND	End time (year,day,seconds)
R	Array giving radial distance of grid pts in magnetospheric equatorial plane (R_e)
P	Array giving hour angle (measured eastward from noon in radians) of grid pts in equatorial plane
TIMTAG	Vector giving times at which E and B parameters are calculated
ITMMAX	Number of time labels in run

c. Processing - following are the subroutines called and their major functions:

TCONV2	Function to take a start year, start decimal day, and current decimal day to produce a value that is the number of seconds from midnight of the start year and day
READ3D	Subroutine to read a record from the standard MSM disk file format
TNORML	Utility function subprogram to calculate run-normalized time
EFLOC	Subroutine to find grid location (BI,BJ) of physical location (RVAL,XLT)
G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)

For the satellite times and energies available, the subroutine calculates and interpolates the model flux values at geosynchronous orbit. The error is defined as the average difference between the log of the model flux and the log of the satellite flux. The standard deviation is the usual definition. The subroutine averages over all available satellites. The format of the file 'EPSAT' will need to be changed when the MSM begins to access the AWS environmental data base. The standard deviation is not saved, just printed out.

d. Output -

ERSHFT Vector of error values

WRTVEC

a. Function - This subroutine writes to disk the energy invariant, the threshold energies, and the error shift for each particle energy species each time step.

b. Input -

NOUNIT	Logical unit number from which to read file
IRDOUT	Output direct access record number
IEMAX	Number of particle energy species for run
IEDIM	Dimension of particle energy species array
ALAM	Vector of energy invariant values used in run
THRSH	Vector of full-traceback/default value used in run
ERSHFT	Vector of error values for this time interval
IFLAV	Vector of chemical species identifier
	1 means electrons
	2 means H ⁺ ions
	3 means O ⁺ ions

c. Processing - No other subroutines are called.

This routine opens the appropriate file, writes the vectors to the file, and closes the file.

d. Output - The vectors are output to unit number NOUNIT.

CEXRAT

a. Function - Function subprogram to return charge exchange loss rate (sec^{-1}) for ions of species ISP, energy ENRG (eV), at L=RLOC (Re) for sunspot number SSN. This routine is based on a table generated by James Bishop of the University of Michigan.

b. Input -

ISP	Species Identifier ISP=2 for H ⁺ Ions ISP=3 for O ⁺ Ions
ENRG	Energy in eV
RLOC	Radial location (Re)
SSN	Sunspot number
DKTIME	Table of ion decay times
IRDK	Radial dimension of DKTIME array
INRGDK	Energy dimension of DKTIME array
ISOLDK	Sunspot number dimension of DKTIME array
IONDK	Number of ion species in DKTIME array

c. Processing - following are the subroutines called and their major functions:

G3NTRP	Utility function subprogram to perform a general 3-d linear interpolation of an arbitrary array A(I,J,K) at point (BI,BJ,BK)
--------	--

This routine interpolates the decay time array in radial distance, energy and sunspot number.

d. Output -

CEXRAT	Ion charge exchange loss rate (sec^{-1})
--------	---

READDK

a. Function - Subroutine to read ion charge exchange decay table furnished by James Bishop of the University of Michigan.

b. Input -

IRDK	Radial dimension of DKTIME array
INRGDK	Energy dimension of DKTIME array
ISOLDK	Sunspot number dimension of DKTIME array
IONDK	Number of ion species in DKTIME array

c. Processing -

Reads the input table of ion decay times.

d. Output -

DKTIME	Table of ion decay times
--------	--------------------------

FLX2ET

a. Function - Convert from particle flux (particles/cm²/s) to invariant density eta (particles/Weber)

b. Input -

LATDIM	Number of latitudinal grid points
LTDIM	Number of longitudinal (local time) grid points
IEDIM	Maximum number of model energy channels
IEMAX	Actual number of model energy channels
ITMDIM	Maximum time depth
ITM	Time index
IFLAV	Vector giving charge and mass species of particles 1 = electrons, 2 = H ⁺ ions, 3 = O ⁺ ions
ALAM	Energy invariant vector
ALMDEL	Width of invariant energy channels
BNDLOC	Boundary location array
VM	(Flux tube volume) ^{-2/3}
FLUX	Particle number flux (#/cm ² /s)

c. Processing - No other subroutines are called.

This subroutine uses a simple formula to translate from number flux FLUX to invariant density ETA.

d. Output -

ETA	Invariant number density (particles / Weber)
-----	--

Appendix B

ET2FLX

a. Function - Convert from invariant density eta (particles/Weber) to particle number flux (particles/cm²/s)

b. Input -

LATDIM	Number of latitudinal grid points
LTDIM	Number of longitudinal (local time) grid points
IEMAX	Maximum number of model energy channels
IEMAX	Actual number of model energy channels
ITMDIM	Maximum time depth
ITM	Time index
IFLAV	Vector giving charge and mass species of particles 1 = electrons, 2 = H ⁺ ions, 3 = O ⁺ ions
ALAM	Energy invariant vector
ALMDEL	Width of invariant energy channels
BNDLOC	Boundary location array
VM	(Flux tube volume) ^{-2/3}
ETA	Invariant number density (particles / Weber)

c. Processing - No other subroutines are called.

This subroutine uses a simple formula to translate from invariant density ETA to number flux FLUX.

d. Output -

FLUX	Particle number flux (#/cm ² /s)
------	---

```
$ define bfield [.bfields] /process
$ define for005 msmin.dat /process
$ define for006 print3.dat /process
$ define for009 error1.dat /process
$ define for010 efield.coeff /process
$ define for011 bfield.coeff /process
$ define for012 parray.dat /process
$ define for013 pieng.dat /process
$ define for015 print.dat /process
$ define for018 tt /process
$ define for020 dktable.dat /process
$ define for021 etabnd.dat /process
$ define for023 shift.dat /process
$ define for024 piflx.dat /process
$ define for025 eavg.dat /process
$ define for026 flxsum.dat /process
$ define for027 flux.dat /process
$ define for035 v.dat /process
$ define for036 vm.dat /process
$ define for037 bmin.dat /process
$ define for038 xmin.dat /process
$ define for039 ymin.dat /process
$ define for040 zmin.dat /process
$ define for041 aloct.dat /process
$ define for042 colat.dat /process
$ define for043 bndloc.dat /process
$ define for044 updat.dat /process
$ define for045 vnorth.dat /process
$ define for046 vsouth.dat /process
$ define efcoef efcoef.dat /process
$ define coord coord.dat /process
$ define hardy hardy.dat /process
$ define epsat epsat.dat /process
$ define epions epions.dat /process
$ define ioneng ioneng.dat /process
$ define ionnum ionnum.dat /process
$ define enchan enchan.dat /process
$ define fkp fkp.dat /process
$ define dst dst.dat /process
$ define eqedge eqedge.dat /process
$ define clapse clapse.dat /process
$ define swden swden.dat /process
$ define swvel swvel.dat /process
$ define pcp pcp.dat /process
$ define xipatt xipatt.dat /process
$ run msml
```

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msm1.for

1

```
PROGRAM MSMCON
C
C VERSION 1.0          DATE: NOVEMBER 10, 1988
C   1.1              MARCH 26, 1990
C   1.2              MAY 11, 1990
C   1.3              JULY 01, 1990
C
C PROGRAMMER: BOB SPIRO
C
C PURPOSE:  MSMCON IS THE MAIN PROGRAM FOR THE MAGNETOSPHERIC
C           SPECIFICATION MODEL.  MSMCON CALLS THE SUBROUTINES PPTCON,
C           HIEPAR, AND OUTPUT.
C
C           PARAMETER (LATDIM=62,LTDIM=51,IEDIM=30,ITMDIM=50,
C   2             NAUGEL=28,IRDIM=4,NRGDIM=29,KPDIM=7,ISPDIM=3,
C   3             IRDK=18,INRGDK=13,ISOLDK=2,IONDK=2,KPPLUS=9)
C
C LATDIM GIVES THE NUMBER OF LATITUINAL GRID LINES (ALIASED AS IDIM
C   IN SOME ROUTINES)
C LTDIM GIVES THE NUMBER OF LOCAL TIME (LONGITUDE) GRID LINES (ALIASED
C   AS JDIM IN SOME ROUTINES)
C IEDIM GIVES THE NUMBER OF INVARIANT ENERGY SPECIES TRACED BY THE
C   PROGRAM
C ITMDIM GIVES THE MAXIMUM NUMBER OF MAJOR TIME STEPS PER RUN OF THE
C   PROGRAM
C NAUGEL GIVES THE NUMBER OF ELEMENTS IN THE AUGMENTED INPUT ARRAY
C
C IRDIM GIVES THE NUMBER OF R VALUES FOR WHICH THE EMPIRICAL FLUX
C   ARRAY, FLXMAT, IS CALCULATED
C NRGDIM GIVES THE NUMBER OF PRESET ENERGY VALUES FOR WHICH FLXMAT IS
C   CALCULATED
C KPDIM GIVES THE NUMBER OF KP VALUES FOR WHICH FLXMAT IS CALCULATED
C
C KPPLUS GIVES THE KP DIMENSION OF THE AUGMENTED FLXMAT ARRAY
C   (KPDIM + 2)
C
C ISPDIM GIVES THE NUMBER OF PLASMA MASS SPECIES (ELECTRONS,H+,O+,ETC)
C
C CHARACTER*80 CHID
C
C COMMON LUNIT CONTAINS LOGICAL UNIT NUMBERS FOR INPUT AND OUTPUT
C   COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
C   1     LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
C   2     LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
C   3     LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C
C COMMON IRDREC CONTAINS RECORD NUMBERS FOR PARTICE TRACE (IRECPT)
C   AND E AND B FIELD FILES (IRECEB)
C   COMMON /IRDREC/ IRECPT,IRECEB,IRDBEG
C
C COMMON SUN CONTAINS THE SUN SPOT NUMBER FOR THE ION CHARGE
C   EXCHANGE ALGORITHM
C   COMMON /SUN/ SSN
C
C WITH FEW EXCEPTIONS, MOST OF THE ARRAYS USED IN THE PROGRAM ARE
C   DIMENSIONED HERE IN MSMCON.
C
C   DIMENSION ISTART(3),IINC(3),IEND(3)
C   DIMENSION ETA(LATDIM,LTDIM,IEDIM),EFLUX(LATDIM,LTDIM,IEDIM),
C   2     FLXSUM(LATDIM,LTDIM,3),EAVG(LATDIM,LTDIM,3),
C   3     FLUX(LATDIM,LTDIM,IEDIM)
C
C   DIMENSION VM(LATDIM,LTDIM,ITMDIM),V(LATDIM,LTDIM,ITMDIM),
```

MSM00010
MSM00020
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MSM00040
MSM00050
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MSM00070
MSM00080
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MSM00100
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MSM00120
MSM00130
MSM00140
MSM00150
MSM00160
MSM00170
MSM00180
MSM00190
MSM00200
MSM00210
MSM00220
MSM00230
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MSM00570
MSM00580
MSM00590
MSM00600
MSM00610
MSM00620
MSM00630
MSM00640

msml.for

```
1  ETABEG (LATDIM, LTDIM, IEDIM), ETABND (LTDIM, IEDIM, ITMDIM),      MSM00650
2  FLXBND (LTDIM, IEDIM, ITMDIM),      MSM00660
3  BNDLOC (LTDIM, ITMDIM), ALAM (IEDIM), COLAT (LATDIM, LTDIM),      MSM00670
4  ALOCT (LATDIM, LTDIM), BMIN (LATDIM, LTDIM), XMIN (LATDIM, LTDIM),  MSM00680
5  YMIN (LATDIM, LTDIM), ZMIN (LATDIM, LTDIM), TIMTAG (ITMDIM),      MSM00690
6  ALMDEL (IEDIM)      MSM00700

C      MSM00710
      DIMENSION VNORTH (LATDIM, LTDIM), VSOUTH (LATDIM, LTDIM)      MSM00720
C      MSM00730
      DIMENSION IFLAV (IEDIM), BNDMAX (LTDIM),      MSM00740
1  ALPHA (LATDIM), BETA (LATDIM), BIR (LATDIM, LTDIM),      MSM00750
2  ASOUTH (3, ITMDIM), BSOUTH (3, ITMDIM), DXS (3, ITMDIM), DYS (3, ITMDIM),  MSM00760
3  ANORTH (3, ITMDIM), BNORTH (3, ITMDIM), DXN (3, ITMDIM), DYN (3, ITMDIM),  MSM00770
4  VMLOSS (LATDIM, LTDIM, ITMDIM),      MSM00780
5  TETA (LATDIM), PHI (LTDIM), SINI (LATDIM, LTDIM)      MSM00790
C      MSM00800
      DIMENSION R (LATDIM, LTDIM, ITMDIM), P (LATDIM, LTDIM, ITMDIM)      MSM00810
C      MSM00820
      DIMENSION SCTFRC (IEDIM, LTDIM, ITMDIM), RPP (ITMDIM)      MSM00830
C      MSM00840
      DIMENSION DKTIME (IRDK, INRGDK, ISOLDK, IONDK)      MSM00850
C      MSM00860
C      MSM00870
      DIMENSION ID (20), RID (20), THRSH (IEDIM), ERSHFT (IEDIM)      MSM00880
C      MSM00890
C      MSM00900
      DIMENSION AUGPAR (NAUGEL, ITMDIM)      MSM00910
      LOGICAL*1 MODE (NAUGEL, ITMDIM)      MSM00920
C      MSM00930
      DIMENSION FLXMAT (IRDIM, NRGDIM, KPPLUS, ISPDIM)      MSM00940
      DIMENSION THRMAT (IRDIM, NRGDIM, KPDIM)      MSM00950
      DIMENSION FLXR (IRDIM), FLXNRG (NRGDIM), FLXKP (KPDIM)      MSM00960
C      MSM00970
C      CALL PRECIPITATION AND PARTICLE TRACER CONTROL      MSM00980
C      MSM00990
C      MSM01000
C      INPUT MAJOR TIME STEP INCREMENT (YEARS, DAYS, SECONDS)      MSM01010
      IINC (1) = 0      MSM01020
      IINC (2) = 0      MSM01030
      IINC (3) = 900      MSM01040
C      MSM01050
C      READ IN START YEAR, START DAY, START TIME IN SECONDS      MSM01060
      READ (5, *) IYEAR, IDAY, ISEC      MSM01070
      ISTART (1) = IYEAR - (IYEAR/100) * 100      MSM01080
      ISTART (2) = IDAY      MSM01090
      ISTART (3) = ISEC      MSM01100
C      MSM01110
C      READ IN STOP YEAR, STOP DAY, STOP TIME IN SECONDS      MSM01120
      READ (5, *) IYEAR, IDAY, ISEC      MSM01130
      IEND (1) = IYEAR - (IYEAR/100) * 100      MSM01140
      IEND (2) = IDAY      MSM01150
      IEND (3) = ISEC      MSM01160
C      MSM01170
C      READ IN START RECORD NUMBER      MSM01180
      READ (5, *) IRECEB      MSM01190
      IRECPT = IRECEB      MSM01200
C      MSM01210
C      READ IN STRING TO IDENTIFY RUN      MSM01220
      READ (5, *) CHID      MSM01230
C      MSM01240
C      READ IN SUN SPOT NUMBER SSN      MSM01250
      READ (5, *) SSN      MSM01260
C      MSM01270
C      WRITE (6, *) ' ISTART=' , ISTART      MSM01280
```

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msm1.for

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WRITE(6,*) 'IEND=', IEND
WRITE(6,*) 'IRECPT=', IRECPT, 'IRECEB=', IRECEB
WRITE(6,*) 'CHID=', CHID
WRITE(6,*) 'SSN=', SSN
C
C      IRDBEG=IRECPT
C
C
C      INITIALIZE TIMER
C
C CALLS TO DTIME ARE PLACED IN THE CODE TO PROVIDE TIMING INFORMATION
C FOR DIFFERENT SECTIONS OF THE PROGRAM. THE DUMMY SUBROUTINE STUB
C DTIME NEEDS TO BE REPLACED WITH MACHINE-SPECIFIC TIMING CALLS IN
C ORDER TO OBTAIN REAL TIMING INFORMATION.
C
C      CALL DTIME(ITODST)
C
C CALL TO PPTCON READS AND ASSIMILATES AVAILABLE INPUT DATA, PRODUCES
C E AND B FIELD MATRICES FOR PERIOD OF INTEREST, AND COMPUTES
C PARTICLE FLUXES IN MAGNETOSPHERE AND PRECIPITATING INTO
C IONOSPHERE.
C
C      CALL PPTCON(ISTART, IINC, IEND, LATDIM, LTDIM, IEDIM, ITMDIM,
1      IRDK, INRGDK, ISOLDK, IONDK,
1      IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP, FLXMAT,
2      THRMAT, CHID, ID, RID, SCTFRG, IFLAV, BNDMAX, ALPHA, BETA, TETA, PHI, BIR,
3      SINI, TIMTAG, COLAT, ALOCT, V, VNORTH, VSOUTH, ASOUTH, BSOUTH, DXS, DYS,
4      ANORTH, BNORTH, DXN, DYN, VM, VMLOSS, BMIN, XMIN, YMIN, ZMIN,
5      ALAM, ETABEG, ETABND, FLXBND, BNDLOC, ETA, FLUX, EFLUX, FLXSUM,
6      EAVG, R, P,
7      ALMDEL, NAUGEL, AUGPAR, MODE, RPP, THRSH, ERSHT, DKTIME)
C
C      FIND TIME TO EXECUTE PPTCON
C
C      CALL DTIME(IPPTIM)
C      WRITE (LUERR,*) 'THE TIME SPENT IN PPTCON IS ',
1      ABS(IPPTIM-ITODST)/100., ' SECONDS.'
C
C CALL HIEPAR
C CALL TO HIEPAR GIVES THE STATISTICS-BASED HIGH ENERGY (> 300 KEV)
C OUTPUT OF THE PROGRAM. THE JULY 1, 1990, VERSION OF THE MSM FOR
C DELIVERY TO THE AIR FORCE CONTAINS ONLY A DUMMY STUB FOR HIEPAR.
C
C      CALL HIEPAR
C
C      FIND TIME TO EXECUTE HIEPAR
C
C      CALL DTIME(IHIETM)
C      WRITE (LUERR,*) 'THE TIME SPENT IN HIEPAR IS ',
1      ABS(IHIETM-IPPTIM)/100., ' SECONDS.'
C
C CALL OUTPUT
C IN THE SFC OPERATIONAL VERSION OF THE MSM, THE CALL TO OUTPUT
C WILL OUTPUT MSM RESULTS TO THE ENVIRONMENTAL DATA BASE.
C THE JULY 1, 1990, DELIVERY VERSION OF THE MSM CONTAINS A STUB FOR
C SUBROUTINE OUTPUT.
C
C      CALL OUTPUT
C
C      FIND TIME TO EXECUTE OUTPUT
C
C      CALL DTIME(IOUTIM)
C      WRITE (LUERR,*) 'THE TIME SPENT IN OUTPUT IS ',
1      ABS(IOUTIM-IHIETM)/100., ' SECONDS.'
```

MSM01290
MSM01300
MSM01310
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MSM01920

msml.for

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C
C   FIND THE TOTAL TIME OF THE RUN
C
C   CALL DTIME(ITODED)
C   WRITE (LUERR,*) 'THE TOTAL TIME SPENT IN MSMCON IS ',
C   1      ABS(ITODED-ITODST)/100.,' SECONDS.'
C
C   STOP
C   END
C
C ***** P P T C O N *****
C
C   SUBROUTINE PPTCON(ISTART, IINC, IEND, LATDIM, LTDIM, IEDIM, ITMDIM,
1   IRDK, INRGDK, ISOLDK, IONDK,
1   IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP, FLXMAT,
2   THRMAT, CHID, ID, RID, SCTFRC, IFLAV, BNDMAX, ALPHA,
3   BETA, TETA, PHI, BIR, SINI, TIMTAG, COLAT,
4   ALOCT, V, VNORTH, VSOUTH, ASOUTH, BSOUTH, DXS, DYS,
5   ANORTH, BNORTH, DXN, DYN, VM, VMLOSS, BMIN, XMIN, YMIN, ZMIN,
6   ALAM, ETABEG, ETABND, FLXBND, BNDLOC, ETA, FLUX, EFLUX, FLXSUM, EAVG,
7   R, P,
8   ALMDEL, NAUGEL, AUGPAR, MODE, RPP, THRSH, ERSHFT, DKTIME)
C
C   VERSION 1.1          DATE: NOVEMBER 23, 1988
C   1.2                SEPTEMBER 8, 1989
C   1.3                NOVEMBER 17, 1989
C   1.4 (APRIL, 1990 VERSION)    MARCH 26, 1990
C   1.5 (JULY 1, 1990 VERSION)  JULY 01, 1990
C
C   PROGRAMMER:  BRYAN BALES/R.W. SPIRO
C
C   PURPOSE:  THIS EXECUTIVE ROUTINE CONTROLS THE ELECTRIC AND MAGNETIC
C   FIELD MODEL (EBCON) AND THE RUNNING OF THE PARTICLE
C   TRACE ALGORITHM (PPTM).
C
C   CALLING PARAMETERS:
C   ISTART      START YEAR, DAY, AND TIME (SEC)
C   IINC        MAJOR TIME STEP INCREMENT (YEAR, DAY, TIME)
C   IEND        ENDING YEAR, DAY, AND TIME (SEC)
C   LATDIM      NUMBER OF LATITUDINAL GRID SPACES
C   LTDIM       NUMBER OF LOCAL TIME (LONGITUDINAL) GRID SPACES
C   IEDIM       NUMBER OF PARTICLE SPECIES TO BE TRACED
C   ITMDIM      MAXIMUM NUMBER OF MAJOR TIME STEPS FOR THIS RUN
C   IRDK        R DIMENSION OF DKTIME ARRAY
C   INRGDK      ENERGY DIMENSION OF DKTIME ARRAY
C   ISOLDK      SUN SPOT NUMBER DIMENSION OF DKTIME ARRAY
C   IONDK       NUMBER OF ION SPECIES IN DKTIME ARRAY
C   IRDIM       R DIMENSION OF FLXMAT ARRAYS
C   NRGDIM      ENERGY DIMENSION OF FLXMAT ARRAYS
C   KPDIM       NUMBER OF KP VALUES FOR FLXMAT ARRAYS
C   KPPLUS      AUGMENTED KP DIMENSION OF FLXMAT (KPDIM+2)
C   ISPDIM      PLASMA MASS SPECIES DIMENSION
C   FLXR        R VALUES AT WHICH FLXMAT ARRAYS ARE CALCULATED
C   FLXNRG      ENERGY VALUES FOR WHICH FLXMAT ARRAYS ARE CALCULATED
C   FLXKP       KP VALUES FOR WHICH FLXMAT ARRAYS ARE CALCULATED
C   FLXMAT      ARRAY OF EMPIRICAL FLUXES AS FUNCTION OF R, ENERGY,
C               AND KP FOR USE IN CALCULATING INITIAL AND BOUNDARY
C               FLUX VALUES. (COMPUTED IN CALL TO FLXNIT)
C   THRMAT      ARRAY OF EMPIRICAL FLUXES AS FUNCTION OF R, ENERGY,
C               AND KP FOR USE AS THRESHOLD FLUXES (COMPUTED IN CALL
C               TO FLXNIT)
C   CHID        CHARACTER HEADER STRING (UP TO 80 CHARACTERS)
C   ID          INTEGER HEADER VECTOR
C   ID(1) = YEAR

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MSM01930
MSM01940
MSM01950
MSM01960
MSM01970
MSM01980
MSM01990
MSM02000
MSM02010
MSM02020
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MSM02040
MSM02050
MSM02060
MSM02070
MSM02080
MSM02090
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MSM02560

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msm1.for

C	ID(2) = DAY	MSM02570	
C	ID(3) = HOURS	MSM02580	
C	ID(4) = MINUTES	MSM02590	
C	ID(5) = SECONDS	MSM02600	
C	ID(6) = PRESENTLY UNUSED	MSM02610	
C	ID(7) = PRESENTLY UNUSED	MSM02620	
C	ID(8) = FIRST DIMENSION OF OUTPUT ARRAY	MSM02630	
C	ID(9) = SECOND DIMENSION OF OUTPUT ARRAY	MSM02640	
C	ID(10) = THIRD DIMENSION OF OUTPUT ARRAY	MSM02650	
C	ID(11) = TIME INDEX L	MSM02660	
C	ID(12) - ID(20) = PRESENTLY UNUSED	MSM02670	
C	RID	REAL HEADER VECTOR	MSM02680
C	RID(1) = TIMTAG	MSM02690	
C	RID(2) = KP	MSM02700	
C	RID(3) = POLAR CAP POTENTIAL DROP	MSM02710	
C	RID(4) = TIME DERIVATIVE OF LOCATION OF	MSM02720	
C	LOW-LATITUDE EDGE OF AURORAL PRECIPITATION	MSM02730	
C	RID(5) - RID(20) = PRESENTLY UNUSED	MSM02740	
C	SCTFRC	ASSUMED PITCH ANGLE SCATTERING EFFICIENCY	MSM02750
C	IFLAV	CHEMICAL SPECIES IDENTIFIER	MSM02760
C		1 MEANS ELECTRONS	MSM02770
C		2 MEANS H+ IONS	MSM02780
C		3 MEANS O+ IONS	MSM02790
C	BNDMAX	MAXIMUM I VALUE OF MODEL BOUNDARY ALONG EACH LOCAL	MSM02800
C		TIME GRID LINE DURING THE DURATION OF THIS RUN.	MSM02810
C	ALPHA	LATITUDINAL GRID SPACING VECTOR	MSM02820
C	BETA	LONGITUDINAL GRID SPACING VECTOR	MSM02830
C	TETA	COLATITUDE OF I GRID LINES (RADIAN) (USED ONLY IN	MSM02840
C		SUBROUTINE RDGRID)	MSM02850
C	PHI	NON-ROTATED HOUR ANGLE OF J GRID LINES (USED ONLY	MSM02860
C		IN SUBROUTINE RDGRID)	MSM02870
C	BIR	RADIAL COMPONENT OF IONOSPHERIC MAGNETIC FIELD (NT)	MSM02880
C	SINI	SIN(MAGNETIC FIELD INCLINATION ANGLE)	MSM02890
C	TIMTAG	VECTOR GIVING TIMES AT WHICH E AND B PARAMETERS ARE	MSM02900
C		CALCULATED	MSM02910
C	COLAT	GRID COLATITUDE ARRAY (RADIAN)	MSM02920
C	ALOCT	GRID LOCAL TIME ARRAY (RADIAN EASTWARD FROM NOON)	MSM02930
C	V	ELECTRIC POTENTIAL DISTRIBUTION ON GRID (OUTPUT FROM	MSM02940
C		EBCON) (AVERAGE OF VNORTH AND VSOUTH)	MSM02950
C	VNORTH	NORTHERN HEMISPHERE ELECTRIC POTENTIAL DISTRIBUTION	MSM02960
C		(OUTPUT FROM EBCON)	MSM02970
C	VSOUTH	SOUTHERN HEMISPHERE ELECTRIC POTENTIAL DISTRIBUTION	MSM02980
C		(OUTPUT FROM EBCON)	MSM02990
C	ASOUTH, BSOUTH, DSX, DYS, ANORTH, BNORTH, DXN, DYN	SPECIFICATIONS OF ELECTRIC FIELD MODEL BOUNDARY	MSM03000
C		ELLIPSES	MSM03010
C	VM	FLUX TUBE VOLUME (OUTPUT FROM EBCON)	MSM03020
C	VMLOSS	GEOMETRIC FACTOR USED IN CALCULATING PRECIPITATION	MSM03030
C		LOSS	MSM03040
C	BMIN	EQUATORIAL MAGNETIC FIELD STRENGTH (NT)	MSM03050
C	XMIN	GSM X LOCATION OF WHERE FIELD LINE GOING THROUGH	MSM03060
C		GRID PT CROSSES THE EQUATORIAL (B-FIELD MINIMUM)	MSM03070
C		PLANE	MSM03080
C	YMIN	GSM Y LOCATION OF WHERE FIELD LINE GOING THROUGH	MSM03090
C		GRID PT CROSSES THE EQUATORIAL PLANE	MSM03100
C	ZMIN	GSM Z LOCATION OF WHERE FIELD LINE GOING THROUGH	MSM03110
C		GRID PT CROSSES THE (B-FIELD MINIMUM) PLANE	MSM03120
C	ALAM	ENERGY INVARIANT VECTOR	MSM03130
C	ETABEG	INITIAL FLUX TUBE CONTENT DISTRIBUTION EACH TIME	MSM03140
C		STEP	MSM03150
C	ETABND	BOUNDARY FLUX TUBE CONTENT DISTRIBUTION	MSM03160
C	FLXBND	FLUX VALUES AT BOUNDARY	MSM03170
C	BNDLOC	LOCATION OF OUTER BOUNDARY OF DETAILED PARTICLE	MSM03180
C		TRACES	MSM03190
C			MSM03200

mssl.for

C	ETA	FLUX TUBE CONTENT ARRAY (PARTICLES/UNIT MAGNETIC	MSM03210
C		FLUX)	MSM03220
C	FLUX	PARTICLE FLUX AT GRID PTS (PARTICLES/CM**2/S)	MSM03230
C	EFLUX	PRECIPITATING ENERGY FLUX ARRAY	MSM03240
C	FLXSUM	TOTAL PRECIPITATION ENERGY FLUX ARRAY (INTEGRATED	MSM03250
C		OVER SPECIES) FOR (1) ELECTRONS (2) H+ & (3) O+	MSM03260
C	EAVG	AVERAGE PRECIPITATING ELECTRON ENERGY	MSM03270
C		FOR (1) ELECTRONS (2) H+ AND (3) O+	MSM03280
C	R	ARRAY GIVING RADIAL DISTANCE OF GRID PTS IN	MSM03290
C		MAGNETOSPHERIC EQUATORIAL PLANE (RE)	MSM03300
C	P	ARRAY GIVING HOUR ANGLE (MEASURED EASTWARD FROM	MSM03310
C		NOON IN RADIANS) OF GRID PTS IN EQUATORIAL PLANE	MSM03320
C	ALMDEL	WIDTH OF ENERGY INVARIANT CHANNELS	MSM03330
C	NAUGEL	DIMENSION OF INPUT ARRAYS	MSM03340
C	AUGPAR	AUGMENTED DATA ARRAY FOR INPUT VALUES	MSM03350
C	MODE	LOGICAL VARIABLE TELLING WHICH INPUT PARAMETERS WE	MSM03360
C		HAVE VALUES FOR	MSM03370
C	RPP	NOMINAL RADIUS OF PLASMAPAUSE DEFINED AS DIPOLE	MSM03380
C		MAPPING OF EQUATORWARD EDGE OF AURORAL ZONE TO	MSM03390
C		MAGNETOSPHERIC EQUATORIAL PLANE	MSM03400
C	DKTIME	ARRAY GIVING CHARGE EXCHANGE DECAY TIMES (SECONDS)	MSM03410
C		FOR AN ARRAY OF RADIAL DISTANCES, ENERGIES, SUN SPOT	MSM03420
C		NUMBERS, AND SPECIES	MSM03430
C			MSM03440
C			MSM03450
C			MSM03460
C		CHARACTER*80 CHID	MSM03470
C			MSM03480
C		INTEGER IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST, DDST,	MSM03490
1		EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,	MSM03500
2		GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,	MSM03510
3		STAND, PCP, DEQDT, IPATT	MSM03520
C			MSM03530
C		COMMON /ARINDX/IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST,	MSM03540
1		EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,	MSM03550
2		GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,	MSM03560
3		STAND, PCP, IPATT, DDST, DEQDT	MSM03570
C			MSM03580
C		COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,	MSM03600
1		LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIX, LUEAVG, LUFLSM, LUFLX,	MSM03610
2		LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,	MSM03620
3		LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH	MSM03630
C		COMMON /MOVE/IBEG, ISTOP, JBEG, JSTOP, IELEG, IEEND	MSM03640
C		COMMON /IRDREC/ IRECPT, IRECEB, IRDBEG	MSM03650
C			MSM03660
C		DIMENSION ISTART (3), IINC (3), IEND (3), ITIME (3),	MSM03670
1		ETA (LATDIM, LTDIM, IEDIM), EFLUX (LATDIM, LTDIM, IEDIM),	MSM03680
2		FLXSUM (LATDIM, LTDIM, 3), EAVG (LATDIM, LTDIM, 3),	MSM03690
3		FLUX (LATDIM, LTDIM, IEDIM)	MSM03700
C			MSM03710
C		DIMENSION VM (LATDIM, LTDIM, ITMDIM), V (LATDIM, LTDIM, ITMDIM),	MSM03720
1		ETABEG (LATDIM, LTDIM, IEDIM), ETABND (LTDIM, IEDIM, ITMDIM),	MSM03730
2		FLXBND (LTDIM, IEDIM, ITMDIM),	MSM03740
3		ALAM (IEDIM), COLAT (LATDIM, LTDIM), TIMTAG (ITMDIM),	MSM03750
4		ALOCT (LATDIM, LTDIM), BMIN (LATDIM, LTDIM), XMIN (LATDIM, LTDIM),	MSM03760
5		YMIN (LATDIM, LTDIM), ZMIN (LATDIM, LTDIM), BNDLOC (LTDIM, ITMDIM),	MSM03770
6		ALMDEL (IEDIM)	MSM03780
C			MSM03790
C		DIMENSION IFLAV (IEDIM), BNDMAX (LTDIM),	MSM03800
1		ALPHA (LATDIM), BETA (LATDIM), BIR (LATDIM, LTDIM),	MSM03810
2		ASOUTH (3, ITMDIM), BSOUTH (3, ITMDIM), DXS (3, ITMDIM), DYS (3, ITMDIM),	MSM03820
3		ANORTH (3, ITMDIM), BNORTH (3, ITMDIM), DXN (3, ITMDIM), DYN (3, ITMDIM),	MSM03830
4		VMLOSS (LATDIM, LTDIM, ITMDIM),	MSM03840

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5 TETA (LATDIM) , PHI (LTDIM) , SINI (LATDIM, LTDIM) MSM03850
C DIMENSION VNORTH (LATDIM, LTDIM) , VSOUTH (LATDIM, LTDIM) MSM03860
C DIMENSION R (LATDIM, LTDIM, ITMDIM) , P (LATDIM, LTDIM, ITMDIM) MSM03870
C DIMENSION SCTFRC (IEDIM, LTDIM, ITMDIM) , RPP (ITMDIM) MSM03880
C DIMENSION AUGPAR (NAUGEL, ITMDIM) MSM03890
C LOGICAL*1 MODE (NAUGEL, ITMDIM) MSM03900
C DIMENSION IDGHV (2) , ID (20) , RID (20) , THRSH (IEDIM) MSM03910
C DIMENSION ERSHFT (IEDIM) MSM03920
C DIMENSION ITMNEW (3) , IRESTR (3) MSM03930
C DIMENSION FLXMAT (IRDIM, NRGDIM, KPPLUS, ISPDIM) MSM03940
C DIMENSION THRMAT (IRDIM, NRGDIM, KPDIM) MSM03950
C DIMENSION FLXR (IRDIM) , FLXNRG (NRGDIM) , FLXKP (KPDIM) MSM03960
C DIMENSION DKTIME (IRDK, INRGDK, ISOLDK, IONDK) MSM03970
C DATA TSHENG, TSHING /100.0, 50./ MSM03980
C SET UP THE GRID MSM03990
C CALL RDGRID (LATDIM, LTDIM, ALPHA, BETA, TETA, PHI, COLAT, BIR, SINI) MSM04000
C ***** WRITE ALL VALUES COMPUTED IN RDGRID MSM04010
C WRITE (6, *) 'LATDIM = ', LATDIM MSM04020
C WRITE (6, *) 'LTDIM = ', LTDIM MSM04030
C WRITE (6, *) 'ALPHA ', ALPHA MSM04040
C WRITE (6, *) 'BETA ', BETA MSM04050
C WRITE (6, *) 'TETA ', TETA MSM04060
C WRITE (6, *) 'PHI ', PHI MSM04070
C CALL OUTP (COLAT, LATDIM, LTDIM, 1, LATDIM, 1, 3, LTDIM, 3, 0., MSM04080
1 'COLAT', 6, 132) MSM04090
C CALL OUTP (BIR, LATDIM, LTDIM, 10, LATDIM, 1, 1, LTDIM, 1, 0., 'BIR', 6, 132) MSM04100
C 1 ) MSM04110
C CALL OUTP (SINI, LATDIM, LTDIM, 10, LATDIM, 2, 3, LTDIM, 3, 0., MSM04120
1 'SINI', 6, 80) MSM04130
C READ TABLE OF CHARGE EXCHANGE DECAY TIMES FOR USE IN COMPUTING MSM04140
C ION CHARGE EXCHANGE LOSS MSM04150
C CALL READDK (IRDK, INRGDK, ISOLDK, IONDK, DKTIME) MSM04160
C WRITE OUT DECAY TIMES MSM04170
C DO 4 IR=1, IRDK MSM04180
C ELVAL=1.+.5*FLOAT (IR) MSM04190
C WRITE (6, 865) ELVAL MSM04200
865 FORMAT (1X/1X, 'L-VALUE = ', F5.2) MSM04210
C DO 6 ION=1, 2 MSM04220
C IF (ION.EQ.1) WRITE (6, 866) MSM04230
C IF (ION.EQ.2) WRITE (6, 867) MSM04240
866 FORMAT (1X, 'H+ DECAY TIMES: (SECONDS)') MSM04250
867 FORMAT (1X, 'O+ DECAY TIMES: (SECONDS)') MSM04260
C WRITE (6, 868) ((DKTIME (IR, INRG, ISOL, ION) , INRG=1, INRGDK) , MSM04270
2 ISOL=1, ISOLDK) MSM04280
868 FORMAT (13 (1X, 1PE9.3)) MSM04290
6 CONTINUE MSM04300
MSM04310
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MSM04470
MSM04480
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4      CONTINUE
C
C
C      SET UP TIME INDEPENDENT ENERGY CHANNELS TO MODEL
C
C          CALL SETALM(ALAM, IEMAX, IEDIM, IFLAV, ALMDEL)
C          IEEND=IEMAX
C
C      WRITE OUT ENERGY CHANNEL INFORMATION
C          DO 999 IE=1, IEMAX
C              WRITE(6,*) 'IFLAV=', IFLAV(IE), ' ALAM=', ALAM(IE),
C              2          ' ALMDEL=', ALMDEL(IE)
C              THRS(IE)=0.0
999      CONTINUE
C
C      INITIALIZE MATRIX OF KP DEPENDENT DEFAULT FLUXES
C
C          CALL FLXNIT(IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP,
C          2          FLXMAT, THRMAT)
C
C
C      SPECIAL PRINTOUT FOR FLXMAT AND THRMAT
C          DO 300 IR=1, IRDIM
C              IF(IR.EQ.1) RDIST=3.
C              IF(IR.EQ.2) RDIST=4.
C              IF(IR.EQ.3) RDIST=6.6
C              IF(IR.EQ.4) RDIST=13.
C
C          DO 310 IKP=1, KPPLUS
C              MYKP=IKP-1
C              WRITE(6,850) RDIST, MYKP
850      FORMAT(1X, 'R=', F6.2, 2X, 'KP=', I2, /)
C              WRITE(6,*) 'ELECTRONS'
C              WRITE(6,851)
851      FORMAT(1X, 'LOG ENERGY', 5X, 'LOG FLUX', 5X, 'LOG THRESHOLD')
C
C          DO 320 INRG=1, NRGDIM
C              WRITE(6,852) FLXNRG(INRG), FLXMAT(IR, INRG, IKP, 1),
C              2          THRMAT(IR, INRG, IKP)
852      FORMAT(F10.4, 5X, F8.4, 5X, F13.4)
C
C          320      CONTINUE
C
C              WRITE(6,853)
853      FORMAT(1X/)
C
C              WRITE(6,*) 'H+ IONS'
C              DO 321 INRG=1, NRGDIM
C                  WRITE(6,859) FLXNRG(INRG), FLXMAT(IR, INRG, IKP, 2)
859      FORMAT(F10.4, 5X, F8.4)
C
C          321      CONTINUE
C
C              WRITE(6,853)
C
C              WRITE(6,*) 'O+ IONS'
C              DO 322 INRG=1, NRGDIM
C                  WRITE(6,859) FLXNRG(INRG), FLXMAT(IR, INRG, IKP, 3)
C
C          322      CONTINUE
C
C              WRITE(6,853)
310     CONTINUE

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300 CONTINUE

C
C

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WRITE (6, *) 'ELECTRONS'
WRITE (6, *) 'FLXMAT ARRAYS (IR, NRG, IKP); IR=1 IS 3RE, IR=2 IS 4RE'
WRITE (6, *) 'IR=3 IS 6.6 RE, IR=4 IS 13 RE; NRG CORRESPONDS TO'
WRITE (6, *) 'LOG OF ENERGY IN EV RUNNING FROM 10 EV TO 10**8 EV'
WRITE (6, *) 'ENERGY= 10.**((3+NRG)/4); KP=IKP-1'
WRITE (6, *) 'KP=0'
CALL OUTP (FLXMAT (1, 1, 1, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=1'
CALL OUTP (FLXMAT (1, 1, 2, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=2'
CALL OUTP (FLXMAT (1, 1, 3, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=3'
CALL OUTP (FLXMAT (1, 1, 4, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=4'
CALL OUTP (FLXMAT (1, 1, 5, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=5'
CALL OUTP (FLXMAT (1, 1, 6, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'KP=6'
CALL OUTP (FLXMAT (1, 1, 7, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'MINIMA'
CALL OUTP (FLXMAT (1, 1, 8, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'MAXIMA'
CALL OUTP (FLXMAT (1, 1, 9, 1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT1', 6, 132)
WRITE (6, *) 'H+ IONS'
WRITE (6, *) 'KP=0'
CALL OUTP (FLXMAT (1, 1, 1, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=1'
CALL OUTP (FLXMAT (1, 1, 2, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=2'
CALL OUTP (FLXMAT (1, 1, 3, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=3'
CALL OUTP (FLXMAT (1, 1, 4, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=4'
CALL OUTP (FLXMAT (1, 1, 5, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=5'
CALL OUTP (FLXMAT (1, 1, 6, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'KP=6'
CALL OUTP (FLXMAT (1, 1, 7, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'MINIMA'
CALL OUTP (FLXMAT (1, 1, 8, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'MAXIMA'
CALL OUTP (FLXMAT (1, 1, 9, 2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT2', 6, 132)
WRITE (6, *) 'O+ IONS'

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WRITE(6,*) 'KP=0'
CALL OUTP (FLXMAT(1,1,1,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=1'
CALL OUTP (FLXMAT(1,1,2,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=2'
CALL OUTP (FLXMAT(1,1,3,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=3'
CALL OUTP (FLXMAT(1,1,4,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=4'
CALL OUTP (FLXMAT(1,1,5,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=5'
CALL OUTP (FLXMAT(1,1,6,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'KP=6'
CALL OUTP (FLXMAT(1,1,7,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'MINIMA'
CALL OUTP (FLXMAT(1,1,8,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
WRITE(6,*) 'MAXIMA'
CALL OUTP (FLXMAT(1,1,9,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'FLXMAT3', 6, 132)
CALL OUTP (THRMAT(1,1,1), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT1', 6, 80)
CALL OUTP (THRMAT(1,1,2), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT2', 6, 80)
CALL OUTP (THRMAT(1,1,3), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT3', 6, 80)
CALL OUTP (THRMAT(1,1,4), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT4', 6, 80)
CALL OUTP (THRMAT(1,1,5), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT5', 6, 80)
CALL OUTP (THRMAT(1,1,6), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT6', 6, 80)
CALL OUTP (THRMAT(1,1,7), IRDIM, NRGDIM, 1, IRDIM, 1, 1, NRGDIM, 1, 0.,
2 'THRMAT7', 6, 80)

C
C GET CURRENT TIME
C
C CALL DTIME(ISTEB)
C
C
C IRECST=MAX(1, IRECEB)
C
C CALL TO EBCON COMPUTES ALL THE ELECTRIC AND MAGNETIC FIELD MODELS
C NEEDED FOR THE RUN
C
C CALL EBCON(ISTART, IINC, IEND, COLAT, ALOCT, LATDIM, LTDIM, ITMDIM,
1 IEDIM, NAUGEL, CHID, ID, RID, VM, BMIN, XMIN, YMIN, ZMIN,
2 V, VNORTH, VSOUTH, ASOUTH, BSOUTH, DXS, DYS,
3 ANORTH, BNORTH, DXN, DYN, BNDLOC,
4 TIMTAG, ITMMAX, R, P, BIR, SINI, VMLOSS, SCTFRC, AUGPAR, MODE,
5 RPP, IEMAX, TETA)

C
C GET CURRENT TIME AND FIND TIME SPENT IN EBCON
C
C CALL DTIME(IENDEB)
C WRITE (LUERR,*) 'THE TIME SPENT IN EBCON IS ',
1 ABS(IENDEB-ISTEB)/100., ' SECONDS.'

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MSM06380
MSM06390
MSM06400

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mssl.for

11

```
C
C      COMPUTE BNDMAX FROM BNDLOC
C
C      DO 8 LT=1, LTDIM
C          BNDMAX(LT)=0.
C          DO 9 ITM=1, ITMMAX
C              IF (BNDLOC(LT, ITM) .GT. BNDMAX(LT))
C                  BNDMAX(LT)=BNDLOC(LT, ITM)
1
C      CONTINUE
9
8      CONTINUE
C
C
C
C
C
C
C
C      FIND THE TIME DEPENDENT PLASMA BOUNDARY CONDITION FOR PPTM
C
C      CALL BNDSET(LATDIM, LTDIM, IEDIM, ITMDIM, ITMMAX,
1          IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP, FLXMAT,
2          NAUGEL, TIMTAG, BNDLOC, IFLAV, AUGPAR, R, P, VM, ETA, ETABND,
3          FLXBND, ALAM, ALMDEL, IEMAX)
C
C
C      CALL OUTP(FLXBND(1, 1, 1), LTDIM, IEDIM, 3, LTDIM, 1, 1, IEMAX, 1,
2          0., 'FLXBND(J, IE, 1)', 6, 132)
C
C
C      IF (IRECPT.EQ.0) THEN
C          AZERO=.2
C          BZERO=0.
C          CZERO=0.
C      ELSE
C
C      READ START FLUX FROM DATA SET
C      IRECMX=ABS(IRECPT)
C      IRDFLX=(IRECMX-1)*IEMAX+1
C      CALL RDHDR(LUFLX, 'AFLX ', IRDFLX, ID, RID, CHID,
2          LATDIM, LTDIM, ITMDIM)
C
C      CHECK IF TIME IS CORRECT
C
C      ISEC=ID(3)*3600+ID(4)*60+ID(5)
C      IF (ID(1).NE.ISTART(1).OR.
1          ID(2).NE.ISTART(2).OR.
2          ISEC.NE.ISTART(3)) THEN
C
C          WRITE(6,*) 'START TIME DOES NOT MATCH ETABEG START TIME'
C          WRITE(6,*) 'STOPPING PROGRAM IN PPTCON'
C          WRITE(6,*) 'ISTART=', ISTART
C          WRITE(6,*) 'ISEC=', ISEC, 'IRECMX=', IRECMX
C
C      STOP
C      END IF
C
C      CALL READ3D(LUFLX, 'AFLX ', IRECMX, LATDIM, LTDIM, IEMAX, ITMDIM,
1          ID, RID, CHID, FLUX)
C
C      CONVERT FROM PARTICLE FLUX TO INVARIANT FLUX ETA
C
C      CALL FLX2ET(LATDIM, LTDIM, IEDIM, IEMAX, ITMDIM, 1, IFLAV, ALAM,
2          ALMDEL, BNDLOC, VM, FLUX, ETA)
```

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msml.for

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```
C
C
C
      AZERO=0.
      BZERO=.2
      CZERO=0.
C
      END IF
C
      IRECPT=MAX(1, IRECPT)
      LL=1
C
C
C INITIALIZE PLASMA DISTRIBUTION
C
      CALL INITAL(LL, LATDIM, LTDIM, IEDIM, ITMDIM, IRDIM,
2          NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP,
3          FLXMAT, IFLAV, AUGPAR(KP, LL), R, P, VM, ETA, ETABEG, ALAM, ALMDEL,
4          BNDLOC, AZERO, BZERO, CZERO, IEMAX)
C
C CONVERT ETABEG TO FLUX AND WRITE OUT TO DISK FILE
      CALL ET2FLX(LATDIM, LTDIM, IEDIM, IEMAX, ITMDIM, 1, IFLAV, ALAM,
2          ALMDEL, BNDLOC, VM, FLUX, ETABEG)
C
      ID(1)=ISTART(1)
      ID(2)=ISTART(2)
      ID(3)=ISTART(3)/3600
      ID(4)=MOD(ISTART(3), 3600)/60
      ID(5)=MOD(ISTART(3), 60)
      ID(11)=1
      ID(8)=LATDIM
      ID(9)=LTDIM
      ID(10)=IEMAX
C
      CALL WRT3D(LUFLX, IRECPT, ID, RID, CHID, FLUX, LATDIM, LTDIM, IEMAX,
2          ITMDIM)
C
C
      DO 400 KK=1, IEMAX
      WRITE(6, *) 'KK= ', KK
      CALL OUTP(ETABEG(1, 1, KK), LATDIM, LTDIM, 20, 45, 1, 3, LTDIM-1,
2          1, 0., 'ETABEG(KK)', 6, 132)
      WRITE(6, *) 'KK=', KK, 'BEGINNING FLUX'
      CALL OUTP(FLUX(1, 1, KK), LATDIM, LTDIM, 20, 45, 1, 3, LTDIM-1,
2          1, 0., 'FLUX(KK)', 6, 132)
400 CONTINUE
C
C
      ITIME(1) = ISTART(1)
      ITIME(2) = ISTART(2)
      ITIME(3) = ISTART(3)
C
C
C
C
C FOLLOWING IS THE MAIN TIME LOOP IN THE PROGRAM
C LOOP OVER ALL TIMES IN TIMTAG (L=1 CORRESPONDS TO INITIAL TIME)
      DO 10 L=2, ITMMAX
      IRECPT=IRECPT+1
      TSTART=TIMTAG(L)
      TSTOP=TIMTAG(L-1)
      PSTEP=TSTART-TSTOP
      WRITE(6, *) ' L= ', L, ' IRECPT= ', IRECPT, ' TSTART= ', TSTART
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msml.for

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C      WRITE(6,*) ' TSTOP= ',TSTOP,' PSTEP= ',PSTEP,' ITMMAX=',ITMMAX      MSM07690
C      CALL OUTP(ETABND(1,1,L),LTDIM,IEDIM,3,LTDIM,1,1,IEMAX,1,      MSM07700
2      0.,'ETABND(J,IE,L)',6,132)      MSM07710
C      MSM07720
C      MSM07730
C      DTNOM=-600.      MSM07740
C      IF (ABS(DTNOM) .GT. PSTEP) DTNOM=-PSTEP      MSM07750
C      MSM07760
C      LL=L      MSM07770
C      MSM07780
C      MSM07790
C      MSM07800
C      MSM07810
C      MSM07820
C      IMODE=0      MSM07830
C      MSM07840
C      IF (MODE(KP,L) .AND. IMODE.EQ.0) THEN      MSM07850
C      PERFORM FULL PARTICLE TRACES      MSM07860
C      MSM07870
C      GET THE CURRENT TIME      MSM07880
C      CALL DTIME(ISTPPT)      MSM07890
C      MSM07900
C      CALL PPTM(TSTART,TSTOP,DTNOM,SCTFRC,IFLAV,BNDMAX,ALPHA,BETA,      MSM07910
1      BIR,ITMMAX,LATDIM,LTDIM,IEDIM,ITMDIM,IRDIM,NRGDIM,KPDIM,      MSM07920
2      KPPLUS,ISPDIM,FLXR,FLXNRG,FLXKP,FLXMAT,THRMAT,TIMTAG,ALAM,      MSM07930
2      ALMDEL,VM,R,P,VMLOSS,V,ETABEG,ETABND,BNDLOC,ETA,EFLUX,      MSM07940
3      FLXSUM,EAVG,LL,RPP,AUGPAR(KP,LL),IEMAX,THRSH,TSHENG,      MSM07950
4      TSHING,IRDK,INRGDK,ISOLDK,IONDK,DKTIME)      MSM07960
C      MSM07970
C      GET THE CURRENT TIME AND FIND THE TIME SPENT IN PPTM      MSM07980
C      MSM07990
C      CALL DTIME(IENPPT)      MSM08000
C      WRITE(LUERR,*) ' THE TIME SPENT IN PPTM IS ',      MSM08010
1      ABS(IENPPT-ISTPPT)/100.,' SECONDS.'      MSM08020
C      MSM08030
C      CALL PWRCAL TO ESTIMATE ELECTRON PRECIPITATION POLEWARD OF MAIN      MSM08040
C      MSM MODELING REGION      MSM08050
C      MSM08060
C      CALL PWRCAL(LATDIM,LTDIM,3,ITMDIM,LL,AUGPAR(KP,LL),FLXSUM,      MSM08070
2      EAVG,COLAT,ALOCT,ALPHA,BETA,BNDLOC,ANORTH,      MSM08080
3      BNORTH,DXN,DYN)      MSM08090
C      MSM08100
C      WRITE(18,*) ' TIME = ',TIMTAG(LL)      MSM08110
C      WRITE(6,*) ' TIME = ',TIMTAG(LL)      MSM08120
C      MSM08130
C      ELSE      MSM08140
C      MSM08150
C      USE EMPIRICAL FLXMAT DENSITIES      MSM08160
C      MSM08170
C      CALL DTIME(ISTFLX)      MSM08180
C      MSM08190
C      CALL FLXDFL(LL,AUGPAR(KP,LL),R,P,ALAM,VM,IRDIM,NRGDIM,      MSM08200
1      KPDIM,KPPLUS,ISPDIM,FLXMAT,FLXR,FLXNRG,FLXKP,EFLUX,ETA,      MSM08210
2      ALMDEL,LATDIM,LTDIM,IEDIM,ITMDIM,BNDLOC,IEMAX,IFLAV,      MSM08220
3      1,IEMAX)      MSM08230
C      MSM08240
C      DO 998 IDO=1,IEMAX      MSM08250
C      IF (IFLAV(IDO) .EQ.1) THEN      MSM08260
C      THRSH(IDO)=TSHENG      MSM08270
C      ELSE      MSM08280
C      THRSH(IDO)=TSHING      MSM08290
C      END IF      MSM08300
998      CONTINUE      MSM08310
C      MSM08320
```

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msml.for

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C
C      CALL DTIME (INDFLX)
C      WRITE (LUERR,*) ' THE TIME SPEND IN FLXDFL IS ',
C 1      ABS (INDFLX-ISTFLX)/100., ' SECONDS.'
C      CALL DTIME (ISTAUR)
C      ENDIF
C
C
C      CALL TO AURL2S PROCURES HARDY ION PRECIPITATION MODEL
C      CALL AURL2S (AUGPAR (KP, L), COLAT, ALOCT, LATDIM, LTDIM,
C 1      FLXSUM (1, 1, 2), EAVG (1, 1, 2))
C      CALL OUTP (FLXSUM (1, 1, 2), LATDIM, LTDIM, 15, LATDIM, 1, 3,
C 1      LTDIM, 1, 0., 'IFLXSUM', 6, 132)
C
C      CALL DTIME (IENAUR)
C      WRITE (LUERR,*) ' THE TIME SPENT IN AURL IS ',
C 1      ABS (IENAUR-ISTAUR)/100., ' SECONDS.'
C
C
C      WRITE (6,*) 'T=', TSTART
C
C      CONVERT TSTOP TO 3 VALUED TIME AND PUT IT INTO ITIME
C      GET ALOCT AT TSTOP
C
C      ITIME (3) = ITIME (3) + INT (PSTEP)
C 11 CONTINUE
C      IF (ITIME (3).GT.86400) THEN
C          ITIME (2) = ITIME (2) + 1
C          ITIME (3) = ITIME (3) - 86400
C          IF (MOD (ITIME (1), 4).NE.0.AND.ITIME (2).GT.365) THEN
C              ITIME (2) = ITIME (2) - 365
C              ITIME (1) = ITIME (1) + 1
C          ELSEIF (MOD (ITIME (1), 4).EQ.0.AND.ITIME (2).GT.366) THEN
C              ITIME (2) = ITIME (2) - 366
C              ITIME (1) = ITIME (1) + 1
C          END IF
C          GO TO 11
C      END IF
C
C      ----> WRITE FLUX, EFLUX, FLXSUM, EAVG
C      ----> TO ARCHIVAL FILES
C
C      DO 2 IND=1, 20
C          ID (IND)=0
C          RID (IND)=0.
C 2      CONTINUE
C      WRITE (6,*) 'L=', L, 'ITIME=', ITIME (3)
C          ID (1)=ITIME (1)
C          ID (2)=ITIME (2)
C          ID (3)=ITIME (3)/3600
C          ID (4)=MOD (ITIME (3), 3600)/60
C          ID (5)=MOD (ITIME (3), 60)
C          ID (11)=L
C
C      ----> WRITE FLXBND TO ARCHIVE FILE
C
C          ID (8)=LTDIM
C          ID (9)=IEDIM
C          ID (10)=1
C
C      CALL WRT3D (LUFLXB, IRECPT, ID, RID, CHID, FLXBND (1, 1, L), LTDIM, IEDIM,
C 2      1, ITMDIM)
C
C
C
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MSM08330
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ID(8)=LATDIM
ID(9)=LTDIM
ID(10)=1
C
C
C ----> WRITE EAVG AND FLXSUM TO ARCHIVE FILES
C
CALL WRT3D(LUEAVG, IRECPT, ID, RID, CHID, EAVG, LATDIM, LTDIM, 1, ITMDIM)
CALL WRT3D(LUFLSM, IRECPT, ID, RID, CHID, FLXSUM, LATDIM, LTDIM, 1, ITMDIM)
CALL WRT3D(LUPIFX, IRECPT, ID, RID, CHID, FLXSUM(1, 1, 2), LATDIM, LTDIM,
2      1, ITMDIM)
CALL WRT3D(LUPIEN, IRECPT, ID, RID, CHID, EAVG(1, 1, 2), LATDIM, LTDIM,
2      1, ITMDIM)
C
C ----> WRITE FLUX AND EFLUX TO ARCHIVE FILES
C
ID(8)=LATDIM
ID(9)=LTDIM
ID(10)=IEMAX
C
C CONVERT ETA TO FLUX FOR OUTPUT
C
CALL ET2FLX(LATDIM, LTDIM, IEDIM, IEMAX, ITMDIM, L, IFLAV, ALAM,
2      ALMDEL, BNDLOC, VM, FLUX, ETA)
C
CALL WRT3D(LUFLX, IRECPT, ID, RID, CHID, FLUX, LATDIM, LTDIM, IEMAX,
1      ITMDIM)
CALL WRT3D(LUEFLX, IRECPT, ID, RID, CHID, EFLUX, LATDIM, LTDIM, IEMAX,
1      ITMDIM)
C
IUT=100*ID(3)+ID(4)
DO 111 IE=1, IEMAX
WRITE(6, *) 'IE=', IE, ' ALAM(IE)=', ALAM(IE), ' SPECIES=', IFLAV(IE),
1      'L=', L, ' DAY=', ID(2), ' ITIME=', ITIME(3), ' UT=', IUT
C      CALL OUTP(ETA(1, 1, IE), LATDIM, LTDIM, 15, 45, 1, 3, LTDIM, 1, 0.,
C      1      'ETA', 6, 132)
CALL OUTP(FLUX(1, 1, IE), LATDIM, LTDIM, 15, 45, 1, 3, LTDIM, 1, 0.,
1      'FLUX', 6, 132)
111 CONTINUE
C
CALL OUTP(ALOCT, LATDIM, LTDIM, 10, 11, 1, 3, LTDIM, 1, 0.,
1      'ALOCT', 6, 132)
WRITE(6, *) 'L=', L, ' DAY=', ID(2), ' UT=', IUT, ' ITIME=', ITIME(3)
CALL OUTP(FLXSUM, LATDIM, LTDIM, 15, 55, 1, 3, LTDIM, 1, 0.,
1      'FLXSUM', 6, 132)
WRITE(6, *) 'L=', L, ' DAY=', ID(2), ' UT=', IUT, ' ITIME=', ITIME(3)
CALL OUTP(EAVG, LATDIM, LTDIM, 15, 55, 1, 3, LTDIM, 3, 0.,
1      'EAVG', 6, 132)
C
C COPY CURRENT VALUES IN ETA TO ETABEG
C
DO 20, I=1, LATDIM
DO 30, J=1, LTDIM
DO 40, K=1, IEMAX
ETABEG(I, J, K) = ETA(I, J, K)
40      CONTINUE
30      CONTINUE
20      CONTINUE
C
10 CONTINUE
CALL OPTERR(ETA, VM, LATDIM, LTDIM, IEDIM, IEMAX, ALAM, ALMDEL, THRSH,
1      ITMDIM, IFLAV, ISTART, IEND, R, P, TIMTAG, ITMMAX, ERSHT)
C

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msml.for

RETURN

END

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C

***** E B C O N *****

SUBROUTINE EBCON (ISTART, IINC, IEND, COLAT, ALOCT, LATDIM, LTDIM, ITMDIM,
1 IEDIM, NAUGEL, CHID, ID, RID, VM, BMIN, XMIN, YMIN, ZMIN, V, VNORTH,
2 VSOUTH, ASOUTH, BSOUTH, DXS, DYS, ANORTH, BNORTH, DXN, DYN, BNDLOC,
3 TIMTAG, ITMMAX, R, P, BIR, SINI, VMLOSS, SCTFRC, AUGPAR, MODE, RPP,
4 IEMAX, TETA)

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VERSION 1.1 DATE: FEBRUARY 5, 1988
09.12.89

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PROGRAMMER: BRYAN A. BALES/R.W. SPIRO

PURPOSE: EBCON CALLS ROUTINES TO CALCULATE THE ELECTRIC AND THE
MAGNETIC FIELD AT OUR GRID POINTS.

C
C

CHARACTER*80 CHID

C
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C

INTEGER IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST, DDST,
1 EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2 GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3 STAND, PCP, DEQDT, IPATT

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COMMON /ARINDX/ IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST,
1 EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2 GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3 STAND, PCP, IPATT, DDST, DEQDT

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COMMON /LUNIT/ LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1 LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2 LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3 LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH

C
C

COMMON /IRDREC/ IRECP, IRECEB, IRDBEG

C
C
C
C

DIMENSION AUGPAR (NAUGEL, ITMDIM)
DIMENSION ISTART (3), IINC (3), IEND (3), ITIME (3),
1 ITMNEW (3), VM (LATDIM, LTDIM, ITMDIM), V (LATDIM, LTDIM, ITMDIM),
2 BMIN (LATDIM, LTDIM), XMIN (LATDIM, LTDIM), TIMTAG (ITMDIM),
3 YMIN (LATDIM, LTDIM), ZMIN (LATDIM, LTDIM),
4 COLAT (LATDIM, LTDIM), ALOCT (LATDIM, LTDIM)

C
C

DIMENSION VNORTH (LATDIM, LTDIM), VSOUTH (LATDIM, LTDIM)
DIMENSION TETA (LATDIM)

C
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C

DIMENSION BNDLOC (LTDIM, ITMDIM),
2 ASOUTH (3, ITMDIM), BSOUTH (3, ITMDIM), DXS (3, ITMDIM), DYS (3, ITMDIM),
3 ANORTH (3, ITMDIM), BNORTH (3, ITMDIM), DXN (3, ITMDIM), DYN (3, ITMDIM),
4 BIR (LATDIM, LTDIM), SINI (LATDIM, LTDIM),
5 VMLOSS (LATDIM, LTDIM, ITMDIM), SCTFRC (IEDIM, LTDIM, ITMDIM),
6 RPP (ITMDIM)

C
C
C

DIMENSION R (LATDIM, LTDIM, ITMDIM), P (LATDIM, LTDIM, ITMDIM)

LOGICAL*1 MODE (NAUGEL, ITMDIM)

C
C

DIMENSION ID (20), RID (20)

C

ITIME (IYEAR) = ISTART (IYEAR)

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msml.for

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      ITIME(IDAY) = ISTART(IDAY)
      ITIME(ISECND) = ISTART(ISECND)
C
C
      PI=ATAN2(0.,-1.)
C
C  INITIALIZE ID ARRAYS
      DO 4 IC=1,20
          ID(IC)=0
          RID(IC)=0.
      4  CONTINUE
C
C  FECON RETURNS TIME-DEPENDENT INPUT PARAMETERS
C
C      CALL DTIME(ISTFE)
C
C      CALL FECON(ISTART,IINC,IEND,ITMDIM,NAUGEL,MODE,AUGPAR,
      2      ITMMAX,TIMTAG)
C
      WRITE(6,*) 'ITMMAX = ',ITMMAX
      DO 101, I=1, ITMMAX
          WRITE(6,800) I,TIMTAG(I)
      101  CONTINUE
      800  FORMAT (' TIMTAG(',I2.2,') = ',F15.1)
C
C  GET THE CURRENT TIME AND FIND THE TIME SPENT IN FECON
C
C      CALL DTIME(IENDFE)
C      WRITE(LUERR,*) 'THE TIME SPENT IN FECON IS ',
      1      ABS(IENDFE-ISTFE)/100.,' SECONDS.'
C
C  BEGINNING OF EB TIME LOOP
      IRECEB=MAX(1,IRECEB)
      IRECEB=IRECEB-1
C
      DO 10 IT=1,ITMMAX
          L = IT
          IRECEB=IRECEB+1
C
C  SET ALOCT TO CORRECT VALUE
C
C      CALL MLTSET(ITIME(ISECND),LATDIM,LTDIM,ALOCT)
C
C  CALCULATE SCTFRC ARRAY = FRACTION OF STRONG PITCH ANGLE SCATTERING
C
C      FKP=AUGPAR(KP,L)
      CALL SETSCT(L,ITIME(ISECND),IEDIM,LTDIM,ITMDIM,LATDIM,
      2      FKP,ALAM,ALOCT,SCTFRC,IEMAX)
C
C
C      ***** PRINT OUT ALOCT
C
      WRITE(6,*) 'MY UT =', (ITIME(ISECND)/3600)*100+
      1      MOD(ITIME(ISECND),3600)/60
      CALL OUTP(ALOCT,LATDIM,LTDIM,10,11,1,3,LTDIM,1,0.,
      1      'ALOCT',6,132)
C
C  GET THE CURRENT TIME
C
C
C      ***** WRITE AUGPAR
C
```

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MSM10880

```
      WRITE (6,*) 'AUGPAR PARAMETERS'
      WRITE (6,810)
810  FORMAT (1X,' IYEAR',2X,' IDAY',2X,' IHOURL',2X,' IMIN',
      2      2X,' ISEC',2X,' KP',2X,' DST',2X,' EQEDGE',
      3      2X,' DLATAZ',2X,' DLATRV',2X,' MLTRV')
      WRITE (6,820) (AUGPAR(LM,IT),LM=1,11)
820  FORMAT (1X,11(F8.2,2X))
      WRITE (6,830)
830  FORMAT (1X)
      WRITE (6,840)
840  FORMAT (1X,' IMFBX',2X,' IMFBY',2X,' IMFBZ',2X,' CLAPSE',
      2      2X,' GEOMGX',2X,' GEOMGY',2X,' GEOMGZ',2X,' GEOMGT',
      3      2X,' LBOUND',2X,' SWVEL',2X,' SWDEN')
      WRITE (6,820) (AUGPAR(LM,IT),LM=12,22)
      WRITE (6,830)
      WRITE (6,850)
850  FORMAT (1X,' TILTW',2X,' STAND',2X,' PCP',2X,' IPATT',
      2      2X,' DDST',2X,' DEQDT')
      WRITE (6,820) (AUGPAR(LM,IT),LM=23,28)
      WRITE (6,830)

C
C
C
C
C      GET THE CURRENT TIME
C
C      CALL DTIME (ISTBT)
C
C      CALCULATE APPROXIMATE PLASMAPAUSE RADIUS FOR USE IN PPTM FOR
C      DETERMINING WEAK LOSS RATE
      RPP (L) = 1. / (COS (AUGPAR (EQEDGE, L) * PI / 180.)) ** 2
C
C
C      CALCULATE B FIELD MATRICES
C
      FSTOFF = AUGPAR (STAND, L)
      FEQEDG = AUGPAR (EQEDGE, L)
      FDST = AUGPAR (DST, L)
      FCLPSE = AUGPAR (CLAPSE, L)
      FTILT = AUGPAR (TILTW, L)
C
      WRITE (6,*) 'L =',L,' FSTOFF =',FSTOFF,' FEQEDG =',FEQEDG,
      1      ' FDST =',FDST,' FCLPSE =',FCLPSE,' FTILT =',
      2      FTILT,' RPP =',RPP (L)
C
      CALL BTRACE (LATDIM, LTDIM, ITMDIM, L, FSTOFF, FEQEDG, FDST,
      2      FCLPSE, FTILT, VM, BMIN, XMIN, YMIN, ZMIN, R, P, ALOCT, TETA)
C
C      GET THE CURRENT TIME AND FIND THE TIME SPENT IN BTRACE
C
C      CALL DTIME (IENDBT)
      WRITE (LUERR,*) 'THE TIME SPENT IN BTRACE IS ',
      1      ABS (IENDBT - ISTBT) / 100., ' SECONDS.'
C
      WRITE (6,*) 'MY UT =', (ITIME (ISECND) / 3600) * 100 +
      1      MOD (ITIME (ISECND), 3600) / 60., ' DAY = ', ITIME (IDAY)
      WRITE (6,*) 'L =', L
C
      ICNTRL = 1
C
C      GET THE CURRENT TIME
C
      CALL DTIME (ISTEF)
C
```

```
C
WRITE(6,*) 'IN EBCON'
WRITE(6,*) 'EQEDGE= ',AUGPAR(EQEDGE,L),' STAND= ',AUGPAR(STAND,L)
C GET BNDYS FOR USE IN EFIELD
VDROP=AUGPAR(PCP,L)*1.E3
CALL EFBNDY(LATDIM,LTDIM,ITMDIM,L,AUGPAR(EQEDGE,L),
2 AUGPAR(STAND,L),VDROP,R,ALOCT,COLAT,
3 ASOUTH(1,L),BSOUTH(1,L),DXS(1,L),DYS(1,L))
CALL EFBNDY(LATDIM,LTDIM,ITMDIM,L,AUGPAR(EQEDGE,L),
2 AUGPAR(STAND,L),VDROP,R,ALOCT,COLAT,
3 ANORTH(1,L),BNORTH(1,L),DXN(1,L),DYN(1,L))
WRITE(6,*) 'AFTER EFBNDY L= ',L,' A= ',(ANORTH(IIC,L),IIC=1,3)
WRITE(6,*) 'BNORTH=',(BNORTH(IIC,L),IIC=1,3)
WRITE(6,*) ' DXN= ',(DXN(IIC,L),IIC=1,3)
WRITE(6,*) ' DYN= ',(DYN(IIC,L),IIC=1,3)
C
C
C
IPATRN=AUGPAR(IPATT,L)
CALL EFIELD(IPATRN,VDROP,AUGPAR(DEQDT,L),
2 ASOUTH,BSOUTH,DXS,DYS,ANORTH,BNORTH,DXN,DYN,COLAT,
3 ALOCT,MODE,LATDIM,LTDIM,JWRAP,ITMDIM,L,ICNTRL,1,V,
4 VNORTH,VSOUTH)
C
C GET THE CURRENT TIME AND FIND THE TIME SPENT IN EFIELD
C
C CALL DTIME(IENDEF)
WRITE(LUERR,*) 'THE TIME SPENT IN EFIELD IS ',
1 ABS(IENDEF-ISTEF)/100.,' SECONDS.'
C
C ***** WRITE V
C
CALL OUTP(V(1,1,L),LATDIM,LTDIM,1,LATDIM,1,1,LTDIM,1,0.,
1 'V',6,132)
WRITE(6,*) 'MY UT =',(ITIME(ISECND)/3600)*100+
1 MOD(ITIME(ISECND),3600)/60,' DAY= ',ITIME(IDAY)
WRITE(6,*) 'L=',L
C
C CALL OUTP(VNORTH,LATDIM,LTDIM,1,LATDIM,1,1,LTDIM,1,0.,
2 'VNORTH',6,132)
C CALL OUTP(VSOUTH,LATDIM,LTDIM,1,LATDIM,1,1,LTDIM,1,0.,
2 'VSOUTH',6,132)
C
C
C FIND BNDLOC FOR THIS TIME
C
CALL FNDBND(L,COLAT,ALOCT,ANORTH(2,L),BNORTH(2,L),
1 DXN(2,L),DYN(2,L),LATDIM,LTDIM,ITMDIM,BNDLOC)
C
C COMPUTE RBNDY
WRITE(6,*) 'L= ',L
DO 8 J=1,LTDIM
BI=BNDLOC(J,L)
BJ=J
BL=L
RBNDY=G3NTRP(R,LATDIM,LTDIM,ITMDIM,BI,BJ,BL)
WRITE(6,*) 'J=',J,' BNDLOC=',BNDLOC(J,L),' RBNDY=',RBNDY
8 CONTINUE
C
C
C
IBM=LATDIM
DO 6 JJ=1,LTDIM
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IF (INT (BNDLOC (JJ, L)) .LT. IBM) THEN
  IBM=INT (BNDLOC (JJ, L))
END IF
6 CONTINUE

C
C
C ***** WRITE VM, BMIN, XMIN, YMIN, ZMIN
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
1 MOD (ITIME (ISECND), 3600) /60
WRITE (6, *) 'L=', L
CALL OUTP (VM (1, 1, L), LATDIM, LTDIM, IBM, LATDIM, 1, 3, LTDIM-1, 1,
1 1., 'VM', 6, 132)
CALL OUTP (BMIN, LATDIM, LTDIM, IBM, LATDIM, 2, 3, LTDIM-3, 3, 10.,
C 'BMIN', 6, 132)
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
C 1 MOD (ITIME (ISECND), 3600) /60, ' DAY= ', ITIME (IDAY)
C
WRITE (6, *) 'L=', L
C CALL OUTP (XMIN, LATDIM, LTDIM, IBM, LATDIM, 2, 3, LTDIM-3, 3, 1.,
C 'XMIN', 6, 132)
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
C 1 MOD (ITIME (ISECND), 3600) /60, ' DAY= ', ITIME (IDAY)
C
WRITE (6, *) 'L=', L
C CALL OUTP (YMIN, LATDIM, LTDIM, IBM, LATDIM, 2, 3, LTDIM-3, 3, 1.,
C 'YMIN', 6, 132)
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
C 1 MOD (ITIME (ISECND), 3600) /60, ' DAY= ', ITIME (IDAY)
C
WRITE (6, *) 'L=', L
C CALL OUTP (ZMIN, LATDIM, LTDIM, IBM, LATDIM, 2, 3, LTDIM-3, 3, 1.,
C 'ZMIN', 6, 132)
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
C 1 MOD (ITIME (ISECND), 3600) /60, ' DAY= ', ITIME (IDAY)
C
WRITE (6, *) 'L=', L
C CALL OUTP (R (1, 1, L), LATDIM, LTDIM, IBM, 45, 1, 1, LTDIM, 1, 1.,
1 'R', 6, 132)
C
WRITE (6, *) 'MY UT =', (ITIME (ISECND) /3600) *100+
C 1 MOD (ITIME (ISECND), 3600) /60, ' DAY= ', ITIME (IDAY)
C
WRITE (6, *) 'L=', L
C CALL OUTP (P (1, 1, L), LATDIM, LTDIM, IBM, LATDIM, 1, 1, LTDIM, 1, 0.01,
1 'P', 6, 132)
C
SET VMLOSS FOR THE CURRENT VM PARAMETERS
C
CALL VMLSET (L, VM, BIR, SINI, LATDIM, LTDIM, ITMDIM, VMLOSS)
C
C ***** WRITE VMLOSS
C
CALL OUTP (VMLOSS (1, 1, L), LATDIM, LTDIM, IBM, LATDIM, 2, 3, LTDIM-3,
C 1 3, 0.01, 'VMLOSS', 6, 132)
C
SET UP ID ARRAYS
C
WRITE (6, *) 'BEFORE ID ARRAY LOADED L=', L
ID (1) =ITIME (IYEAR)
ID (2) =ITIME (IDAY)
ID (3) =ITIME (ISECND) /3600
ID (4) =MOD (ITIME (ISECND), 3600) /60
ID (5) =MOD (ITIME (ISECND), 60)
ID (11) =L
RID (1) =TIMTAG (L)
RID (2) =AUGPAR (KP, L)
RID (3) =AUGPAR (PCP, L)
RID (4) =AUGPAR (DEQDT, L)
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C
C -----> WRITE AUGPAR TO AN ARCHIVAL FILE *****
      ID(8)=NAUGEL
      ID(9)=1
      ID(10)=ITMMAX
      CALL WRT3D (LUPDAT, IRECEB, ID, RID, CHID, AUGPAR(1, L), NAUGEL,
2          1, 1, ITMDIM)
C
C -----> WRITE VM, BMIN, XMIN, YMIN, ZMIN, AND V TO AN ARCHIVAL FILE
C
C      ID(8)=LATDIM
C      ID(9)=LTDIM
C      ID(10)=1
C
C      CALL WRT3D (LUBFLD, IRECEB, ID, RID, CHID, VM(1, 1, L),
1          LATDIM, LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUBMIN, IRECEB, ID, RID, CHID, BMIN,
1          LATDIM, LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUXMIN, IRECEB, ID, RID, CHID, XMIN, LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUYMIN, IRECEB, ID, RID, CHID, YMIN, LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUZMIN, IRECEB, ID, RID, CHID, ZMIN, LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUEFLD, IRECEB, ID, RID, CHID, V(1, 1, L), LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUVN, IRECEB, ID, RID, CHID, VNORTH, LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUVS, IRECEB, ID, RID, CHID, VSOUTH, LATDIM,
1          LTDIM, 1, ITMDIM)
C
C -----> WRITE ALOCT, COLAT, AND BNDLOC TO ARCHIVAL FILE
C
C      ID(8)=LATDIM
C      ID(9)=LTDIM
C      ID(10)=1
C
C      CALL WRT3D (LUALOC, IRECEB, ID, RID, CHID, ALOCT, LATDIM,
1          LTDIM, 1, ITMDIM)
C      CALL WRT3D (LUCOLT, IRECEB, ID, RID, CHID, COLAT, LATDIM,
1          LTDIM, 1, ITMDIM)
C
C      ID(8)=LTDIM
C      ID(9)=1
C      ID(10)=1
C
C      CALL WRT3D (LUBNDL, IRECEB, ID, RID, CHID, BNDLOC(1, L),
1          LTDIM, 1, 1, ITMDIM)
C
C
C INCREMENT ITIME
C
C 12 CONTINUE
C
C CALL TIMINC(ITIME, ITMNEW, IINC)
C
C ITIME(IYEAR)=ITMNEW(IYEAR)
C ITIME(IDAY)=ITMNEW(IDAY)
C ITIME(ISECND)=ITMNEW(ISECND)
C
C
C
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C	POINTS, SPECIFIED BY COLAT(I,J) AND ALOCT(I,J).	MSM14090
C		MSM14100
C		MSM14110
C	REFERENCE: SECTION 2.4 OF THE FINAL REPORT FOR CONTRACT #F19628-	MSM14120
C	87-K-0001.	MSM14130
C		MSM14140
C		MSM14150
C		MSM14160
C	GENERAL CALL PARAMETERS FOR SUBROUTINE EMODEL	MSM14170
C		MSM14180
C	IPATT = HEPPNER-MAYNARD PATTERN NO. MUST BE SPECIFIED AS AN	MSM14190
C	INTEGER BETWEEN 1 AND 7.	MSM14200
C	IPATT=1 MEANS PATTERN A, FOR BZ SOUTH, BY=0.	MSM14210
C	IPATT=2 MEANS PATTERN BC, FOR BZ SOUTH, BYNORTH>0	MSM14220
C	IPATT=3 MEANS PATTERN DE, FOR BZ SOUTH, BYNORTH<0	MSM14230
C	IPATT=4 MEANS PATTERN BCP, TWISTED BC, FOR BZ>0	MSM14240
C	IPATT=5 MEANS PATTERN BCPP, TWISTED BC, BZ STRONG>0	MSM14250
C	IPATT=6 MEANS PATT. DEP, TWISTED DE, BZ WEAK >0	MSM14260
C	IPATT=7 MEANS PATT. DEPP, TWISTED DE, BZ STRONG>0	MSM14270
C		MSM14280
C	PCP = POLAR-CAP POTENTIAL DROP IN VOLTS. MUST BE SPECIFIED	MSM14290
C	UNLESS USING UNSCALED HEPPNER-MAYNARD POTENTIAL(ICNTRL=-1)	MSM14300
C		MSM14310
C	DEQDT = ESTIMATED D/DT OF LATITUDE OF EQUATORWARD EDGE OF	MSM14320
C	AURORAL ZONE AT LOCAL MIDNIGHT, IN DEGREES/HOUR. THIS	MSM14330
C	IS A PARAMETER IN LOW-LATITUDE E-FIELD MODEL. NOT	MSM14340
C	NEEDED IF ICNTRL.LE.0.	MSM14350
C		MSM14360
C	VECTORS A(3), B(3), DX(3), DY(3) DESCRIBE THE ELLIPSES THAT FORM	MSM14370
C	THE BOUNDARIES BETWEEN REGIONS 1, 2, AND 3. BOUNDARY 1 IS THE	MSM14380
C	EQUATORWARD EDGE OF THE POLAR CAP. BOUNDARY 2 IS THE EQUATORWARD	MSM14390
C	EDGE OF REGION 1 OR THE EQUATORWARD EDGE OF THE FIELD-REVERSAL	MSM14400
C	REGION. BOUNDARY 3 IS THE SHIELDING LAYER.	MSM14410
C	A(L) = RADIUS OF ELLIPSE MEASURED IN X(SUNWARD) DIRECTION.	MSM14420
C	B(L) = RADIUS OF ELLIPSE MEASURED IN Y(DUSKWARD) DIRECTION.	MSM14430
C	DX(L) = SUNWARD DISPLACEMENT OF COORD.SYSTEM CENTER FROM POLE.	MSM14440
C	DY(L) = DUSKWARD DISPL. OF COORD. SYSTEM CENTER FROM POLE.	MSM14450
C	TO USE EFIELD WITH RCM, CHOOSE A(2) = B(2) = TETA(IMIN),	MSM14460
C	DX(2) = -OFFSET*180./PI, DY(2) = 0. ELLIPSE PARAMETERS FOR	MSM14470
C	BOUNDARIES 1 AND 3 NEED NOT BE SPECIFIED.	MSM14480
C		MSM14490
C	COLAT AND ALOCT ARE THE USUAL MAGNETIC COLATITUDE AND MAGNETIC	MSM14500
C	LOCAL TIME ANGLES IN RADIANs.	MSM14510
C		MSM14520
C	MODE IS A DUMMY PARAMETER, NOT CURRENTLY USED.	MSM14530
C		MSM14540
C	IMAX, JMAX, JWRAP HAVE THEIR USUAL MEANING, SAME AS IN RCM.	MSM14550
C		MSM14560
C	ITMDIM = NUMBER OF TIME LABELS IN THE V-MATRIX. FOR USE WITH	MSM14570
C	RCM, IT SHOULD BE SET EQUAL TO 1.	MSM14580
C		MSM14590
C	ITMCUR = TIME-LABEL NUMBER OF V-MATRIX CURRENTLY BEING COMPUTED.	MSM14600
C	FOR USE WITH RCM, IT SHOULD BE SET EQUAL TO 1.	MSM14610
C		MSM14620
C	ICNTRL = 1 MEANS DIFFERENT FORMULAS ARE USED IN REGIONS 1,2,3.	MSM14630
C	= 0 MEANS HEPPNER-MAYNARD FORMULA IS USED FOR ALL	MSM14640
C	LATITUDES, BUT SCALED TO EXTERNALLY SPECIFIED PCP AND	MSM14650
C	ELLIPSE PARAMETERS.	MSM14660
C	= -1 MEANS HEPPNER-MAYNARD FORMULA IS USED FOR ALL	MSM14670
C	LATITUDES, UNSCALED.	MSM14680
C	= -2 IS THE MODE USED FOR USE WITH RCM. HEPPNER-MAYNARD	MSM14690
C	IS USED POLEWARD OF ELLIPSE 2, AND ON ELLIPSE 2,	MSM14700
C	SCALED TO FIT SPECIFIED POTENTIAL DROP AND DIMENSIONS	MSM14710
C	OF ELLIPSE 2.	MSM14720

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C
C      ITOP = 1 MEANS THAT A(1), B(1), DX(1), DY(1) ARE COMPUTED
C      INTERNALLY IN EFIELD.  OTHERWISE THEY MUST BE PASSED TO
C      EFIELD FROM OUTSIDE.  ITOP IS NORMALLY = 1 FOR USE IN
C
C      MSM.  ITOP SHOULD BE SET TO 1 FOR USE WITH RCM.
C      V = POTENTIAL MATRIX COMPUTED IN EMODEL.  IT IS DIMENSIONED AT
C      LATDIM X LTDIM
C
C
C
C
C      SUBROUTINE EMODEL CALLS SUBROUTINES EPOT(HEPPNER-MAYNARD),
C      LOW(LOW-LATITUDES), AURORA(REGION 2), REG1(REGION 1).
C
C
C
C
C      PARAMETER(JDIM=51)
C      DIMENSION THETAA(JDIM), THETAB(JDIM), THETAC(JDIM)
C      DIMENSION COLAT(LATDIM, LTDIM), ALOCT(LATDIM, LTDIM)
C      DIMENSION V(LATDIM, LTDIM)
C      DIMENSION VA(JDIM), DVADT(JDIM), VC(JDIM), DVCDT(JDIM)
C      DIMENSION VB(JDIM), VBLow(JDIM), VBAZ(JDIM), DVBLow(JDIM)
C      DIMENSION DVBDT(JDIM), DVBAZ(JDIM)
C      DIMENSION COEF(18,18), MLBL(5)
C      DIMENSION A(3), B(3), DX(3), DY(3)
C      DIMENSION XCO(18,18), AHM(2,7), BHM(2,7), DXHM(2,7)
C      DIMENSION DYHM(2,7), VMIN(7), VMAX(7)
C
C
C      PARAMETER VALUES
C
C      NTAPE = FILE NUMBER FROM WHICH MAYNARD-RICH COEFFICIENTS ARE
C      READ.
C
C      IMAX = LATDIM
C      JMAX = LTDIM
C      IF(JDIM.NE.LTDIM) THEN
184      WRITE(6,184) JDIM, LTDIM
      FORMAT(1H , 'JDIM = ', I4, ' LTDIM = ', I4, ' IN EFIELD.')
      END IF
C
C      WRITE(6,*) 'IPATT,PCP,DEQDT', IPATT,PCP,DEQDT
C
C      PI = 3.141593
C      PI2 = 2.*PI
C      NTAPE = 7
C      NNMAX = 16
C      EPS = .01
C      G = 1.
C      IEFF = IMAX
C      CALL INPUT(NTAPE, COEF, IPATT, XCO, AHM, BHM, DXHM, DYHM, VMIN,
1      VMAX)
C
C      FG = SCALING FACTOR THAT CONVERTS HM POTENTIAL TO PRESENT SITUATION
C
C      IF(ICNTRL.GE.0) THEN
C      FG = PCP/(VMAX(IPATT)-VMIN(IPATT))
C      ELSE
C      FG = 1.
C      END IF
C      WRITE(6,903) IPATT, VMAX(IPATT), VMIN(IPATT), FG
903  FORMAT(1H , 'IPATT, VMAX, VMIN, FG = ', I5, 3E15.5)
C
C      COMPUTE A(1), B(1), DX(1), DY(1) IF ITOP = 1.

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MSM15360

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C
      IF (ITOP.EQ.1) THEN
          A(1) = A(2)*AHM(1,IPATT)/AHM(2,IPATT)
          B(1) = B(2)*BHM(1,IPATT)/BHM(2,IPATT)
          DX(1) = DX(2) + A(2)*(DXHM(1,IPATT)-DXHM(2,IPATT))/AHM(2,IPATT)
          DY(1) = DY(2) + B(2)*(DYHM(1,IPATT)-DYHM(2,IPATT))/BHM(2,IPATT)
      END IF
C
      VMAXX = VMAX(IPATT)*FG
      VMINN = VMIN(IPATT)*FG
      SA=SIN((A(3)-DX(3))*PI/180.)
      VPENET = -13112.*G*DEQDT*SA
      VBAR = 0.6*VMAXX + 0.4*VMINN -0.22*VPENET
C
      IF (ICNTRL.NE.-2) THEN
          WRITE(6,905) IPATT,VMAXX,VMINN
905      FORMAT(1H,'IPATT,VMAXX,VMINN = ',I5,2E15.5)
          WRITE(6,906) A(1),A(2),A(3)
906      FORMAT(1H,'A(1),A(2),A(3) = ',3E15.5)
          WRITE(6,907) B(1),B(2),B(3)
907      FORMAT(1H,'B(1),B(2),B(3) = ',3E15.5)
          WRITE(6,908) DX(1),DX(2),DX(3)
908      FORMAT(1H,'DX(1),DX(2),DX(3) = ',3E15.5)
          WRITE(6,909) DY(1),DY(2),DY(3)
909      FORMAT(1H,'DY(1),DY(2),DY(3) = ',3E15.5)
          WRITE(6,899) VPENET,VBAR,VMAXX,VMINN
899      FORMAT(1H,'VPENET,VBAR,VMAX,VMIN=',4E15.5)
C
      END IF
C
C
C      IF (ICNTRL.EQ.0.OR.ICNTRL.EQ.-1) GO TO 15
C
C      COMPUTATION OF BOUNDARY LOCATIONS AS FCNS OF J.
C
C      GUARD AGAINST IRRELEVANT A'S OR B'S BEING ZERO OR NEGATIVE.
C
      DO 811 L=1,3
          IF (A(L).LT.0.001) A(L)=0.001
          IF (B(L).LT.0.001) B(L) = 0.001
811  CONTINUE
C
C
      DO 1 J = 1, JMAX
          AL = ALOCT(IEFF,J)
          THETAA(J) = THET(A(1),B(1),DX(1),DY(1),AL)*PI/180.
          THETAB(J) = THET(A(2),B(2),DX(2),DY(2),AL)*PI/180.
          THETAC(J) = THET(A(3),B(3),DX(3),DY(3),AL)*PI/180.
1      CONTINUE
C
C      SEGMENT FOR DEFINING BOUNDARY POTENTIALS AND E-FIELDS
C
      DO 7 J=1, JMAX
C
C      POTENTIAL AND DERIVATIVE AT BOUNDARY A
C
          GLONG = ALOCT(IEFF,J) + PI
          IF (GLONG.GT.(2.*PI)) GLONG = GLONG - 2.*PI
          GMLAT = 90. - THETAA(J)*180./PI
          CALL EPOT(COEF,GMLAT,GLONG,VA(J),NTAPE,IPATT,NNMAX,A,B,
1          DX,DY,XCO,AHM,BHM,DXHM,DYHM,VMIN,VMAX,PCP,ICNTRL)
          GMLAT = GMLAT - EPS*180./PI
          CALL EPOT(COEF,GMLAT,GLONG,VT,NTAPE,IPATT,NNMAX,A,B,
1          DX,DY,XCO,AHM,BHM,DXHM,DYHM,VMIN,VMAX,PCP,ICNTRL)
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      DVADT(J) = (VT-VA(J))/EPS
7  CONTINUE
C
C  POTENTIAL AND DERIVATIVE AT C
C
      DO 8 J=1, JMAX
      CALL LOW(THETAC(J),ALOCT(IEFF,J),VC(J),DEQDT,A(3),DX(3),VBAR,G)
      TT = THETAC(J) + EPS
      CALL LOW(TT,ALOCT(IEFF,J),VT,DEQDT,A(3),DX(3),VBAR,G)
      DVCDT(J) = (VT-VC(J))/EPS
8  CONTINUE
C
C  POTENTIAL AT B
C
      DO 9 J=1, JMAX
      GLONG = ALOCT(IEFF,J)+PI
      IF(GLONG.GT.(2.*PI)) GLONG = GLONG-2.*PI
      GMLAT = 90. - THETAB(J)*180./PI
      CALL EPOT(COEF,GMLAT,GLONG,VB(J),NTAPE,IPATT,NNMAX,A,B,
1     DX,DY,XCO,AHM,BHM,DXHM,DYHM,VMIN,VMAX,PCP,ICNTRL)
      VBLOW(J) = VC(J) - DVCDT(J)*(THETAC(J)-THETAB(J))
      VBAZ(J) = VB(J) - VBLOW(J)
9  CONTINUE
C
C  DERIVATIVE AT POTENTIAL AT B
C
      DO 10 J = 1, JMAX
      DVBLO(J) = DVCDT(J)
      TT = THETAB(J) + EPS
      CALL AURORA(TT,ALOCT(IEFF,J),VT,VBAZ,THETAB(J),THETAC(J),J,
1     JMAX,JWRAP)
      DVBAZ(J) = (VT-VBAZ(J))/EPS
      DVBDT(J) = DVBLO(J) + DVBAZ(J)
10 CONTINUE
      NMAX=NNMAX
C
C  MAIN DO LOOP OVER GRID
C
15 CONTINUE
      DO 5 I = 1, IMAX
      DO 5 J = 1, JMAX
      V(I,J) = 0.
C
C  CALLS OF DIFFERENT SUBROUTINE SEQUENCES
C
      REGION ZERO = POLAR CAP
C
      IF(COLAT(I,J).LE.THETAA(J).OR.ICNTRL.EQ.0.OR.ICNTRL.EQ.-1) THEN
      GLONG = ALOCT(I,J) + PI
      IF(GLONG.GT.PI2) GLONG=GLONG-PI2
      GMLAT = 90. - COLAT(I,J)*180./PI
      CALL EPOT(COEF,GMLAT,GLONG,VTEMP,NTAPE,IPATT,NNMAX,A,
1     B,DX,DY,XCO,AHM,BHM,DXHM,DYHM,VMIN,VMAX,PCP,ICNTRL)
      END IF
C
C  REGION 3 = LOW LATITUDES
C
      IF(COLAT(I,J).GE.THETAC(J).AND.ICNTRL.GT.0) THEN
      CALL LOW(COLAT(I,J),ALOCT(I,J),VTEMP,DEQDT,A(3),DX(3),VBAR,G)

```

```

C           END IF
C
C           REGION 2 = LOWER AURORAL ZONE
C
C           IF (COLAT (I, J) .LT. THETAC (J) .AND. COLAT (I, J) .GE. THETAB (J) .AND. ICNTRL.
1  GT.0) THEN
C               VLOW = VC (J) + DVCDT (J) * (COLAT (I, J) - THETAC (J))
C               CALL AURORA (COLAT (I, J) , ALOCT (I, J) , VAZ , VBAZ , THETAB (J) , THETAC (J) ,
%               J , JMAX , JWRAP)
C               VTEMP = VAZ + VLOW
C           END IF
C
C           IF (COLAT (I, J) .LT. THETAB (J) .AND. COLAT (I, J) .GT. THETAA (J) .AND. ICNTRL.
1  GT.0) THEN
C               CALL REG1 (COLAT (I, J) , ALOCT (I, J) , VTEMP , THETAA (J) ,
%               THETAB (J) , VA (J) , VB (J) , DVADT (J) , DVBDT (J) )
C           END IF
C
C           USE HEPPNER-MAYNARD DIRECTLY IN REGION 1 FOR USE WITH RCM.
C
C           TB = THETAB (J) + 1.E-4
C           IF (COLAT (I, J) .LT. TB .AND. COLAT (I, J) .GT. THETAA (J) .AND. ICNTRL.EQ. -2)
1  THEN
C               GLONG = ALOCT (I, J) + PI
C               IF (GLONG.GT.PI2) GLONG = GLONG - PI2
C               CALL EPOT (COEF, GMLAT, GLONG, VTEMP, NTAPE, IPATT, NNMAX, A,
1               B, DX, DY, XCO, AHM, BHM, DXHM, DYHM, VMIN, VMAX, PCP, ICNTRL)
C           END IF
C
C           V (I, J) = VTEMP
C
C           5  CONTINUE
C           RETURN
C           END
C
C           SUBROUTINE EPOT (COEF, TLAT, TLON, VALUE, NTAPE, IPATT, NNMAX, A, B,
1  DX, DY, XCO, AHM, BHM, DXHM, DYHM, VMIN, VMAX, PCP, ICNTRL)
C
C           PURPOSE:  THIS SUBROUTINE USES THE SCALED HEPPNER-MAYNARD MODEL TO
C                   RETURN THE ELECTRIC POTENTIAL AT A SPECIFIC POINT.
C
C           REFERENCE:  SECTION 2.4 OF THE FINAL REPORT FOR CONTRACT #F19628-
C                   87-K-0001.
C
C           INPUTS:
C           COEF          COEFFICIENTS FROM DIGITIZATION OF HEPPNER-MAYNARD
C                       E-FIELD MODEL
C           TLAT          COLATITUDE OF PT WHERE V IS TO BE CALCULATED
C                       (RADIAN)S
C           TLON          MLT OF PT WHERE V IS TO BE CALCULATED
C           NTAPE         UNIT NUMBER OF FILE FROM WHICH COEFFICIENTS ARE READ
C           IPATT         HEPPNER-MAYNARD PATTERN TYPE
C           NNMAX         NUMBER OF COEFFICIENTS
C           A             RADIUS OF ELLIPSE IN X (SUNWARD) DIRECTION
C           B             RADIUS OF ELLIPSE IN Y (DUSKWARD) DIRECTION
C           DX            OFFSET OF ELLIPSE IN X DIRECTION
C           DY            OFFSET OF ELLIPSE IN Y DIRECTION

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C XCO COEFFICIENTS MSM17290
C AHM HEPPNER-MAYNARD X RADIUS MSM17300
C BHM HEPPNER-MAYNARD Y RADIUS MSM17310
C DXHM HEPPNER-MAYNARD X OFFSET MSM17320
C DYHM HEPPNER-MAYNARD Y OFFSET MSM17330
C VMIN ELECTRIC POTENTIAL MIN FROM HEPPNER-MAYNARD MODEL MSM17340
C VMAX ELECTRIC POTENTIAL MAX FROM HEPPNER-MAYNARD MODEL MSM17350
C PCP MEASURED CROSS-POLAR-CAP POTENTIAL DROP MSM17360
C ICNTRL = 1 MEANS DIFFERENT FORMULAS USED IN REGIONS 1,2,3 MSM17370
C = 2 H-M USED AT ALL LATITUDES, BUT SCALED TO PCP AND MSM17380
C ELLIPSE PARAMETERS MSM17390
C =-1 H-M USED AT ALL LATITUDES, UNSCALED MSM17400
C =-2 SHOULD NOT BE USED. RESERVED FOR USE WITH RICE MSM17410
C CONVECTION MODEL MSM17420
C MSM17430
C OUTPUT: MSM17440
C VALUE ELECTRIC POTENTIAL (VOLTS) MSM17450
C MSM17460
C MSM17470
C DIMENSION AHM(2,7),BHM(2,7),DXHM(2,7),DYHM(2,7) MSM17480
C DIMENSION VMIN(7),VMAX(7) MSM17490
C DIMENSION A(3),B(3),DX(3),DY(3) MSM17500
C DIMENSION COEF(18,18),P(18,18) MSM17510
C MSM17520
C DIMENSION DP(18,18),CONST(18,18),SP(18), MSM17530
C X CP(18),FN(18),FM(18) MSM17540
C DIMENSION XCO(18,18),MLBL(5) MSM17550
C MSM17560
C DATA CMIN,CMAX/50.,90./ MSM17570
C DATA P,CONST/648*0./ MSM17580
80 CONTINUE MSM17590
C MSM17600
C MSM17610
C NMAX = NNMAX MSM17620
C MSM17630
C PI = 3.1415927 MSM17640
C VALUE=-1.E-9 MSM17650
C IF (TLAT.GT.CMIN)GOTO70 MSM17660
C PRINT *,'LATITUDE ',TLAT,' OUT OF MODEL RANGE' MSM17670
C RETURN MSM17680
C MSM17690
70 CONTINUE MSM17700
C MSM17710
C SEGMENT FOR SCALING GRID-PT. LOCATION TO FIT H-M ELLIPSE. MSM17720
C TCOL = 90.-TLAT MSM17730
C TLONG = TLON - PI MSM17740
C IF (ICNTRL.GE.0) THEN MSM17750
C XX = DXHM(1,IPATT)+AHM(1,IPATT)*(TCOL*COS(TLONG)-DX(1))/A(1) MSM17760
C YY = DYHM(1,IPATT)+BHM(1,IPATT)*(TCOL*SIN(TLONG)-DY(1))/B(1) MSM17770
C ELSE MSM17780
C XX = TCOL*COS(TLONG) MSM17790
C YY = TCOL*SIN(TLONG) MSM17800
C END IF MSM17810
C XCOL = SQRT(XX**2 + YY**2) MSM17820
C XLAT = 90.-XCOL MSM17830
C XL = ATAN2(YY,XX) MSM17840
C XLON = XL+PI MSM17850
C ALPHA=2./(CMAX-CMIN) MSM17860
C BETA=1.-ALPHA*CMAX MSM17870
C CT=XLAT*ALPHA+BETA MSM17880
C ST=SQRT(1.-CT*CT) MSM17890
C SPH=SIN(XLON) MSM17900
C CPH=COS(XLON) MSM17910
C MSM17920
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```
IF (P(1,1).NE.0.) GOTO 3
P(1,1)=1.0
DP(1,1)=0.0
SP(1)=0.0
CP(1)=1.0
DO 2 N=2,18
FN(N)=N
DO 2 M=1,N
FM(M)=M-1
2 CONST(N,M)=FLOAT((N-2)**2-(M-1)**2)/
X  FLOAT((2*N-3)*(2*N-5))
C
3 SP(2)=SPH
P(1,1)=1.
CP(2)=CPH
DO 4 M=3,NMAX
SP(M)=SP(2)*CP(M-1)+CP(2)*SP(M-1)
4 CP(M)=CP(2)*CP(M-1)-SP(2)*SP(M-1)
C
VALUE=COEF(1,1)
C
DO 8 N=2,NMAX
DO 8 M=1,N
C
IF(N.NE.M) GOTO 6
P(N,N)=ST*P(N-1,N-1)
C
DP(N,N)=ST*DP(N-1,N-1)+CT*P(N-1,N-1)
GOTO 8
6 IF(N.NE.2) P(N,M)=CT*P(N-1,M)-CONST(N,M)*P(N-2,M)
IF(N.EQ.2) P(N,M)=CT*P(N-1,M)
C
DP(N,M)=CT*DP(N-1,M)-ST*P(N-1,M)-
C
X  CONST(N,M)*DP(N-2,M)
C
C
8 CONTINUE
C
P(1,1)=P(1,1)*XCO(1,1)
C
VALUE=COEF(1,1)*P(1,1)
DO 10 N=2,NMAX
DO 10 M=1,N
IF(M.EQ.1) GOTO 11
POL=P(N,M)*XCO(N,M)
P(M-1,N)=CP(M)*POL
P(N,M)=SP(M)*POL
VALUE=VALUE+P(M-1,N)*COEF(M-1,N)+
X  P(N,M)*COEF(N,M)
GOTO 10
11 P(N,M)=P(N,M)*XCO(N,M)
VALUE=VALUE+P(N,M)*COEF(N,M)
10 CONTINUE
IF(ICNTRL.NE.-1) THEN
VALUE=(PCP/(VMAX(IPATT)-VMIN(IPATT)))*VALUE*1000.
ELSE
VALUE=1000.*VALUE
END IF
C
C
RETURN
END
C
C
SUBROUTINE LOW(COL,ALO,VLOW,DEQDT,AEQEDG,DXEQEG,VBAR,G)
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MSM18560

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C PURPOSE: RETURN THE ELECTRIC POTENTIAL AT A SPECIFIC LOCATION IN
C THE LOW-LATITUDE REGION OF THE ELECTRIC FIELD MODEL.
C
C REFERENCE: SECTION 2.4 OF THE FINAL REPORT FOR CONTRACT #F19628-
C 87-K-0001.
C
C INPUTS:
C COL COLATITUDE (RADIAN)
C ALO MLT (RADIAN)
C DEQDT TIME RATE OF CHANGE OF EQUATORWARD EDGE OF AURORAL
C ZONE (DEGREE/HOUR)
C AEQEDG RADIUS OF ELLIPSE 3 IN X (SUNWARD) DIRECTION
C DXEQEG OFFSET OF ELLIPSE 3 IN X DIRECTION
C VBAR AVERAGE POTENTIAL AT LOW LATITUDES
C G WEIGHTING FACTOR
C
C OUTPUT:
C VLOW ELECTRIC POTENTIAL (VOLTS)
C
C
C

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MSM18570
MSM18580
MSM18590
MSM18600
MSM18610
MSM18620
MSM18630
MSM18640
MSM18650
MSM18660
MSM18670
MSM18680
MSM18690
MSM18700
MSM18710
MSM18720
MSM18730
MSM18740
MSM18750
MSM18760
MSM18770
MSM18780
MSM18790
MSM18800
MSM18810
MSM18820
MSM18830
MSM18840
MSM18850
MSM18860
MSM18870
MSM18880
MSM18890
MSM18900

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PI = 3.1415927
AK = 1.38
SA = SIN((AEQEDG-DXEQEG)*PI/180.)
CF = 2.75*1000.*1.576*G*DEQDT*SA/SIN(.4363)
FAC = .6103*SIN(ALO) - .0154*SIN(2.*ALO) - .021*SIN(3.*ALO)
FAC = FAC - .1092*COS(ALO) + .1676*COS(2.*ALO) - .0314*COS(3.*ALO)
VLOW = CF*FAC*(SA/SIN(COL))**AK + VBAR
RETURN
END

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```

C
C
C SUBROUTINE AURORA(COL, ALO, VAZ, VBAZ, TB, TC, J, JMAX, JWRAP)
C
C PURPOSE: PROVIDE THE ELECTRIC POTENTIAL AT A SPECIFIC LOCATION IN
C THE AURORAL REGION OF THE ELECTRIC FIELD MODEL.
C
C REFERENCE: SECTION 2.4 OF THE FINAL REPORT FOR CONTRACT #F19628-
C 87-K-0001.
C
C INPUTS:
C COL COLATITUDE OF POINT
C ALO MLT OF POINT
C VBAZ AURORAL CONTRIBUTION TO POTENTIAL
C TB LOCATION OF BOUNDARY B FOR SPECIFIC LOCAL TIME
C TC LOCATION OF BOUNDARY C FOR SPECIFIC LOCAL TIME
C J LOCAL TIME INDEX
C JMAX MAXIMUM NUMBER OF PTS IN J (LONGITUDE) DIRECTION
C JWRAP NUMBER OF PTS OF OVERLAP IN J DIRECTION
C
C OUTPUT:
C VAZ ELECTRIC POTENTIAL (VOLTS)
C
C
C

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MSM18910
MSM18920
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MSM18940
MSM18950
MSM18960
MSM18970
MSM18980
MSM18990
MSM19000
MSM19010
MSM19020
MSM19030
MSM19040
MSM19050
MSM19060
MSM19070
MSM19080
MSM19090
MSM19100
MSM19110
MSM19120
MSM19130
MSM19140
MSM19150
MSM19160
MSM19170
MSM19180
MSM19190
MSM19200

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PARAMETER (JDIM=51)
DIMENSION VBAZ(JDIM)

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C
C
C IF (JDIM.NE.JMAX) THEN

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```

WRITE(6,147)JDIM,JMAX
147 FORMAT(1H,'JDIM = ',I4,' LTDIM = ',I4,' IN AURORA.')
END IF
DPWIDE = 1.
DPAMP = 2.0
PI = 3.1415927
ALMIN = PI - .5*DPWIDE
ALMAX = PI + .5*DPWIDE
C
IF(ALO.GT.ALMIN.AND.ALO.LT.ALMAX) THEN
  PHIP = COS((PI*(ALO-PI))/DPWIDE)
ELSE
  PHIP = 0.
END IF
IF (J.EQ.1) THEN
  JM1 = JMAX - JWRAP
ELSE
  JM1 = J-1
END IF
C
IF (J.EQ.JMAX) THEN
  JP1 = JWRAP + 1
ELSE
  JP1 = J+1
END IF
C
C
DVBDPH = (VBAZ(JP1) - VBAZ(JM1))*PI/FLOAT(JMAX-3)
DENOM = TC - COL
ANUM = TC - TB
IF (DENOM.LT.0.001) DENOM = 0.001
C
CORR = -DVBDPH*PHIP*DPAMP*6.75*(TC-COL)**2*(COL-TB)/(TC-TB)**3
C
R = 1.
DTHETA = (1.25-.75*COS(ALO-.75*PI))*(TC-TB)
FAC2 = (1.+(TC-COL)**2/DTHETA**2)**(-R)
FAC3 = (1.+(TC-TB)**2/DTHETA**2)**(-R)
VAZ = VBAZ(J)*(1.-FAC2)/(1.-FAC3) + CORR
C
RETURN
END
C
C
SUBROUTINE REG1(COL,AL,V1,TA,TB,VAA,VBB,DVAA,DVBB)
C
C PURPOSE: PROVIDE ELECTRIC POTENTIAL IN REGION 1 OF THE ELECTRIC
C FIELD MODEL
C
C
C REFERENCE: SECTION 2.4 OF THE FINAL REPORT FOR CONTRACT #F19628-
C 87-K-0001.
C
C
C INPUTS:
C COL COLATITUDE (RADIANS)
C AL MLT
C TA LOCATION OF BOUNDARY A
C TB LOCATION OF BOUNDARY B
C VAA ELECTRIC POTENTIAL FOR PT ON BOUNDARY A
C VBB ELECTRIC POTENTIAL FOR PT ON BOUNDARY B
C DVAA DERIVATIVE OF V FOR PT ON BOUNDARY A
C DVBB DERIVATIVE OF V FOR PT ON BOUNDARY B

```

MSM19210
MSM19220
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MSM19270
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MSM19780
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MSM19800
MSM19810
MSM19820
MSM19830
MSM19840

90/06/30
12:03:44

msm1.for

32

```
C
C
C OUTPUT:
C V1 ELECTRIC POTENTIAL FOR A POINT IN REGION 1 (VOLTS)
C
C
C DT = TB - TA
C V1 = VAA + DVAA*(COL-TA)
C V1 = V1 + (3.*(VBB-VAA) - (2.*DVAA+DVBB)*DT)*(COL-TA)**2/DT**2
C V1 = V1 + (2.*(VAA-VBB) + (DVAA+DVBB)*DT)*(COL-TA)**3/DT**3
C RETURN
C END
C
C
C FUNCTION THET(AA,BB,XC,YC,PHI)
C THIS FUNCTION GIVES SOLUTION TO EQUATION FOR ELLIPSE IN
C IN FLAT POLAR COORDINATES. IT SPECIFIES COLATITUDE AS A
C FUNCTION OF LOCAL TIME.
C
C INPUTS:
C AA RADIUS OF ELLIPSE IN X (SUNWARD) DIRECTION
C BB RADIUS OF ELLIPSE IN Y (DUSKWARD) DIRECTION
C XC X DISPLACEMENT OF ELLIPSE
C YC Y DISPLACEMENT OF ELLIPSE
C PHI MLT HOUR ANGLE
C
C
C OUTPUT:
C THET COLATITUDE OF INPUT ELLIPSE AT GIVEN PHI
C
C
C CPHI = COS(PHI)
C SPHI = SIN(PHI)
C CA = (CPHI/AA)**2 + (SPHI/BB)**2
C CB = -XC*CPHI/AA**2 - YC*SPHI/BB**2
C CC = (XC/AA)**2 + (YC/BB)**2 - 1.
C THET = (-CB+SQRT(CB**2-CA*CC))/CA
C RETURN
C END
C
C
C SUBROUTINE INPUT(NTAPE,COEF,IPATT,XCO,AHM,BHM,DXHM,
C 1 DYHM,VMIN, VMAX)
C
C PURPOSE: READ IN NECESSARY INPUT FOR THE COMPUTATION OF THE
C HEPNER-MAYNARD ELECTRIC FIELD MODEL
C
C DIMENSION COEF(18,18)
C DIMENSION DXHM(2,7),DYHM(2,7)
C DIMENSION XCO(18,18), AHM(2,7),BHM(2,7)
C DIMENSION VMIN(7),VMAX(7),YCO(18,18)
C DIMENSION AAHM(2,7),BBHM(2,7),DDXHM(2,7)
C DIMENSION DDYHM(2,7), VVMAX(7), VVMIN(7)
C
C CHARACTER*50 MLBL
C DATA (YCO( 1,J),J=1,18)/
C X .282095E+00, .488603E+00, .109255E+01, .228523E+01,
C X .468333E+01, .951188E+01, .192265E+02, .387523E+02,
C X .779645E+02, .156658E+03, .314501E+03, .630964E+03,
C X .126523E+04, .253611E+04, .508196E+04, .101809E+05,
C X .203918E+05, .408366E+05/
C DATA (YCO( 2,J),J=1,18)/
C X .488603E+00, .488603E+00, .546274E+00, .144531E+01,
C X .331161E+01, .719031E+01, .151999E+02, .316411E+02,
C X .652298E+02, .133599E+03, .272366E+03, .553392E+03,
C
C MSM19850
C MSM19860
C MSM19870
C MSM19880
C MSM19890
C MSM19900
C MSM19910
C MSM19920
C MSM19930
C MSM19940
C MSM19950
C MSM19960
C MSM19970
C MSM19980
C MSM19990
C MSM20000
C MSM20010
C MSM20020
C MSM20030
C MSM20040
C MSM20050
C MSM20060
C MSM20070
C MSM20080
C MSM20090
C MSM20100
C MSM20110
C MSM20120
C MSM20130
C MSM20140
C MSM20150
C MSM20160
C MSM20170
C MSM20180
C MSM20190
C MSM20200
C MSM20210
C MSM20220
C MSM20230
C MSM20240
C MSM20250
C MSM20260
C MSM20270
C MSM20280
C MSM20290
C MSM20300
C MSM20310
C MSM20320
C MSM20330
C MSM20340
C MSM20350
C MSM20360
C MSM20370
C MSM20380
C MSM20390
C MSM20400
C MSM20410
C MSM20420
C MSM20430
C MSM20440
C MSM20450
C MSM20460
C MSM20470
C MSM20480
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mmsl.for

X .112151E+04, .226837E+04, .458082E+04, .923904E+04,	MSM20490
X .186151E+05, .374743E+05/ DATA (YCO(3,J),J=1,18)/	MSM20500
X .946175E+00, .109255E+01, .546274E+00, .590044E+00,	MSM20510
X .177013E+01, .440314E+01, .101333E+02, .223736E+02,	MSM20520
X .481754E+02, .102038E+03, .213661E+03, .443701E+03,	MSM20530
X .915709E+03, .188083E+04, .384856E+04, .785168E+04,	MSM20540
X .159791E+05, .324537E+05/ DATA (YCO(4,J),J=1,18)/	MSM20550
X .186588E+01, .228523E+01, .144531E+01, .590044E+00,	MSM20560
X .625836E+00, .207566E+01, .555021E+01, .134918E+02,	MSM20570
X .310971E+02, .693209E+02, .151081E+03, .324033E+03,	MSM20580
X .686782E+03, .144253E+04, .300864E+04, .623988E+04,	MSM20590
X .128827E+05, .264983E+05/ DATA (YCO(5,J),J=1,18)/	MSM20600
X .370249E+01, .468333E+01, .331161E+01, .177013E+01,	MSM20610
X .625836E+00, .656382E+00, .236662E+01, .674590E+01,	MSM20620
X .172496E+02, .414272E+02, .955522E+02, .214328E+03,	MSM20630
X .471128E+03, .102002E+04, .218269E+04, .462762E+04,	MSM20640
X .973844E+04, .203694E+05/ DATA (YCO(6,J),J=1,18)/	MSM20650
X .736787E+01, .951188E+01, .719031E+01, .440314E+01,	MSM20660
X .207566E+01, .656382E+00, .683184E+00, .264596E+01,	MSM20670
X .798499E+01, .213929E+02, .534153E+02, .127330E+03,	MSM20680
X .293800E+03, .661878E+03, .146420E+04, .319336E+04,	MSM20690
X .688612E+04, .147131E+05/ DATA (YCO(7,J),J=1,18)/	MSM20700
X .146845E+02, .192265E+02, .151999E+02, .101333E+02,	MSM20710
X .555021E+01, .236662E+01, .683184E+00, .707163E+00,	MSM20720
X .291571E+01, .926339E+01, .259102E+02, .671087E+02,	MSM20730
X .165101E+03, .391572E+03, .903721E+03, .204248E+04,	MSM20740
X .454057E+04, .996084E+04/ DATA (YCO(8,J),J=1,18)/	MSM20750
X .292940E+02, .387523E+02, .316411E+02, .223736E+02,	MSM20760
X .134918E+02, .674590E+01, .264596E+01, .707163E+00,	MSM20770
X .728927E+00, .317732E+01, .105778E+02, .307916E+02,	MSM20780
X .825507E+02, .209304E+03, .509767E+03, .120459E+04,	MSM20790
X .278052E+04, .629979E+04/ DATA (YCO(9,J),J=1,18)/	MSM20800
X .584734E+02, .779645E+02, .652298E+02, .481754E+02,	MSM20810
X .300971E+02, .172496E+02, .798499E+01, .291571E+01,	MSM20820
X .728927E+00, .748901E+00, .343190E+01, .119255E+02,	MSM20830
X .360281E+02, .997819E+02, .260366E+03, .650553E+03,	MSM20840
X .157290E+04, .370647E+04/ DATA (YCO(10,J),J=1,18)/	MSM20850
X .116766E+03, .156658E+03, .133599E+03, .102038E+03,	MSM20860
X .693209E+02, .414272E+02, .213929E+02, .926339E+01,	MSM20870
X .317732E+01, .748901E+00, .767395E+00, .368030E+01,	MSM20880
X .133043E+02, .416119E+02, .118840E+03, .318704E+03,	MSM20890
X .816138E+03, .201755E+04/ DATA (YCO(11,J),J=1,18)/	MSM20900
X .233240E+03, .314501E+03, .272366E+03, .213661E+03,	MSM20910
X .151081E+03, .955522E+02, .534153E+02, .259102E+02,	MSM20920
X .105778E+02, .343190E+01, .767395E+00, .784642E+00,	MSM20930
X .392321E+01, .147120E+02, .475361E+02, .139761E+03,	MSM20940
X .384731E+03, .100877E+04/ DATA (YCO(12,J),J=1,18)/	MSM20950
X .465998E+03, .630964E+03, .553392E+03, .443701E+03,	MSM20960
X .324033E+03, .214328E+03, .127330E+03, .671087E+02,	MSM20970
X .307916E+02, .119255E+02, .368030E+01, .784642E+00,	MSM20980
X .800822E+00, .416119E+01, .161472E+02, .537941E+02,	MSM20990
X .162579E+03, .458849E+03/ DATA (YCO(13,J),J=1,18)/	MSM21000
X .931187E+03, .126523E+04, .112151E+04, .915709E+03,	MSM21010
	MSM21020
	MSM21030
	MSM21040
	MSM21050
	MSM21060
	MSM21070
	MSM21080
	MSM21090
	MSM21100
	MSM21110
	MSM21120

msml.for

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X .686782E+03, .471128E+03, .293800E+03, .165101E+03,
X .825507E+02, .360281E+02, .133043E+02, .392321E+01,
X .800822E+00, .816077E+00, .439471E+01, .176082E+02,
X .603802E+02, .187325E+03/
  DATA (YCO(14,J),J=1,18)/
X .186100E+04, .253611E+04, .226837E+04, .188083E+04,
X .144253E+04, .102002E+04, .661878E+03, .391572E+03,
X .209304E+03, .997819E+02, .416119E+02, .147120E+02,
X .416119E+01, .816077E+00, .830522E+00, .462415E+01,
X .190939E+02, .672889E+02/
  DATA (YCO(15,J),J=1,18)/
X .371962E+04, .508196E+04, .458082E+04, .384866E+04,
X .300864E+04, .218269E+04, .146420E+04, .903721E+03,
X .509767E+03, .260366E+03, .118840E+03, .475361E+02,
X .161472E+02, .439471E+01, .830522E+00, .844251E+00,
X .484985E+01, .206029E+02/
  DATA (YCO(16,J),J=1,18)/
X .743510E+04, .101809E+05, .923904E+04, .785168E+04,
X .623988E+04, .462762E+04, .319336E+04, .204248E+04,
X .120459E+04, .650553E+03, .318704E+03, .139761E+03,
X .537941E+02, .176082E+02, .462415E+01, .844251E+00,
X .857341E+00, .507210E+01/
  DATA (YCO(17,J),J=1,18)/
X .148629E+05, .203918E+05, .186151E+05, .159791E+05,
X .128827E+05, .973844E+04, .688612E+04, .454057E+04,
X .278052E+04, .157290E+04, .816138E+03, .384731E+03,
X .162579E+03, .603802E+02, .190939E+02, .484985E+01,
X .857341E+00, .869857E+00/
  DATA (YCO(18,J),J=1,18)/
X .297130E+05, .408366E+05, .374743E+05, .324537E+05,
X .264983E+05, .203694E+05, .147131E+05, .996084E+04,
X .629979E+04, .370647E+04, .201755E+04, .100877E+04,
X .458849E+03, .187325E+03, .672889E+02, .206029E+02,
X .507210E+01, .869857E+00/

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MSM21130
MSM21140
MSM21150
MSM21160
MSM21170
MSM21180
MSM21190
MSM21200
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MSM21760

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C

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DATA (AAHM(1,IP),IP=1,7)/17.45,12.13,16.06,13.72,14.79,12.82,15./
DATA (AAHM(2,IP),IP=1,7)/20.,16.17,18.88,19.31,18.3,16.6,17.93/
DATA (BBHM(1,IP),IP=1,7)/14.26,13.78,14.31,13.78,14.73,11.70,12.07/
DATA (BBHM(2,IP),IP=1,7)/16.97,16.7,17.07,17.23,17.93,17.5,16.6/
DATA (DDXHM(1,IP),IP=1,7)/-2.66,-5.53,-3.19,-.11,-2.45,-1.65,-2.23/
DATA (DDXHM(2,IP),IP=1,7)/-3.3,-7.45,-4.1,-1.76,-2.77,-2.98,-3.14/
DATA (DDYHM(1,IP),IP=1,7)/1.6,.8,1.12,.05,.48,3.4,1.22/
DATA (DDYHM(2,IP),IP=1,7)/1.33,.32,1.54,.85,.69,1.86,.21/
DATA (VVMAX(IP),IP=1,7)/34007.,55354.,14390.,11287.,9329.,13249.,
1 13221./
DATA (VVMIN(IP),IP=1,7)/-42280.,-16003.,-60935.,-16250.,-12947.,
1 -14428.,-13460./

```

C
C

```

DO 4 IP = 1,7
  DO 3 N=1,2
    AHM(N,IP) = AAHM(N,IP)
    BHM(N,IP) = BBHM(N,IP)
    DXHM(N,IP) = DDXHM(N,IP)
    DYHM(N,IP) = DDYHM(N,IP)

```

3

```

CONTINUE
VMAX(IP) = VVMAX(IP)
VMIN(IP) = VVMIN(IP)

```

4

CONTINUE

C
C
C
C

INITIALIZE COEF FROM UNIT NTAPE

DO 1 I=1,18

```

DO 2 J=1,18
  COEF(I,J) = 0.
  XCO(I,J) = YCO(I,J)
2   CONTINUE
1   CONTINUE
C
C   OPEN FILE TO GET ELECTRIC FIELD COEFFICIENTS
C
C   OPEN(UNIT=NTAPE,FILE='EFCOEF',STATUS='OLD')
C
DO 81 IA=1,IPATT
  READ(NTAPE,400,ERR=1001,END=1001)MLBL
1001 CONTINUE
400  FORMAT(A)
82  READ(NTAPE,*)NNN,MMM,I,J,CCF
C   WRITE(8,100) IA,NNN,MMM,I,J,CCF
C100 FORMAT(1H,'IA,NNN,MMM,I,J,CCF = ',5I4,E15.5)
IF(NNN.EQ.-1) GO TO 81
IF(I.GT.18.OR.J.GT.18) THEN
  WRITE(6,737) IA,NNN,MMM,I,J
737  FORMAT(1H,'OUT OF BOUNDS IN INPUT.IA,NNN,MMM,I,J = ',5I5)
END IF
COEF(I,J)=CCF
GO TO 82
81  CONTINUE
C   WRITE(8,401)MLBL
C401 FORMAT(1H,'MLBL = ',5A10)
NMAX=NNMAX
C
C   CLOSE(NTAPE)
C
C   RETURN
C
C   END
C
C   SUBROUTINE BTRACE(LATDIM,LTDIM,ITMDIM,L,FSTOFF,FEQEDG,FDST,
2   FCLPSE,FTILT,VM,BMIN,XMIN,YMIN,ZMIN,R,P,ALOCT,TETA)
C
C   VERSION 2.02
C   DATE: 09.16.89
C
C   PURPOSE: SUBROUTINE TO CALCULATE B FIELD MODELS APPROPRIATE FOR
C   GEOPHYSICAL CONDITIONS AS SPECIFIED IN BFPAR. BTRACE
C   CALCULATES VM, BMIN, XMIN, YMIN, AND ZMIN ON THE MSM SPATIAL
C   GRID BY INTERPOLATING BETWEEN PRECOMPUTED MAGNETIC FIELD
C   MODELS AS PARAMETERIZED BY THE VARIABLES OF BFPAR.
C
C   INPUT:
C   LATDIM NUMBER OF LATITUDINAL GRID POINTS
C   LTDIM NUMBER OF LOCAL TIME GRID POINTS (INCL WRAPAROUND)
C   ITMDIM MAX NUMBER OF TEMPORAL GRID POINTS
C   L CURRENT TEMPORAL GRID INDEX
C   ..... GEOPHYSICAL PARAMETERS THAT DETERMINE WHICH BFIELD
C   MODELS TO USE
C   FSTOFF STANDOFF DIST = AUGPAR(STAND)
C   FEQEDG EQUATORWARD EDGE OF AURORA = AUGPAR(EQEDGE)
C   FDST DST = AUGPAR(DST)
C   FCLPSE COLLAPSE PARAMETER = AUGPAR(CLAPSE)
C   FTILT TILT PARAMETER = AUGPAR(TILTW)
C   ALOCT LOCAL TIME HOUR ANGLE (MEASURED EAST FROM NOON)
C   TETA COLATITUDE OF I GRID LINES (RADIAN)
C
C   OUTPUT:
C   VM (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3

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MSM21770
MSM21780
MSM21790
MSM21800
MSM21810
MSM21820
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MSM21880
MSM21890
MSM21900
MSM21910
MSM21920
MSM21930
MSM21940
MSM21950
MSM21960
MSM21970
MSM21980
MSM21990
MSM22000
MSM22010
MSM22020
MSM22030
MSM22040
MSM22050
MSM22060
MSM22070
MSM22080
MSM22090
MSM22100
MSM22110
MSM22120
MSM22130
MSM22140
MSM22150
MSM22160
MSM22170
MSM22180
MSM22190
MSM22200
MSM22210
MSM22220
MSM22230
MSM22240
MSM22250
MSM22260
MSM22270
MSM22280
MSM22290
MSM22300
MSM22310
MSM22320
MSM22330
MSM22340
MSM22350
MSM22360
MSM22370
MSM22380
MSM22390
MSM22400

```



```
DO 15 J=1,LTDIM
DO 16 I=1,LATDIM
  VM(I,J,L)=0.
  BMIN(I,J)=0.
  XMIN(I,J)=0.
  YMIN(I,J)=0.
  ZMIN(I,J)=0.
  SUMC(I,J)=0.
16 CONTINUE
15 CONTINUE
C
  WRITE (6,*) 'GETMAT IS REQUESTING THE FOLLOWING B-MATRICES:'
C
C LOOP OVER FIVE FLAVORS OF B FIELD ARRAYS
  DO 20 NN=1,5
    IWANT=NN
C
C CALL GETMAT TO READ APPROPRIATE ARRAYS FOR INTERPOLATION
C
  CALL GETMAT(IWANT,LATDIM,LTDIM,BFPAR,WORK,BFLIM,BFEXST)
  CALL RMVBSH(WORK,LATDIM,LTDIM)
C
C SET UP WEIGHTING PARAMETERS FOR INTERPOLATION
C
  DO 10 II=1,5
    T(2,II)=(BFPAR(II)-BFLIM(1,II))/(BFLIM(2,II)-BFLIM(1,II))
    T(1,II)=1.-T(2,II)
10 CONTINUE
C
  IF(IWANT.EQ.1) THEN
    WRITE(6,*) 'T ARRAY',T
  END IF
C
C MAIN INTERPOLATION LOOPS
C
  DO 21 N1=1,2
    N(1)=N1
  DO 22 N2=1,2
    N(2)=N2
  DO 23 N3=1,2
    N(3)=N3
  DO 24 N4=1,2
    N(4)=N4
  DO 25 N5=1,2
    N(5)=N5
C
    COEFF=1.
C
    DO 30 M=1,5
      COEFF=COEFF*T(N(M),M)
30 CONTINUE
C
C CHECK TO SEE IF B FIELD MODEL EXISTS
C
  WRITE(6,*) 'N1,N2,N3,N4,N5',N1,N2,N3,N4,N5
  WRITE(6,*) 'COEFF',COEFF
  WRITE(6,*) 'BFEXST',BFEXST(N1,N2,N3,N4,N5)
  IF(.NOT.BFEXST(N1,N2,N3,N4,N5)) THEN
    COEFF=0.
  END IF
C
C
C
```

MSM23050
MSM23060
MSM23070
MSM23080
MSM23090
MSM23100
MSM23110
MSM23120
MSM23130
MSM23140
MSM23150
MSM23160
MSM23170
MSM23180
MSM23190
MSM23200
MSM23210
MSM23220
MSM23230
MSM23240
MSM23250
MSM23260
MSM23270
MSM23280
MSM23290
MSM23300
MSM23310
MSM23320
MSM23330
MSM23340
MSM23350
MSM23360
MSM23370
MSM23380
MSM23390
MSM23400
MSM23410
MSM23420
MSM23430
MSM23440
MSM23450
MSM23460
MSM23470
MSM23480
MSM23490
MSM23500
MSM23510
MSM23520
MSM23530
MSM23540
MSM23550
MSM23560
MSM23570
MSM23580
MSM23590
MSM23600
MSM23610
MSM23620
MSM23630
MSM23640
MSM23650
MSM23660
MSM23670
MSM23680

```
C LOOP OVER SPATIAL GRID
C
      IF (IWANT.EQ.1) THEN
        DO 40 J=1,LTDIM
          DO 50 I=1,LATDIM
            IF (WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH) THEN
              XMIN(I,J)=XMIN(I,J)+COEFF*
                WORK(I,J,N1,N2,N3,N4,N5)
              MSM23690
              MSM23700
              MSM23710
              MSM23720
              MSM23730
              MSM23740
              MSM23750
              MSM23760
              MSM23770
              MSM23780
              MSM23790
              MSM23800
              MSM23810
              MSM23820
              MSM23830
              MSM23840
              MSM23850
              MSM23860
              MSM23870
              MSM23880
              MSM23890
              MSM23900
              MSM23910
              MSM23920
              MSM23930
              MSM23940
              MSM23950
              MSM23960
              MSM23970
              MSM23980
              MSM23990
              MSM24000
              MSM24010
              MSM24020
              MSM24030
              MSM24040
              MSM24050
              MSM24060
              MSM24070
              MSM24080
              MSM24090
              MSM24100
              MSM24110
              MSM24120
              MSM24130
              MSM24140
              MSM24150
              MSM24160
              MSM24170
              MSM24180
              MSM24190
              MSM24200
              MSM24210
              MSM24220
              MSM24230
              MSM24240
              MSM24250
              MSM24260
              MSM24270
              MSM24280
              MSM24290
              MSM24300
              MSM24310
              MSM24320
            ENDIF
          CONTINUE
        CONTINUE
      CONTINUE
      WRITE(6,*)' XMIN VALUES'
      WRITE(6,*)(XMIN(I,33),I=20,26)
      WRITE(6,*)(XMIN(I,12),I=20,26)
      WRITE(6,*)' WORK VALUES '
      WRITE(6,*)(WORK(I,33,N1,N2,N3,N4,N5),I=20,26)
      WRITE(6,*)(WORK(I,12,N1,N2,N3,N4,N5),I=20,26)
      WRITE(6,*)N1,N2,N3,N4,N5
    ELSE IF (IWANT.EQ.2) THEN
      DO 60 J=1,LTDIM
        DO 70 I=1,LATDIM
          IF (WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH) THEN
            YMIN(I,J)=YMIN(I,J)+COEFF*
              WORK(I,J,N1,N2,N3,N4,N5)
            MSM23930
            MSM23940
            MSM23950
            MSM23960
            MSM23970
            MSM23980
            MSM23990
            MSM24000
            MSM24010
            MSM24020
            MSM24030
            MSM24040
            MSM24050
            MSM24060
            MSM24070
            MSM24080
            MSM24090
            MSM24100
            MSM24110
            MSM24120
            MSM24130
            MSM24140
            MSM24150
            MSM24160
            MSM24170
            MSM24180
            MSM24190
            MSM24200
            MSM24210
            MSM24220
            MSM24230
            MSM24240
            MSM24250
            MSM24260
            MSM24270
            MSM24280
            MSM24290
            MSM24300
            MSM24310
            MSM24320
          END IF
        CONTINUE
      CONTINUE
    ELSE IF (IWANT.EQ.3) THEN
      DO 80 J=1,LTDIM
        DO 90 I=1,LATDIM
          IF (WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH) THEN
            ZMIN(I,J)=ZMIN(I,J)+COEFF*
              WORK(I,J,N1,N2,N3,N4,N5)
            MSM24030
            MSM24040
            MSM24050
            MSM24060
            MSM24070
            MSM24080
            MSM24090
            MSM24100
            MSM24110
            MSM24120
            MSM24130
            MSM24140
            MSM24150
            MSM24160
            MSM24170
            MSM24180
            MSM24190
            MSM24200
            MSM24210
            MSM24220
            MSM24230
            MSM24240
            MSM24250
            MSM24260
            MSM24270
            MSM24280
            MSM24290
            MSM24300
            MSM24310
            MSM24320
          END IF
        CONTINUE
      CONTINUE
    ELSE IF (IWANT.EQ.4) THEN
      DO 100 J=1,LTDIM
        DO 110 I=1,LATDIM
          IF (WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH) THEN
            BMIN(I,J)=BMIN(I,J)+COEFF*
              WORK(I,J,N1,N2,N3,N4,N5)
            MSM24130
            MSM24140
            MSM24150
            MSM24160
            MSM24170
            MSM24180
            MSM24190
            MSM24200
            MSM24210
            MSM24220
            MSM24230
            MSM24240
            MSM24250
            MSM24260
            MSM24270
            MSM24280
            MSM24290
            MSM24300
            MSM24310
            MSM24320
          END IF
        CONTINUE
      CONTINUE
    ELSE
      DO 120 J=1,LTDIM
        DO 130 I=1,LATDIM
          IF (WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH) THEN
            VM(I,J,L)=VM(I,J,L)+COEFF*
              WORK(I,J,N1,N2,N3,N4,N5)
            SUMC(I,J)=SUMC(I,J)+COEFF
          END IF
        CONTINUE
      CONTINUE
    ENDIF
  CONTINUE
CONTINUE
CONTINUE
CONTINUE
CONTINUE
```

```

21 CONTINUE
20 CONTINUE
C
C CALL OUTP (SUMC, IIDIM, JJDIM, 10, IIDIM, 1, 3, JJDIM-3, 1, 1., 'SUMC', 6, 132)
C
C CORRECT FOR MISSING B FIELD MATRICES
C
DO 140 J=1, LTDIM
DO 150 I=1, LATDIM
IF (SUMC(I, J) .GT. 1.E-10) THEN
VM(I, J, L) = VM(I, J, L) / SUMC(I, J)
BMIN(I, J) = BMIN(I, J) / SUMC(I, J)
XMIN(I, J) = XMIN(I, J) / SUMC(I, J)
YMIN(I, J) = YMIN(I, J) / SUMC(I, J)
ZMIN(I, J) = ZMIN(I, J) / SUMC(I, J)
END IF
150 CONTINUE
140 CONTINUE
C
C
C
C ROTATE BFIELD ARRAYS TO MATCH GRID ORIENTATION
C NOTE: IN THE CALLS TO BFGYRO, R IS BEING USED AS A WORK ARRAY
C
CALL BFGYRO (LATDIM, LTDIM, VM(1, 1, L), R(1, 1, L), ALOCT)
CALL BFGYRO (LATDIM, LTDIM, BMIN, R(1, 1, L), ALOCT)
CALL BFGYRO (LATDIM, LTDIM, XMIN, R(1, 1, L), ALOCT)
CALL BFGYRO (LATDIM, LTDIM, YMIN, R(1, 1, L), ALOCT)
CALL BFGYRO (LATDIM, LTDIM, ZMIN, R(1, 1, L), ALOCT)
C
C
DO 160 J=1, LTDIM
DO 170 I=1, LATDIM
R(I, J, L) = SQRT (XMIN(I, J) **2 + YMIN(I, J) **2 + ZMIN(I, J) **2)
C
IF (XMIN(I, J) .EQ. 0. .AND. YMIN(I, J) .EQ. 0.) THEN
P(I, J, L) = 0.
ELSE
P(I, J, L) = ATAN2 (YMIN(I, J), XMIN(I, J))
IF (P(I, J, L) .LT. 0.) THEN
P(I, J, L) = P(I, J, L) + 2.*PI
END IF
END IF
C
170 CONTINUE
160 CONTINUE
C
RETURN
END
SUBROUTINE BFGYRO (LATDIM, LTDIM, ARRAY, WORK, ALOCT)
C
C VERSION 1.00 DATE: 08.29.89
C
C PURPOSE: SUBROUTINE TO ROTATE FIXED GRID B FIELD ARRAYS TO MATCH
C ROTATING COORDINATE SYSTEM
C
C NOTE: THIS SUBROUTINE USES ARRAY AS BOTH AN INPUT AND OUTPUT
C ARRAY. ON INPUT, ARRAY CONTAINS THE UNROTATED DATA; ON
C OUTPUT, IT CONTAINS THE APPROPRIATELY ROTATED DATA.
C
C INPUTS:
C LATDIM NUMBER OF LATITUDINAL GRID LINES
C LTDIM NUMBER OF LOCAL TIME (LONGITUDE) GRID LINES

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MSM24330
MSM24340
MSM24350
MSM24360
MSM24370
MSM24380
MSM24390
MSM24400
MSM24410
MSM24420
MSM24430
MSM24440
MSM24450
MSM24460
MSM24470
MSM24480
MSM24490
MSM24500
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MSM24600
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MSM24690
MSM24700
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MSM24870
MSM24880
MSM24890
MSM24900
MSM24910
MSM24920
MSM24930
MSM24940
MSM24950
MSM24960

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msm1.for

C	ARRAY	UNROTATED MAGNETIC FIELD ARRAY	MSM24970
C	WORK	INTERNAL WORKING ARRAY	MSM24980
C	ALOCT	LOCAL TIME HOUR ANGLE (MEASURED EAST FROM NOON)	MSM24990
C		(RADIAN)	MSM25000
C			MSM25010
C	OUTPUT:		MSM25020
C	ARRAY	ROTATED MAGNETIC FIELD ARRAY	MSM25030
C			MSM25040
C			MSM25050
C	COMMON	/GRID/DLAM,DPSI,RI,JWRAP	MSM25060
C			MSM25070
C	DIMENSION	ARRAY (LATDIM, LTDIM), WORK (LATDIM, LTDIM)	MSM25080
C	DIMENSION	ALOCT (LATDIM, LTDIM)	MSM25090
C			MSM25100
C	PI=ATAN2	(0., -1.)	MSM25110
C			MSM25120
C	CALCULATE	ROTATION OF COORDINATE SYSTEM	MSM25130
C			MSM25140
C	ROT=ALOCT	(1, 3) * (LTDIM-JWRAP) / (2.*PI)	MSM25150
C	JROT=ROT		MSM25160
C	F=ROT-FLOAT	(JROT)	MSM25170
C			MSM25180
C	DO 10 J=1, LTDIM		MSM25190
C	J1=J+JROT		MSM25200
C	J1=MOD	(J1, LTDIM-JWRAP)	MSM25210
C	IF	(J1.EQ.0) J1=LTDIM-JWRAP	MSM25220
C	J2=J1+1		MSM25230
C	DO 20 I=1, LATDIM		MSM25240
C	WORK	(I, J) = (1.-F) * ARRAY (I, J1) + F * ARRAY (I, J2)	MSM25250
C	20	CONTINUE	MSM25260
C	10	CONTINUE	MSM25270
C			MSM25280
C			MSM25290
C	PUT	ROTATED ARRAY BACK INTO ARRAY	MSM25300
C			MSM25310
C	DO 30 J=1, LTDIM		MSM25320
C	DO 40 I=1, LATDIM		MSM25330
C	ARRAY	(I, J) = WORK (I, J)	MS.125340
C	40	CONTINUE	MSM25350
C	30	CONTINUE	MSM25360
C			MSM25370
C			MSM25380
C	RETURN		MSM25390
C	END		MSM25400
C			MSM25410
C			MSM25420
C	SUBROUTINE	PPTM (TSTART, TSTOP, DTNOM, SCTFR, IFLAV, BNDMAX,	MSM25430
C	1	ALPHA, BETA, BIR, ITMMAX, IDIM, JDIM, IEDIM, ITMDIM, IRDIM,	MSM25440
C	2	NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP, FLXMAT,	MSM25450
C	3	THRMAT, TIMTAG, ALAM, ALMDEL, VM, R, P, VMLOSS, V, ETABEG,	MSM25460
C	4	ETABND, BNDLOC, ETA, EFLUX, FLXSUM, EAVG, LL, RPP, FKP,	MSM25470
C	5	IEMAX, THRSH, TSHENG, TSHING, IRDK, INRGDK, ISOLDK, IONDK,	MSM25480
C	6	DKTIME)	MSM25490
C			MSM25500
C	VERSION	1.00	DATE: 01.07.88
C		1.10	09.12.89
C		1.20	10.10.89
C		1.30	05.09.90
C			MSM25540
C			MSM25550
C	PURPOSE:	SUBROUTINE TO TRACE PARTICLE TRAJECTORIES FROM EACH GRID	MSM25560
C		POINT FOR EACH PARTICLE SPECIES BACK IN TIME FROM	MSM25570
C		TIME=TSTART TO TIME=TSTOP. LOSS BY PRECIPITATION INTO	MSM25580
C		THE LOSS CONE IS CALCULATED FOR EACH TEST PARTICLE ALONG	MSM25590
C		ITS TRAJECTORY. PARTICLE DISTRIBUTIONS AND PRECIPITATING	MSM25600

msml.for

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C ENERGY FLUXES ARE CALCULATED AT EACH GRID POINT FOR TIME MSM25610
C TSTART FROM INITIAL AND BOUNDARY VALUES AT TIME TSTOP. MSM25620
C NOTE: TSTART.GT.TSTOP MSM25630
C MSM25640
C INPUT: MSM25650
C TSTART TIME AT WHICH TO BEGIN PARTICLE TRACEBACK MSM25660
C TSTOP TIME AT WHICH TO END PARTICLE TRACEBACK MSM25670
C DTNOM NOMINAL TIME STEP TO BEGIN TRACES. DTNOM.LT.0 MSM25680
C TO TRACE BACK IN TIME. PPTM WILL ADJUST MSM25690
C TIME STEP AS NEEDED. MSM25700
C SCTFRSC SCATTERING FRACTION OF STRONG PITCH ANGLE DIFFUSION MSM25710
C IFLAV SPECIES DEFINITION INDEX. IFLAV=1 FOR ELECTRONS MSM25720
C IFLAV=2 FOR H+ IONS; IFLAV=3 FOR O+ IONS MSM25730
C BNDMAX MAX I VALUE OF BNDY IN TIME INTERVAL MSM25740
C ALPHA LATITUDINAL GRID SPACING VECTOR MSM25750
C BETA LOCAL TIME GRID SPACING VECTOR MSM25760
C BIR IONSOPHERIC MAGNETIC FIELD STRENGTH MSM25770
C ITMMAX NUMBER OF TEMPORAL GRID POINTS USED MSM25780
C IDIM NUMBER OF LATITUDINAL GRID POINTS MSM25790
C JDIM NUMBER OF LOCAL TIME GRID POINTS (INCL WRAPAROUND) MSM25800
C IEDIM NUMBER OF ENERGY SPECIES MSM25810
C ITMDIM MAX NUMBER OF TEMPORAL GRID POINTS MSM25820
C IRDIM R DEPTH IN FLXMAT ARRAY MSM25830
C NRGDIM ENERGY DEPTH IN FLXMAT ARRAY MSM25840
C KPDIM KP DEPTH IN FLXMAT ARRAY MSM25850
C KPPLUS AUGMENTED KP DIMENSION OF FLXMAT (KPDIM+2) MSM25860
C ISPDIM NUMBER OF MASS SPECIES IN FLXMAT ARRAY MSM25870
C FLXR ALOG10(R) VALUES FOR WHICH FLXMAT ARRAY IS MSM25880
C CALCULATED MSM25890
C FLXNRG ALOG10(ENERGY) VALUES FOR WHICH FLXMAT ARRAY IS MSM25900
C CALCULATED MSM25910
C FLXKP KP VALUES FOR WHICH FLXMAT ARRAY IS CALCULATED MSM25920
C FLXMAT ALOG10(FLUX) FOR A GIVEN R,ENERGY, AND KP MSM25930
C THRMAT ARRAY GIVING LOG OF THRESHOLD FLUXES MSM25940
C TIMTAG VECTOR GIVING UNIVERSAL TIMES FOR WHICH DATA ARRAYS MSM25950
C ARE GIVEN. (SECONDS FROM BEGINNING OF START DAY) MSM25960
C ALAM ENERGY INVARIANT OF PARTICLE MSM25970
C ALMDEL ENERGY INVARIANT SPACING MSM25980
C VM (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3 MSM25990
C R DISTANCE TO BMIN PT (RE) MSM26000
C P HOUR ANGLE (EASTWARD FROM NOON) (RADIAN) MSM26010
C VMLOSS AUX. LOSS ARRAY= (SINI/BIR)*VM**2 MSM26020
C V ELECTRIC POTENTIAL ARRAY (VOLTS) MSM26030
C ETABEG INITIAL ETA DISTRIBUTION (IE., AT T=TSTOP) MSM26040
C ETABND ETA DISTRIBUTION ON BOUNDARY (DEPENDS ON TIME) MSM26050
C BNDLOC OUTER BNDY OF CALCULATION (DEPENDS ON TIME) MSM26060
C LL CURRENT TEMPORAL GRID INDEX MSM26070
C RPP NOMINAL RADIUS OF PLASMAPAUSE MSM26080
C FKP CURRENT KP VALUE MSM26090
C IEMAX NUMBER OF ENERGY CHANNELS BEING USED MSM26100
C THRSH VECTOR GIVING FULL TRACE/DEFAULT FLUX INFORMATION MSM26110
C TSHENG THRESHOLD ENERGY FOR SWITCHING FROM FULL TRACE MSM26120
C TO EMPIRICAL MODEL FOR ELECTRONS MSM26130
C TSHING THRESHOLD ENERGY FOR SWITCHING FROM FULL TRACE TO MSM26140
C EMPIRICAL MODEL FOR IONS MSM26150
C IRDK R DIMENSION FOR DKTIME ARRAY MSM26160
C INRGDK ENERGY DIMENSION FOR DKTIME ARRAY MSM26170
C ISOLDK SUN SPOT NUMBER DIMENSION FOR DKTIME ARRAY MSM26180
C IONDK NUMBER OF ION SPECIES IN DKTIME ARRAY MSM26190
C DKTIME TABLE OF ION CHARGE EXCHANGE DECAY TIMES MSM26200
C MSM26210
C OUTPUT: MSM26220
C ETA COMPUTED ETA DISTRIBUTION CORRESPONDING TO T=TSTART MSM26230
C EFLUX PRECIPITATING ENERGY FLUX FOR EACH SPECIES MSM26240

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msml.for

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C CALCULATE REFERENCE FLUX ARRAY FOR TIME=TSTART          MSM26890
  CALL SETREF (IDIM,JDIM,IEDIM,ITMDIM,ITMMAX,IRDIM,NRGDIM,KPDIM,  MSM26900
  2          KPPLUS,ISPDIM,TIMTAG,TSTART,IFLAV,VM,R,P,BNDLOC,ALAM,  MSM26910
  3          ALMDEL,FLXMAT,FLXR,FLXNRG,FLXKP,FLXREF,IEMAX)      MSM26920
C                                                         MSM26930
C DEBUG PRINTOUT                                           MSM26940
C   DO 400 IE=1,IEMAX                                       MSM26950
C     WRITE(6,*) 'IE= ',IE                                   MSM26960
C     CALL OUTP (FLXREF(1,1,IE),IDIM,JDIM,20,IDIM,1,3,JDIM-1,1,0.,  MSM26970
C     2          'FLXREF',6,132)                             MSM26980
C 400 CONTINUE                                             MSM26990
C                                                         MSM27000
C                                                         MSM27010
C                                                         MSM27020
C                                                         MSM27030
C           JMID=(JDIM-3)/2+3                               MSM27040
C           ETAEQK = 0.                                     MSM27050
C                                                         MSM27060
C INITIALIZE FLXSUM AND DENSUM                             MSM27070
C   DO 100 I=1,IDIM                                        MSM27080
C   DO 100 J=1,JDIM                                        MSM27090
C   DO 110 IK=1,IKDIM                                     MSM27100
C IK=1 FOR ELECTRONS; IK=2 FOR H+ IONS; IK=3 FOR O+ IONS  MSM27110
C   FLXSUM(I,J,IK)=0.                                    MSM27120
C   DENSUM(I,J,IK)=0.                                    MSM27130
110 CONTINUE                                             MSM27140
C                                                         MSM27150
C INITIALIZE EFLUX                                         MSM27160
C   DO 120 IE=1,IEMAX                                     MSM27170
C   EFLUX(I,J,IE)=0.                                     MSM27180
120 CONTINUE                                             MSM27190
C                                                         MSM27200
100 CONTINUE                                             MSM27210
C                                                         MSM27220
C                                                         MSM27230
C DO 10 LOOP GOES OVER PARTICLE SPECIES TO BE TRACED    MSM27240
C                                                         MSM27250
C           DO 10 IE=IEBEG,IEEND                          MSM27260
C                                                         MSM27270
C FOR ELECTRONS WITH ENERGY GREATER THAN TSHENG KEV AT  MSM27280
C GEOSYNCHRONOUS ORBIT, USE EMPIRICAL FLUXES AND DISREGARD FULL  MSM27290
C TRACEBACKS. SIMILARLY FOR IONS GREATER THAN TSHING KEV  MSM27300
C                                                         MSM27310
C           HIENG=(ABS(ALAM(IE))*VMGEO)/1000.0            MSM27320
C           IF((HIENG.GE.TSHENG).AND.(IFLAV(IE).EQ.1)) THEN  MSM27330
C             CALL FLXDFL(LL,FKP,R,P,ALAM,VM,IRDIM,NRGDIM,KPDIM,KPPLUS,  MSM27340
C             1     ISPDIM,FLXMAT,FLXR,FLXNRG,FLXKP,EFLUX,ETA,ALMDEL,IDIM,JDIM,  MSM27350
C             2     IEDIM,ITMDIM,BNDLOC,IEMAX,IFLAV,IE,IE)  MSM27360
C             THRSH(IE)=TSHENG                             MSM27370
C             IEUSE=IE                                     MSM27380
C             GO TO 10                                     MSM27390
C           ENDIF                                          MSM27400
C                                                         MSM27410
C           IF((HIENG.GE.TSHING).AND.(IFLAV(IE).NE.1)) THEN  MSM27420
C             CALL FLXDFL(LL,FKP,R,P,ALAM,VM,IRDIM,NRGDIM,KPDIM,KPPLUS,  MSM27430
C             1     ISPDIM,FLXMAT,FLXR,FLXNRG,FLXKP,EFLUX,ETA,ALMDEL,IDIM,JDIM,  MSM27440
C             2     IEDIM,ITMDIM,BNDLOC,IEMAX,IFLAV,IE,IE)  MSM27450
C             THRSH(IE)=TSHING                             MSM27460
C             IEUSE=IE                                     MSM27470
C             GO TO 10                                     MSM27480
C           ENDIF                                          MSM27490
C                                                         MSM27500
C           IK=IFLAV(IE)                                   MSM27510
C           ISP=IK                                         MSM27520
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```
C
C      TIMING INFO FOR TOTAL K VALUE COMP. TIME
C
C      CALL DTIME(ITKST)
C
C      IEUSE=IE
C      AALAM=ALAM(IE)
C
C DO 20 LOOP GOES OVER GRID POINTS
C
C      DO 20 I=IBEG,ISTOP
C          II=1
C          CALL DTIME(ITRCST)
C      DO 24 J=JBEG,JSTOP
C          III=I
C          JJJ=J
C          JJ=J
C          BBT=TNORML(TSTART,TIMTAG,ITMMAX)
C          IBT=BBT
C          BNDJT=(1.-BBT+REAL(IBT))*BNDLOC(JJ,IBT)
1          + (BBT-REAL(IBT))*BNDLOC(JJ,IBT+1)
C
C          IF (REAL(I).LT.BNDJT) THEN
C              ETA(I,J,IE)=(1.-BBT+REAL(IBT))*ETABND(J,IE,IBT)
1              + (BBT-REAL(IBT))*ETABND(J,IE,IBT+1)
C              GO TO 24
C          END IF
C
C      TIME LOOP HAS POSSIBILITY FOR VARYING TIME STEPS. STOP TRACING
C      PARTICLE TRAJECTORY WHEN (1) BOUNDARY IS CROSSED OR (2) TSTOP IS
C      REACHED.
C
C      INITIALIZATION
C
C          T=TSTART
C          IT=NINT(T)
C          DTNEXT=DTNOM
C          FXLOSS=0.
C          FXL2=0.
C          BBI=I
C          BBJ=J
C          BBT=TNORML(T,TIMTAG,ITMMAX)
C          M=1
C          TM(M)=T
C          BIM(M)=BBI
C          BJM(M)=BBJ
C          RR(M)=G3NTRP(R,IDIM,JDIM,ITMDIM,BBI,BBJ,BBT)
C          PP(M)=G3TRPA(P,IDIM,JDIM,ITMDIM,BBI,BBJ,BBT)
C          VVM(M)=G3NTRP(VM,IDIM,JDIM,ITMDIM,BBI,BBJ,BBT)
C          RPPM=G3NTRP(RPP,ITMDIM,1,1,BBT,1.,1.)
C          ENRGM=ABS(AALAM)*VVM(M)
C
C      IF (ISP.EQ.1) THEN
C          FZERO=G3NTRP(SCTFRC,IEDIM,JDIM,ITMDIM,FLOAT(IE),BBJ,BBT)
C          RATEF=(4.45E-17)*SQRT(ABS(AALAM)/XMASS(IK))*G3NTRP(VMLOSS,
2          IDIM,JDIM,ITMDIM,BBI,BBJ,BBT)
C          STRONG(M)=FZERO*RATEF
C          WEAK(M)=WKRATE(RR(M),RPPM,PP(M),ENRGM)
C      ELSE
C          STRONG(M)=0.
C          WEAK(M)=CEXRAT(ISP,ENRGM,RR(M),SSN,DKTIME,IRDK,INRGDK,
2          ISOLDK,IONDK)
C      END IF
```

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C
C
C  DEBUG 1.5.90
C  WRITE (6,789)
C 789  FORMAT (1X, '*****')
C  WRITE (6,790) M, TM (M), BIM (M), BJM (M), RR (M), PP (M), VVM (M), RPPM, ENRGM
C 790  FORMAT (1X, 'M=', I3, 2X, 'T=', F8.0, 2X, 'BI=', F6.3, 2X, 'BJ=', F6.3, 2X,
C 2  'R=', F6.3, 2X, 'P=', F8.3, 2X, 'VM=', F8.3, 2X, 'RPP=', F6.3, 2X,
C 3  'ENRG=', 1PE12.3)
C  WRITE (6,791) M, T, RATEF, STRONG (M), WEAK (M)
C 791  FORMAT (1X, 'DEBUG 1.5.90 M=', I5, 2X, 'T=', F10.0, 2X,
C 2  'RATEF=', 1PE12.3, 2X, 'STRONG LOSS RATE=', E12.3, 2X,
C 3  'WEAK LOSS RATE=', E12.3)
C
C  BEGINNING OF TIME LOOP
C
C 30  CONTINUE
C
C  MOVE PARTICLE A TIME STEP
C
C  TOLD=T
C  BIOLD=BBI
C  BJOLD=BBJ
C  DTRY=DTNEXT
C
C  IF (DTNOM.GT.0..AND.DTRY.GT. (TSTOP-TOLD) ) DTRY=TSTOP-TOLD
C  IF (DTNOM.LT.0..AND.DTRY.LT. (TSTOP-TOLD) ) DTRY=TSTOP-TOLD
C
C  IF (BIOLD.GT.REAL (IDIM) -1.) THEN
C  ETA (I, J, IE) =0.
C  GO TO 24
C  END IF
C  CALL MOVER (T, DTRY, BIOLD, BJOLD, EPS, BBISCL, BBJSCS, DTUSED, DTNEXT,
C 1  AALAM, V, VM, TIMTAG, ALPHA, BETA, BIR, IDIM, JDIM, ITMDIM, BBI, BBJ)
C
C  DEBUG PRINTOUT 12.29.89
C  WRITE (6,888) IE, T, DTRY, BIOLD, BJOLD, DTUSED, BBI, BBJ
C 888  FORMAT (1X, 'IE=', I2, 2X, 'T=', F10.2, 2X, 'DTRY=', F5.0, 2X, 'BIOLD=',
C 2  F6.2, 2X, 'BJOLD=', F6.2, 2X, 'DTUSED=', F5.0, 2X, 'NEW BI=', F6.2,
C 3  2X, 'NEW BJ=', F6.2)
C
C
C
C
C  IT=IT+NINT (DTUSED)
C  T=REAL (IT)
C  BBT=TNORML (T, TIMTAG, ITMMAX)
C
C  M=M+1
C  BIM (M) =BBI
C  BJM (M) =BBJ
C  CALL MODFIX (BJM (M), JDIM, JWRAP)
C  TM (M) =T
C
C  RR (M) =G3NTRP (R, IDIM, JDIM, ITMDIM, BIM (M), BJM (M), BBT)
C  PP (M) =G3TRPA (P, IDIM, JDIM, ITMDIM, BIM (M), BJM (M), BBT)
C  VVM (M) =G3NTRP (VM, IDIM, JDIM, ITMDIM, BIM (M), BJM (M), BBT)
C  RPPM=G3NTRP (RPP, ITMDIM, 1, 1, BBT, 1., 1.)
C
C
C
C
C  ENRG=ABS (ALAM (IE) ) *VVM (M)
C  FZERO=G3NTRP (SCTFRC, IEDIM, JDIM, ITMDIM, FLOAT (IE), BBJ, BBT)

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C
C CALCULATE LOSS RATE THIS TIME STEP
C
C     IF (ISP.EQ.1) THEN
C
C             CALCULATE LOSS RATE FOR ELECTRONS
C
C FIRST, CALCULATE STRONG PITCH ANGLE SCATTERING RATE
C     RATEF=(4.45E-17)*SQRT (ABS (AALAM) /XMASS (IK) ) *G3NTRP (VMLOSS,
C     2     IDIM, JDIM, ITMDIM, BBI, BBJ, BBT)
C     STRONG (M) =FZERO*RATEF
C
C NEXT, CALCULATE WEAK LOSS RATE
C     WEAK (M) =WKRATE (RR (M) , RPPM, PP (M) , ENRG)
C
C
C ELSE
C
C     CALCULATE LOSS RATE FOR IONS
C     STRONG IS SET TO ZERO FOR IONS
C     WEAK IS USED AS AN ALIAS FOR CHARGE EXCHANGE LOSS RATE
C     SSN IS SUNSPOT NUMBER
C     ISP IS SPECIES NUMBER (2 FOR H+, 3 FOR O+)
C
C     WEAK (M) =CEXRAT (ISP, ENRG, RR (M) , SSN, DKTIME, IRDK, INRGDK,
C     2     ISOLDK, IONDK)
C
C
C
C     STRONG (M) =0.
C
C END IF
C
C
C CORRECT J MODULUS OF BBJ
C
C     CALL MODFIX (BBJ, JDIM, JWRAP)
C
C CHECK IF PARTICLE HAS PASSED EITHER TIME OR SPATIAL BOUNDARY
C IF SO, EXIT TIME LOOP
C
C
C
C     IEXIT=0
C
C IF TIME BOUNDARY IS CROSSED, SET IEXIT=1 AND INTERPOLATE
C TO FIND ETABEG AT LOCATION (BBI, BBJ)
C
C 25 CONTINUE
C     CALL TCHK (T, TSTOP, DTNOM, BBI, BBJ, IEUSE, ETABEG, IDIM, JDIM,
C     1     IEDIM, ETANIL, IEXIT)
C
C     IF (IEXIT.EQ.0) THEN
C
C             CHECK TO SEE IF SPATIAL BNDY IS CROSSED
C
C             CALL BNDCHK (T, IEUSE, BBI, BBJ, BIOLD, BJOLD, TIMTAG, ETABND,
C     1     BNDMAX, BNDLOC, JDIM, IEDIM, ITMDIM, ITMMAX, JWRAP, ETANIL, IEXIT)
C
C END IF
C
C
C     IF (IEXIT.EQ.0) THEN
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C          GO TO 30
C          FOR NEXT TIME STEP
ELSE
C          CALCULATE ETA (I, J, IE)
C
C          DO 300 N=M, 2, -1
C
C          CALCULATE EQUILIBRIUM ETA AT PT (N-1)
          BT=TNORML(TM(N-1), TIMTAG, ITMMAX)
          BIT=BIM(N-1)
          BJT=BJM(N-1)
          BIE=FLOAT(IE)
          ENRG=ABS(ALAM(IE))*VVM(N-1)
          FKPEQ=-(KPDIM+1)
          FLXEQK=FLXVAL(ISP, FKPEQ, RR(N-1), PP(N-1), ENRG, IRDIM,
2             NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXMAT, FLXR,
3             FLXNRG, FLXKP)
C
C          IF (ISP.EQ.1) THEN
C
C             ETAEQK=FLXEQK*ALMDEL(IE)/7.392E-16/
2             Sqrt(ABS(ALAM(IE)))/VVM(N-1)
C
C          ELSE
          IF (ISP.EQ.2) AWT=1.
          IF (ISP.EQ.3) AWT=16.
          ETAEQK=(FLXEQK*ALMDEL(IE)*Sqrt(AWT))/(1.731E-17*
2             Sqrt(ABS(ALAM(IE))))/VVM(N-1)
C          END IF
C
C
C          IF (ISP.EQ.1) THEN
C             CALCULATE THRESHOLD ETA
C             SET UP INTERPOLATION PARAMETERS FOR THRMAT ARRAY
          BKP=FKP+1.
          IF (BKP.GT.7.) BKP=7.
          BNRG=4.*ALOG10(ENRG)-3.
C
          RLOG=ALOG10(RR(N-1))
          IF (RLOG.GE.FLXR(IRDIM)) THEN
          BR=IRDIM
          THRLOG=G3NTRP(THRMAT, IRDIM, NRGDIM, KPDIM, BR, BNRG,
2             BKP)+ALOG10(13./RR(N-1))
C          ELSE
C
          DO 18 IR=1, IRDIM-1
          IF (RLOG.LE.FLXR(IR+1)) THEN
          BR=FLOAT(IR)+(RLOG-FLXR(IR))/(FLXR(IR+1)-
2             FLXR(IR))
          GO TO 19
          END IF
18          CONTINUE
C
19          CONTINUE
C
          THRLOG=G3NTRP(THRMAT, IRDIM, NRGDIM, KPDIM, BR, BNRG,
2             BKP)
C
C          END IF
C
C          THRSHJ=10.**THRLOG
C
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C
      ETATHR=THRSJ*ALMDEL(IE)/7.392E-16/
      SQRT(ABS(ALAM(IE)))/VVM(N-1)
2
C
C
C
      END IF
C
C
C
      CALCULATE RHS OF D(ETA)/DT EQN
      WKMID=.5*(WEAK(N)+WEAK(N-1))
      STRMID=.5*(STRONG(N)+STRONG(N-1))
      DETDTW=AMAX1(0.,(ETANIL-ETAEQK))*WKMID
C
      DETDTS=AMAX1(0.,(ETANIL-ETATHR))*STPMID
C
C
C
      IF(DETDTW.EQ.0..AND.DETDTS.EQ.0.) THEN
      ETANIL=ETANIL
      RATE=0.
      GO TO 300
      END IF
C
      IF(DETDTW.GT.DETDTS) THEN
      RATE=WKMID
      ETAM=ETAEQK
      RATE=DETDTW
      ELSE
      RATE=STRMID
      ETAM=ETATHR
      RATE=DETDTS
      END IF
C
      IF(RATE.GT.10.) THEN
      WRITE(6,*) 'I,J,IE,WKMID,STRMID',I,J,IE,WKMID,STRMID
      WRITE(6,795) DETDTW,DETDTS,ETANIL
795 FORMAT(1X,'DETDW=',1PE12.3,2X,'DETDTS=',E12.3,2X,'ETA(N)=' ,E12.3)
      WRITE(6,799) N,ETAM,ETANIL, TM(N-1), TM(N), RATE
799 FORMAT(1X,'N=',I6,2X,'ETAM=',1PE12.3,2X,'ETANIL=' ,E12.3,2X,
2      'TM(N-1)=' ,F10.2,2X,'TM(N)=' ,F10.2,2X,'RATE=' ,E12.3)
      WRITE(6,*) 'STOPPING IN PPTM'
      STOP
      END IF
C
      ETAOLD=ETANIL
      ETANIL=ETAM+(ETAOLD-ETAM)*EXP(-(TM(N-1)-TM(N))*RATE)
C
C
C
C
      300 CONTINUE
C
C
      ETA(I,J,IE)=ETANIL
C
      BI=I
      BJ=J
      BT=TNORML(TSTART,TIMTAG,ITMMAX)
      VMVAL=G3NTRP(VM, IDIM, JDIM, ITMDIM, BI, BJ, BT)
      ENRG=ABS(ALAM(IE))*VMVAL
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C
C
C
C COMPUTE PARTICLE FLUX ASSOCIATED WITH ETA(I,J,IE). IF COMPUTED
C FLUX IS GREATER THAN UPPER LIMIT REFERENCE FLUX, THEN REDUCE ETA
C TO BE CONSISTENT WITH REFERENCE FLUX. REF: SECTION 2.5.6 OF THE
C FINAL REPORT FOR CONTRACT #F19628-87-K-0001.
C
      IF(ISP.EQ.1) THEN
          FLUX=7.392E-16*SQRT(ABS(ALAM(IE)))*VMVAL*
2          ETA(I,J,IE)/ALMDEL(IE)
      ELSE
          IF(ISP.EQ.2) THEN
              AWT=1.
          ELSE
              AWT=16.
          END IF
      FLUX=1.731E-17*SQRT(ABS(ALAM(IE)))*VMVAL*
2          ETA(I,J,IE)/(ALMDEL(IE)*SQRT(AWT))
      END IF
C
C
892 FORMAT(1X,'VMVAL=',F8.3,2X,'ALMDEL=',1PE12.3,2X,'FLUX=',E12.3,2X,
2          'FLXREF=',E12.3)
      IF(FLUX.GT.FLXREF(I,J,IE)) THEN
C          WRITE(6,*) 'COMPUTED FLUX EXCEEDS REFERENCE FLUX',
C 2          ' I=',I,' J=',J,' IE=',IE,
C 3          ' FLUX=',FLUX,' REF FLUX=',FLXREF(I,J,IE)
C CORRECT ETA TO REFERENCE FLUX VALUE
          ETAS=ETA(I,J,IE)
          ETA(I,J,IE)=ETA(I,J,IE)*FLXREF(I,J,IE)/FLUX
C DEBUG PRINTOUT
C          WRITE(6,*) 'COMPUTED ETA= ',ETAS,
C 2          ' CORRECTED ETA=',ETA(I,J,IE)
      END IF
C
      END IF
C
C
C
C
C          END IF
C
23 CONTINUE
C
      IF(ISP.EQ.1) THEN
C
C CALCULATE PRECIPITATING ENERGY FLUX AND FLUX SUMS
          BBI=I
          BBJ=J
          BIRM=G3NTRP(BIR, IDIM, JDIM, 1, BBI, BBJ, 1.)
          DETDTW=AMAX1(0., (ETA(I,J,IE)-ETAEQK))*WEAK(1)
          DETDTS=AMAX1(0., (ETA(I,J,IE)-ETATHR))*STRONG(1)
          RATETA=AMAX1(DETDTW, DETDTS)
          FLUXN=RATETA*BIRM/2.E13
          EFLUX(I,J,IE)=.8E-25*RATETA*BIRM*ABS(AALAM)*VVM(1)
          FLXSUM(I,J,IK)=FLXSUM(I,J,IK)+EFLUX(I,J,IE)
          DENSUM(I,J,IK)=DENSUM(I,J,IK)+FLUXN
C
          END IF
24 CONTINUE
          ETA(I,1,IE)=ETA(I,JDIM-JWRAP+1,IE)
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ETA(I,2,IE)=ETA(I,JDIM-JWRAP+2,IE)
ETA(I,JDIM,IE)=ETA(I,JWRAP,IE)
IF(ISP.EQ.1) THEN
  EFLUX(I,1,IE)=EFLUX(I,JDIM-JWRAP+1,IE)
  EFLUX(I,2,IE)=EFLUX(I,JDIM-JWRAP+2,IE)
  EFLUX(I,JDIM,IE)=EFLUX(I,JWRAP,IE)
  FLXSUM(I,1,IK)=FLXSUM(I,JDIM-JWRAP+1,IK)
  FLXSUM(I,2,IK)=FLXSUM(I,JDIM-JWRAP+2,IK)
  FLXSUM(I,JDIM,IK)=FLXSUM(I,JWRAP,IK)
  DENSUM(I,1,IK)=DENSUM(I,JDIM-JWRAP+1,IK)
  DENSUM(I,2,IK)=DENSUM(I,JDIM-JWRAP+2,IK)
  DENSUM(I,JDIM,IK)=DENSUM(I,JWRAP,IK)
END IF

C
C
C PRINT THE TIME SPENT PROCESSING LATITUDE I
C
C CALL DTIME(ITRCEN)
C WRITE(LUERR,*) 'THE TIME SPENT TRACING PARTICLE ',IE,
C $ 'AT LATITUDE INDEX ',I,' WAS ',
C $ ABS(ITRCEN-ITRCST) ', SECONDS.'
C
C
C
C 20 CONTINUE
C
C
C WRITE(18,*) 'IE=',IE,'T=',TSTART
C WRITE(6,*) 'IE=',IE,'T=',TSTART
C
C
C IBM=IDIM
C DO 6 JJJ=1,JDIM
C IF(INT(BNDLOC(JJJ,LL)).LT.IBM) IBM=BNDLOC(JJJ,LL)
C 6 CONTINUE
C
C
C
C PRINT TOTAL COMP. TIME FOR THIS K VALUE
C
C CALL DTIME(ITKEND)
C WRITE(LUERR,*) 'THE TOTAL TIME SPENT TRACING K = ',IE,
C $ ' WAS ', ABS(ITKEND-ITKST) ', SECONDS.'
C
C 10 CONTINUE
C
C
C
C CALCULATE PRECIPITATING FLUXES AND ENERGIES
C
C INITIALIZATION OF PRECIPITATION ARRAYS
C
C
C DO 200 I=IBEG,ISTOP
C DO 200 J=JBEG,JSTOP
C IF(DENSUM(I,J,1).GT.0.) THEN
C EAVG(I,J,1)=FLXSUM(I,J,1)/DENSUM(I,J,1)
C CONVERT EAVG TO EV FROM ERGS
C EAVG(I,J,1)=EAVG(I,J,1)*6.242E11
C ELSE
C EAVG(I,J,1)=0.
C END IF
C
C 1 EAVG(I,J,1)
C
C 200 CONTINUE
```

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MSM31370
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MSM31930
MSM31940
MSM31950
MSM31960
MSM31970
MSM31980
MSM31990
MSM32000
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mssl.for

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C  DEBUG - FAILED TO FIND BOUNDARY CROSSING                      MSM33290
C                                                                    MSM33300
C  WRITE(6,*) 'FAILED TO FIND BNDY CROSSING IN SUBROUTINE PPTM'  MSM33310
C  WRITE(6,*) 'T,IE,BBI,BBJ,BIOLD,BBJOLD',T,IE,BBI,BBJ,BIOLD,BBJOLD MSM33320
C  WRITE(6,*) 'BJCRSS',BJCRSS                                    MSM33330
C  BJCRESS=BBJ                                                  MSM33340
C  WRITE(6,*) 'USING BBJ AS CROSSING POINT=',BBJ              MSM33350
C                                                                    MSM33360
C                                                                    MSM33370
C  50          CONTINUE                                         MSM33380
C                                                                    MSM33390
C  CROSSING POINT IS BJCRESS.  COMPUTE ETANIL= ETA AT BNDY CROSSING MSM33400
C                                                                    MSM33410
C          JJ=BJCRSS                                           MSM33420
C          ETAJ=(1.-BBT+REAL(ITM))*ETABND(JJ,IE,ITM)           MSM33430
C  1          + (BBT-REAL(ITM))*ETABND(JJ,IE,ITM+1)           MSM33440
C          ETAJP=(1.-BBT+REAL(ITM))*ETABND(JJ+1,IE,ITM)       MSM33450
C  1          + (BBT-REAL(ITM))*ETABND(JJ+1,IE,ITM+1)       MSM33460
C                                                                    MSM33470
C          ETANIL=(1.-BJCRSS+REAL(JJ))*ETAJ+(BJCRSS-REAL(JJ))*ETAJP MSM33480
C          IF(IE.EQ.1.OR.IE.EQ.17) WRITE(6,900)III,JJJ,ITM,IE,  MSM33490
C  1          BBT,BBI,BBJ,JJ,ETAJ,ETAJP,ETANIL                MSM33500
C900        FORMAT(1H,'III,JJJ,ITM,IE,BBT,BBI,BBJ,JJ,ETAJ,ETAJP,  MSM33510
C  1          ETANIL'/4I4,3F15.5,I4,3E15.5)                   MSM33520
C          END IF                                              MSM33530
C                                                                    MSM33540
C          END IF                                              MSM33550
C                                                                    MSM33560
C          END IF                                              MSM33570
C                                                                    MSM33580
C          RETURN                                              MSM33590
C          END                                                 MSM33600
C          FUNCTION DVEFDI(I,J,BT,AALAM,V,VM,IDIM,JDIM,ITMDIM)  MSM33610
C                                                                    MSM33620
C  VERSION 1.00          DATE: 12.16.87                        MSM33630
C          1.01A          02.02.89                            MSM33640
C                                                                    MSM33650
C  PURPOSE:  FUNCTION SUBPROGRAM TO COMPUTE THE I DERIVATIVE OF THE MSM33660
C            EFFECTIVE POTENTIAL AT GRID POINT (I,J) AT NORMALIZED MSM33670
C            TIME BT.                                          MSM33680
C                                                                    MSM33690
C  INPUT:                                                MSM33700
C  I          I COORDINATE OF THE GRID POINT                MSM33710
C  J          J COORDINATE OF THE GRID POINT                MSM33720
C  BT         NORMALIZED TIME                               MSM33730
C  AALAM      ENERGY INVARIANT (EV (RE/NT)**2/3)           MSM33740
C  V          ELECTRIC POTENTIAL ARRAY (VOLTS)              MSM33750
C  VM         (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3 MSM33760
C  IDIM       I DIMENSION OF V AND VM                       MSM33770
C  JDIM       J DIMENSION OF V AND VM                       MSM33780
C  ITMDIM     TIME DIMENSION OF V AND VM                   MSM33790
C                                                                    MSM33800
C  OUTPUT:                                                MSM33810
C  DVEFDI     D(V+AALAM*VM)/DI AT (I,J,BT)                 MSM33820
C                                                                    MSM33830
C  PROGRAMMER: R. W. SPIRO                                  MSM33840
C                                                                    MSM33850
C                                                                    MSM33860
C                                                                    MSM33870
C  COMMON /GRID/DLAM,DPSI,RI,JWRAP                         MSM33880
C                                                                    MSM33890
C  COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,  MSM33900
C  1  LUDK,LUFLXB,LUEBEG,LUSHFT,LUIFX,LUEAVG,LUFLSM,LUFLX,  MSM33910
C  2  LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC, MSM33920

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msml.for

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3      LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
DIMENSION V (IDIM, JDIM, ITMDIM), VM (IDIM, JDIM, ITMDIM)
C
ITT=BT
FT=REAL (ITT)
IMIN=1
IMAX=IDIM
IF (J.LT.2) THEN
    JX=J+(JDIM-JWRAP)
ELSE IF (J.GT.JDIM-1) THEN
    JX=J-(JDIM-JWRAP)
ELSE
    JX=J
END IF
C
C COMPUTE DVEFDI
C
IF (I.EQ.IMIN) THEN
    DVEFDI=(1.-BT+FT)*(-1.5*(V(IMIN, JX, ITT)+AALAM*VM(IMIN, JX, ITT))
1      +2.*(V(IMIN+1, JX, ITT)+AALAM*VM(IMIN+1, JX, ITT))
2      - .5*(V(IMIN+2, JX, ITT)+AALAM*VM(IMIN+2, JX, ITT)))
3      +(BT-FT)*(-1.5*(V(IMIN, JX, ITT+1)+AALAM*VM(IMIN, JX, ITT+1))
4      +2.*(V(IMIN+1, JX, ITT+1)+AALAM*VM(IMIN+1, JX, ITT+1))
5      - .5*(V(IMIN+2, JX, ITT+1)+AALAM*VM(IMIN+2, JX, ITT+1)))
ELSE IF (I.EQ.IMAX) THEN
    DVEFDI=(1.-BT+FT)*(-1.5*(V(IMAX, JX, ITT)+AALAM*VM(IMAX, JX, ITT))
1      +2.*(V(IMAX-1, JX, ITT)+AALAM*VM(IMAX-1, JX, ITT))
2      - .5*(V(IMAX-2, JX, ITT)+AALAM*VM(IMAX-2, JX, ITT)))
3      +(BT-FT)*(-1.5*(V(IMAX, JX, ITT+1)+AALAM*VM(IMAX, JX, ITT+1))
4      +2.*(V(IMAX-1, JX, ITT+1)+AALAM*VM(IMAX-1, JX, ITT+1))
5      - .5*(V(IMAX-2, JX, ITT+1)+AALAM*VM(IMAX-2, JX, ITT+1)))
ELSE IF (I.GT.IMIN.AND.I.LT.IMAX) THEN
    DVEFDI=((1.-BT+FT)*(V(I+1, JX, ITT)+AALAM*VM(I+1, JX, ITT))
1      -V(I-1, JX, ITT)-AALAM*VM(I-1, JX, ITT))+
2      (BT-FT)*(V(I+1, JX, ITT+1)+AALAM*VM(I+1, JX, ITT+1))
3      -V(I-1, JX, ITT+1)-AALAM*VM(I-1, JX, ITT+1))/2.
ELSE
    WRITE (LUERR,*) 'Error in Function DVEFDI, I out of range.'
    WRITE (LUERR,*) 'I = ', I, ' JX = ', JX, ' ITT = ', ITT
    WRITE (LUERR,*) ' '
END IF
C
RETURN
END
FUNCTION DVEFDJ (I, J, BT, AALAM, V, VM, IDIM, JDIM, ITMDIM)
C
C VERSION 1.00
C      1.01A
C
C DATE: 12.16.87
C      02.02.89
C
C PURPOSE: FUNCTION SUBPROGRAM TO COMPUTE THE J DERIVATIVE OF THE
C EFFECTIVE POTENTIAL AT GRID POINT (I, J) AT NORMALIZED
C TIME BT.
C
C INPUT:
C I I COORDINATE OF THE GRID POINT
C J J COORDINATE OF THE GRID POINT
C BT NORMALIZED TIME
C AALAM ENERGY INVARIANT (EV (RE/NT)**2/3)
C V ELECTRIC POTENTIAL ARRAY (VOLTS)
C VM (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3
C IDIM I DIMENSION OF V AND VM
C JDIM J DIMENSION OF V AND VM
C ITMDIM TIME DIMENSION OF V AND VM
C JWRAP J WRAP AROUND

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```

C
C OUTPUT:
C   DVEFDI          D(V+AALAM*VM)/DI AT (I,J,BT)
C
C PROGRAMMER:  R. W. SPIRO
C
C
C   COMMON /GRID/DLAM,DPSI,RI,JWRAP
C
C   COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
1     LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
2     LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
3     LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C   DIMENSION V(IDIM,JDIM,ITMDIM),VM(IDIM,JDIM,ITMDIM)
C
C   ITT=BT
C   FT=REAL(ITT)
C
C PUT J IN CORRECT MODULUS FOR CALCULATION
C
C   IF(J.LT.2) THEN
C     JX=J+(JDIM-JWRAP)
C   ELSE IF(J.GT.JDIM-1) THEN
C     JX=J-(JDIM-JWRAP)
C   ELSE
C     JX=J
C   END IF
C
C COMPUTE DVEFDJ
C
C   DVEFDJ=( (I.-BT+FT)*(V(I,JX+1,ITT)+AALAM*VM(I,JX+1,ITT)
1     -V(I,JX-1,ITT)-AALAM*VM(I,JX-1,ITT)) +
2     (BT-FT)*(V(I,JX+1,ITT+1)+AALAM*VM(I,JX+1,ITT+1)
3     -V(I,JX-1,ITT+1)-AALAM*VM(I,JX-1,ITT+1)))/2.
C
C   RETURN
C   END
C   FUNCTION G3NTRP(A,IMAX,JMAX,KMAX,BI,BJ,BK)
C
C VERSION 1.00          DATE: 01.11.88
C   1.01A              02.02.89
C
C PURPOSE: FUNCTION SUBPROGRAM TO PERFORM A GENERAL 3-D LINEAR
C   INTERPOLATION OF ARRAY A(I,J,K) AT PT(BV(1),BV(2),BV(3))
C
C INPUT:
C   A          3-D ARRAY TO BE INTERPOLATED
C   IMAX      I DIMENSION OF ARRAY A
C   JMAX      J DIMENSION OF ARRAY A
C   KMAX      K DIMENSION OF ARRAY A
C   BI        FLOATING POINT VALUE TO INTERPOLATE IN I DIMENSION
C   BJ        FLOATING POINT VALUE TO INTERPOLATE IN J DIMENSION
C   BK        FLOATING POINT VALUE TO INTERPOLATE IN K DIMENSION
C
C OUTPUT:
C   G3NTRP     INTERPOLATED VALUES OF ARRAY A
C
C               INTERPOLATE A

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MSM34570
MSM34580
MSM34590
MSM34600
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MSM35090
MSM35100
MSM35110
MSM35120
MSM35130
MSM35140
MSM35150
MSM35160
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MSM35190
MSM35200

msm1.for

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COMMON /LUNIT/ LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1   LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2   LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3   LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
DIMENSION A (IMAX, JMAX, KMAX)
DIMENSION NDX (3), NDIM (3), BV (3), COEF (3, 2)

C
C   PREPARE INDICES FOR INTERPOLATION
C
NDIM (1) = IMAX
NDIM (2) = JMAX
NDIM (3) = KMAX
BV (1) = BI
BV (2) = BJ
BV (3) = BK
DO 10 L = 1, 3
NDX (L) = BV (L)
IF (NDX (L) .LT. 1) NDX (L) = 1
IF (NDX (L) .GT. NDIM (L) - 1) NDX (L) = NDIM (L) - 1
IF (NDX (L) .LE. 0) NDX (L) = 1

C
FNDX = REAL (NDX (L))
COEF (L, 1) = 1. - BV (L) + FNDX
COEF (L, 2) = BV (L) - FNDX
10 CONTINUE

C
C
G3NTRP = 0.
KSTOP = MIN (KMAX, 2)
JSTOP = MIN (JMAX, 2)
DO 20 I = 1, 2
DO 20 J = 1, JSTOP
DO 20 K = 1, KSTOP
G3NTRP = G3NTRP +
1   COEF (1, I) * COEF (2, J) * COEF (3, K) * A (NDX (1) + I - 1, NDX (2) + J - 1,
2   NDX (3) + K - 1)
20 CONTINUE
RETURN
END
SUBROUTINE MODFIX (BBJ, JDIM, JWRAP)

C
C   VERSION 1.00                      DATE: 01.15.88
C
C   PURPOSE:  SUBROUTINE TO ADJUST BBJ TO BE BETWEEN 2 AND JDIM-1
C
C   INPUT:
C   BBJ          VALUE TO BE ADJUSTED
C   JDIM         J DIMENSION OF ARRAYS
C   JWRAP       J WRAP AROUND

COMMON /LUNIT/ LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1   LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, JEAVG, LUFLSM, LUFLX,
2   LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3   LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
IF (BBJ .LT. REAL (2)) BBJ = BBJ + REAL (JDIM - JWRAP)
IF (BBJ .GT. REAL (JDIM - 1)) BBJ = BBJ - REAL (JDIM - JWRAP)
RETURN
END
SUBROUTINE MOVER (T, DTRY, BOLD, BJOLD, EPS, BBISCL, BJSCL, DTUSED,
1 DTNEXT, AALAM, V, VM, TIMTAG, ALPHA, BETA, BIR, IDIM, JDIM, ITMDIM, BBI, BBJ)

C
C   VERSION 1.00                      DATE: 01.15.88
C
C   PURPOSE:  SUBROUTINE TO ADVANCE ONE PARTICLE LOCATION ONE TIME

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```
C TAKE TWO HALF STEPS
C
  DT2=DT/2.
  CALL RK4 (TSAV,DT2,BBISAV,BBJSV,BBIOUT,BBJOUT,AALAM,V,VM,
1      TIMTAG,ALPHA,BETA,BIR,IDIM,JDIM,ITMDIM)
C
C SECOND HALF STEP
C
  BBIIN=BBIOUT
  BBJIN=BBJOUT
  CALL RK4 (T+DT2,DT2,BBIIN,BBJIN,BBIA,BBJA,AALAM,V,VM,
1      TIMTAG,ALPHA,BETA,BIR,IDIM,JDIM,ITMDIM)
C
C TAKE LARGE STEP
C
  CALL RK4 (TSAV,DT,BBISAV,BBJSV,BBIB,BBJB,AALAM,V,VM,
1      TIMTAG,ALPHA,BETA,BIR,IDIM,JDIM,ITMDIM)
C
C EVALUATE ACCURACY
C
  ERRMAX=0.
C
  BIERR=BBIB-BBIA
  ERRMAX=MAX (ERRMAX,ABS (BIERR/BBISCL) )
C
  BJERR=BBJB-BBJA
  ERRMAX=MAX (ERRMAX,ABS (BJERR/BBJSCL) )
C
C SCALE RELATIVE TO REQUIRED TOLERANCE
C
  ERRMAX=ERRMAX/EPS
C
  IF (ERRMAX.GT.ONE) THEN
C      ERROR TOO LARGE, REDUCE STEPSIZE
      DT=SAFETY*DT*(ERRMAX**PSHRNK)
      GO TO 10
C      FOR ANOTHER TRY
  ELSE
      DTUSED=DT
      IF (ERRMAX.GT.ERRCON) THEN
          DTNEXT=SAFETY*DT*(ERRMAX**PGROW)
      ELSE
          DTNEXT=4.*DT
      END IF
  END IF
C
C PUT IN FIFTH ORDER CORRECTION
C
  BBI=BBIA+BIERR*FCOR
  IF (BBI.GT.REAL (IDIM) ) BBI=REAL (IDIM)
  BBJ=BBJA+BJERR*FCOR
C
C
  RETURN
  END
  SUBROUTINE RK4 (T,DT,BBIIN,BBJIN,BBIOUT,BBJOUT,AALAM,V,VM,TIMTAG,
1      ALPHA,BETA,BIR,IDIM,JDIM,ITMDIM)
C
C VERSION 1.00 DATE: 12.30.87
C
C PURPOSE: SUBROUTINE TO ADVANCE ONE PARTICLE LOCATION ONE TIME
C STEP DT USING 4TH ORDER RUNGE KUTTA ALGORITHM.
C
C INPUT:
MSM36490
MSM36500
MSM36510
MSM36520
MSM36530
MSM36540
MSM36550
MSM36560
MSM36570
MSM36580
MSM36590
MSM36600
MSM36610
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MSM37020
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MSM37040
MSM37050
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MSM37070
MSM37080
MSM37090
MSM37100
MSM37110
MSM37120
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msm1.for

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C      T                TIME PARAMETER                MSM37130
C      DT              TIME STEP, DT.LT.0 MOVES PARTICLES BACK IN TIME  MSM37140
C                        DT.GT.0 MOVES PARTICLES FORWARD                MSM37150
C      BBIIN          CURRENT I LOCATION OF PARTICLE                MSM37160
C      BBJIN          CURRENT J LOCATION OF PARTICLE                MSM37170
C      AALAM          ENERGY INVARIANT OF PARTICLE                MSM37180
C      V              ELECTRIC POTENTIAL ARRAY (VOLTS)                MSM37190
C      VM              (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3    MSM37200
C      TIMTAG         VECTOR GIVING UNIVERSAL TIMES FOR WHICH DATA ARRAYS  MSM37210
C                        ARE GIVEN                                     MSM37220
C      ALPHA          LATITUDINAL GRID SPACING VECTOR                MSM37230
C      BETA           LOCAL TIME GRID SPACING VECTOR                MSM37240
C      BIR            IONSOPHERIC MAGNETIC FIELD STRENGTH            MSM37250
C      IDIM           NUMBER OF LATITUDINAL GRID POINTS            MSM37260
C      JDIM           NUMBER OF LOCAL TIME GRID POINTS + WRAPAROUND    MSM37270
C      ITMDIM         MAX NUMBER OF TEMPORAL GRID POINTS            MSM37280
C                                                                MSM37290
C      OUTPUT:                                             MSM37300
C      BBIOUT         COMPUTED I LOCATION AT END OF TIME STEP        MSM37310
C      BBJOUT         COMPUTED J LOCATION AT END OF TIME STEP        MSM37320
C                                                                MSM37330
C      PROGRAMMER: R. W. SPIRO                                MSM37340
C                                                                MSM37350
C      REFERENCE:  ABRAMOWITZ AND STEGUN, HANDBOOK OF MATHEMATICAL FUNCTIONSMSM37360
C                  NATIONAL BUREAU OF STANDARDS, 1970. P. 896, SECT. 25.5.10MSM37370
C                                                                MSM37380
C                                                                MSM37390
C      COMMON /GRID/ DLAM,DPSI,RI,JWRAP                      MSM37400
C                  COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,  MSM37410
C      1  LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,  MSM37420
C      2  LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,  MSM37430
C      3  LUCOLT, LUBNDJ, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH  MSM37440
C                                                                MSM37450
C      DIMENSION ALPHA(IDIM), BETA(IDIM), BIR(IDIM,JDIM)        MSM37460
C      DIMENSION V(IDIM,JDIM,ITMDIM), VM(IDIM,JDIM,ITMDIM), TIMTAG(ITMDIM)  MSM37470
C      DIMENSION BITEMP(4), BJTEMP(4)                          MSM37480
C                                                                MSM37490
C                                                                MSM37500
C      EVALUATE DERIVATIVE AT TIME=T, LOCATION=(BBI,BBJ)        MSM37510
C      BT=TNORML(T, TIMTAG, ITMDIM)                             MSM37520
C      BIUSE=BBIIN                                             MSM37530
C      BJUSE=BBJIN                                             MSM37540
C      CALL VLOCTY(BIUSE, BJUSE, BT, AALAM, ALPHA, BETA, BIR, V, VM, IDIM, JDIM,  MSM37550
C      1  ITMDIM, DBIDT, DBJDT)                                MSM37560
C      BITEMP(1)=DT*DBIDT                                       MSM37570
C      BJTEMP(1)=DT*DBJDT                                       MSM37580
C                                                                MSM37590
C      EVALUATE DERIVATIVE AT TIME=T+DT/2, LOCATION=(BBIIN+BITEMP(1)/2,  MSM37600
C                  BBJIN+BJTEMP(1)/2)                            MSM37610
C      BT=TNORML(T+DT/2., TIMTAG, ITMDIM)                       MSM37620
C      BIUSE=BBIIN+.5*BITEMP(1)                                  MSM37630
C      BJUSE=BBJIN+.5*BJTEMP(1)                                  MSM37640
C      CALL VLOCTY(BIUSE, BJUSE, BT, AALAM, ALPHA, BETA, BIR, V, VM, IDIM, JDIM,  MSM37650
C      1  ITMDIM, DBIDT, DBJDT)                                MSM37660
C      BITEMP(2)=DT*DBIDT                                       MSM37670
C      BJTEMP(2)=DT*DBJDT                                       MSM37680
C                                                                MSM37690
C      EVALUATE DERIVATIVE AT TIME=T+DT/2, LOCATION=(BBIIN+BITEMP(2)/2,  MSM37700
C                  BBJIN+BJTEMP(2)/2)                            MSM37710
C      BIUSE=BBIIN+.5*BITEMP(2)                                  MSM37720
C      BJUSE=BBJIN+.5*BJTEMP(2)                                  MSM37730
C      CALL VLOCTY(BIUSE, BJUSE, BT, AALAM, ALPHA, BETA, BIR, V, VM, IDIM, JDIM,  MSM37740
C      1  ITMDIM, DBIDT, DBJDT)                                MSM37750
C      BITEMP(3)=DT*DBIDT                                       MSM37760

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```
C          BJTEMP (3) =DT*DBJDT
C
C  EVALUATE DERIVATIVE AT TIME=T+DT, LOCATION=(BBIIN+BITEMP (3) ,
C                                     BBJIN+BJTEMP (3))
C          BT=TNORML (T+DT, TIMTAG, ITMDIM)
C          BIUSE=BBIIN+BITEMP (3)
C          BJUSE=BBJIN+BJTEMP (3)
C          CALL VLOCTY (BIUSE, BJUSE, BT, AALAM, ALPHA, BETA, BIR, V, VM, IDIM, JDIM,
1             ITMDIM, DBIDT, DBJDT)
C          BITEMP (4) =DT*DBIDT
C          BJTEMP (4) =DT*DBJDT
C
C
C  COMPUTE NEW LOCATIONS AT END OF TIME STEP
C          BBIOUT=BBIIN+ (BITEMP (1)+2. * (BITEMP (2)+BITEMP (3) )+BITEMP (4) )/6.
C          BBJOUT=BBJIN+ (BJTEMP (1)+2. * (BJTEMP (2)+BJTEMP (3) )+BJTEMP (4) )/6.
C          RETURN
C          END
C          SUBROUTINE TCHK (T, TSTOP, DTNOM, BBI, BBJ, IEUSE, ETABEG, IDIM, JDIM,
1             IEDIM, ETANIL, IEXIT)
C
C  VERSION 1.00                DATE: 01.11.88
C
C  PURPOSE:  SUBROUTINE TO CHECK WHETHER TIME BOUNDARY WAS CROSSED THIS
C            TIME STEP.  IS SO, SET IEXIT=1 AND INTERPOLATE TO FIND
C            ETABEG AT LOCATION (BBI, BBJ) .
C
C  INPUT:
C          T          TIME
C          TSTOP      TIME AT WHICH TO END PARTICLE TRACEBACK
C          DTNOM      NOMINAL TIME STEP TO BEGIN TRACES.
C          BBI        I LOCATION OF PARTICLE
C          BBJ        J LOCATION OF PARTICLE
C          IEUSE      ENERGY INDEX OF PARTICLES
C          ETABEG     INITIAL ETA DISTRIBUTION (IE., AT T=TSTOP)
C          IDIM       NUMBER OF LATITUDINAL GRID POINTS
C          JDIM       NUMBER OF LOCAL TIME GRID POINTS (INCL WRAPAROUND)
C          IEDIM      NUMBER OF ENERGY SPECIES
C
C  OUTPUT:
C          ETANIL     ETABEG VALUE AT LOCATION (BBI, BBJ) AT TIME T FOR
C                   ENERGY SPECIES IEUSE IF PARTICLE HAS CROSSED
C                   TIME BOUNDARY
C          IEXIT      SET EQUAL TO 1 IF PARTICLE HAS CROSSED TIME BNDY
C
C  PROGRAMMER: R. W. SPIRO
C
C
C          COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1             LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2             LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3             LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
C          DIMENSION ETABEG (IDIM, JDIM, IEDIM)
C
C  IF TIME BOUNDARY IS CROSSED, SET IEXIT=1 AND INTERPOLATE
C  TO FIND ETABEG AT LOCATION (BBI, BBJ)
C
C          IF ( (ABS (T-TSTOP) .LT. .01*ABS (DTNOM)) .OR.
1             (DTNOM.GT.0. .AND. T.GE. TSTOP) ) .OR.
2             (DTNOM.LT.0. .AND. T.LE. TSTOP) ) THEN
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IEXIT=1
RIEUSE=REAL (IEUSE)
ETANIL=G3NTRP (ETABEG, IDIM, JDIM, IEDIM, BBI, BBJ, RIEUSE)
END IF
C
RETURN
END
FUNCTION TNORML (TT, TIMTAG, ITMMAX)
C
C VERSION 1.00
C DATE: 12.16.87
C
C PURPOSE: FUNCTION TO CALCULATE RUN-NORMALIZED TIME CORRESPONDING
C TO TIME TT
C
C INPUT:
C TT TIME IN SECONDS
C TIMTAG VECTOR GIVING TIMES FOR WHICH MODEL ARRAYS
C ARE CALCULATED
C ITMMAX NUMBER OF TEMPORAL GRID POINTS USED
C
C OUTPUT:
C TNORML NON-INTEGGER TIME INDEX CORRESPONDING TO
C TIME TT
C
C PROGRAMMER: R. W. SPIRO
C
C
C COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1 LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2 LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3 LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
DIMENSION TIMTAG (ITMMAX)
C
DO 10 I=1, ITMMAX-1
IF ((TT.GE.TIMTAG (I) .AND. TT.LE.TIMTAG (I+1)) .OR.
1 (TT.LE.TIMTAG (I) .AND. TT.GE.TIMTAG (I+1))) THEN
II=I
GO TO 20
END IF
10 CONTINUE
C
C TIME TT NOT WITHIN TIMTAG RANGE
C
WRITE (LUERR, *) 'TT NOT WITHIN TIMTAG RANGE, TT= ', TT
WRITE (LUERR, *) 'TIMTAG (1)=', TIMTAG (1)
WRITE (LUERR, *) 'ITMMAX=', ITMMAX
WRITE (LUERR, *) 'TIMTAG (ITMMAX)=', TIMTAG (ITMMAX)
WRITE (LUERR, *) 'STOPPING PROGRAM IN FUCTION TNORML'
STOP
C
C LOCALIZED TT TO WITHIN THE RIGHT TIME RANGE
C
20 CONTINUE
TNORML=REAL (II) + (TT-TIMTAG (II)) / (TIMTAG (II+1) -TIMTAG (II))
C
RETURN
END
SUBROUTINE VLOCTY (BBII, BBJJ, BT, AALAM, ALPHA, BETA, BIR, V, VM,
1 IDIM, JDIM, ITMDIM, DBIDT, DBJDT)
C
C VERSION 1.00
C DATE: 12.16.87
C 1.01A
C 02.02.89
C
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MSM38990
MSM39000
MSM39010
MSM39020
MSM39030
MSM39040
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C  PURPOSE:  SUBROUTINE TO COMPUTE I AND J COMPONENTS OF PARTICLE      MSM39050
C  VELOCITY WITH ENERGY INVARIANT AALAM AT LOCATION                MSM39060
C  (BBI,BBJ) AT NORMALIZED TIME BT.                                MSM39070
C                                                                    MSM39080
C                                                                    MSM39090
C  INPUT:                                                                    MSM39100
C  BBII          I LOCATION OF PARTICLE                                MSM39110
C  BBJJ          J LOCATION OF PARTICLE                                MSM39120
C  BT            NORMALIZED TIME                                      MSM39130
C  AALAM         ENERGY INVARIANT (EV (RE/NT)**2/3)                 MSM39140
C  ALPHA        LATITUDINAL GRID SPACING VECTOR                    MSM39150
C  BETA         LONGITUDINAL GRID SPACING VECTOR                    MSM39160
C  BIR          IONOSPHERIC RADIAL MAGNETIC FIELD STRENGTH          MSM39170
C  V            ELECTRIC POTENTIAL ARRAY (VOLTS)                     MSM39180
C  VM           (FLUX TUBE VOLUME)**-2/3 ARRAY (RE/NT)**-2/3        MSM39190
C  IDIM         1ST (LAT) DIMENSION OF V, VM, AND BIR               MSM39200
C  JDIM         2ND (LONG) DIMENSION OF V,VM, AND BIR              MSM39210
C  ITMDIM       3RD (TIME) DIMENSION OF V AND VM                   MSM39220
C                                                                    MSM39230
C  OUTPUT:                                                                    MSM39240
C  DBIDT        I (LAT) VELOCITY OF PARTICLE (I UNITS/SEC)          MSM39250
C  DBJDT        J (LAT) VELOCITY OF PARTICLE (J UNITS/SEC)          MSM39260
C                                                                    MSM39270
C  PROGRAMMER:  R. W  SPIRO                                           MSM39280
C                                                                    MSM39290
C                                                                    MSM39300
C                                                                    MSM39310
C  COMMON /GRID/ DLAM,DPSI,RI,JWRAP                                    MSM39320
C  COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,      MSM39330
C  1  LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,    MSM39340
C  2  LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC, MSM39350
C  3  LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH    MSM39360
C                                                                    MSM39370
C  DIMENSION ALPHA (IDIM) , BETA (IDIM) , BIR (IDIM, JDIM)          MSM39380
C  DIMENSION V (IDIM, JDIM, ITMDIM) , VM (IDIM, JDIM, ITMDIM)      MSM39390
C  DIMENSION DVDI2 (2, 2) , DVDJ2 (2, 2)                             MSM39400
C                                                                    MSM39410
C  BBI=BBII                                                    MSM39420
C  BBJ=BBJJ                                                    MSM39430
C  CALL MODFIX (BBJ, JDIM, JWRAP)                                  MSM39440
C  INTERPOLATE GRID ARRAY FOR LOCATION (BBI, BBJ)                 MSM39450
C                                                                    MSM39460
C  BIR2=G3NTRP (BIR, IDIM, JDIM, 1, BBI, BBJ, 1.)                MSM39470
C  ALPH2=G3NTRP (ALPHA, IDIM, 1, 1, BBI, 1., 1.)                  MSM39480
C  BETA2=G3NTRP (BETA, IDIM, 1, 1, BBI, 1., 1.)                  MSM39490
C                                                                    MSM39500
C  COMPUTE DVEFDI AND DVEFDJ AT NORMALIZED TIME BT FOR GRID PTS   MSM39510
C  SURROUNDING (BBI, BBJ)                                         MSM39520
C                                                                    MSM39530
C  I=BBI                                                       MSM39540
C  FI=REAL (I)                                                 MSM39550
C  J=BBJ                                                       MSM39560
C  FJ=REAL (J)                                                 MSM39570
C                                                                    MSM39580
C  DO 10 II=1,2                                                MSM39590
C     IUSE=I+II-1                                              MSM39600
C     IF (IUSE.GT.IDIM) IUSE=IDIM                               MSM39610
C  DO 20 JJ=1,2                                                MSM39620
C     JUSE=J+JJ-1                                              MSM39630
C     DVDI2 (II, JJ) =DVEFDI (IUSE, JUSE, BT, AALAM, V, VM, IDIM, JDIM, ITMDIM)
C     DVDJ2 (II, JJ) =DVEFDJ (IUSE, JUSE, BT, AALAM, V, VM, IDIM, JDIM, ITMDIM)
C 20 CONTINUE
C 10 CONTINUE
C                                                                    MSM39660
C                                                                    MSM39670
C  INTERPOLATE DVDI2 AND DVDJ2 FOR LOCATION (BBI, BBJ)           MSM39680
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C
  DVDI=(1.-BBJ+FJ)*(1.-BBI+FI)*DVDI2(1,1)+(BBI-FI)*DVDI2(2,1)
1      + (BBJ-FJ)*(1.-BBI+FI)*DVDI2(1,2)+(BBI-FI)*DVDI2(2,2)
C
  DVDJ=(1.-BBJ+FJ)*(1.-BBI+FI)*DVDJ2(1,1)+(BBI-FI)*DVDJ2(2,1)
1      + (BBJ-FJ)*(1.-BBI+FI)*DVDJ2(1,2)+(BBI-FI)*DVDJ2(2,2)
C
C COMPUTE VELOCITIES
C
  DBIDT=DVDJ*1000./(BIR2*ALPH2*BETA2*DLAM*DPSI*RI**2)
  DBJDT=-DVDI*1000./(BIR2*ALPH2*BETA2*DLAM*DPSI*RI**2)
C
  RETURN
  END
  SUBROUTINE RDGRID(IDIM,JDIM,ALPHA,BETA,TETA,PHI,COLAT,BIR,SINI)
C
C VERSION 1.0                      DATE: 01.23.88
C
C PROGRAMMER: R. W. SPIRO
C
C PURPOSE:  READ GRID SYSTEM COORDINATES AND CALCULATE ESSENTIAL GRID
C           QUANTITIES
C
  COMMON /GRID/ DLAM,DPSI,RI,JWRAP
  COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
1      LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
2      LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
3      LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C
  DIMENSION      ALPHA(IDIM),BETA(IDIM),TETA(IDIM),PHI(JDIM)
  DIMENSION COLAT(IDIM,JDIM),BIR(IDIM,JDIM),SINI(IDIM,JDIM)
C
  CHARACTER      ID(2)
  PI=ATAN2(0.,-1.)
  JWRAP = 3
C
C READ GRID PARAMETERS
C
  OPEN(UNIT=LUCORD,FILE='COORD',STATUS='OLD')
C
  READ(LUCORD,1000) ID,OFFSET,DLAM,DPSI,RI,RE
1000  FORMAT(2A4,1X,5(E12.6,1X))
  READ(LUCORD,1001)TETA,ALPHA,BETA,PHI
1001  FORMAT(10(E12.6,1X))
C
  DO 10 I=1,IDIM
  DO 20 J=1,JDIM
    COSTET=COS(TETA(I))*COS(OFFSET)+SIN(TETA(I))*COS(PHI(J))*
1      SIN(OFFSET)
    BIR(I,J)=62000.*COSTET
    COLAT(I,J)=ACOS(COSTET)
    SINI(I,J)=2.*COSTET/SQRT(1.+3.*COSTET**2)
20  CONTINUE
10  CONTINUE
C
  RETURN
  END
  SUBROUTINE MLTSET(ISEC,IDIM,JDIM,ALOCT)
C
C VERSION 1.0                      DATE: 01.23.88
C
C PROGRAMMER: R. W. SPIRO
C
C PURPOSE:  CALCULATE TIME DEPENDENT ALOCT OF ROTATING GRID PTS
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C
C INPUTS:
C   ISEC          TIME (SECONDS)
C   IDIM          I DIMENSION
C   JDIM          J DIMENSION
C
C OUTPUT:
C   ALOCT         LOCAL TIME ARRAY CORRESPONDING TO T=ISEC
C
C   COMMON /GRID/ DLAM,DPSI,RI,JWRAP
C   DIMENSION ALOCT(IDIM,JDIM)
C
C   PI=ATAN2(0.,-1.)
C   DPHI=2.*PI/REAL(JDIM-JWRAP)
C   DPHIDT=2.*PI/86400.
C   T=REAL(ISEC)
C
C   DO 10 I=1, IDIM
C   DO 10 J=1, JDIM
C       ALOCT(I,J)=REAL(J-3)*DPHI+T*DPHIDT
C       IF(ALOCT(I,J).GT.2.*PI) ALOCT(I,J)=ALOCT(I,J)-2.*PI
C       IF(ALOCT(I,J).LT.0.) ALOCT(I,J)=ALOCT(I,J)+2.*PI
C 10 CONTINUE
C
C   RETURN
C   END
C   SUBROUTINE VMLSET(ITMCUR,VM,BIR,SINI, IDIM,JDIM,ITMDIM,VMLOSS)
C
C   VERSION 1.0          DATE: 01.23.88
C
C   PROGRAMMER: R. W. SPIRO
C
C   PURPOSE:  COMPUTE VMLOSS ARRAY FOR ITMCUR
C
C   DIMENSION VMLOSS(IDIM,JDIM,ITMDIM),BIR(IDIM,JDIM),SINI(IDIM,JDIM)
C   DIMENSION VM(IDIM,JDIM,ITMDIM)
C
C   DO 10 I=1, IDIM
C   DO 10 J=1, JDIM
C       VMLOSS(I,J,ITMCUR)=(SINI(I,J)/BIR(I,J))*VM(I,J,ITMCUR)**2
C 10 CONTINUE
C
C   RETURN
C   END
C   SUBROUTINE FNDBND(ITMCUR,COLAT,ALOCT,A2,B2,DX2,DY2, IDIM,JDIM,
C   1          ITMDIM,BNDLOC)
C
C   VERSION 1.0          DATE: 01.23.88
C
C   PROGRAMMER: R. W. SPIRO
C
C   PURPOSE:  COMPUTE TIME DEPENDENT OUTER BOUNDARY LOCATION
C
C   COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
C   1   LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
C   2   LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
C   3   LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C
C   DIMENSION COLAT(IDIM,JDIM),ALOCT(IDIM,JDIM)
C   DIMENSION BNDLOC(JDIM,ITMDIM)
C
C   PI = ATAN2(0.,-1.)
C   DO 10 J=1,JDIM
C   DO 20 I=1, IDIM-1
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IUSE=I
THETAB=THET(A2,B2,DX2,DY2,ALOCT(I+1,J))*PI/180.
IF(COLAT(I+1,J).GE.THETAB) GO TO 30
20 CONTINUE
C
C ERROR EXIT
WRITE(LUERR,*) 'ERROR IN FFNDBND'
WRITE(LUERR,*) 'THETAB=',THETAB,'J=',J,'I=',I
WRITE(LUERR,*) 'STOPPING PGM'
STOP
C
30 CONTINUE
C
THETAC=THET(A2,B2,DX2,DY2,ALOCT(IUSE,J))*PI/180.
BNDLOC(J,ITMCUR)=(REAL(IUSE)*(COLAT(IUSE+1,J)-THETAB)+
1 REAL(IUSE+1)*(THETAC-COLAT(IUSE,J)))/
2 (COLAT(IUSE+1,J)-COLAT(IUSE,J)-THETAB+THETAC)
C
10 CONTINUE
C
RETURN
END
SUBROUTINE OUTP(R,ISIZE,JSIZE,IBEG,IEND,IINC,JBEG,JEND,JINC,
$ XSCALE,TITLE,NTP,NCOL)
C
C AUTHOR: R.W. SPIRO LAST MODIFIED: 06-25-85
C
C*****
C DESCRIPTION OF INPUT PARAMETERS
C*****
C R(ISIZE,JSIZE)=ARRAY TO BE OUTPUT
C THIS SUBROUTINE IS ABLE TO OUTPUT SELECTED ELEMENTS OF ARRAY
C IBEG= INITIAL I VALUE TO BE OUTPUT
C IEND= FINAL I VALUE TO BE OUTPUT
C IINC= I VALUE INCREMENT FOR OUTPUT
C (NOTE: (IEND-IBEG)/IINC SHOULD BE AN INTEGER)
C JBEG,JEND, AND JINC ARE DEFINED SIMILARLY
C SCALE=SCALE FACTOR
C IF(SCALE.EQ.0.) SCALE IS CALCULATED TO GIVE BEST DISPLAY
C ALL ELEMENTS OR ARRAY ARE DIVIDED BY SCALE BEFORE BEING OUTPUT
C TITLE=CHARACTER STRING THAT IDENTIFIES THE ARRAY BEING OUTPUT
C NTP= OUTPUT UNIT NUMBER
C NCOL= NUMBER OF COLUMNS FOR OUTPUT DEVICE (80 OR 132)
C*****
C
PARAMETER (JCOL=16)
DIMENSION R(ISIZE,JSIZE), Y(JCOL)
REAL*8 SUM0, SUM1, SUM2, TERM, AVE, SD
CHARACTER TITLE *(*)
C
C
C INITIALIZATION
C
SCALE=XSCALE
ISCLMX=-12
SUM0=0.0
SUM1=0.0
SUM2=0.0
MXLINE=57
JJCOL=(NCOL-4)/8
C
C
C CALCULATE SIZE OF PRINTOUT ARRAY (NI BY NJ)
C

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MSM41490
MSM41500
MSM41510
MSM41520
MSM41530
MSM41540
MSM41550
MSM41560
MSM41570
MSM41580
MSM41590

```

```
NI=(IEND-IBEG)/IINC+1
NJ=(JEND-JBEG)/JINC+1
C
C IF SCALE=0. THEN COMPUTE AUTO SCALE FACTOR
C
C IF(SCALE.EQ.0.) THEN
C DETERMINE MAXIMUM # OF PLACES TO LEFT OF DECIMAL PT
DO 10 I=IBEG,IEND,IINC
DO 10 J=JBEG,JEND,JINC
IF(R(I,J).NE.0..AND.ABS(R(I,J)).GT.1.E-36) THEN
TEST=LOG10(ABS(R(I,J)))
IF(TEST.GE.0.) THEN
TEST=TEST+.000001
ELSE
TEST=TEST-.999999
END IF

ITEST=TEST
ELSE
ITEST=0
END IF
IF(R(I,J).LT.0.) ITEST=ITEST+1
ISCLMX=MAX0(ISCLMX,ITEST)
10 CONTINUE
C DETERMINE SCALE FACTOR SUCH THAT MAX # OF PLACES TO LEFT OF
C DECIMAL POINT IS 3.
IPOWER=ISCLMX-2
SCALE=10.**IPOWER
ELSE
IPOWER=NINT(LOG10(SCALE))
END IF
C
C
C COMPUTE MEAN AND STD DEVIATION OF OUTPUTTED ARRAY ELEMENTS
C
C
DO 20 I=1,ISIZE
DO 20 J=1,JSIZE
TERM=R(I,J)
SUM0=SUM0+1.
IF (ABS(TERM).LT.1.E-20) GO TO 20
SUM1=SUM1+TERM
SUM2=SUM2+TERM**2
20 CONTINUE
AVE=SUM1/SUM0
SD=SQRT((SUM2-SUM0*AVE**2)/(SUM0-1.))
C
C
C OUTPUT DATA
C
C
JSTART=JBEG
ISTART=IBEG
IFINAL=IEND
IUTT=0
WRITE(NTP,810) TITLE,IPOWER,IUTT,AVE,SD
810 FORMAT('0',4X,A,'/(1.E',I2,',)',4X,'UT=',I6,2X,'AVE=',1PE15.8,2X,
$ 'SD=',E15.8)
LCOUNT=0
C
C
C BEGIN OUTPUT LOOP
C
C
```

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MSM41600
MSM41610
MSM41620
MSM41630
MSM41640
MSM41650
MSM41660
MSM41670
MSM41680
MSM41690
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MSM41850
MSM41860
MSM41870
MSM41880
MSM41890
MSM41900
MSM41910
MSM41920
MSM41930
MSM41940
MSM41950
MSM41960
MSM41970
MSM41980
MSM41990
MSM42000
MSM42010
MSM42020
MSM42030
MSM42040
MSM42050
MSM42060
MSM42070
MSM42080
MSM42090
MSM42100
MSM42110
MSM42120
MSM42130
MSM42140
MSM42150
MSM42160
MSM42170
MSM42180
MSM42190
MSM42200
MSM42210
MSM42220
MSM42230
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```
30 CONTINUE
  JFINAL=(JJCOL-1)*JINC+JSTART
  IF (JFINAL.GT.JEND) JFINAL=JEND
C
C FOLLOWING IS MAIN IF STATEMENT IN LOOP
C
  IF (JSTART.LE.JEND) THEN
C
C           OUTPUT A BLOCK
C
  IF (MXLINE-LCOUNT.LE.5) THEN
C
C           START A NEW PAGE
C
    IUTT=0
    WRITE (NTP,810) TITLE,IPOWER,IUTT,AVE,SD
    LCOUNT=0
  END IF
  WRITE (NTP,830) (JJ,JJ=JSTART,JFINAL,JINC)
830 FORMAT ('0',3X,16(5X,I3))
  LCOUNT=LCOUNT+2
  DO 40 II=ISTART,IFINAL,IINC
    ICOUNT=LCOUNT+1
    IF (LCOUNT.GT.MXLINE) THEN
C
C           START A NEW PAGE
C
      IUTT=0
      WRITE (NTP,810) TITLE,IPOWER,IUTT,AVE,SD
      WRITE (NTP,830) (JJ,JJ=JSTART,JFINAL,JINC)
      LCOUNT=2
    END IF
    JCOUNT=0
    DO 50 JJ=JSTART,JFINAL,JINC
      JCOUNT=JCOUNT+1
      Y (JCOUNT)=R (II, JJ) /SCALE
50    CONTINUE
      WRITE (NTP,840) II, (Y (JJ), JJ=1, JCOUNT)
840 FORMAT (1X,I3,16(F8.3))
40    CONTINUE
      JSTART=JFINAL+JINC
      ISTART=IBEG
      GO TO 30
    END IF
  RETURN
  END
  SUBROUTINE HIEPAR
C
C PURPOSE:  SUBROUTINE TO COMPUTE EMPIRICAL MODEL OF MEV ENERGY
C           ELECTRONS.  THIS ROUTINE IS A DUMMY TO REPRESENT THE
C           TRUE SUBROUTINE TO BE FURNISHED BY D. BAKER OF GSFC.
C
  RETURN
  END
C
  SUBROUTINE OUTPUT
C
C PURPOSE:  DUMMY SUBROUTINE TO REPRESENT ALGORITHM TO OUTPUT MSM
C           RESULTS TO ENVIRONMENTAL DATA BASE.  THIS ROUTINE WILL BE
C           THE OUTPUT INTERFACE BETWEEN THE MSM AND THE ENVIRONMENTAL
C           DATA BASE.
C
  RETURN
  END
  SUBROUTINE AURL1 (FKP, COLAT, ALOCT, LATDIM, LTDIM, AEFLUX, AEMEAN)
C
  Determines the number and energy fluxes given Kp, corrected
  MSM42240
  MSM42250
  MSM42260
  MSM42270
  MSM42280
  MSM42290
  MSM42300
  MSM42310
  MSM42320
  MSM42330
  MSM42340
  MSM42350
  MSM42360
  MSM42370
  MSM42380
  MSM42390
  MSM42400
  MSM42410
  MSM42420
  MSM42430
  MSM42440
  MSM42450
  MSM42460
  MSM42470
  MSM42480
  MSM42490
  MSM42500
  MSM42510
  MSM42520
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  MSM42590
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  MSM42610
  MSM42620
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  MSM42680
  MSM42690
  MSM42700
  MSM42710
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  MSM42770
  MSM42780
  MSM42790
  MSM42800
  MSM42810
  MSM42820
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  MSM42840
  MSM42850
  MSM42860
  MSM42870
```

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C      geomagnetic latitude, and local time                                MSM42880
C                                                                                               MSM42890
C      FKP=The most recent Kp value                                         MSM42900
C      COLAT=An array listing pertinent colatitudes (less than 40 deg.)    MSM42910
C      preferably using corrected geomagnetic coordinates                  MSM42920
C      ALOCT=An array listing pertinent magnetic local times                MSM42930
C      LATDIM=DIMENSION IN LATITUDE                                         MSM42940
C      LTDIM=DIMENSION IN LOCAL TIME                                         MSM42950
C      AEFLUX=The integral electron energy flux given in units of ergs     MSM42960
C      per cm**2-sec for a given latitude and local time                   MSM42970
C      AEMEAN=AVERAGE ENERGY IN EV                                         MSM42980
C      AFLUX=The integral electron number flux given in units of inverse   MSM42990
C      cm**2-sec for a given latitude and local time                       MSM43000
C                                                                                               MSM43010
C      PARAMETER(IIDIM=62, JJDIM=51)                                         MSM43020
C      COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,         MSM43030
1      LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,         MSM43040
2      LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,     MSM43050
3      LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH         MSM43060
C                                                                                               MSM43070
C      DIMENSION ALOCT(LATDIM, LTDIM), COLAT(LATDIM, LTDIM),              MSM43080
1      AEFLUX(LATDIM, LTDIM), AFLUX(IIDIM, JJDIM), AEMEAN(LATDIM, LTDIM), MSM43090
2      RDC(2), H0DC(2), S1DC(2), S2DC(2), RCOS(6, 2), RSIN(6, 2),         MSM43100
3      H0COS(6, 2), H0SIN(6, 2), S1COS(6, 2), S1SIN(6, 2), S2COS(6, 2),  MSM43110
4      S2SIN(6, 2)                                                         MSM43120
C                                                                                               MSM43130
C      PI=ACOS(-1.)                                                         MSM43140
C                                                                                               MSM43150
C      Read off the model coefficients for the given Kp                     MSM43160
C      CALL FNDHDY(FKP, RDC, RCOS, RSIN, H0DC, H0COS, H0SIN,              MSM43170
1      S1DC, S1COS, S1SIN, S2DC, S2COS, S2SIN, 6, 2)                      MSM43180
C                                                                                               MSM43190
C      DO 20 J=1, LTDIM                                                       MSM43200
C      DO 10 I=1, LATDIM                                                       MSM43210
C                                                                                               MSM43220
C      XLT=ALOCT(I, J)                                                       MSM43230
C                                                                                               MSM43240
C                                                                                               MSM43250
C      Determine the values of the energy flux array                         MSM43260
C      CALL ADDHDY(RDC, RCOS, RSIN, H0DC, H0COS, H0SIN, S1DC, S1COS,      MSM43270
1      S1SIN, S2DC, S2COS, S2SIN, 6, 2, 1, XLT, COLAT(I, J),            MSM43280
2      AEFLUX(I, J))                                                       MSM43290
C                                                                                               MSM43300
C      Convert units from keV/cm**2-ster-sec to erg/cm**2-sec             MSM43310
C      AEFLUX(I, J)=(10.**AEFLUX(I, J))*PI*1.6021E-9                       MSM43320
C                                                                                               MSM43330
C                                                                                               MSM43340
C                                                                                               MSM43350
10      CONTINUE                                                            MSM43360
20      CONTINUE                                                            MSM43370
C                                                                                               MSM43380
C      DO 40 J=1, LTDIM                                                       MSM43390
C      DO 30 I=1, LATDIM                                                       MSM43400
C                                                                                               MSM43410
C      XLT=ALOCT(I, J)                                                       MSM43420
C                                                                                               MSM43430
C      Determine the values of the number flux array                         MSM43440
C      CALL ADDHDY(RDC, RCOS, RSIN, H0DC, H0COS, H0SIN, S1DC, S1COS,      MSM43450
1      S1SIN, S2DC, S2COS, S2SIN, 6, 2, 2, XLT, COLAT(I, J),            MSM43460
2      AFLUX(I, J))                                                       MSM43470
C                                                                                               MSM43480
C      Convert units from (ster-cm**2-sec)**-1 to (cm**2-sec)**-1         MSM43490
C      AFLUX(I, J)=(10.**AFLUX(I, J))*PI                                     MSM43500
C      IF(AFLUX(I, J).NE.0.0)AEMEAN(I, J)=AEFLUX(I, J)/AFLUX(I, J)       MSM43510
```

```
AEMEAN(I,J)=AEMEAN(I,J)*6.24E11
30 CONTINUE
40 CONTINUE
C
RETURN
END
C
C
SUBROUTINE FNDHDY(FKP,RDC,RCOS,RSIN,H0DC,H0COS,H0SIN,
1 S1DC,S1COS,S1SIN,S2DC,S2COS,S2SIN,MDIM,NDIM)
C Find and read the pertinent Fourier coefficients
C
COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
1 LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
2 LUEFLX,LUEFLD,LUBF D,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
3 LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C
DIMENSION RDC(NDIM),H0DC(NDIM),S1DC(NDIM),S2DC(NDIM),
1 RCOS(MDIM,NDIM),RSIN(MDIM,NDIM),H0COS(MDIM,NDIM),
2 H0SIN(MDIM,NDIM),S1COS(MDIM,NDIM),S1SIN(MDIM,NDIM),
3 S2COS(MDIM,NDIM),S2SIN(MDIM,NDIM)
C
DATA IKPCHK /-1/
C
IFKP2=NINT(FKP)
IF(IFKP2.GT.6) IFKP2=6
C
IF THESE KP COEFS WERE THE LAST READ, DON'T REREAD
C IF(IKPCHK.EQ.IFKP2) GO TO 99
C
OPEN(UNIT=LUHDYE,FILE='HARDY',STATUS='OLD')
C
IF(IREWCK.NE.1) THEN
GO TO 10
ELSE IF (IKPCHK.NE.IFKP2) THEN
REWIND LUHDYE
ELSE
GO TO 99
ENDIF
C
10 IF(IFKP2.EQ.0)GO TO 30
C Read off irrelevant entries
DO 20 I=1,IFKP2*26
READ(LUHDYE,*)COEFF
20 CONTINUE
C
30 DO 60 N=1,NDIM
C
Read off the constant and trigonometric coefficients
C for the Epstein-Fourier equation
READ(LUHDYE,*)RDC(N),H0DC(N),S1DC(N),S2DC(N)
C
DO 40 M=1,MDIM
READ(LUHDYE,*)RCOS(M,N),H0COS(M,N),S1COS(M,N),S2COS(M,N)
40 CONTINUE
C
DO 50 M=1,MDIM
READ(LUHDYE,*)RSIN(M,N),H0SIN(M,N),S1SIN(M,N),S2SIN(M,N)
50 CONTINUE
C
60 CONTINUE
C
IKPCHK=IFKP2
IREWCK=1
```

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MSM43520
MSM43530
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MSM43980
MSM43990
MSM44000
MSM44010
MSM44020
MSM44030
MSM44040
MSM44050
MSM44060
MSM44070
MSM44080
MSM44090
MSM44100
MSM44110
MSM44120
MSM44130
MSM44140
MSM44150
```

```
C
CLOSE (LUHDYE)
C
99 RETURN
END
C
C
SUBROUTINE ADDHDY (RDC, RCOS, RSIN, H0DC, H0COS, H0SIN, S1DC,
1 S1COS, S1SIN, S2DC, S2COS, S2SIN, MDIM, NDIM, K, ALTIME, COLTDE, FLUX)
C Calculate the Hardy average value for the given point
C
DIMENSION RDC (NDIM), H0DC (NDIM), S1DC (NDIM), S2DC (NDIM),
1 RCOS (MDIM, NDIM), RSIN (MDIM, NDIM), H0COS (MDIM, NDIM),
2 H0SIN (MDIM, NDIM), S1COS (MDIM, NDIM), S1SIN (MDIM, NDIM),
3 S2COS (MDIM, NDIM), S2SIN (MDIM, NDIM)
C
X=90.-ABS (COLTDE) *180./3.14159
ALCT=12.+ALTIME*12./3.14159
IF (ALCT.GT.24.) ALCT=ALCT-24.
C
C Check to see if the Fourier series have to be recalculated
IF (TEST.EQ.ALCT) GO TO 10
C
C Determine the coefficients for the Epstein equation
R=FSUM (RDC, RSIN, RCOS, ALCT, 6, 2, K)
H0=FSUM (H0DC, H0SIN, H0COS, ALCT, 6, 2, K)
S1=FSUM (S1DC, S1SIN, S1COS, ALCT, 6, 2, K)
S2=FSUM (S2DC, S2SIN, S2COS, ALCT, 6, 2, K)
C
C Use the Epstein equation to calculate the average value
10 FLUX=R+S1*(X-H0)+(S2-S1)*ALOG((1-S1/S2*EXP(X-H0))/(1-S1/S2))
C Set the equatorward lower limit flux value at 6 and
C the poleward lower limit at 7.
IF ((FLUX.LT.6.).AND. (X.LT.70.)) FLUX=6.
IF ((FLUX.LT.7.).AND. (X.GT.70.)) FLUX=7.
C
TEST=ALCT
C
RETURN
END
C
REAL FUNCTION FSUM (DC, BSIN, BCOS, ALCT, MDIM, NDIM, K)
C Determines the sum of a Fourier series
C
DIMENSION BSIN (MDIM, NDIM), BCOS (MDIM, NDIM), DC (NDIM)
C
FSUM=0.
C
DO 10 L=1, MDIM
FSUM=FSUM+BSIN (L, K) *SIN (L*3.141592*ALCT/12.)+
1 BCOS (L, K) *COS (L*3.141592*ALCT/12.)
10 CONTINUE
C
FSUM=FSUM+DC (K)
C
RETURN
END
SUBROUTINE WRT3D (LUN, IRECMX, ID, RID, CHID, ARRAY, IDIM, JDIM, KDIM,
1 ITMDIM)
C
PROGRAMMER: BOB SPIRO DATE: 6/26/88
C
PURPOSE: THIS SUBROUTINE WRITES 3-D ARRAYS INTO THE STANDARD
```

```
MSM44160
MSM44170
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MSM44250
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MSM44270
MSM44280
MSM44290
MSM44300
MSM44310
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MSM44710
MSM44720
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```
C MAGNETOSPHERIC SPECIFICATIONS MODEL FILE FORMAT. MSM44800
C CHARACTER*80 CHID MSM44810
  DIMENSION ID(20),RID(20),ARRAY(IDIM,JDIM,KDIM) MSM44820
C IRECL =IDIM*JDIM + 2*80 MSM44830
  OPEN (UNIT=LUN,ACCESS='DIRECT',RECL=IRECL,STATUS='UNKNOWN') MSM44840
C ID(12)=KDIM MSM44850
C WRITE THE ARRAY MSM44860
C DO 10, K=1, KDIM MSM44870
C CALCULATE THE RECORD NUMBER MSM44880
C ID(13)=K MSM44890
  IREC = (IRECMX-1)*KDIM + K MSM44900
  WRITE (LUN,REC=IREC) ID,RID,CHID, MSM44910
2 ((ARRAY(I,J,K),I=1,IDIM),J=1,JDIM) MSM44920
10 CONTINUE MSM44930
C CLOSE (LUN) MSM44940
C RETURN MSM44950
END MSM44960
C SUBROUTINE RDHDR(LUN,FILNAM,IRECMX,ID,RID,CHID,IDIM,JDIM,ITMDIM) MSM44970
C PROGRAMMER: BOB SPIRO DATE: 6/26/88 MSM44980
C PURPOSE: THIS ROUTINE READS THE HEADER OF THE STANDARD MSM44990
C MAGNETOSPHERIC SPECIFICATIONS MODEL FILE FORMAT. MSM45000
C CHARACTER CHID*80, FILNAM*6 MSM45010
  DIMENSION ID(20),RID(20) MSM45020
C OPEN THE FILE MSM45030
C IRECL = IDIM*JDIM + 2*80 MSM45040
  OPEN (UNIT=LUN,ACCESS='DIRECT',RECL=IRECL,STATUS='OLD') MSM45050
C READ THE HEADER MSM45060
C READ (LUN,REC=IRECMX) ID,RID,CHID MSM45070
C CLOSE (LUN) MSM45080
C RETURN MSM45090
END MSM45100
C SUBROUTINE READ3D(LUN,FILNAM,LREC,IDIM,JDIM,KDIM,ITMDIM,ID,RID, MSM45110
2 CHID,ARRAY) MSM45120
C PROGRAMMER: BOB SPIRO DATE: 6/26/88 MSM45130
C PURPOSE: THIS SUBROUTINE READS A LOGICAL RECORD FROM THE MSM45140
C STANDARD MAGNETOSPHERIC SPECIFICATIONS MODEL FILE FORMAT. MSM45150
C CHARACTER CHID*80, FILNAM*6 MSM45160
  DIMENSION ARRAY(IDIM,JDIM,KDIM) MSM45170
  DIMENSION ID(20),RID(20) MSM45180
  DIMENSION ID(20),RID(20) MSM45190
  DIMENSION ID(20),RID(20) MSM45200
  DIMENSION ID(20),RID(20) MSM45210
  DIMENSION ID(20),RID(20) MSM45220
  DIMENSION ID(20),RID(20) MSM45230
  DIMENSION ID(20),RID(20) MSM45240
  DIMENSION ID(20),RID(20) MSM45250
  DIMENSION ID(20),RID(20) MSM45260
  DIMENSION ID(20),RID(20) MSM45270
  DIMENSION ID(20),RID(20) MSM45280
  DIMENSION ID(20),RID(20) MSM45290
  DIMENSION ID(20),RID(20) MSM45300
  DIMENSION ID(20),RID(20) MSM45310
  DIMENSION ID(20),RID(20) MSM45320
  DIMENSION ID(20),RID(20) MSM45330
  DIMENSION ID(20),RID(20) MSM45340
  DIMENSION ID(20),RID(20) MSM45350
  DIMENSION ID(20),RID(20) MSM45360
  DIMENSION ID(20),RID(20) MSM45370
  DIMENSION ID(20),RID(20) MSM45380
  DIMENSION ID(20),RID(20) MSM45390
  DIMENSION ID(20),RID(20) MSM45400
  DIMENSION ID(20),RID(20) MSM45410
  DIMENSION ID(20),RID(20) MSM45420
  DIMENSION ID(20),RID(20) MSM45430
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```
C
C      OPEN THE FILE
C
C      IRECL = IDIM*JDIM + 2*80
C      OPEN (UNIT=LUN,ACCESS='DIRECT',RECL=IRECL,STATUS='OLD')
C
C      READ THE ARRAY
C
C      DO 10, K=1, KDIM
C
C          CALCULATE THE RECORD NUMBER
C
C          IREC = (LREC-1)*KDIM + K
C          READ (LUN,REC=IREC) ID,RID,CHID,
10 2          ((ARRAY(I,J,K),I=1,IDIM),J=1,JDIM)
C      CONTINUE
C
C      CLOSE (LUN)
C
C      RETURN
C      END
C      SUBROUTINE SETALM(ALAM,IEMAX,IEDIM,IFLAV,ALMDEL)
C
C      THIS SUBROUTINE READS THE NUMBER OF ENERGY CHANNELS AND THEIR
C      ENERGIES AT GEOSYNCHRONOUS ORBIT AND CALCULATES THE ENERGY
C      INVARIANTS NEEDED TO RUN THE PROGRAM.
C      THE INPUT ENERGY IS IN EV AND MUST BE IN ASCENDING ORDER SO THAT THE
C      ALMDEL VARIABLES CAN BE CORRECTLY CALCULATED.
C
C      COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LIUDAT,LUHDYE,
1  LUDK,LUFLXB,LUEBEG,LUSHFT,LUIFX,LUEAVG,LUFLSM,LUFLX,
2  LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
3  LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C
C      PARAMETER (VM6=7.0)
C
C      DIMENSION ALAM(IEDIM)
C      DIMENSION IFLAV(IEDIM)
C      DIMENSION ALMDEL(IEDIM)
C      DIMENSION NUM(3)
C
C      OPEN (UNIT=LUENCH,FILE='ENCHAN',STATUS='OLD')
C
C      READ (LUENCH,*) IEMAX
C      IF (IEMAX.GT.IEDIM) THEN
C          WRITE(6,*) ' NUMBER OF ENERGY CHANNELS GREATER THAN MAXIMUM'
C          STOP
C      ENDIF
C
C      DO 5 N=1,3
C          NUM(N)=0
5  CONTINUE
C
C      DO 10 IE=1,IEMAX
C          READ (LUENCH,*) IFLAV(IE),ENCHNL
C          ISP=IFLAV(IE)
C          NUM(ISP)=NUM(ISP)+1
C          ALAM(IE)= ENCHNL/VM6
C          IF (IFLAV(IE).EQ.1)ALAM(IE)=-ALAM(IE)
C          IF (NUM(ISP).GT.1.AND.(ABS(ALAM(IE)).LT.ABS(ALAM(IE-1)))) THEN
C              WRITE(6,*) ' ENERGY CHANNELS NOT IN INCREASING ORDER'
C              STOP
C          ENDIF
10 CONTINUE
```

MSM45440
MSM45450
MSM45460
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MSM45990
MSM46000
MSM46010
MSM46020
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MSM46040
MSM46050
MSM46060
MSM46070

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C
C COMPUTE ALMDEL
  DO 20 IE=1, IEMAX
    ISP=IFLAV (IE)
    IF (NUM (ISP) .GE. 2) THEN
      IF (IE.EQ.1.OR.IFLAV (IE-1) .NE. ISP) THEN
        ALMMIN=0.
      ELSE
        ALMMIN=(ALAM (IE-1)+ALAM (IE) ) /2.
      END IF
C
    IF (IE.EQ. IEMAX.OR. IFLAV (IE+1) .NE. ISP) THEN
      ALMMAX=1.5*ALAM (IE) - .5*ALAM (IE-1)
    ELSE
      ALMMAX=(ALAM (IE) +ALAM (IE+1) ) /2.
    END IF
C
    ALMDEL (IE) =ABS (ALMMAX) -ABS (ALMMIN)
C
  END IF
20 CONTINUE
C
C
  WRITE (6, 997)
997  FORMAT (1H1, 'K  ALAM (K)           ALMDEL (K) ' )
    DO 30 K=1, IEMAX
      WRITE (6, 996) K, ALAM (K) , ALMDEL (K)
996  FORMAT (1H , I3, 2F15.4)
30   CONTINUE
    CLOSE (LUENCH)
    RETURN
  END
  SUBROUTINE BNDSET (LATDIM, LTDIM, IEDIM, ITMDIM, ITMMAX,
1   IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR, FLXNRG, FLXKP, FLXMAT,
2   NAUGEL, TIMTAG, BNDLOC, IFLAV, AUGPAR, R, P, VM, ETA, ETABND,
3   FLXBND, ALAM, ALMDEL, IEMAX)
C
C
C VERSION: 1.00           DATE: 09.02.89
C                          05.08.90
C
C PURPOSE: SUBROUTINE TO COMPUTE BNDY PLASMA DISTRIBUTION BASED ON
C           STATISTICAL (KP-BASED) DATA. THE
C           GENERAL SCHEME IS DESCRIBED IN SECTION 2.5.5 OF
C           CONTRACT #F19c28-87-K-0001 FINAL REPORT.
C
C INPUT:
C   LATDIM      NUMBER OF LATITUDINAL GRID PTS      MSM46560
C   LTDIM       NUMBER OF LOCAL TIME GRID POINTS (INCL WRAP) MSM46570
C   IEDIM       NUMBER OF ENERGY SPECIES           MSM46580
C   ITMDIM      MAX NUMBER OF TEMPORAL GRID PTS     MSM46590
C   ITMMAX      ACTUAL NUMBER                       MSM46600
C               THIS FUN                           MSM46610
C   IRDIM       NUMBER OF R BINS IN FLXMAT ARRAY     MSM46620
C   NRGDIM      NUMBR OF LOGARITHMICALLY SPACE ENERGY BINS MSM46630
C               IN FLXMAT ARRAY                   MSM46640
C   KPDIM       NUMBER OF KP BINS IN FLXMAT ARRAY     MSM46650
C   KPPLUS      AUGMENTED KP DIMENSION OF FLXMAT (KPDIM+2) MSM46660
C   ISPDIM      NUMBER OF MASS SPECIES IN FLXMAT ARRAY MSM46670
C   FLXR        LOG (R) VALUES FOR WHICH FLXMAT IS COMPUTED (RE) MSM46680
C   FLXNRG      LOG OF ENERGY VALUES FOR WHICH FLXMAT IS
C               COMPUTED (LOG10 (EV))              MSM46700
C   FLXKP       KP VALUES FOR WHICH FLXMAT IS COMPUTED MSM46710

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C      FLXMAT      ARRAY OF KP-DEPENDENT LOG(FLUX) VALUES      MSM46720
C      AS FCN OF R AND ENERGY (LOG10(PARTICLES/CM**2/      MSM46730
C      S/SR/EV))      MSM46740
C      NAUGEL      DIMENSION OF AUGMENTED PARRAY, AUGPAR      MSM46750
C      TIMTAG      STRING GIVING TIMES FOR WHICH E AND B FIELD      MSM46760
C      VALUES ARE CALCULATED      MSM46770
C      BNDLOC      ARRAY GIVING BNDY LOCATIONS      MSM46780
C      IFLAV      STRING THAT GIVES WHAT KIND OF PARTICLE      MSM46790
C      IFLAV=1 FOR ELECTRONS, IFLAV=2 FOR H+,      MSM46800
C      IFLAV=3 FOR O+ IONS      MSM46810
C      AUGPAR      AUGMENTED PARAMETER ARRAY      MSM46820
C      R      RADIAL DISTANCE TO BMIN PT (RE)      MSM46830
C      P      HOUR ANGLE MEASURED EASTWARD FROM NOON IN X-Y      MSM46840
C      PLANE OF MAGNETOSPHERE (RADIANS)      MSM46850
C      VM      (FLUX TUBE VOLUME)**-2/3 (RE/NT)**-2/3      MSM46860
C      ETA      INVARIANT DENSITY ARRAY      MSM46870
C      ALAM      STRING GIVING ENERGY INVARIANTS      MSM46880
C      ALMDEL      STRING GIVING ENERGY INVARIANT INTERVALS      MSM46890
C      IEMAX      NUMBER OF ENERGY SPECIES FOR RUN      MSM46900
C      MSM46910
C      MSM46920
C      MSM46930
C      OUTPUT:      MSM46940
C      ETABND      BOUNDARY ETA DISTRIBUTION      MSM46950
C      FLXBND      BOUNDARY FLUX VALUES      MSM46960
C      MSM46970
C      MSM46980
C      MSM46990
C      PROGRAMMER: R.W. SPIRO      MSM47000
C      MSM47010
C      MSM47020
C      MSM47030
C      MSM47040
C      COMMON /IRDREC/ IRECPT, IRECEB, IRDBEG      MSM47050
C      MSM47060
C      INTEGER IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST, DDST,      MSM47070
C      1 EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,      MSM47080
C      2 GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,      MSM47090
C      3 STAND, PCP, DEQDT, IPATT      MSM47100
C      MSM47110
C      COMMON /ARINDX/IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST,      MSM47120
C      1 EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,      MSM47130
C      2 GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,      MSM47140
C      3 STAND, PCP, IPATT, DDST, DEQDT      MSM47150
C      MSM47160
C      MSM47170
C      DIMENSION VM(LATDIM, LTDIM, ITMDIM), ETA(LATDIM, LTDIM, IEDIM)      MSM47180
C      DIMENSION R(LATDIM, LTDIM, ITMDIM), P(LATDIM, LTDIM, ITMDIM)      MSM47190
C      DIMENSION BNDLOC(LTDIM, ITMDIM), TIMTAG(ITMDIM), IFLAV(IEDIM)      MSM47200
C      DIMENSION ETABND(LTDIM, IEDIM, ITMDIM), ALAM(IEDIM), ALMDEL(IEDIM)      MSM47210
C      DIMENSION FLXBND(LTDIM, IEDIM, ITMDIM)      MSM47220
C      DIMENSION AUGPAR(NAUGEL, ITMDIM)      MSM47230
C      MSM47240
C      DIMENSION FLXMAT(IRDIM, NRGDIM, KPPLUS, ISPDIM)      MSM47250
C      DIMENSION FLXR(IRDIM), FLXNRG(NRGDIM), FLXKP(KPDIM)      MSM47260
C      MSM47270
C      DATA VM13 /2.182/      MSM47280
C      MSM47290
C      PI=ATAN2(0., -1.)      MSM47300
C      WRITE(6, *) 'IN BNDSET'      MSM47310
C      MSM47320
C      MAIN DO LOOPS      MSM47330
C      MSM47340
C      ITBEG=1      MSM47350

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C          ITEND=ITMMAX
C          VMBND=VM13
C          RBND=13.
C          PBND=PI
C
C LOOP OVER TIME LABELS
C   DO 5 IT=ITBEG,ITEND
C
C LOOP OVER LOCAL TIME COORDINATE
C   DO 10 J=2,LTDIM-2
C
C           BI=BNDLOC(J,IT)
C           BJ=J
C           BT=IT
C
C LOOP OVER ENERGY SPECIES
C   DO 20 K=1,IEMAX
C       ISP=IFLAV(K)
C       IF(IFLAV(K).EQ.2) ATOMWT=1.
C       IF(IFLAV(K).EQ.3) ATOMWT=16.
C
C
C
C
C           FKP=AUGPAR(KP,IT)
C           ENRG=VMBND*ABS(ALAM(K))
C
C   DEBUG 590
C       IF(J.EQ.2) THEN
C           WRITE(6,*)'IT,ISP,FKP,RBND,PBND,ENRG',IT,ISP,FKP,RBND,
C   2           PBND,ENRG
C       END IF
C
C           FLUX=FLXVAL(ISP,FKP,RBND,PBND,ENRG,IRDIM,
C   2           NRGDIM,KPDIM,KPPLUS,ISPDIM,FLXMAT,FLXR,
C   3           FLXNRG,FLXKP)
C
C
C
C
C           FLXBND(J,K,IT)=FLUX
C
C   CONVERT FLUX TO INVARIANT DENSITY
C
C       IF(ALAM(K).LT.0.) THEN
C           ETABND(J,K,IT)=FLUX*ALMDEL(K)/7.392E-16/
C   2           Sqrt(ABS(ALAM(K)))/VMBND
C       ELSE
C           ETABND(J,K,IT)=FLUX*ALMDEL(K)*Sqrt(ATOMWT)/1.731E-17/
C   2           Sqrt(ABS(ALAM(K)))/VMBND
C       END IF
C
C
C   20   CONTINUE
C
C   10   CONTINUE
C
C   DO 15 K=1,IEMAX
C       ETABND(1,K,IT)=ETABND(LTDIM-3,K,IT)
C       ETABND(LTDIM-1,K,IT)=ETABND(2,K,IT)
C       ETABND(LTDIM,K,IT)=ETABND(3,K,IT)
C       FLXBND(1,K,IT)=FLXBND(LTDIM-3,K,IT)
C       FLXBND(LTDIM-1,K,IT)=FLXBND(2,K,IT)

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FLXBND (LTDIM, K, IT) = FLXBND (3, K, IT)
15 CONTINUE
C
  5 CONTINUE
C
C
  RETURN
  END
  FUNCTION CFACT (IDIM, JDIM, IEDIM, IUSE, JUSE, IEUSE, ETAEQK, ALAM,
2          PWR, ETA, ALAME)
C
C  FUNCTION SUBPROGRAM TO CALCULAT CORRECTION FACTOR BASED ON
C  EQUILIBRIUM ETA VALUE.
C
  CFACT = (1. - ETAEQK / ETA)
  RETURN
  END
  SUBROUTINE SETSCT (L, ISEC, IEDIM, LTDIM, ITMDIM, LATDIM, FKP, ALAM,
2          ALOCT, SCTFRC, IEMAX)
C
C  VERSION 2.00                      DATE: 09.11.89
C
C  PURPOSE:
C  SUBROUTINE TO COMPUTE SPECIES-DEPENDENT PITCH
C  ANGLE SCATTERING EFFICIENCY SCTFRC (IE, J, L).
C
C  PROGRAMMER: R.W. SPIRO
C
C  REF: SECTION 2.6.3 OF THE FINAL REPORT FOR
C  CONTRACT #F19628-87-K-0001
C
  DIMENSION SCTFRC (IEDIM, LTDIM, ITMDIM)
  DIMENSION ALOCT (LATDIM, LTDIM), ALAM (IEDIM)
C
C  PI = ATAN2 (0., -1.)
C  LOOP OVER ALL LOCAL TIME GRID LINES
  DO 10 J = 1, LTDIM
C
C  LOOP OVER ALL ENERGY SPECIES
  DO 20 IE = 1, IEMAX
    IF (ALAM (IE) .LT. 3000.) THEN
C
C      USE KP DEPENDENT FORM, INDEPENDENT OF LOCAL TIME
      IF (FKP .LE. 1.5) THEN
        SCTFRC (IE, J, L) = .333
      ELSE IF (FKP .GT. 1.5 .AND. FKP .LE. 2.5) THEN
        SCTFRC (IE, J, L) = .333 * (2.5 - FKP) + .667 * (FKP - 1.5)
      ELSE
        SCTFRC (IE, J, L) = .667
      END IF
C
    ELSE
C
C      USE LOCAL TIME DEPENDENT FORM, INDEPENDENT OF KP
      IF (ALOC (LATDIM, J) .GE. PI / 2. .AND. ALOCT (LATDIM, J) .LE.
2          3. * PI / 2.) THEN
        SCTFRC (IE, J, L) = 0.1 / SQRT (ABS (ALAM (IE)) / 3000.)
      ELSE
2          SCTFRC (IE, J, L) = (0.1 + 0.9 * COS (ALOC (LATDIM, J))) /
          SQRT (ABS (ALAM (IE)) / 3000.)
      END IF
C
    END IF
  END DO
END DO
END IF
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C		MSM48640
	20 CONTINUE	MSM48650
	10 CONTINUE	MSM48660
C		MSM48670
C		MSM48680
	RETURN	MSM48690
	END	MSM48700
	SUBROUTINE PFIX(P1,P2,P3,P4,P5)	MSM48710
C		MSM48720
C	PURPOSE: SUBROUTINE TO ADJUST MODULUS OF P2 AND P3 TO MATCH P1.	MSM48730
C	ON OUTPUT P4 CORRESPONDS TO P2, P5 TO P3	MSM48740
C		MSM48750
C	VERSION 1.00	MSM48760
C	DATE: 09.04.89	MSM48770
C		MSM48780
C	PROGRAMMER: R.W. SPIRO	MSM48790
C		MSM48800
	PI=ATAN2(0.,-1.)	MSM48810
C		MSM48820
	P4=P2	MSM48830
	P5=P3	MSM48840
C		MSM48850
	IF (ABS(P2-P3).GT.PI) THEN	MSM48860
	IF (P2.LT.P3) THEN	MSM48870
	P4=P2+2.*PI	MSM48880
	ELSE	MSM48890
	P5=P3+2.*PI	MSM48900
	END IF	MSM48910
C		MSM48920
	IF (P1.LT.PI) THEN	MSM48930
	P4=P4-2.*PI	MSM48940
	P5=P5-2.*PI	MSM48950
	END IF	MSM48960
C		MSM48970
	END IF	MSM48980
C		MSM48990
C		MSM49000
	RETURN	MSM49010
	END	MSM49020
	SUBROUTINE INITAL(LL,LATDIM,LTDIM,IEDIM,ITMDIM,IRDIM,	MSM49030
	2 NRGDIM,KPDIM,KPPLUS,ISPDIM,FLXR,FLXNRG,FLXKP,	MSM49040
	3 FLXMAT,IPLAV,FKP,R,P,VM,ETA,ETABEG,ALAM,ALMDEL,	MSM49050
	4 BNDLOC,AZERO,BZERO,	MSM49060
	5 CZERO,IEMAX)	MSM49070
C		MSM49080
C		MSM49090
C	VERSION: 1.00	MSM49100
C	DATE: 10.10.89	MSM49110
C		MSM49120
C	PURPOSE: SUBROUTINE TO COMPUTE INITIAL PLASMA DISTRIBUTION BASED ON	MSM49130
C	EITHER STATISTICAL (KP-BASED) DATA OR RESULTS	MSM49140
C	FROM PREVIOUS RUNS. THE GENERAL SCHEME IS DESCRIBED IN	MSM49150
C	SECTION 2.5.4 OF THE FINAL REPORT FOR	MSM49160
C	CONTRACT #F19628-87-K-0001	MSM49170
C		MSM49180
C	INPUT:	MSM49190
C	LL TEMPORAL GRID INDEX	MSM49200
C	LATDIM NUMBER OF LATITUDINAL GRID PTS	MSM49210
C	LTDIM NUMBER OF LOCAL TIME GRID POINTS (INCL WRAP)	MSM49220
C	IEDIM MAX NUMBER OF ENERGY SPECIES	MSM49230
C	ITMDIM MAX NUMBER OF TEMPORAL GRID PTS	MSM49240
C	IRDIM R DEPTH IN FLXMAT ARRAY	MSM49250
C	NRGDIM ENERGY DEPTH IN FLXMAT ARRAY	MSM49260
C	KPDIM KP DEPTH IN FLXMAT ARRAY	MSM49270
C	KPPLUS AUGMENTED KP DIMENSION OF FLXMAT (KPDIM+2)	

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C      ISPDIM      NUMBER OF MASS SPECIES      MSM49280
C      FLXR        ALOG10(R) VALUES FOR WHICH FLXMAT ARRAY IS      MSM49290
C                  CALCULATED      MSM49300
C      FLXNRG      ALOG10(ENERGY) VALUES FOR WHICH FLXMAT ARRAY IS      MSM49310
C                  CALCULATED      MSM49320
C      FLXKP      KP VALUES FOR WHICH FLXMAT ARRAY IS CALCULATED      MSM49330
C      FLXMAT      ALOG10(FLUX) FOR A GIVEN R,ENERGY, AND KP      MSM49340
C      IFLAV      STRING THAT GIVES WHAT KIND OF PARTICLE      MSM49350
C                  IFLAV=1 FOR ELECTRONS, IFLAV=2 FOR H+,      MSM49360
C                  IFLAV=3 FOR O+ IONS      MSM49370
C      FKP        FLOATING PT KP VALUE      MSM49380
C      R          RADIAL DISTANCE TO BMIN PT (RE)      MSM49390
C      P          HOUR ANGLE MEASURED EASTWARD FROM NOON IN X-Y      MSM49400
C                  PLANE OF MAGNETOSPHERE (RADIANS)      MSM49410
C      VM         (FLUX TUBE VOLUME)**-2/3 (RE/NT)**-2/3      MSM49420
C      ETA        INVARIANT DENSITY ARRAY      MSM49430
C      ALAM       STRING GIVING ENERGY INVARIANTS      MSM49440
C      ALMDEL     STRING GIVING ENERGY INVARIANT INTERVALS      MSM49450
C      BNDLOC     ARRAY GIVING BNDY LOCATIONS      MSM49460
C      AZERO      STATISTICAL MODEL WEIGHTING PARAMETER      MSM49470
C      BZERO      OLD RESULTS WEIGHTING PARAMETER      MSM49480
C      CZERO      TRACEBACK WEIGHTING PARAMETER      MSM49490
C      IEMAX      NUMBER OF PARTICLE SPECIES USED      MSM49500
C                  MSM49510
C                  MSM49520
C      WEIGHTING PARAMETERS SET IN DATA STATEMENTS      MSM49530
C      GRZERO     PARAMETER TO SPECIFY R GAUSSIAN WIDTH      MSM49540
C      GPZERO     PARAMETER TO SPECIFY P GAUSSIAN WIDTH      MSM49550
C      GLZERO     PARAMETER TO SPECIFY ALAM GAUSSIAN WIDTH      MSM49560
C                  MSM49570
C                  MSM49580
C      OUTPUT:    MSM49590
C      ETABEG     INITIAL ETA DISTRIBUTION      MSM49600
C                  MSM49610
C                  MSM49620
C                  MSM49630
C      PROGRAMMER: R.W. SPIRO      MSM49640
C                  MSM49650
C                  MSM49660
C                  MSM49670
C                  MSM49680
C                  COMMON /IRDREC/ IRECPT, IRECEB, IRDBEG      MSM49690
C                  MSM49700
C                  MSM49710
C                  DIMENSION VM(LATDIM, LTDIM, ITMDIM), ETA(LATDIM, LTDIM, IEDIM)      MSM49720
C                  DIMENSION R(LATDIM, LTDIM, ITMDIM), P(LATDIM, LTDIM, ITMDIM)      MSM49730
C                  DIMENSION IFLAV(IEDIM)      MSM49740
C                  DIMENSION ETABEG(LATDIM, LTDIM, IEDIM), ALAM(IEDIM), ALMDEL(IEDIM)      MSM49750
C                  DIMENSION BNDLOC(LTDIM, ITMDIM)      MSM49760
C                  MSM49770
C                  DIMENSION FLXMAT(IRDIM, NRGDIM, KPPLUS, ISPDIM)      MSM49780
C                  DIMENSION FLXR(IRDIM), FLXNRG(NRGDIM), FLXKP(KPDIM)      MSM49790
C                  MSM49800
C                  DATA GRZERO/.05/, GPZERO/.05/, GLZERO/.3/      MSM49810
C                  MSM49820
C                  MSM49830
C                  PI=ATAN2(0., -1.)      MSM49840
C                  MSM49850
C      INITIALIZE ETABEG ARRAY      MSM49860
C      DO 2 K=1, IEMAX      MSM49870
C      DO 4 J=1, LTDIM      MSM49880
C      DO 6 I=1, LATDIM      MSM49890
C      ETABEG(I, J, K)=0.      MSM49900
C      6      CONTINUE      MSM49910
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4 CONTINUE
2 CONTINUE
C
C MAIN DO LOOPS
C
DO 10 K=1,IEMAX
ISP=IFLAV(K)
IF(IFLAV(K).EQ.2) ATOMWT=1.
IF(IFLAV(K).EQ.3) ATOMWT=16.
DO 20 J=1,LTDIM
IBEG=BNDLOC(J,LL)
DO 30 I=IBEG,LATDIM
SUM1=0.
SUM2=0.
ENRG=ABS(ALAM(K))*VM(I,J,LL)
C
C
C
C PREVIOUS RESULT COMPONENT OF SUM
IF(ETA(I,J,K).GT.0.) THEN
IF(ALAM(K).LT.0.) THEN
FLXOLD=7.392E-16*SQRT(ABS(ALAM(K)))*VM(I,J,LL)*
2 ETA(I,J,K)/ALMDEL(K)
ELSE
FLXOLD=1.731E-17*SQRT(ABS(ALAM(K)))*VM(I,J,LL)*
2 ETA(I,J,K)/SQRT(ATOMWT)/ALMDEL(K)
END IF
C
SUM1=SUM1+BZERO
SUM2=SUM2+BZERO*FLXOLD
C
END IF
C
C
C STATISTICAL (KP-BASED) MODEL COMPONENT OF SUM
C
SUM1=SUM1+AZERO
SUM2=SUM2+AZERO*FLXVAL(ISP,FKP,R(I,J,LL),P(I,J,LL),ENRG,
2 IRDIM,NRGDIM,KPDIM,KPPLUS,ISPDIM,FLXMAT,FLXR,
3 FLXNRG,FLXKP)
C
C
C CALCULATE DIFFERENTIAL FLUX
C
IF(SUM1.GT.0.) THEN
FLUX=SUM2/SUM1
ELSE
FLUX=0.
END IF
C
C
C CONVERT FLUX TO INVARIANT DENSITY
C
IF(ALAM(K).LT.0.) THEN
2 ETABEG(I,J,K)=FLUX*ALMDEL(K)/7.392E-16/
SQRT(ABS(ALAM(K)))/VM(I,J,LL)
ELSE
2 ETABEG(I,J,K)=FLUX*ALMDEL(K)*SQRT(ATOMWT)/1.731E-17/
SQRT(ABS(ALAM(K)))/VM(I,J,LL)
END IF
C
C
C 30 CONTINUE
```

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DO 32 I=1, IBEG-1
  ETABEG(I, J, K) = ETABEG( IBEG, J, K)
32  CONTINUE
C
C
20  CONTINUE
10  CONTINUE
C
C
  RETURN
  END
  SUBROUTINE TIMINC( ITIME, ITMNEW, IINC )
C
C  VERSION 2.00                      DATE: 09.06.89
C
C  PURPOSE:  INCREMENT TIME FOR NEXT E AND B FIELD RECORD
C
C  PROGRAMMER:  R.W. SPIRO
C
C
C      INTEGER IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST, DDST,
1      EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2      GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3      STAND, PCP, DEQDT, IPATT
C
C      COMMON /ARINDX/ IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST,
1      EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2      GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3      STAND, PCP, IPATT, DDST, DEQDT
C
C      DIMENSION ITIME(3), ITMNEW(3), IINC(3)
C
C      ITMNEW( IYEAR ) = ITIME( IYEAR )
C      ITMNEW( IDAY ) = ITIME( IDAY )
C
C      ITMNEW( ISECND ) = ITIME( ISECND ) + IINC( ISECND )
C
C      IF( ITMNEW( ISECND ) .GE. 86400 ) THEN
C          ITMNEW( ISECND ) = MOD( ITMNEW( ISECND ), 86400 )
C          ITMNEW( IDAY ) = ITMNEW( IDAY ) + 1
C
C      -----> CHANGE BEFORE THE YEAR 2100 *****
C
C      IF( ITMNEW( IDAY ) .GT. 365 .AND. MOD( ITIME( IYEAR ), 4 ) .NE. 0 ) THEN
C          ITMNEW( IDAY ) = MOD( ITMNEW( IDAY ), 365 )
C          ITMNEW( IYEAR ) = ITMNEW( IYEAR ) + 1
C      ELSEIF( ITMNEW( IDAY ) .GT. 366 .AND. MOD( ITIME( IYEAR ), 4 ) .EQ. 0 ) THEN
C          ITMNEW( IDAY ) = MOD( ITMNEW( IDAY ), 366 )
C          ITMNEW( IYEAR ) = ITMNEW( IYEAR ) + 1
C      ENDIF
C
C      END IF
C
C      RETURN
C      END
C
C
C      SUBROUTINE SETREF( LATDIM, LTDIM, IEDIM, ITMDIM, ITMMAX,
2      IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, TIMTAG, TVAL, IFLAV,
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3          VM, R, P, BNDLOC, ALAM, ALMDEL, FLXMAT, FLXR, FLXNRG,
4          FLXKP, FLXREF, IEMAX)
C
C  VERSION 2.00                      DATE: 10.10.89
C                                     05.08.90
C
C  PURPOSE:
C    SUBROUTINE TO SET UPPER LIMIT REFERENCE FLUX FOR TIME TVAL
C
C  PROGRAMMER: R.W. SPIRO
C
C  REF:  SECTION 2.5.6 OF THE FINAL REPORT FOR
C        CONTRACT #F19628-87-K-0001
C
C    LATDIM      NUMBER OF LATITUDINAL GRID SPACES
C    LTDIM       NUMBER OF LOCAL TIME (LONGITUDINAL) GRID SPACES
C    IEDIM       MAXIMUM NUMBER OF ENERGY SPECIES
C    ITMDIM      MAXIMUM NUMBER OF TEMPORAL STEPS
C    ITMMAX      ACTUAL NUMBER OF TEMPORAL STEPS FOR THIS RUN
C    IRDIM       R DIMENSION OF FLXMAT ARRAYS
C    NRGDIM      ENERGY DIMENSION OF FLXMAT ARRAYS
C    KPDIM       KP DIMENSION OF FLXMAT ARRAYS
C    KPPLUS      KP DIMENSION OF AUGMENTED FLXMAT ARRAYS
C                (KPPLUS=KPDIM+2)
C    ISPDIM      PLASMA MASS SPECIES DIMENSION
C    TIMTAG      VECTOR GIVING TIME AT WHICH E AND B FIELD PARAMETERS
C                ARE COMPUTED (SECONDS)
C    TVAL        CURRENT TIME (SECONDS)
C    IFLAV       MASS SPECIES FOR A GIVEN PARTICLE ENERGY SPECIES
C                1=ELECTRONS, 2=H+ IONS, 3=O+ IONS
C    VM          (FLUX TUBE VOLUME)**(-2/3)
C    R           ARRAY GIVING RADIAL DISTANCE OF GRID POINTS IN
C                MAGNETOSPHERIC EQUATORIAL PLANE (RE)
C    P           LOCAL TIME HOUR ANGLE MEASURED EASTWARD FROM NOON
C                OF GRID PTS IN MAGNETOSPHERIC EQUATORIAL PLANE
C                (RADIAN)
C    BNDLOC      LOCATION OF OUTER BOUNDARY OF DETAILED MODEL
C    ALAM        ENERGY INVARIANT VECTOR (EV (RE/NT)**2/3)
C    ALMDEL      WIDTH OF ENERGY INVARIANT CHANNELS
C    FLXMAT      ARRAY OF EMPIRICAL FLUXES AS FUNCTION OF R, ENERGY,
C                AND KP
C    FLXR        R VALUES AT WHICH FLXMAT IS CALCULATED
C    FLXNRG      ENERGY VALUES AT WHICH FLXMAT IS CALCULATED
C    FLXKP       KP VALUES AT WHICH FLXMAT IS CALCULATED
C    IEMAX       ACTUAL NUMBER OF ENERGY CHANNELS USED
C
C
C  OUTPUT:
C    FLXREF      UPPER LIMIT REFERENCE FLUX (LOG(#/CM**2 S EV))
C
C    DIMENSION TIMTAG (ITMDIM), ALAM (IEDIM), ALMDEL (IEDIM)
C    DIMENSION VM (LATDIM, LTDIM, ITMDIM), R (LATDIM, LTDIM, ITMDIM)
C    DIMENSION P (LATDIM, LTDIM, ITMDIM), FLXREF (LATDIM, LTDIM, IEDIM)
C    DIMENSION IFLAV (IEDIM)
C    DIMENSION BNDLOC (LTDIM, ITMDIM)
C    DIMENSION FLXMAT (IRDIM, NRGDIM, KPPLUS, ISPDIM)
C    DIMENSION FLXR (IRDIM), FLXNRG (NRGDIM), FLXKP (KPDIM)
C
C  CALCULATE NORMALIZED TIME BT
C    BT=TNORML (TVAL, TIMTAG, ITMDIM)
C    ITT=BT
C    FT=REAL (ITT)

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C
C
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C
C
C      DIMENSION R(LATDIM,LTDIM,ITMDIM),ALOCT(LATDIM,LTDIM)
C
C      PI=ATAN2(0.,-1.)
C
C
C
C
C
C
C
C
C      SEARCH GRID AND TRY TO LOCALIZE (RVAL,XLT) WITHIN A GRID SQUARE
C      DO 30 J=2,LTDIM-2
C          JJ=J
C
C          DO 40 I=2,LATDIM
C              II=I
C
C      GET XLT,ALOCT(I,J), AND ALOCT(I,J+1) IN SAME MODULUS
C          CALL PFIX(XLT,ALOCT(I,J),ALOCT(I,J+1),P4,P5)
C          WRITE(6,*) I,J,RVAL,R(I-1,J,LL),R(I,J,LL),XLT,P4,P5
C
C          IF(RVAL.LE.R(I-1,J,LL)
C      2      .AND.
C      3      RVAL.GT.R(I,J,LL)
C      4      .AND.
C      5      XLT.GE.P4
C      6      .AND.
C      7      XLT.LT.P5)
C      8      THEN
C          GO TO 50
C          END IF
C
C
C      40 CONTINUE
C      30 CONTINUE
C
C      WRITE(6,*) 'STOPPING IN EFLOC'
C      WRITE(6,*) 'UNABLE TO FIND (BI,BJ)'
C      WRITE(6,*) 'RVAL= ',RVAL,' XLT= ',XLT
C      STOP
C
C
C
C      50 CONTINUE
C
C      DO 45 IK=2,LATDIM
C          IIK=IK
C          IF(RVAL.LE.R(IK-1,J+1,LL).AND.RVAL.GT.R(IK,J+1,LL)) GO TO 60
C      45 CONTINUE
C
C      WRITE(6,*) 'STOPPING IN EFLOC'
C      WRITE(6,*) 'UNABLE TO FIND (BI,BJ)'
C      WRITE(6,*) 'RVAL= ',RVAL,' XLT= ',XLT
C      STOP
C
C
C      60 CONTINUE
C
C
C
C      COMPUTE COEFFICIENTS FOR INTERPOLATION
C      F1=(RVAL-R(II-1,JJ,LL))/(R(II,JJ,LL)-R(II-1,JJ,LL))+FLOAT(II-1)
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F2=(RVAL-R(IIK-1,JJ+1,LL))/(R(IIK,JJ+1,LL)-R(IIK-1,JJ+1,LL))+
2  FLOAT(IIK-1)
C
C  CALL PFIX(XLT,ALOCT(1I,JJ),ALOCT(IIK,JJ+1),P4,P5)
C
C  BJ=(XLT-P4)/(P5-P4)+FLOAT(JJ)
C
C  BI=F1+(BJ-FLOAT(JJ))*(F2-F1)/(FLOAT(JJ+1)-FLOAT(JJ))
C
C
C  RETURN
C  END
C
C  SUBROUTINE EFBNDY(LATDIM,LTDIM,ITMDIM,LL,EQEDG,STDOFF,VDROP,R,
2  ALOCT,COLAT,A,B,DX,DY)
C
C  VERSION 1.00          DATE: 09.13.89
C  1.01              10.25.89
C  PURPOSE:
C  SUBROUTINE TO CALCULATE LATITUDES AND WIDTHS OF EFIELD BNDYS 2 & 3
C
C  PROGRAMMER: R.W. SPIRO
C
C  REF: SECTION 2.4.2 OF THE FINAL REPORT FOR
C  CONTRACT #F19628-87-K-0001
C
C  DIMENSION R(LATDIM,LTDIM,ITMDIM),ALOCT(LATDIM,LTDIM)
C  DIMENSION COLAT(LATDIM,LTDIM)
C  DIMENSION A(3),B(3),DX(3),DY(3)
C  DIMENSION XLAMDA(4,3),DLAMDA(4)
C
C  PI=ATAN2(0.,-1.)
C
C  WRITE(6,*) 'IN EFBNDY EQEDG= ',EQEDG,'STDOFF= ',STDOFF
C
C  RNOON=.95*STDOFF
C  RDAWN=1.4*STDOFF
C  RDUSK=1.4*STDOFF
C  RMIDNT=2.0*STDOFF
C
C  XLAMDA(1,N) REFERS TO NOON; XLAMDA(2,N) REFERS TO DUSK
C  XLAMDA(3,N) REFERS TO MIDNIGHT; XLAMDA(4,N) REFERS TO DAWN
C  WHERE N=1,2,3 REFERS TO THE THREE BNDYS OF THE E FIELD CALCULATION
C  BNDY 1 IS CALCULATED INTERNALLY IN EFIELD
C  BNDYS 2 AND 3 ARE CALCULATED HERE
C
C  XLAMDA(3,3)=EQEDG
C  XLAMDA(2,3)=EQEDG+1.
C  XLAMDA(4,3)=EQEDG+1.
C  XLAMDA(1,3)=EQEDG+((66.95-EQEDG)*7.725+2.8*(EQEDG-56.8))/10.15
C
C  CALCULATION OF PARAMETERS USED IN CALCULATING BNDY 2
C
C  LOCATE RNOON,RDAWN, RDUSK, AND RMIDNT IN OUR GRID, IE., FIND
C  (BINOON,BJNOON), (BIDUSK,BJDUSK), (BIMDNT,BJMDNT), (BIDAWN,BJDAWN)
C
C  TNOON=0.
C  CALL EFLOC(RNOON,TNOON,LL,LATDIM,LTDIM,ITMDIM,R,ALOCT,
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2          BINOON, BJNOON)
C
C      TDUSK=PI/2.
      CALL EFLOC (RDUSK, TDUSK, LL, LATDIM, LTDIM, ITMDIM, R, ALOCT,
2          BIDUSK, BJDUSK)
C
C      TMIDNT=PI
      CALL EFLOC (RMIDNT, TMIDNT, LL, LATDIM, LTDIM, ITMDIM, R, ALOCT,
2          BIMDNT, BJMDNT)
C
C      TDAWN=3.*PI/2.
      CALL EFLOC (RDAWN, TDAWN, LL, LATDIM, LTDIM, ITMDIM, R, ALOCT,
2          BIDAWN, BJDAWN)
C
C      XLAT1=G3NTRP (COLAT, LATDIM, LTDIM, 1, BINOON, BJNOON, 1.)
      XLAMDA (1, 2) = (PI/2. - XLAT1) * 180. / PI
C
C      XLAT2=G3NTRP (COLAT, LATDIM, LTDIM, 1, BIDUSK, BJDUSK, 1.)
      XLAMDA (2, 2) = (PI/2. - XLAT2) * 180. / PI
C
C      XLAT3=G3NTRP (COLAT, LATDIM, LTDIM, 1, BIMDNT, BJMDNT, 1.)
      XLAMDA (3, 2) = (PI/2. - XLAT3) * 180. / PI
C
C      XLAT4=G3NTRP (COLAT, LATDIM, LTDIM, 1, BIDAWN, BJDAWN, 1.)
      XLAMDA (4, 2) = (PI/2. - XLAT4) * 180. / PI
C
C      CHECK BOUNDARY 3 (EQ. EDGE OF SUNWARD FLOW) FOR RIDICULOUS VALUE;
C      CHANGE IF NECESSARY
C
C      EMAX=.1
      DLAMDA (1) = 3.
      DLAMDA (3) = 3.
      DLAMDA (2) = 4.5E-6 * VDROD / EMAX
      DLAMDA (4) = DLAMDA (2)
C
C      LOOP OVER NOON, DUSK, MIDNIGHT, AND DAWN
      DO 8 II=1, 4
          DELTA=XLAMDA (II, 2) - DLAMDA (II) - XLAMDA (II, 3)
          IF (DELTA.LT.0.) THEN
              WRITE (6, *) 'ADJUSTING XLAMDA (II, 3) IN EFBNDY'
              WRITE (6, *) 'LL=', LL, ' II=', II, ' XLAMDA (OLD) =', XLAMDA (II, 3)
              XLAMDA (II, 3) = XLAMDA (II, 3) + DELTA
              WRITE (6, *) ' XLAMDA (NEW) =', XLAMDA (II, 3)
          END IF
      8 CONTINUE
C
C      DO 10 II=2, 3
          DX (II) = -.5 * (XLAMDA (1, II) - XLAMDA (3, II))
          DY (II) = -.5 * (XLAMDA (2, II) - XLAMDA (4, II))
C
C          X = .5 * (180. - XLAMDA (1, II) - XLAMDA (3, II))
          Y = .5 * (180. - XLAMDA (4, II) - XLAMDA (2, II))
C
C          A (II) = SQRT (( (X*Y)**2 - (DX (II) * DY (II)) **2) / (Y**2 - DY (II) **2))
          B (II) = SQRT (( (X*Y)**2 - (DX (II) * DY (II)) **2) / (X**2 - DX (II) **2))
C
C      10 CONTINUE
C
C      RETURN
      END
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C
C ***** F E C O N *****
C
C   SUBROUTINE FECON(ISTART,IINC,IEND,ITMDIM,NAUGEL,MODE,AUGPAR,
1     ITMMAX,TIMTAG)
C
C   VERSION 1.0          DATE: JANUARY 9, 1988
C     2.0              SEPTEMBER 14, 1989
C
C   PROGRAMMER: BRYAN A. BALES
C
C   PURPOSE: FECON CALLS PARGEN TO OBTAIN TIME-NORMALIZED OBSERVED DATA
C             THAT IS THEN USED TO CALCULATE OTHER VALUES NEEDED BY THE
C             EFIELD AND BFIELD ROUTINES.
C
C             PARAMETER (NELTS=28,ITDIM=50)
C
C             INTEGER IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST, DDST,
1             EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2             GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3             STAND, PCP, DEQDT, IPATT
C
C             LOGICAL*1 MODE (NAUGEL, ITMDIM)
C             COMMON /ARINDX/IYEAR, IDAY, ISECND, IPHOUR, IPMIN, IPSEC, KP, DST,
1             EQEDGE, DLATAZ, DLATRV, MLTRV, IMFBX, IMFBY, IMFBZ, CLAPSE,
2             GEOMGX, GEOMGY, GEOMGZ, GEOMGT, LBOUND, SWVEL, SWDEN, TILTW,
3             STAND, PCP, IPATT, DDST, DEQDT
C
C             DIMENSION PARRAY (NELTS, ITDIM), AUGPAR (NAUGEL, ITMDIM), ITIME (3)
C             DIMENSION ITMNEW (3), ISTART (3), IINC (3), IEND (3)
C             DIMENSION TIMTAG (ITMDIM)
C
C             IF (ITDIM.NE.ITMDIM) STOP 'STOPPING IN FECON. ITDIM.NE.ITMDIM'
C
C             DO 30 IDO=1,NAUGEL
C               DO 40 JDO=1,ITMDIM
C                 MODE (IDO, JDO) = .FALSE.
40            CONTINUE
30            CONTINUE
C
C             CALL PARGEN(ISTART, IINC, IEND, ITMDIM, NELTS, MODE, PARRAY,
1             ITMMAX, TIMTAG, NAUGEL)
C
C             ITIME (1) = ISTART (1)
C             ITIME (2) = ISTART (2)
C             ITIME (3) = ISTART (3)
C
C             DO 20, ITM=1, ITMMAX
C               DO 10, I=1, NELTS
C                 AUGPAR (I, ITM) = PARRAY (I, ITM)
10            CONTINUE
C
C             CALL TILT (ITIME (IDAY), ITIME (IYEAR), AUGPAR (TILTW, ITM))
C
C             CALL STNDFL (MODE (STAND, ITM), MODE (SWVEL, ITM),
1             MODE (SWDEN, ITM), PARRAY (SWVEL, ITM), PARRAY (SWDEN, ITM),
2             PARRAY (KP, ITM), AUGPAR (STAND, ITM))
C
C             CALL DSTDFL (MODE (DST, ITM), AUGPAR, NAUGEL, ITMDIM, ITM, ITMMAX,
1             TIMTAG)
C
C             CALL EQTDFL (MODE (EQEDGE, ITM), AUGPAR, NAUGEL, ITMDIM, ITM,

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MSM54400
MSM54410
MSM54420
MSM54430
MSM54440
MSM54450
MSM54460
MSM54470
MSM54480
MSM54490
MSM54500
MSM54510
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MSM54670
MSM54680
MSM54690
MSM54700
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MSM54930
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MSM54950
MSM54960
MSM54970
MSM54980
MSM54990
MSM55000
MSM55010
MSM55020
MSM55030

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90/06/30
12:03:44

msml.for

88

```
REND = TCONV3 (IEND, ISTART)
NODATA = 0
C
DO 10, I=6, NELTS
  ITM = 1
  ITIME (1) = ISTART (1)
  ITIME (2) = ISTART (2)
  ITIME (3) = ISTART (3)
C
IF (I.EQ.KP.OR.I.EQ.DST.OR.I.EQ.PCP.OR.I.EQ.IPATT.OR.
1  I.EQ.CLAPSE.OR.I.EQ.SWDEN.OR.I.EQ.SWVEL.OR.
2  I.EQ.EQEDGE) THEN
C
  CALL INDATA (PARAM (I), ISTART, IEND, NDIM, DARRY, NUMNUM)
  WRITE (6, *) 'COMING OUT OF INDATA, I= ', I, ' NUMNUM= ', NUMNUM
  IF ((NUMNUM.EQ.0).AND.(I.EQ.KP)) THEN
    WRITE (6, *) ' NO KP AVAILABLE TO RUN PROGRAM.'
    STOP
  ENDIF
C
  STARTY = REAL (ISTART (1))
  IF (ISTART (3).LT.86400) THEN
    STARTD = REAL (ISTART (2)) + REAL (ISTART (3)) / 86400.
  ELSE IF (ISTART (3).EQ.86400) THEN
    STARTD = REAL (ISTART (2))
  ELSE
    WRITE (6, *) ' INCORRECT START TIME HAS BEEN INPUT'
    WRITE (6, *) ' STOPPING PROGRAM IN PARGEN'
    STOP
  END IF
C
  CALL SMOOTH (DARRY, NDIM, NUMNUM, STARTY, STARTD, NA, XA, YA, IERR)
C
  WRITE (6, *) ' NA= ', NA, ' NUMNUM= ', NUMNUM, ' NDIM= ', NDIM
  DO 42 NX=1, NA
    WRITE (6, *) ' TIME= ', XA (NX), ' VALUE= ', YA (NX)
42 CONTINUE
C
  WRITE (6, *) ' RETURNED FROM SMOOTH FOR PARAMETER ', PARAM (I)
C
  IF (IERR.NE.0) THEN
    WRITE (6, *) ' TIME REVERSAL IN PARAMETER ', PARAM (I)
    STOP ' SERIOUS ERROR IN ENVIRONMENTAL DATA.'
  ENDIF
C
  IF (NUMNUM.EQ.0) GO TO 10
20 CONTINUE
  IF (I.EQ.KP) THEN
    PARRAY (IYEAR, ITM) = ITIME (IYEAR)
    PARRAY (IDAY, ITM) = ITIME (IDAY)
    PARRAY (IPHOUR, ITM) = REAL (ITIME (ISECND) / 3600)
    PARRAY (IPMIN, ITM) = REAL (MOD (ITIME (ISECND), 3600) / 60)
    PARRAY (IPSEC, ITM) = REAL (MOD (ITIME (ISECND), 60))
    TIMTAG (ITM) = TCONV3 (ITIME, ISTART)
    WRITE (6, *) ' TIMTAG (', ITM, ') = ', TIMTAG (ITM)
  ENDIF
C
  IF (I.EQ.IPATT) THEN
    CALL DTXIPT (TIMTAG (ITM), NA, XA, YA, Y, DYDX, DELTA, IERR)
    PARRAY (I, ITM) = Y
  ELSEIF (I.NE.DDST.AND.I.NE.DEQDT) THEN
    CALL DTNTRP (TIMTAG (ITM), NA, XA, YA, Y, DYDX, DELTA, IERR)
C
    PARRAY (I, ITM) = Y
MSM55680
MSM55690
MSM55700
MSM55710
MSM55720
MSM55730
MSM55740
MSM55750
MSM55760
MSM55770
MSM55780
MSM55790
MSM55800
MSM55810
MSM55820
MSM55830
MSM55840
MSM55850
MSM55860
MSM55870
MSM55880
MSM55890
MSM55900
MSM55910
MSM55920
MSM55930
MSM55940
MSM55950
MSM55960
MSM55970
MSM55980
MSM55990
MSM56000
MSM56010
MSM56020
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MSM56100
MSM56110
MSM56120
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MSM56140
MSM56150
MSM56160
MSM56170
MSM56180
MSM56190
MSM56200
MSM56210
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MSM56230
MSM56240
MSM56250
MSM56260
MSM56270
MSM56280
MSM56290
MSM56300
MSM56310
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msm1.for

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IF ((DELTA.LE.IGAP(I)).OR.(IGAP(I).EQ.0)) THEN
  MODE(I,ITM) = .TRUE.
ELSE
  MODE(I,ITM) = .FALSE.
ENDIF

C
C DYDX IS IN UNITS OF Y/SEC
C NEED TO CHANGE TO UNITS OF Y/HOUR
  IF (I.EQ.DST) PARRAY(DDST,ITM) = DYDX*3600.
  IF (I.EQ.EQEDGE) PARRAY(DEQDT,ITM) = DYDX*3600.
  IF(I.EQ.DST)
    1 WRITE(6,*)' ITM,DST,DYDX ',TIMTAG(ITM),
    1 PARRAY(DST,ITM),PARRAY(DDST,ITM)
  IF(I.EQ.EQEDGE)
    2 WRITE(6,*)' ITM,EQED,DYDX',TIMTAG(ITM),
    1 PARRAY(EQEDGE,ITM),PARRAY(DEQDT,ITM)
  ENDIF

C
  ITM = ITM + 1
  CALL TIMINC(ITIME,ITMNEW,IINC)
  ITIME(1) = ITMNEW(1)
  ITIME(2) = ITMNEW(2)
  ITIME(3) = ITMNEW(3)

C
  IF (NINT(TCONV3(ITIME,ISTART)).LE.NINT(REND)) GO TO 20
C
  IF (I.EQ.KP) ITMMAX = ITM-1
  ENDIF

C
  10 CONTINUE
C
  RETURN
  END

C
C ***** INDATA *****
C
  SUBROUTINE INDATA(PARAM,STARTT,ENDT,NDIM,DARRY,NUMNUM)
C
C THIS IS A DUMMY SUBROUTINE TO READ IN DATA FOR THE
C MAGNETOSHPERIC SPECIFICATION MODEL DURING DEVELOPMENT
C AND TESTING. THIS ROUTINE WILL BE REPLACED IN THE
C OPERATIONAL MSM WITH AN INTERFACE ROUTINE TO THE
C AWS ENVIRONMENTAL DATABASE.
C
C BRYAN BALES 9/12/89
C
  CHARACTER*(*) PARAM
C
  DIMENSION STARTT(3),ENDT(3),DARRY(7,NDIM)
C
  NUMNUM = 1
  OPEN (UNIT=98,FILE=PARAM,STATUS='OLD')
C
  10 CONTINUE
  READ (98,*,END=20) (DARRY(I,NUMNUM),I=1,7)
  NUMNUM = NUMNUM + 1
  IF (NUMNUM.LE.NDIM) GO TO 10
C
  STOP 'Stopping in INDATA. NUMNUM is greater than NDIM.'
C
  20 CONTINUE
  NUMNUM = NUMNUM - 1
  CLOSE (98)
C

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MSM56320
MSM56330
MSM56340
MSM56350
MSM56360
MSM56370
MSM56380
MSM56390
MSM56400
MSM56410
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MSM56430
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MSM56690
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MSM56800
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MSM56830
MSM56840
MSM56850
MSM56860
MSM56870
MSM56880
MSM56890
MSM56900
MSM56910
MSM56920
MSM56930
MSM56940
MSM56950

RETURN
END

MSM56960
MSM56970
MSM56980
MSM56990
MSM57000
MSM57010
MSM57020
MSM57030
MSM57040
MSM57050
MSM57060
MSM57070
MSM57080
MSM57090
MSM57100
MSM57110
MSM57120
MSM57130
MSM57140
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MSM57560
MSM57570
MSM57580
MSM57590

***** GETMAT *****
SUBROUTINE GETMAT (IWANT, LATDIM, LTDIM, BFPAR, WORK, BFLIM, BFEKST)

THIS SUBROUTINE FINDS THE MAGNETIC FIELD MATRICES NEEDED TO
INTERPOLATE ONE MATRIX THAT IS REPRESENTATIVE OF CURRENT
CONDITIONS.

BRYAN BALES 9/12/89

PARAMETER (IMSTND=5, IMTILT=5, IMINED=16, IMDST=8, IMSTCH=2)

INTEGER BFNDX (2, 5)
LOGICAL*1 BFEKST (2, 2, 2, 2, 2)
LOGICAL MEXIST

DIMENSION STNDPR (IMSTND), TILTPR (IMTILT), FINEDP (IMINED)
DIMENSION DSTPR (IMDST), STCHPR (IMSTCH)
DIMENSION BFLIM (2, 5), BFPAR (5)
DIMENSION WORK (LATDIM, LTDIM, 2, 2, 2, 2, 2)
DIMENSION XDEB (62, 51), YDEB (62, 51), ZDEB (62, 51)
DATA MSTND/IMSTND/
DATA MTILT/IMTILT/
DATA MINED/IMINED/
DATA MDST/IMDST/
DATA MSTCH/IMSTCH/

DATA STNDPR/6.0, 8.0, 10.0, 12.0, 14.0/
DATA TILTPR/-35.0, -17.5, 0.0, 17.5, 35.0/
DATA FINEDP/49.47, 53.20, 55.89, 57.96, 59.60,
1 60.95, 62.06, 63.02, 63.99, 65.01,
2 65.91, 66.72, 67.45, 68.12, 68.73,
3 69.30/
DATA DSTPR/-400.0, -300.0, -200.0, -150.0,
1 -100.0, -50.0, 0.0, 50.0/
DATA STCHPR/0.0, 1.0/

EXTERNAL MEXIST

CALL FNDBRK (BFPAR (1), STNDPR, MSTND, BFNDX (1, 1), BFNDX (2, 1))
CALL FNDBRK (BFPAR (2), TILTPR, MTILT, BFNDX (1, 2), BFNDX (2, 2))
CALL FNDBRK (BFPAR (3), FINEDP, MINED, BFNDX (1, 3), BFNDX (2, 3))
CALL FNDBRK (BFPAR (4), DSTPR, MDST, BFNDX (1, 4), BFNDX (2, 4))
CALL FNDBRK (BFPAR (5), STCHPR, MSTCH, BFNDX (1, 5), BFNDX (2, 5))

DO 5, I=1, 2
BFLIM (I, 1) = STNDPR (BFNDX (I, 1))
BFLIM (I, 2) = TILTPR (BFNDX (I, 2))
BFLIM (I, 3) = FINEDP (BFNDX (I, 3))
BFLIM (I, 4) = DSTPR (BFNDX (I, 4))
BFLIM (I, 5) = STCHPR (BFNDX (I, 5))

CONTINUE

DO 10, I=1, 2
DO 20, J=1, 2
DO 30, K=1, 2
DO 40, L=1, 2
DO 50, M=1, 2
IF (MEXIST (BFNDX (I, 1), BFNDX (J, 2), BFNDX (K, 3),
BFNDX (L, 4), BFNDX (M, 5))) THEN

mms1.for

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1      CALL LOADBM(IWANT,LATDIM,LTDIM,I,J,K,L,M,BFNDX, MSM57600
      WORK) MSM57610
      BFEKST(I,J,K,L,M) = .TRUE. MSM57620
ELSE   MSM57630
      CALL ZEROBM(LATDIM,LTDIM,I,J,K,L,M,WORK) MSM57640
      BFEKST(I,J,K,L,M) = .FALSE. MSM57650
ENDIF  MSM57660
C      MSM57670
      IF(BFNDX(J,2).EQ.3.AND.IWANT.EQ.1) THEN MSM57680
      IF((3-BFNDX(M,5)).EQ.1.OR.BFPAR(5).LT.1) THEN MSM57690
C      MSM57700
      WRITE(6,*) 'STANDOFF=',BFLIM(I,1),' TILT=', MSM57710
C      BFLIM(J,2),' EQEDGE=',BFLIM(K,3), MSM57720
C      1 ' DST=',BFLIM(L,4),' COLLAPSE', MSM57730
C      2 BFLIM(M,5) MSM57740
C      3 WRITE(6,1001) BFNDX(J,2),BFNDX(I,1),BFNDX(L,4), MSM57750
C      BFNDX(K,3),(3-BFNDX(M,5)) MSM57760
C1001  FORMAT('BF',I1,I1,I1,I2.2,I1) MSM57770
      WRITE(6,1001) BFNDX(J,2),BFNDX(I,1),BFNDX(L,4), MSM57780
      BFNDX(K,3),(3-BFNDX(M,5)),BFEKST(I,J,K,L,M), MSM57790
      BFLIM(I,1),BFLIM(J,2),BFLIM(K,3), MSM57800
      BFLIM(L,4),BFLIM(M,5) MSM57810
1001  FORMAT('BF',I1,I1,I1,I2.2,I1,1X,L1,3X,'STANDOFF=',F8.2,3X, MSM57820
      2 'TILT=',F8.2,3X,'EQEDGE=',F8.2,3X,'DST=',F8.2,3X, MSM57830
      3 'COLLAPSE=',F4.2) MSM57840
      END IF MSM57850
      END IF MSM57860
C      IF((IWANT.EQ.1).AND.(BFEKST(I,J,K,L,M))) THEN MSM57870
C      DO 999 LAT=1,LATDIM MSM57880
C      DO 998 LT=1,LTDIM MSM57890
C      XDEB(LAT,LT)=WORK(LAT,LT,I,J,K,L,M) MSM57900
998    CONTINUE MSM57910
999    CONTINUE MSM57920
C      CALL OUTP(XDEB,LATDIM,LTDIM,10,LATDIM,1,3, MSM57930
C      1 LTDIM-3,1,1.,'XDEB',6,132) MSM57940
C      ENDIF MSM57950
C      IF((IWANT.EQ.2).AND.(BFEKST(I,J,K,L,M))) THEN MSM57960
C      DO 997 LAT=1,LATDIM MSM57970
C      DO 996 LT=1,LTDIM MSM57980
C      YDEB(LAT,LT)=WORK(LAT,LT,I,J,K,L,M) MSM57990
996    CONTINUE MSM58000
997    CONTINUE MSM58010
C      CALL OUTP(YDEB,LATDIM,LTDIM,10,LATDIM,1,3, MSM58020
C      1 LTDIM-3,1,1.,'YDEB',6,132) MSM58030
C      ENDIF MSM58040
C      IF((IWANT.EQ.3).AND.(BFEKST(I,J,K,L,M))) THEN MSM58050
C      DO 995 LAT=1,LATDIM MSM58060
C      DO 994 LT=1,LTDIM MSM58070
C      ZDEB(LAT,LT)=WORK(LAT,LT,I,J,K,L,M) MSM58080
994    CONTINUE MSM58090
995    CONTINUE MSM58100
C      CALL OUTP(ZDEB,LATDIM,LTDIM,10,LATDIM,1,3, MSM58110
C      1 LTDIM-1,1,1.,'ZDEB',6,132) MSM58120
C      ENDIF MSM58130
C      MSM58140
50     CONTINUE MSM58150
40     CONTINUE MSM58160
30     CONTINUE MSM58170
20     CONTINUE MSM58180
10     CONTINUE MSM58190
C      RETURN MSM58200
      END MSM58210
C      MSM58220
      MSM58230

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msml.for

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C ***** FNDBRK *****MSM58240
C SUBROUTINE FNDBRK(PARVAL,PVALS,IPDIM,MIN,MAX)MSM58250
C THIS SUBROUTINE FINDS THE INDICES OF THE VALUES IN ARRAYMSM58260
C PVALS THAT BRACKET PARVAL.MSM58270
C BRYAN BALES 9/12/89MSM58280
C DIMENSION PVALS(IPDIM)MSM58290
C MIN = 0MSM58300
C 10 CONTINUEMSM58310
C MIN = MIN + 1MSM58320
C MAX = MIN + 1MSM58330
C IF (PARVAL.LE.PVALS(MIN)) THENMSM58340
C MAX = MINMSM58350
C ELSEIF (PARVAL.GT.PVALS(MAX).AND.MAX.EQ.IPDIM) THENMSM58360
C MIN = MAXMSM58370
C IF (PARVAL.GT.PVALS(MAX).AND.MAX.LT.IPDIM) THENMSM58380
C GO TO 10MSM58390
C ENDDIFMSM58400
C RETURNMSM58410
C ENDMSM58420
C ***** MEXIST *****MSM58430
C LOGICAL FUNCTION MEXIST(MSTND,MTILT,MINED,MDST,MSTCH)MSM58440
C THIS FUNCTION CHECKS TO SEE IF A PARTICULAR B-MATRIX EXISTSMSM58450
C IN THE B-SUPERMATRIX(TM).MSM58460
C CHARACTER*8 FILNAMMSM58470
C LOGICAL TESTMSM58480
C WRITE (FILNAM,1000) MTILT,MSTND,MDST,MINED,(3-MSTCH)MSM58490
C 1000 FORMAT ('BFIELD:BF',I1,I1,I1,I2.2,I1,'.DAT')MSM58500
C INQUIRE (FILE=FILNAM,EXIST=TEST)MSM58510
C MEXIST = TESTMSM58520
C RETURNMSM58530
C ENDMSM58540
C ***** ZEROBM *****MSM58550
C SUBROUTINE ZEROBM(LATDIM,LTDIM,I,J,K,L,M,WORK)MSM58560
C THIS SUBROUTINE ERASES AN INDIVIDUAL B-MATRIX WITHIN THEMSM58570
C WORKING B-MATRICES. THIS IS DONE WHEN AN INDIVIDUAL MATRIXMSM58580
C DOES NOT EXIST IN THE OFFLINE B-SUPERMATRIX.MSM58590
C DIMENSION WORK(LATDIM,LTDIM,2,2,2,2)MSM58600
C DO 10, LAT=1, LATDIMMSM58610
C DO 20, LT=1, LTDIMMSM58620
C WORK(LAT,LT,I,J,K,L,M) = 0.0MSM58630
C 20 CONTINUEMSM58640
C 10 CONTINUEMSM58650
C RETURNMSM58660
C ENDMSM58670
C *****MSM58680
C *****MSM58690
C *****MSM58700
C *****MSM58710
C *****MSM58720
C *****MSM58730
C *****MSM58740
C *****MSM58750
C *****MSM58760
C *****MSM58770
C *****MSM58780
C *****MSM58790
C *****MSM58800
C *****MSM58810
C *****MSM58820
C *****MSM58830
C *****MSM58840
C *****MSM58850
C *****MSM58860
C *****MSM58870
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C
C ***** LOADBM *****
C
C SUBROUTINE LOADBM(IWANT, LATDIM, LTDIM, I, J, K, L, M, BFNDX, WORK)
C
C THIS SUBROUTINE LOADS INDIVIDUAL B-MATRICES FROM THE OFFLINE
C B-SUPERMATRIX INTO THE WORK B-MATRICES. A CHECK IS MADE TO
C VERIFY THAT THE CORRECT MATRIX HAS BEEN RETRIEVED. IF THIS
C CHECK FAILS THE PROGRAM WILL STOP.
C
C INTEGER BFNDX(2, 5)
C CHARACTER*32 FILNAM
C
C DIMENSION WORK(LATDIM, LTDIM, 2, 2, 2, 2, 2)
C
C THE FILE DEFINITIONS FOR THE B-MATRICES IN THE SUPERMATRIX
C ARE AS FOLLOWS :
C
C 'BFvwxyz'.
C WHERE v IS THE TILT INDEX,
C w IS THE STANDOFF INDEX,
C x IS THE DST INDEX,
C yy IS THE INNER EDGE INDEX,
C z IS THE COLLAPSE INDEX.
C
C WRITE (FILNAM, 1000) BFNDX(J, 2), BFNDX(I, 1), BFNDX(L, 4),
1 BFNDX(K, 3), (3-BFNDX(M, 5))
1000 FORMAT ('BFIELD:BF', I1, I1, I1, I2.2, I1, ' .DAT')
C
C OPEN (UNIT=99, FILE=FILNAM, ERR=199, FORM='FORMATTED',
1 ACCESS='SEQUENTIAL', STATUS='OLD')
C
C READ (99, 800) IDF1, IDF2, IDF3, IDF4, IDF5, IDF6
800 FORMAT(3I1, I2.2, I1, I3)
C
C IF ((BFNDX(I, 1).NE.IDF2).OR.(BFNDX(J, 2).NE.IDF1).OR.
1 (BFNDX(K, 3).NE.IDF4).OR.(BFNDX(L, 4).NE.IDF3).OR.
2 ((3-BFNDX(M, 5)).NE.IDF5).OR.(IDF6.NE.201)) THEN
C WRITE (LUERR, *) 'FILE ', FILNAM, ' IS INCORRECT.'
C WRITE (6, *) 'FILE ', FILNAM, ' IS INCORRECT.'
C STOP 'INCORRECT B-FIELD. STOPPING IN LOADBM.'
C ENDIF
C
C DO 10, N=1, IWANT
C READ(99, 801) ((WORK(II, JJ, I, J, K, L, M), II=1, LATDIM), JJ=1, LTDIM)
801 FORMAT(11E12.4)
10 CONTINUE
C
C CLOSE (99)
C RETURN
C
199 CONTINUE
C WRITE(6, *) 'STOPPING IN LOADBM. OPEN FAILED ON ', FILNAM
C STOP 'STOPPING IN LOADBM. OPEN FAILED ON B-MATRIX.'
C END
C
C ***** TCONV2 *****
C
C REAL FUNCTION TCONV2(YR, DD, STRTYR, STRTDD)
C
C THIS FUNCTION TAKES A START YEAR, START DECIMAL DAY,
C A CURRENT YEAR, AND A CURRENT DECIMAL DAY. IT PRODUCES
C A VALUE THAT IS THE SECONDS FROM THE START YEAR AND DAY.
C THIS VALUE IS RELATIVE TO MIDNIGHT OF THE START DAY.
C
```

```

C      INTRINSIC INT
C      TEMP = 0.0
C      IF (STRTYR.EQ.YR) THEN
C          TEMP = (DD - INT(STRTDD)) * 86400.0
C      ELSEIF (MOD(INT(STRTYR),4).EQ.0) THEN
C          TEMP = (DD + 366.0 - INT(STRTDD)) * 86400.0
C      ELSE
C          TEMP = (DD + 365.0 - INT(STRTDD)) * 86400.0
C      ENDIF
C      TCONV2 = TEMP
C      RETURN
C      END
C      ***** TCONV3 *****
C      REAL FUNCTION TCONV3(ITIME,ISTART)
C      THIS FUNCTION TAKES A START YEAR, START DAY, A CURRENT YEAR,
C      A CURRENT DAY, AND A CURRENT SECOND.. IT PRODUCES
C      A VALUE THAT IS THE SECONDS FROM THE START YEAR AND DAY.
C      THIS VALUE IS RELATIVE TO MIDNIGHT OF THE START DAY.
C      PARAMETER (IYR=1, IDY=2, ISEC=3)
C      DIMENSION ITIME(3), ISTART(3)
C      INTRINSIC REAL
C      IF (ISTART(IYR).EQ.ITIME(IYR)) THEN
C          TEMP = REAL(ITIME(IDY) - ISTART(IDY))*86400.0 +
1          REAL(ITIME(ISEC))
C      ELSEIF (MOD(ISTART(IYR),4).EQ.0) THEN
C          TEMP = REAL(ITIME(IDY) + 366 - ISTART(IDY))*86400.0 +
1          REAL(ITIME(ISEC))
C      ELSE
C          TEMP = REAL(ITIME(IDY) + 365 - ISTART(IDY))*86400.0 +
1          REAL(ITIME(ISEC))
C      ENDIF
C      TCONV3 = TEMP
C      RETURN
C      END
C      ***** SMOOTH *****
C      SUBROUTINE SMOOTH(DARRY,NDIM,NUMNUM,STARTY,STARTD,NA,XA,YA,IERR)
C      DIMENSION DARRY(7,NDIM),XA(NDIM),YA(NDIM)
C      REAL STARTY,STARTD
C      INTEGER NUMNUM,NDIM,NA,IERR
C      EXTERNAL TCONV2
C      This routine checks and extracts data from DARRY() into XA(),YA().
C      September 10, 1989 Akira NAGAI
C      INPUTS:
C      DARRY() : Source data
C      NDIM : A Dimension of DARRY()
C      NUMNUM : Number of source data
C      STARTY, STARTD : Start year and day
C      OUTPUTS:

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IF (X.EQ.XA(NA)) IERR=0
Y = YA(NA)
DYDX = ( YA(NA)-YA(NA-1) ) / ( XA(NA)-XA(NA-1) )
DELTA = X - XA(NA)
ELSE IF (X.LT.XA(1)) THEN
IERR=-1
Y = YA(1)
DYDX = ( YA(2)-YA(1) ) / ( XA(2)-XA(1) )
DELTA = XA(1) - X
ELSE
C Scan to find the position of X.
C Maybe binary search would be better.
I = NA
10 CONTINUE
XD = X - XA(I)
IF (XD.GT.0.0) GOTO 20
I = I - 1
GOTO 10
20 CONTINUE
IERR = 0
DELTA2= XA(I+1)-XA(I)
DELTA = MIN(X-XA(I), XA(I+1)-X)
DYDX = (YA(I+1)-YA(I)) / DELTA2
Y = DYDX * XD + YA(I)
ENDIF
RETURN
END
C
C ***** DTXIPT *****
C
SUBROUTINE DTXIPT(X, NA, XA, YA, Y, DYDX, DELTA, IERR)
C
INTEGER NA, IERR, I
REAL X, XA(*), YA(*), XD, Y, DYDX, DELTA
C
C This function returns interpolation values for XIPATT
C
C INPUTS:
C X : Given value of X
C NA : Number of data points.
C XA : Data XA(1) to XA(NA)
C YA : Data YA(1) to YA(NA)
C
C OUTPUTS:
C Y : Interpolated value of Y.
C DYDX: Interpolated value of dY/dX.
C DELTA : Gap of X.
C IERR: Error code.
C
C September 08, 1989
C
IF (X.GT.XA(NA)) THEN
IERR=-1
IF (X.EQ.XA(NA)) IERR=0
Y = YA(NA)
DELTA = X - XA(NA)
ELSE IF (X.LE.XA(1)) THEN
IERR=-1
IF (X.EQ.XA(1)) IERR=0
Y = YA(1)
DELTA = XA(1) - X
ELSE
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C      Scan to find the position of X.
      I = NA
10     CONTINUE
      XD = X - XA(I)
      IF (XD.GE.0.0) GOTO 20
      I = I - 1
      GOTO 10

20     CONTINUE
      IERR = 0
      DELTA = MIN(X-XA(I),XA(I+1)-X)
      A=X-XA(I)
      B=XA(I+1)-X

      IF (A.LT.B) THEN
        Y = YA(I)
      ELSE
        Y = YA(I+1)
      END IF
      ENDIF

      RETURN
      END

C***** STDOFF ****
C
C      SUBROUTINE STNDOF(VELOC,DENS,STAND)
C
C          ANALYTIC CALCULATION OF THE STAND-OFF DISTANCE *
C          FORMULA ACCORD. TO ALPBACH - PAPER (1979)
C
C          B0 = MAGNETIC FIELD AT THE EQUATOR IN (GAUSS)
C          FAK = REFLECTION FACTOR FOR SOLAR-WIND PATICLES
C          F = GEOMETRY FAKTOR OF THE MAGNETOPAUSE
C          PSOL = SOLARWIND-PRESS IN (1.E-08 DYN/(CM**2))
C          PEFF = SOLARWIND-PRESS IN (1.E-16 DYN/(CM**2))
C
C      * * * INPUT PARAMTERS:   VELOC  SOL WIND VELOCITY IN [KM/SEC]
C                               DENS   SOL WIND DESITY IN [1/CM]**3
C
C      * * * OUTPUT PARAMETERS:  BSTAG  MAGNETIC FIELD AT SUBSOLAR POINT IN [
C                               STAND  STAND OFF DISTANCE IN [EARTH RADII]
C
C      * * * CALCULATION OF HELIUM PERCENTAGE IN THE SOLAR WIND * * * * *
C
C      HELIUM = HELIUM-PROZENT
C
C      HELIUM = 0.00
C
C      PERC1 = HELIUM/100.
C      PERC2 = 1.0 - PERC1
C
C      DENGES = DENS * (PERC2 + 4.*PERC1)
C
C      V0 = VELOC
C
C      FAK = 1.0
C      PROTMA = 1.6726 * 1.E-24
C      VAU = V0 * 1.E+05
C      PI = ACOS(-1.00000)

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DRUCK = 8.*PI * FAK * DENGES * PROTMA * VAU * VAU
DRUCK = DRUCK * 1.E+10
DRUCK = SQRT(DRUCK)

FELD = DRUCK

PSOL = DRUCK * 1.E-05
PSOL = PSOL * PSOL
PSOL = PSOL / (8.*PI)
PSOL = PSOL * 1.E+08

PI = ACOS(-1.00000)
B0 = 0.23
B0 = 0.311829

PGES = PSOL * (PERC2 + 4.*PERC1)

* * IN THIS SPECIAL VERSION OF THE ROUTINE STDOFF, THE MAGNETOSPHERE
ASSUMED TO BE COMPLETELY CLOSED.

BZIMF = 0.00
CD = 0.00
CIMF = 0.00

BZIMF = BZIMF * 1.E-05

F = 1.16000
FAK = 1.0
FQK = F * F / FAK

PEFF = 2.*PI * PGES * 1.E-08
EX = 1./6.

R0 = (FQK * B0*B0*(1.-CD)*(1.-CD) / PEFF)**EX
R0 = R0 * (1. + (EX*CIMF*BZIMF) / (SQRT(PEFF)))

FELD = PGES * 1.E-08
FELD = FELD * 8.*PI
FELD = SQRT(FELD)
FELD = FELD * 1.E+05

BSTAG = FELD
STAND = R0

RETURN
END
SUBROUTINE FLXNIT(IRDIM, NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXR,
2 FLXNRG, FLXKP, FLXMAT, THRMAT)

VERSION 1.00

DATE: 10.04.89

PURPOSE: SUBROUTINE TO CALCULATE KP-BASED PARTICLE NUMBER FLUX
IN UNITS OF PARTICLES/CM**2/S/SR/EV AS FCN OF R, ENERGY,
AND KP.

DIMENSION FLXMAT(IRDIM, NRGDIM, KPPLUS, ISPDIM)
DIMENSION THRMAT(IRDIM, NRGDIM, KPDIM)
DIMENSION FLXR(IRDIM), FLXNRG(NRGDIM), FLXKP(KPDIM)
DIMENSION THR(4)

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C
DO 10 IKP=1, KPDIM
  FLXKP (IKP) =FLOAT (IKP-1)
10 CONTINUE
C
DO 20 INRG=1, NRGDIM
  FLXNRG (INRG) =FLOAT (INRG+3) /4.
20 CONTINUE
C
FLXR (1) =ALOG10 (3.)
FLXR (2) =ALOG10 (4.)
FLXR (3) =ALOG10 (6.6)
FLXR (4) =ALOG10 (13.)
C
C
DO 90 ISP=1, ISPDIM
  ISPP=ISP
  DO 100 IKP=1, KPDIM
    DO 110 INRG=1, NRGDIM
      CALL FLXCAL (ISPDIM, KPDIM, ISPP, FLXKP (IKP), FLXNRG (INRG),
2          FLX3, FLX4, FLX6, FLX13)
      DO 120 IR=1, IRDIM
        FLXMAT (IR, INRG, IKP, ISP) =FLXTRP (FLXR (IR), FLX3, FLX4,
2          FLX6, FLX13)
120 CONTINUE
110 CONTINUE
100 CONTINUE
90 CONTINUE
C
DO 200 IKP=1, KPDIM
  IIKP=IKP
  DO 210 INRG=1, NRGDIM
    IINRG=INRG
    CALL THRCAL (FLXKP (IKP), FLXNRG (INRG), IINRG, IIKP, IRDIM,
2      NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXMAT, THR)
    DO 220 IR=1, IRDIM
      THRMAT (IR, INRG, IKP) =THR (IR)
220 CONTINUE
210 CONTINUE
200 CONTINUE
C
C CYCLE THROUGH KP VALUES AND PUT MIN FLUX IN KPDIM+1
C          MAX FLUX IN KPDIM+2
C
DO 300 ISP=1, ISPDIM
  DO 310 INRG=1, NRGDIM
    DO 320 IR=1, IRDIM
      FLXMIN=1.E20
      FLXMAX=-1.E20
      DO 330 IKP=1, KPDIM
        FLXMIN=MIN (FLXMAT (IR, INRG, IKP, ISP), FLXMIN)
        FLXMAX=MAX (FLXMAT (IR, INRG, IKP, ISP), FLXMAX)
330 CONTINUE
C
      FLXMAT (IR, INRG, KPDIM+1, ISP) =FLXMIN
      FLXMAT (IR, INRG, KPDIM+2, ISP) =FLXMAX
320 CONTINUE
310 CONTINUE
300 CONTINUE
C
C
C
RETURN
END
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IF (ISPSIZ.NE.ISPDIM) THEN
  WRITE(6,*) 'DIMENSION ERROR IN SUBROUTINE FLXNIT'
  WRITE(6,*) 'ISPSIZ IS NOT EQUAL TO ISPDIM'
  WRITE(6,*) 'ISPSIZ=', ISPSIZ, 'ISPDIM=', ISPDIM
  WRITE(6,*) 'STOPPING PROGRAM IN FLXNIT'
  STOP
END IF
C
IF (IKPSIZ.NE.KPDIM) THEN
  WRITE(6,*) 'DIMENSION ERROR IN SUBROUTINE FLXNIT'
  WRITE(6,*) 'IKPSIZ IS NOT EQUAL TO KPDIM'
  WRITE(6,*) 'IKPSIZ=', ISPSIZ, 'KPDIM=', KPDIM
  WRITE(6,*) 'STOPPING PROGRAM IN FLXNIT'
  STOP
END IF
C
FNRG=10.**FNRGLG
C
IF (ISPP.EQ.1) THEN
  CALCULATE ELECTRON FLUX VALUES
  RKAP=6.
  FKAP=.9359421
C
CALCULATE PLASMA SHEET FLUX, FLX13
  DENSTY=(.4*(FKP-1.)+0.5*(5.-FKP))/4.
  EZERO=.2885*(FKP-1.)+.15625*(5.-FKP)
  FLX13=1.68E5*FKAP*DENSTY*(FNRG*1.E-3/EZERO)/SQRT(EZERO)/
  2 (1.+(FNRG*1.E-3)/RKAP/EZERO)**(RKAP+1.)
C
CALCULATE GEOSYNCHRONOUS FLUX, FLX6
  IKP=NINT(FKP+1.)
  FLX6=0.
  DO 10 N=1,2
    WRITE(6,*) 'IKP=', IKP, ' N=', N, ' FNRG=', FNRG
    WRITE(6,*) 'DENSITY=', DENGEO(N, IKP), ' EZERO=', EGEO(N, IKP)
    WRITE(6,*) 'FKAP=', FKAP, ' RKAP=', RKAP
    FLX6=FLX6+1.68E5*FKAP*DENGEO(N, IKP)*(FNRG/EGEO(N, IKP))/
    2 SQRT(EGEO(N, IKP)*1.E-3)/
    3 (1.+MIN(FNRG/RKAP/EGEO(N, IKP), 1.E5))** (RKAP+1.)
    WRITE(6,*) 'FLX6=', FLX6
  10 CONTINUE
C
CALCULATE FLUX AT L=4, FLX4
  FLX4=1.106E1*(FNRG*1.E-3)*(10.**((FKP-2.)/6.))/
  2 (1.+FNRG*1.E-3/32.))**3
  WRITE(6,*) 'FLX4=', FLX4
C
CALCULATE FLUX AT L=3, FLX3
  FLX3=4.795E0*(FNRG*1.E-3)*(10.**((FKP-2.)/6.))/
  2 (1.+FNRG*1.E-3/65.8))**3.8
C
ELSE
  CALCULATE H+ OR O+ FLUXES
C
PLASMA SHEET FLUX, FLX13
  DENSTY=(.4*(FKP-1.)+0.5*(5.-FKP))/4.
  EZERO=2.25*(FKP-1.)+1.219*(5.-FKP)
C
EZERO IN KEV
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RKAP=6.
FKAP=.9359421
C
IF (FKP.GE.1.) THEN
  RATOH=(0.6*(FKP-1.)+0.06*(5.-FKP))/4.
ELSE
  RATOH=0.06
END IF
C
IF (ISPP.EQ.2) THEN
  DENION=DENSTY/(1.+RATOH)
  AWT=1.
ELSE
  DENION=DENSTY*RATOH/(1.+RATOH)
  AWT=16.
END IF
C
FLX13=3.93E3*FKAP*DENION*(FNRG*1.E-3/EZERO)/SQRT(AWT*EZERO)/
2      (1.+(FNRG*1.E-3)/RKAP/EZERO)**(RKAP+1.)
C
C
C CALCULATE GEOSYNCHRONOUS ION FLUX, FLX6
  RKAP1=10.
  RKAP2=4.
  FKAP1=.96194826
  FKAP2=.9027036
C
  RATOH1=(0.7*(FKP-1.)+0.4*(5.-FKP))/4.
C
IF (FKP.GE.1.) THEN
  RATOH2=(0.154*(5.-FKP)+0.767*(FKP-1.))/4.
ELSE
  RATOH2=0.154
END IF
C
IKP=NINT(FKP+1.)
FLX6=0.
C
DO 20 N=1,2
C
  IF (N.EQ.1) THEN
    RKAP=RKAP1
    FKAP=FKAP1
    RATOH=RATOH1
  ELSE
    RKAP=RKAP2
    FKAP=FKAP2
    RATOH=RATOH2
  END IF
C
  IF (ISPP.EQ.2) THEN
    H+ IONS
    DENION=DIONG(N,IKP)/(1.+RATOH)
    AWT=1.
  ELSE
    O+ IONS
    DENION=DIONG(N,IKP)*RATOH/(1.+RATOH)
    AWT=16.
  END IF
C
  FLX6=FLX6+3.93E3*FKAP*DENION*(FNRG/EIONG(N,IKP))/
2      SQRT(AWT*EIONG(N,IKP)*1.E-3)/
3      (1.+FNRG/RKAP/EIONG(N,IKP)**(RKAP+1.)
C
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MSM65120
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MSM65170
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MSM65200
MSM65210
MSM65220
MSM65230
MSM65240
MSM65250
MSM65260
MSM65270

30/06/30
12:03:44

msm1.for

104

```
60      CONTINUE
C
50      CONTINUE
C
      IF (FKP.LE.5.34) THEN
          FLXLOG=ALOG10 (FLX43 (1) )+ALOG10 (FLX43 (2) /FLX43 (1) ) *
2              (FKP/5.34)
      ELSE IF (FKP.GT.5.34.AND.FKP.LE.8.67) THEN
          FLXLOG=ALOG10 (FLX43 (2) )+ALOG10 (FLX43 (3) /FLX43 (2) ) *
2              ((FKP-5.34) / (8.67-5.34))
      ELSE
          FLXLOG=ALOG10 (FLX43 (3) )
      END IF
C
      FLX3=10.**FLXLOG
C
C
      END IF
C
      RETURN
      END
      FUNCTION FLXTRP (RLOG, FLX3, FLX4, FLX6, FLX13)
C
C  VERSION 1.00                      DATE: 10.04.89
C
C  PURPOSE: FUNCTION SUBPROGRAM TO RETURN FLUX VALUE INTERPOLATED
C           BETWEEN VALUES AT L=3, 4, 6.6, AND 13 RE.
C
C
      FR=10.**RLOG
      IF (FR.LE.4.) THEN
          FLXLOG=(ALOG10 (FR/3.) *ALOG10 (FLX4)+ALOG10 (4./FR) *ALOG10 (FLX3) )
2              /ALOG10 (4./3.)
      ELSE IF (FR.GT.4..AND.FR.LE.6.6) THEN
          FLXLOG=(ALOG10 (FR/4.) *ALOG10 (FLX6)+ALOG10 (6.6/FR) *ALOG10 (FLX4) )
2              /ALOG10 (6.6/4.)
      ELSE
          FLXLOG=ALOG10 (FLX13)+ALOG10 (13./FR)
      END IF
C
      FLXTRP=FLXLOG
C
C
      RETURN
      END
      FUNCTION FLXVAL (ISP, FKP, RR, PP, ENRG, IRDIM, NRGDIM, KPDIM, KPPLUS,
2              ISPDIM, FLXMAT, FLXR, FLXNRG, FLXKP)
C
C  VERSION 1.00                      DATE: 05.08.90
C                                       12.31.89
C                                       05.30.90
C
C  PURPOSE: CALCULATE KP-DEPENDENT FLUX VALUE AT R=RR, FOR PARTICLES OF
C           SPECIES ISP, OF ENERGY ENRG AND KP=FKP CONDITIONS BY
C           INTERPOLATING FLXMAT ARRAY.
C
C  PROGRAMMER: R.W. SPIRO
C
      DIMENSION FLXMAT (IRDIM, NRGDIM, KPPLUS, ISPDIM)
      DIMENSION FLXR (IRDIM) , FLXNRG (NRGDIM) , FLXKP (KPDIM)
C
C  DETERMINE INTERPOLATION INDICES
C
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MSM65920
MSM65930
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MSM65990
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MSM66490
MSM66500
MSM66510
MSM66520
MSM66530
MSM66540
MSM66550

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IF (FKP.GE.0.) THEN
  BKP=FKP+1.
  IF (BKP.GT.FLOAT (KPDIM)) BKP=FLOAT (KPDIM)
ELSE
  BKP=ABS (FKP)
END IF
C
BNRG=4.*ALOG10 (ENRG) -3.
C
RLOG=ALOG10 (RR)
C
IF (RLOG.GT.FLXR (IRDIM)) THEN
  BR=IRDIM
  FLXLOG=G3NTRP (FLXMAT (1,1,1,ISP), IRDIM, NRGDIM, KPPLUS, BR, BNRG,
2
  BKP) + ALOG10 (13./RR)
C
ELSE
C
  DO 10 IR=1,IRDIM-1
    IF (RLOG.LE.FLXR (IR+1)) THEN
      BR=FLOAT (IR) + (RLOG-FLXR (IR)) / (FLXR (IR+1) -FLXR (IR))
      GO TO 20
    END IF
10  CONTINUE
C
20  CONTINUE
C
  WRITE (6,*) 'FKP,RR,ENRG',FKP,RR,ENRG
  WRITE (6,*) 'BKP,BR,BNRG',BKP,BR,BNRG
C
  FLXLOG=G3NTRP (FLXMAT (1,1,1,ISP), IRDIM, NRGDIM, KPPLUS, BR, BNRG,
2
  BKP)
C
  END IF
C
  FLXVAL=10.**FLXLOG
C
  WRITE (6,*) 'FLXLOG=',FLXLOG,' FLXVAL=',FLXVAL
C
  RETURN
  END
  SUBROUTINE EFIELD (KPATT,PCP,DEQDT,ASOUTH,BSOUTH,DXS,DYS,ANORTH,
2
  BNORTH,DXN,DYN,COLAT,ALECT,MODE,LATDIM,LTDIM,
3
  JWRAP,ITMDIM,ITMCUR,ICNTRL,ITOP,V,VNORTH,
4
  VSOUTH)
C
C PURPOSE: SUBROUTINE TO RETURN VALUES OF THE POTENTIAL ON THE
C NORTHERN HEMISPHERE GRID (VNORTH), ON THE SOUTHERN
C HEMISPHERE GRID (VSOUTH), AND THE AVERAGE OF THE TWO
C HEMISPHERES (V). THE POTENTIAL DISTRIBUTION GIVEN BY
C V IS THE ACTUAL DISTRIBUTION USED TO FOLLOW PARTICLE
C TRACES. THIS ROUTINE CALLS SUBROUTINE EMODEL TO ACTUALLY
C COMPUTE THE POTENTIAL DISTRIBUTIONS.
C
C NOTE: KPATT GIVES THE UTD DEFINED PATTERN TYPE WITH 0 CORRESPONDING
C TO NORTHWARD IMF CASES; 1 TO BZ SOUTH WITH STRONGER FLOW ON
C THE DAWN SIDE OF THE POLAR CAP; 2 TO BZ SOUTH WITH SYMMETRIC
C FLOW; AND 3 TO BZ SOUTH WITH STRONGER FLOW ON THE DUSK SIDE.
C THIS SUBROUTINE CALLS EMODEL AFTER TRANSLATING THE PATTERN
C TYPE TO THE INTERNAL EMODEL CONVENTION AS GIVEN BELOW:
C
C GENERAL CALL PARAMETERS FOR SUBROUTINE EMODEL
C
C IPATT = HEPPNER-MAYNARD PATTERN NO. MUST BE SPECIFIED AS AN
C INTEGER BETWEEN 1 AND 7.
C IPATT=1 MEANS PATTERN A, FOR BZ SOUTH, BY=0.

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MSM66560
MSM66570
MSM66580
MSM66590
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MSM66670
MSM66680
MSM66690
MSM66700
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MSM67130
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MSM67150
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MSM67180
MSM67190

msml.for

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C          IPATT=2 MEANS PATTERN BC, FOR BZ SOUTH, BYNORTH>0      MSM67200
C          IPATT=3 MEANS PATTERN DE, FOR BZ SOUTH, BYNORTH<0      MSM67210
C          IPATT=4 MEANS PATTERN BCP, TWISTED BC, FOR BZ>0        MSM67220
C          IPATT=5 MEANS PATTERN BCPP, TWISTED BC, BZ STRONG>0    MSM67230
C          IPATT=6 MEANS PATT. DEP, TWISTED DE, BZ WEAK >0       MSM67240
C          IPATT=7 MEANS PATT. DEPP, TWISTED DE, BZ STRONG>0      MSM67250
C          MSM67260
C          FOR THE PRESENT, NORTHWARD IMF CASES ARE ALL TREATED AS IPATT=1  MSM67270
C          PROGRAMMER: R.W. SPIRO                                LAST UPDATE: 11-17-89  MSM67280
C          MSM67290
C          MSM67300
C          MSM67310
C          DIMENSION COLAT (LATDIM, LTDIM), ALOCT (LATDIM, LTDIM)  MSM67320
C          DIMENSION V (LATDIM, LTDIM, ITMDIM), VNORTH (LATDIM, LTDIM)  MSM67330
C          DIMENSION VSOUTH (LATDIM, LTDIM)                        MSM67340
C          DIMENSION ASOUTH (3, ITMDIM), BSOUTH (3, ITMDIM)       MSM67350
C          DIMENSION DXS (3, ITMDIM), DYS (3, ITMDIM)             MSM67360
C          DIMENSION ANORTH (3, ITMDIM), BNORTH (3, ITMDIM)      MSM67370
C          DIMENSION DXN (3, ITMDIM), DYN (3, ITMDIM)             MSM67380
C          MSM67390
C          MSM67400
C          IF (KPATT.EQ.0) THEN                                     MSM67410
C          NORTHWARD BZ CASE                                       MSM67420
C          IPATT=1                                                 MSM67430
C          CALL EMODEL (IPATT, PCP, DEQDT, ASOUTH (1, ITMCUR), BSOUTH (1, ITMCUR), MSM67440
C          2          DXS (1, ITMCUR), DYS (1, ITMCUR), COLAT, ALOCT,  MSM67450
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VSOUTH)  MSM67460
C          CALL EMODEL (IPATT, PCP, DEQDT, ANORTH (1, ITMCUR), BNORTH (1, ITMCUR), MSM67470
C          2          DXN (1, ITMCUR), DYN (1, ITMCUR), COLAT, ALOCT,  MSM67480
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VNORTH)  MSM67490
C          MSM67500
C          ELSE IF (KPATT.EQ.-1.OR.KPATT.EQ.3) THEN               MSM67510
C          CASE OF BZ SOUTH, BY<0                                  MSM67520
C          IPATT=2                                                 MSM67530
C          CALL EMODEL (IPATT, PCP, DEQDT, ASOUTH (1, ITMCUR), BSOUTH (1, ITMCUR), MSM67540
C          2          DXS (1, ITMCUR), DYS (1, ITMCUR), COLAT, ALOCT,  MSM67550
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VSOUTH)  MSM67560
C          MSM67570
C          IPATT=3                                                 MSM67580
C          CALL EMODEL (IPATT, PCP, DEQDT, ANORTH (1, ITMCUR), BNORTH (1, ITMCUR), MSM67590
C          2          DXN (1, ITMCUR), DYN (1, ITMCUR), COLAT, ALOCT,  MSM67600
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VNORTH)  MSM67610
C          MSM67620
C          ELSE IF (KPATT.EQ.1.OR.KPATT.EQ.-3) THEN               MSM67630
C          CASE OF BZ SOUTH, BY>0                                  MSM67640
C          IPATT=3                                                 MSM67650
C          CALL EMODEL (IPATT, PCP, DEQDT, ASOUTH (1, ITMCUR), BSOUTH (1, ITMCUR), MSM67660
C          2          DXS (1, ITMCUR), DYS (1, ITMCUR), COLAT, ALOCT,  MSM67670
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VSOUTH)  MSM67680
C          MSM67690
C          IPATT=2                                                 MSM67700
C          CALL EMODEL (IPATT, PCP, DEQDT, ANORTH (1, ITMCUR), BNORTH (1, ITMCUR), MSM67710
C          2          DXN (1, ITMCUR), DYN (1, ITMCUR), COLAT, ALOCT,  MSM67720
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VNORTH)  MSM67730
C          MSM67740
C          ELSE                                                    MSM67750
C          CASE OF BZ SOUTH, SYMMETRIC FLOW                         MSM67760
C          IPATT=1                                                 MSM67770
C          CALL EMODEL (IPATT, PCP, DEQDT, ASOUTH (1, ITMCUR), BSOUTH (1, ITMCUR), MSM67780
C          2          DXS (1, ITMCUR), DYS (1, ITMCUR), COLAT, ALOCT,  MSM67790
C          3          MODE, LATDIM, LTDIM, JWRAP, ICNTRL, ITOP, VSOUTH)  MSM67800
C          MSM67810
C          MSM67820
C          MSM67830

```


msml.for

DIMENSION XMLT(26), PWRKP(26,7), PTOT(JDIM), PWRTOT(JDIM)
DIMENSION FRACT(JDIM), RENORM(JDIM), PWRMDL(JDIM)

MSM68480
MSM68490
MSM68500

C PWRMDL(J)=TOTAL PRECIPITATED POWER WITHIN MODEL REGION PER J GRID LINEMSM68510
C PTOT(J)=OBSERVED POWER PER HOUR OF LOCAL TIME*D(LT)/DJ AT JGRID FOR MSM68520
C GIVEN KP VALUE MSM68530

MSM68540

C PWRTOT(J)=OBSERVED POWER CORRECTED FOR OUR MODELING REGION MSM68550
C =PTOT(J)*(1.-FRACT(J)) MSM68560

MSM68570

C RENORM(J)=PWRMDL(J)/PWRTOT(J) MSM68580

MSM68590

C
C

DATA XMLT/11.5,12.5,13.5,14.5,15.5,16.5,17.5,18.5,
\$ 19.5,20.5,21.5,22.5,23.5,24.5,
\$ 25.5,26.5,27.5,28.5,29.5,30.5,
\$ 31.5,32.5,33.5,34.5,35.5,36.5/

MSM68600

MSM68610

MSM68620

MSM68630

MSM68640

MSM68650

C PWRKP VALUES COME FROM INTEGRATING HARDY MODEL OVER LATITUDE USING MSM68660
C PROGRAM SUMHDY (NOVEMBER, 1989) MSM68670

MSM68680

C

DATA PWRKP /.161,.171,.156,.168,.140,.127,.126,.109,.095,.097,
1 .131,.222,.280,.209,.147,.142,.168,.211,.185,.159,
1 .173,.189,.174,.156,.161,.171,
2 .201,.146,.132,.164,.168,.161,.171,.226,.290,.303,
2 .320,.387,.483,.520,.454,.424,.453,.464,.403,.353,
2 .346,.326,.285,.243,.201,.146,
3 .280,.183,.156,.207,.271,.258,.254,.317,.430,.532,
3 .624,.751,.898,1.05,1.14,1.15,.959,.689,.615,.605,
3 .564,.515,.455,.388,.280,.183,
4 .263,.209,.224,.271,.300,.368,.585,.915,1.09,1.01,
4 .973,1.23,1.64,1.83,1.72,1.61,1.63,1.60,1.31,.999,
4 .872,.841,.688,.428,.263,.209,
5 .263,.189,.166,.195,.215,.360,.699,1.01,1.48,1.65,
5 1.57,1.57,1.92,2.18,1.84,1.55,1.76,2.25,2.12,1.49,
5 1.21,1.10,.784,.433,.263,.189,
6 .287,.229,.265,.340,.550,.880,.969,1.39,2.19,2.24,
6 1.72,1.62,2.00,2.41,1.91,1.84,2.58,2.98,2.34,1.69,
6 1.32,.978,.644,.425,.287,.229,
7 .360,.315,.279,.309,.472,.849,1.60,2.42,3.12,3.27,
7 3.15,3.99,6.21,7.26,5.63,4.19,4.45,5.02,4.12,2.89,
7 2.06,1.38,.730,.431,.360,.315/

MSM68690

MSM68700

MSM68710

MSM68720

MSM68730

MSM68740

MSM68750

MSM68760

MSM68770

MSM68780

MSM68790

MSM68800

MSM68810

MSM68820

MSM68830

MSM68840

MSM68850

MSM68860

MSM68870

MSM68880

MSM68890

C

PI=ATAN2(0.,-1.)
DLTDJ=24./FLOAT(LTDIM-JWRAP)
BKP=FKP+1.
IF(BKP.GT.7.) BKP=7.

MSM68900

MSM68910

MSM68920

MSM68930

MSM68940

MSM68950

C

C CHECK DIMENSION COMPATIBILITY

MSM68960

IF(JDIM.NE.LTDIM) THEN

MSM68970

WRITE(6,*) '**** DIMENSION ERROR IN SUBROUTINE PWRCAL ****'

MSM68980

WRITE(6,*) ' JDIM=',JDIM,' LTDIM=',LTDIM

MSM68990

WRITE(6,*) '**** STOPPING PROGRAM IN PWRCAL ****'

MSM69000

STOP

MSM69010

END IF

MSM69020

C

C COMPUTE PTOT AND PWRTOT

MSM69030

MSM69040

MSM69050

MSM69060

MSM69070

DO 10 J=JWRAP,LTDIM-1

MSM69080

IMIN=NINT(BNDLOC(J,ITMCUR)+.5)

MSM69090

FRACT(J)=0.5+.3*SIN(ALOCT(IMIN,J))

MSM69100

TIME=ALOCT(IMIN,J)*12./PI+12.

MSM69110

```
C
DO 20 N=1,25
  IF (TIME.GT.XMLT(N).AND.TIME.LE.XMLT(N+1)) THEN
    F=(TIME-XMLT(N))/(XMLT(N+1)-XMLT(N))
    BXMLT=FLOAT(N)+F
    GO TO 15
  END IF
20 CONTINUE
  WRITE(6,*)'**** ERROR IN PWRCAL ****'
  WRITE(6,*) 'J=',J,' TIME=',TIME
  WRITE(6,*) 'STOPPING PGM IN PWRCAL'
  STOP
15 CONTINUE
C
  PTOT(J)=G3NTRP(PWRKP,26,7,1,BXMLT,BKP,1.)
  PTOT(J)=PTOT(J)*DLTDJ
  PWRTOT(J)=PTOT(J)*(1.-FRACT(J))
C
  PWRMDL(J)=0.
C
  IMAX=LATDIM
C
  DO 30 I=IMIN,IMAX
    PWRMDL(J)=PWRMDL(J)+FLXSUM(I,J,1)*ALPHA(I)*BETA(I)
30 CONTINUE
  PWRMDL(J)=1.E-6*DLAM*DPSI*RI**2*PWRMDL(J)
40 CONTINUE
C
C PWRMDL(J) IS IN UNITS OF GW/GRID LINE
C
  RENORM(J)=PWRMDL(J)/PWRTOT(J)
10 CONTINUE
C CIRCULARIZE
  RENORM(1)=RENORM(JDIM-2)
  RENORM(2)=RENORM(JDIM-1)
  RENORM(JDIM)=RENORM(JWRAP)
  PTOT(1)=PTOT(JDIM-2)
  PTOT(2)=PTOT(JDIM-1)
  PTOT(JDIM)=PTOT(JWRAP)
C
  FRACT(1)=FRACT(JDIM-2)
  FRACT(2)=FRACT(JDIM-1)
  FRACT(JDIM)=FRACT(JWRAP)
C
  PWRTOT(1)=PWRTOT(JDIM-2)
  PWRTOT(2)=PWRTOT(JDIM-1)
  PWRTOT(JDIM)=PWRTOT(JWRAP)
C
  PWRMDL(1)=PWRMDL(JDIM-2)
  PWRMDL(2)=PWRMDL(JDIM-1)
  PWRMDL(JDIM)=PWRMDL(JWRAP)
C
C DEBUG 6.06.90 $$$$
  CALL OUTP(PWRMDL,1,JDIM,1,1,1,1,JDIM,1,0.0,'PWRMDL',6,132)
  CALL OUTP(PTOT,1,JDIM,1,1,1,1,JDIM,1,0.0,'PTOT',6,132)
  CALL OUTP(PWRTOT,1,JDIM,1,1,1,1,JDIM,1,0.0,'PWRTOT',6,132)
  CALL OUTP(RENORM,1,JDIM,1,1,1,1,JDIM,1,0.0,'RENORM',6,132)
C END DEBUG 6.06.90 $$$$
C
C WRITE(6,*) 'A(1)= ',A(1),' B(1)= ',B(1),' DX(1)= ',DX(1)
C WRITE(6,*) 'DY(1)= ',DY(1)
C
DO 100 J=1,JDIM
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MSM69740
MSM69750
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C
C INPUT PARAMETERS:
C   RMID           R VALUE AT PT WHERE WKRATE IS TO BE EVALUATED
C                   (RE)
C   RPPMID        ESTIMATE OF PLASMAPAUSE RADIUS (RE)
C   PMJD          LOCAL TIME HOUR ANGLE IN EQUATORIAL PLANE
C                   (RADIAN FROM LOCAL NOON)
C   ENRG          PARTICLE ENERGY (EV)
C
C   IF (RMID.LE.RPPMID) THEN
C USE LYONS RESULTS
C   WKRATE=RLYONS (RMID,ENRG)
C   GO TO 100
C   ELSE IF (ENRG.LE.20.E3) THEN
C   WKRATE=0.
C   GO TO 100
C   ELSE
C   WKGEO=MIN(ENRG/20.E3-1.,1.)*(1.+(9./11.)*COS(PMID))/1200.
C
C   IF (RMID.GT.6.6) THEN
C   WKRATE=WKGEO
C   GO TO 100
C   ELSE
C   XLYONS=RLYONS (RPPMID,ENRG)
C   WKRATE=((6.6-RMID)/(6.6-RPPMID))*XLYONS+
2       ((RMID-RPPMID)/(6.6-RPPMID))*WKGEO
C   END IF
C   END IF
C
C 100 CONTINUE
C   IF (WKRATE.GT.10.) THEN
C   WRITE(6,800) RMID,RPPMID,PMJD,ENRG,WKRATE
C 800 FORMAT(1X,'WKRATE.GT.10'/1X,'RMID=',F6.3,2X,'RPPMID=',F6.3,2X,
2       'PMJD=',F6.3,2X,'ENRG=',1PE12.3,2X,'WKRATE=',E12.3)
C   END IF
C   RETURN
C   END
C   REAL FUNCTION RLYONS (RMID,ENRG)
C
C PURPOSE: FUNCTION SUBPROGRAM TO EVALUATE LYONS-BASED WEAK LOSS RATE.
C
C PROGRAMMER: R.W. SPIRO           DATE: 01.05.90
C
C   IF (ENRG.LE.50.E3) THEN
C   XLOGLO=(4.9365+15.8621)-6.06897*RMID+0.551724*RMID**2
C   XLOGHI=(4.9365+13.5172)-5.58621*RMID+0.551724*RMID**2
C   F=(ENRG-20.E3)/(50.E3-20.E3)
C   ELSE IF (ENRG.GT.50.E3.AND.ENRG.LE.200.E3) THEN
C   XLOGLO=(4.9365+13.5172)-5.58621*RMID+0.551724*RMID**2
C   XLOGHI=(4.9365+1.15517)-0.42069*RMID+0.0275862*RMID**2
C   F=(ENRG-50.E3)/(200.E3-50.E3)
C   ELSE
C   XLOGLO=(4.9365+1.15517)-0.42069*RMID+0.0275862*RMID**2
C   XLOGHI=(4.9365+3.89655)-1.75862*RMID+0.206897*RMID**2
C   F=(ENRG-200.E3)/(500.E3-200.E3)
C   END IF
C
C   XLOG=(1.-F)*XLOGLO+F*XLOGHI
C
C   TAU=10.**XLOG
C
C   XLYONS=1./TAU
C   RLYONS=XLYONS
C
MSM71040
MSM71050
MSM71060
MSM71070
MSM71080
MSM71090
MSM71100
MSM71110
MSM71120
MSM71130
MSM71140
MSM71150
MSM71160
MSM71170
MSM71180
MSM71190
MSM71200
MSM71210
MSM71220
MSM71230
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MSM71490
MSM71500
MSM71510
MSM71520
MSM71530
MSM71540
MSM71550
MSM71560
MSM71570
MSM71580
MSM71590
MSM71600
MSM71610
MSM71620
MSM71630
MSM71640
MSM71650
MSM71660
MSM71670

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90/06/30
12:03:44

mssl.for

113

```
C          RETURN
          END
          FUNCTION G3TRPA(A, IMAX, JMAX, KMAX, BI, BJ, BK)
C
C  VERSION 1.00                      DATE: 01.09.90
C
C  PURPOSE: FUNCTION SUBPROGRAM TO PERFORM A GENERAL 3-D LINEAR
C           INTERPOLATION OF ANGULAR ARRAY A(I,J,K) AT PT(BV(1),BV(2),BV(3))
C
C  INPUT:
C           A                        3-D ARRAY TO BE INTERPOLATED
C                                     INTERPOLATE A
C
C
C           COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1          LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2          LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3          LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
          DIMENSION A(IMAX, JMAX, KMAX)
          DIMENSION NDX(3), NDIM(3), BV(3), COEF(3, 2)
C
C  PREPARE INDICES FOR INTERPOLATION
C
          PI=ATAN2(0., -1.)
          NDIM(1)=IMAX
          NDIM(2)=JMAX
          NDIM(3)=KMAX
          BV(1)=BI
          BV(2)=BJ
          BV(3)=BK
          DO 10 L=1, 3
             NDX(L)=BV(L)
             IF (NDX(L) .LT. 1) NDX(L)=1
             IF (NDX(L) .GT. NDIM(L)-1) NDX(L)=NDIM(L)-1
             IF (NDX(L) .LE. 0) NDX(L)=1
C
C           FNDX=REAL(NDX(L))
C           COEF(L, 1)=1.-BV(L)+FNDX
C           COEF(L, 2)=BV(L)-FNDX
10 CONTINUE
C
C          G3TRPA=0.
          IC=0
          KSTOP = MIN(KMAX, 2)
          JSTOP = MIN(JMAX, 2)
          DO 20 I=1, 2
             DO 20 J=1, JSTOP
                DO 20 K=1, KSTOP
                   IC=IC+1
                   AVAL=A(NDX(1)+I-1, NDX(2)+J-1, NDX(3)+K-1)
                   IF (IC.EQ.1) THEN
C  USE FIRST VALUE OF ARRAY TO SET MODULUS
                   REFMOD=AVAL
                   END IF
C
C                   IF ((AVAL-REFMOD) .GT. PI) THEN
C                       AVAL=AVAL-2.*PI
C                   ELSE IF ((AVAL-REFMOD) .LE. -PI) THEN
C                       AVAL=AVAL+2.*PI
C                   END IF

```

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msm1.for

114

```
C
      G3TRPA=G3TRPA+
1      COEF (1, I) *COEF (2, J) *COEF (3, K) *AVAL
20 CONTINUE
C
C GET RESULT IN A REASONABLE MODULUS
      IF (G3TRPA.GT.2.*PI) THEN
          G3TRPA=G3TRPA-2.*PI
      ELSE IF (G3TRPA.LT.0.) THEN
          G3TRPA=G3TRPA+2.*PI
      END IF
      RETURN
      END
      SUBROUTINE THRCAL (FKP, FNRGLG, NRGNDX, KPNDX, IRDIM, NRGDIM, KPDIM,
2          KPPLUS, ISPDIM, FLXMAT, THR)
C
C PURPOSE: SUBROUTINE TO CALCULATE THRESHOLD FLUX AT R=3,4,6.6, AND
C          13 RE FOR KP=FKP AND LOG(ENERGY)=FNRGLG. THR IS IN UNITS
C          OF PARTICLES/CM**2/S/SR/EV.
C
C PROGRAMMER: R.W. SPIRO          DATE: 05.09.90
C
C          DIMENSION FLXMAT (IRDIM, NRGDIM, KPPLUS, ISPDIM), THR (4), RTHR (4)
C          DIMENSION EZERO (4, 7), RKAP (4)
C
C          DATA RTHR /3., 4., 6.6, 13./
C
C          DATA EZERO /23.5E3, 16.E3, 21.E3, .49275E3,
1          23.5E3, 16.E3, 4.8324E3, .625E3,
2          23.5E3, 16.E3, 4.814E3, .75725E3,
3          23.5E3, 16.E3, 4.7978E3, .8895E3,
4          23.5E3, 16.E3, 4.816E3, 1.02175,
5          23.5E3, 16.E3, 4.8943E3, 1.154E3,
6          23.5E3, 16.E3, 5.0752E3, 1.28625E3/
C
C          DATA RKAP /2.8, 2.0, 6., 6./
C
C          ETOP=40.E3
C          ELOW=20.E3
C          ENRG=10.**FNRGLG
C
C          IF (ENRG.LE.ELOW) THEN
              THR (1) =FLXMAT (1, NRGNDX, 1, 1)
              THR (2) =FLXMAT (2, NRGNDX, 1, 1)
              THR (3) =FLXMAT (3, NRGNDX, 1, 1)
              THR (4) =FLXMAT (4, NRGNDX, 1, 1)
C
C          ELSE IF (ENRG.GE.ETOP) THEN
              DO 10 N=1, 4
                  RK=RKAP (N)
                  EZ=EZERO (N, KPNDX)
C
C                  IF (RK.GE.6.0) THEN
                      ER=(1./EZ) * ((RK-1.)/RK) * (ENRG/EZ) * (1.+ETOP/(RK*EZ)) **RK/
2                      (1.+MIN(ENRG/RK/EZ, 1.E5)) ** (RK+1.)/(1.+ETOP/EZ)
                      ELSE
2                      ER=(1./EZ) * ((RK-1.)/RK) * (ENRG/EZ) * (1.+ETOP/(RK*EZ)) **RK/
                      (1.+ENRG/RK/EZ) ** (RK+1.)/(1.+ETOP/EZ)
                  ENDIF
C
C                  THR (N) =ALOG10 (5.E7*ER* (6.6/RTHR (N)) **4)
C
C          MSM72320
C          MSM72330
C          MSM72340
C          MSM72350
C          MSM72360
C          MSM72370
C          MSM72380
C          MSM72390
C          MSM72400
C          MSM72410
C          MSM72420
C          MSM72430
C          MSM72440
C          MSM72450
C          MSM72460
C          MSM72470
C          MSM72480
C          MSM72490
C          MSM72500
C          MSM72510
C          MSM72520
C          MSM72530
C          MSM72540
C          MSM72550
C          MSM72560
C          MSM72570
C          MSM72580
C          MSM72590
C          MSM72600
C          MSM72610
C          MSM72620
C          MSM72630
C          MSM72640
C          MSM72650
C          MSM72660
C          MSM72670
C          MSM72680
C          MSM72690
C          MSM72700
C          MSM72710
C          MSM72720
C          MSM72730
C          MSM72740
C          MSM72750
C          MSM72760
C          MSM72770
C          MSM72780
C          MSM72790
C          MSM72800
C          MSM72810
C          MSM72820
C          MSM72830
C          MSM72840
C          MSM72850
C          MSM72860
C          MSM72870
C          MSM72880
C          MSM72890
C          MSM72900
C          MSM72910
C          MSM72920
C          MSM72930
C          MSM72940
C          MSM72950
```

```
10 CONTINUE
C
  ELSE
C ENRG IS BETWEEN ELOW AND ETOP
C
  DO 20 N=1, 4
    RK=RKAP (N)
    EZ=EZERO (N, KPNDX)
C
    ERTOP=(1./EZ)*((RK-1.)/RK)*(ETOP/EZ)/
  2      (1.+ETOP/RK/EZ)/(1.+ETOP/EZ)
C
    THRTOP=ALOG10(5.E7*ERTOP*(6.6/RTHR(N))**4)
C
    THRLOW=FLXMAT(N, NRGNDX, 1, 1)
C
    THR(N) = (ETOP-ENRG)*THRLOW + (ENRG-ELOW)*THRTOP / (ETOP-ELOW)
C
20 CONTINUE
C
  END IF
C
  RETURN
  END
  SUBROUTINE FLXDFL(ITM, FKP, R, P, ALAM, VM, IRDIM, NRGDIM, KPDIM, KPPLUS,
1  ISPDIM, FLXMAT, FLXR, FLXNRG, FLXKP, EFLUX, ETA, ALMDEL, LATDIM,
2  LTDIM, IEDIM, ITMDIM, BNDLOC, IEMAX, IFLAV, IEBEG, IEEND)
C
C SUBROUTINE WHICH USES THE FLXMAT ARRAYS TO
C CALCULATE THE ENERGY-DEPENDENT ETA ARRAYS. THIS IS THE
C DEFAULT MODEL WHEN ONLY KP IS AVAILABLE TO RUN THE PROGRAM.
C
  PARAMETER(JJDIM=51)
  DIMENSION R(LATDIM, LTDIM, ITMDIM), P(LATDIM, LTDIM, ITMDIM),
1  ALAM(IEDIM), VM(LATDIM, LTDIM, ITMDIM),
2  FLXMAT(IRDIM, NRGDIM, KPPLUS, ISPDIM),
3  FLXR(IRDIM), FLXNRG(NRGDIM), FLXKP(KPDIM),
4  BNDLOC(LTDIM, ITMDIM), EFLUX(LATDIM, LTDIM, IEDIM), IBLOC(JJDIM),
5  ETA(LATDIM, LTDIM, IEDIM), ALMDEL(IEDIM), IFLAV(IEDIM)
C
  IF(JJDIM.NE.LTDIM) THEN
    WRITE(6,*)' DIMENSION ERROR IN FLXDFL SUBROUTINE, PROGRAM STOPS.'
    STOP
  ENDIF
C
  DO 10 J=1, LTDIM
    IBLOC(J)=IFIX(BNDLOC(J, ITM))
    DO 20 I=IBLOC(J), LATDIM
      DO 30 K=IEBEG, IEEND
        EFLUX(I, J, K)=0.0
30 CONTINUE
20 CONTINUE
10 CONTINUE
    DO 50 J=1, LTDIM
      DO 60 I=IBLOC(J), LATDIM
        DO 70 K=IEBEG, IEEND
          ISP=IFLAV(K)
          ENRG=ABS(ALAM(K))*VM(I, J, ITM)
          FLXOUT=FLXVAL(ISP, FKP, R(I, J, ITM), P(I, J, ITM), ENRG, IRDIM,
1  NRGDIM, KPDIM, KPPLUS, ISPDIM, FLXMAT, FLXR, FLXNRG, FLXKP)
          IF(IFLAV(K).EQ.1) THEN
            XMSCNT=7.392E-16
C
            IF((K.EQ.1).OR.(K.EQ.5).OR.(K.EQ.9).OR.(K.EQ.13)) THEN
C
              WRITE(6,*)' I, J, K, FLUX, ENRG ', I, J, K, FLXOUT, ENRG
              MSM72960
              MSM72970
              MSM72980
              MSM72990
              MSM73000
              MSM73010
              MSM73020
              MSM73030
              MSM73040
              MSM73050
              MSM73060
              MSM73070
              MSM73080
              MSM73090
              MSM73100
              MSM73110
              MSM73120
              MSM73130
              MSM73140
              MSM73150
              MSM73160
              MSM73170
              MSM73180
              MSM73190
              MSM73200
              MSM73210
              MSM73220
              MSM73230
              MSM73240
              MSM73250
              MSM73260
              MSM73270
              MSM73280
              MSM73290
              MSM73300
              MSM73310
              MSM73320
              MSM73330
              MSM73340
              MSM73350
              MSM73360
              MSM73370
              MSM73380
              MSM73390
              MSM73400
              MSM73410
              MSM73420
              MSM73430
              MSM73440
              MSM73450
              MSM73460
              MSM73470
              MSM73480
              MSM73490
              MSM73500
              MSM73510
              MSM73520
              MSM73530
              MSM73540
              MSM73550
              MSM73560
              MSM73570
              MSM73580
              MSM73590
            END IF
          END IF
        END DO
      END DO
    END DO
  END DO

```

```

C      WRITE(6,*)' VM,ALMDEL,MSCNST',VM(I,J,ITM),ALMDEL(K),MSCNST
C      WRITE(6,*)' IFLAV ',IFLAV(K)
C      ENDIF
C      ETA(I,J,K)=(FLXOUT*ALMDEL(K))/(XMSCNT*SQRT(ABS(ALAM(K)))
1          *VM(I,J,ITM))
C      IF((K.EQ.1).OR.(K.EQ.5).OR.(K.EQ.9).OR.(K.EQ.13))THEN
C      WRITE(6,*)' ETA ',ETA(I,J,K)
C      ENDIF
C      ELSE
C      IONS
C      XMSCNT=1.731E-17
C      IF(IFLAV(K).EQ.2) THEN
C      ATOMWT=1.0
C      ELSE
C      ATOMWT=16.0
C      ENDIF
C      ETA(I,J,K)=(FLXOUT*ALMDEL(K)*SQRT(ATOMWT))/(XMSCNT*
1          SQRT(ABS(ALAM(K)))*VM(I,J,ITM))
C      ENDIF
70      CONTINUE
60      CONTINUE
50      CONTINUE
C      DO 100 K=IEBEG,IEEND
C      IF((K.EQ.1).OR.(K.EQ.5).OR.(K.EQ.9).OR.(K.EQ.13))THEN
C      WRITE(18,*)' K = ',K
C      WRITE(6,*)' K = ',K
C      CALL OUTP(ETA(1,1,K),LATDIM,LTDIM,10,50,1,3,LTDIM-1,1,
C      1      0.,'ETA',6,132)
C      ENDIF
100     CONTINUE
        RETURN
        END
        SUBROUTINE RMVBSH(WORK,LATDIM,LTDIM)
C
C      TEMPORARY FIX TO THE B-FIELD MATRICES TO REMOVE THE LARGE DATA
C      VALUES SIGNIFYING THAT THE FIELD LINES HAD 'GONE INTO THE BUSHES'.
C      IT LOOKS FOR THE CLOSEST VALUE IN J AND LINEARLY INTERPOLATES FOR
C      THE I VALUES.
C
        DIMENSION WORK(LATDIM,LTDIM,2,2,2,2)
        BFBUSH = 1.E20
        DO 10 N1=1,2
        DO 20 N2=1,2
        DO 30 N3=1,2
        DO 40 N4=1,2
        DO 50 N5=1,2
        DO 60 J=1,LTDIM
        DO 70 I=1,LATDIM
            IF(WORK(I,J,N1,N2,N3,N4,N5).LT.BFBUSH)GO TO 70
            IDO=I
999          CONTINUE
            IDO=IDO+1
            IF(WORK(IDO,J,N1,N2,N3,N4,N5).GT.BFBUSH)GO TO 999
            COEF1=WORK(IDO,J,N1,N2,N3,N4,N5)
            COEF2= WORK(IDO+1,J,N1,N2,N3,N4,N5)
            STRTLN=COEF2-COEF1
            DO 80 ICHK=IDO-1,1,-1
                WORK(ICHK,J,N1,N2,N3,N4,N5)=WORK(ICHK+1,J,N1,N2,N3,N4,N5)
1          - STRTLN
80          CONTINUE
70          CONTINUE
60          CONTINUE
50          CONTINUE
40          CONTINUE

```

MSM73600
MSM73610
MSM73620
MSM73630
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MSM73700
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MSM73990
MSM74000
MSM74010
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MSM74040
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MSM74070
MSM74080
MSM74090
MSM74100
MSM74110
MSM74120
MSM74130
MSM74140
MSM74150
MSM74160
MSM74170
MSM74180
MSM74190
MSM74200
MSM74210
MSM74220
MSM74230

msml.for

```
AUGPAR(EQEDGE,ITM) = 67.78 - (2.068 * AUGPAR(KP,ITM))
IF (ITM.GT.1) THEN
  YA (1) =AUGPAR(EQEDGE,ITM-1)
  YA (2) =AUGPAR(EQEDGE,ITM)
  XA (1) =TIMTAG (ITM-1)
  XA (2) =TIMTAG (ITM)
  CALL DTNTRP (TIMTAG (ITM) , 2, XA, YA, Y, DYDX, DELTA, IERR)
  AUGPAR (DEQDT, ITM-1) =DYDX*3600.
ENDIF
IF (ITM.EQ.ITMMAX) AUGPAR (DEQDT, ITM) =AUGPAR (DEQDT, ITM-1)
RETURN
END
SUBROUTINE PCPDFL(MODE,XKP, PCP)
C
C THIS SUBROUTINE CALCULATES THE CROSS-POLAR CAP POTENTIAL (IN KV)
C BASED ON THE WORK OF REIFF ET AL IF MODE IS FALSE. IF MODE IS TRUE
C THE POTENTIAL HAS ALREADY BEEN RECEIVED FROM THE ENVIRONMENTAL DATA
C BASE AND THE SUBROUTINE JUST RETURNS.
C
  LOGICAL*1 MODE
  IF (MODE) RETURN
  PCP = 14.587 + (1.7 * (XKP * 10.0))
  RETURN
  END
  SUBROUTINE PATDFL(MODE,MODEBY,MODEBZ, BY, BZ, IPATT)
C
C THIS SUBROUTINE USES THE BY AND BZ COMPONENTS OF THE IMF TO
C DETERMINE THE ELECTRIC FIELD PATTERN TYPE TO BE USED.
C THE DIFFERENT TYPES ARE:
C BZ>0 - TYPE 0.0
C BZ<0,BY>0 - TYPE 1.0
C BZ<0,BY=0 - TYPE 2.0 (DEFAULT)
C BZ<0,BY<0 - TYPE 3.0
C IF MODE IS TRUE, THE PATTERN TYPE HAS ALREADY BEEN RECEIVED FROM
C THE ENVIRONMENTAL DATA BASE AND THE SUBROUTINE JUST RETURNS.
C
  LOGICAL*1 MODE, MODEBY,MODEBZ
  IF (MODE) RETURN
  IF (.NOT. (MODEBZ)) THEN
    XIPATT=2.0
  ELSE
    IF (BZ.GT.0.0) THEN
      XIPATT=0.0
    ELSE
      IF (.NOT. (MODEBY)) THEN
        XIPATT=2.0
      ELSE
        IF (BY.GT.0.0) XIPATT=1.0
        IF (BY.EQ.0.0) XIPATT=2.0
        IF (BY.LT.0.0) XIPATT=3.0
      ENDIF
    ENDIF
  ENDIF
  RETURN
  END
  SUBROUTINE CLPDFL(MODE,CLAPSE)
C
C CLPASE IS THE INDICATOR FOR WHETHER OR NOT TO USE THE COLLAPSED
C TAIL VERSION OF THE MAGNETIC FIELD MODEL. IF MODE IS FALSE, NO
C VALUE HAS BEEN RETURNED FROM THE ENVIRONMENTAL DATA BASE. THE
C DEFAULT VALUE IS NO COLLAPSE (CLAPSE=1.0).
C
  LOGICAL*1 MODE
  IF (MODE) RETURN
```

MSM74880
MSM74890
MSM74900
MSM74910
MSM74920
MSM74930
MSM74940
MSM74950
MSM74960
MSM74970
MSM74980
MSM74990
MSM75000
MSM75010
MSM75020
MSM75030
MSM75040
MSM75050
MSM75060
MSM75070
MSM75080
MSM75090
MSM75100
MSM75110
MSM75120
MSM75130
MSM75140
MSM75150
MSM75160
MSM75170
MSM75180
MSM75190
MSM75200
MSM75210
MSM75220
MSM75230
MSM75240
MSM75250
MSM75260
MSM75270
MSM75280
MSM75290
MSM75300
MSM75310
MSM75320
MSM75330
MSM75340
MSM75350
MSM75360
MSM75370
MSM75380
MSM75390
MSM75400
MSM75410
MSM75420
MSM75430
MSM75440
MSM75450
MSM75460
MSM75470
MSM75480
MSM75490
MSM75500
MSM75510

```

CLAPSE=1.0
RETURN
END
SUBROUTINE STNDFL(MODE,MODVEL,MODDEN,SWVEL,SWDEN,XKP,STAND)

```

MSM75520
MSM75530
MSM75540
MSM75550

```

C THIS SUBROUTINE CALCULATES THE STANDOFF DISTANCE. IF SOLAR WIND
C VELOCITY AND DENSITY DATA IS AVAILABLE SUBROUTINE STNDOF DOES THE
C THE ACTUAL CALCULATION. OTHERWISE THE DEFAULT IS A KP-BASED
C FORMULA.

```

MSM75560
MSM75570
MSM75580
MSM75590
MSM75600

```

LOGICAL*1 MODE,MODVEL,MODDEN
IF (MODE) RETURN
IF (MODVEL.AND.MODDEN) THEN
CALL STNDOF (SWVEL,SWDEN,STAND)
ELSE
IF (XKP.LT.6.7) STAND=11.7-XKP
IF (XKP.GE.6.7) STAND=5.0
ENDIF
RETURN
END
SUBROUTINE TILT(DAY,YEAR,XTILT)

```

MSM75610
MSM75620
MSM75630
MSM75640
MSM75650
MSM75660
MSM75670
MSM75680
MSM75690
MSM75700
MSM75710
MSM75720

```

C SUBROUTINE TO CALCULATE THE EARTH'S TILT ANGLE. CURRENTLY SET
C TO 0.0

```

MSM75730
MSM75740
MSM75750

```

XTILT=0.0
RETURN
END

```

MSM75760
MSM75770
MSM75780
MSM75790

C-----

```

C SUBROUTINE AURL2S (FKP, COLAT, ALOCT, LATDIM, LTDIM,
* AEFLUX, AEMEAN)

```

MSM75800
MSM75810
MSM75820
MSM75830
MSM75840

```

[Inputs]
FKP : The most recent Kp value
COLAT:An array listing pertinent colatitudes <40 deg
ALOCT:An array listing pertinent magnetic loca time
[Outputs]
AEFLUX:The integral ION energy flux (erg/cm2/sec)
AEMEAN:AVERAGE ENERGY IN EV
AFLUX :The integral ION number flux (/cm2/sec)
This subroutine calls REGEN() and EFUN()
June 04, 1989 by Akira NAGAI

```

MSM75850
MSM75860
MSM75870
MSM75880
MSM75890
MSM75900
MSM75910
MSM75920
MSM75930
MSM75940
MSM75950

```

Note: The feature is optimized for the speed.
At least 10KB static memory area is required
for REAL*2 in MSM Model.

```

MSM75960
MSM75970
MSM75980
MSM75990

```

PARAMETER (IIDIM=62, JJDIM=51)

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MSM76000
MSM76010

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COMMON /LUNIT/LUERR, LUPIEN, LUCORD, LUPRNT, LUIDAT, LUHDYE,
1 LUDK, LUFLXB, LUEBEG, LUSHFT, LUPIFX, LUEAVG, LUFLSM, LUFLX,
2 LUEFLX, LUEFLD, LUBFLD, LUBMIN, LUXMIN, LUYMIN, LUZMIN, LUALOC,
3 LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH

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MSM76020
MSM76030
MSM76040
MSM76050
MSM76060

```

DIMENSION COLAT (LATDIM, LTDIM), ALOCT (LATDIM, LTDIM),
1 AFLUX (IIDIM, JJDIM), AEFLUX (LATDIM, LTDIM),
2 AEMEAN (LATDIM, LTDIM),
3 X1 (JJDIM, 0:6, 2), X2 (JJDIM, 0:6, 2), X3 (JJDIM, 0:6, 2),
4 X4 (JJDIM, 0:6, 2), X5 (JJDIM, 0:6, 2), X6 (JJDIM, 0:6, 2),
5 C1 (0:12), C2 (0:12), C3 (0:12), C4 (0:12), C5 (0:12), C6 (0:12)

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MSM76070
MSM76080
MSM76090
MSM76100
MSM76110
MSM76120
MSM76130
MSM76140
MSM76150

```
IKP=NINT(FKP)
IF((IPASS.EQ.0).AND.(IKP.EQ.0)) GOTO 60
IF(IKP.EQ.KP) GOTO 80
60 KP=IKP
IF(KP.GT.6) KP=6

C Just once is OK for this loop(10) for the entire run.
DO 10 ICASE=1,2

IF(IPASS.EQ.1) GOTO 80

IF(ICASE.EQ.1) THEN
OPEN(UNIT=LIONNO,ACCESS='SEQUENTIAL',FILE='IONNUM',
1 STATUS='OLD')
ELSE
OPEN(UNIT=LIONEG,ACCESS='SEQUENTIAL',FILE='IONENG',
1 STATUS='OLD')
ENDIF

C DO 20 IKP=0,6
DO 30 J=0,12
IF(ICASE.EQ.1) THEN
READ(LIONNO,*) IDX,C1(J),C2(J),C3(J),C4(J),C5(J),C6(J)
ELSE
READ(LIONEG,*) IDX,C1(J),C2(J),C3(J),C4(J),C5(J),C6(J)
ENDIF
30 CONTINUE
CALL REGEN(LATDIM,LTDIM,ALOCT,C1,X1,JJDIM,IKP,ICASE)
CALL REGEN(LATDIM,LTDIM,ALOCT,C2,X2,JJDIM,IKP,ICASE)
CALL REGEN(LATDIM,LTDIM,ALOCT,C3,X3,JJDIM,IKP,ICASE)
CALL REGEN(LATDIM,LTDIM,ALOCT,C4,X4,JJDIM,IKP,ICASE)
CALL REGEN(LATDIM,LTDIM,ALOCT,C5,X5,JJDIM,IKP,ICASE)
CALL REGEN(LATDIM,LTDIM,ALOCT,C6,X6,JJDIM,IKP,ICASE)
20 CONTINUE
CLOSE(LIONNO)
CLOSE(LIONEG)
10 CONTINUE

IPASS=1

80 DO 40 IMLT=1,LTDIM
DO 50 ILAT=1,LATDIM
H=90.-ABS(COLAT(ILAT,IMLT))*180/3.14159
FX=EFUN(1,KP,H,X1(IMLT,KP,1),X2(IMLT,KP,1),
* X3(IMLT,KP,1),X4(IMLT,KP,1),X5(IMLT,KP,1),X6(IMLT,KP,1))
C Unit from 1/cm2/sec/str to 1/cm2/sec
AFLUX(ILAT,IMLT) = (10.**FX)*3.1415265358
FX=EFUN(2,KP,H,X1(IMLT,KP,2),X2(IMLT,KP,2),
* X3(IMLT,KP,2),X4(IMLT,KP,2),X5(IMLT,KP,2),X6(IMLT,KP,2))
C Unit from keV/cm2/sec/str to erg/cm2/sec
AEFLUX(ILAT,IMLT) = (10.**FX)*3.14159265358*1.6021E-9
IF(AFLUX(ILAT,ILMT).NE.0.0) AEMEAN(ILAT,IMLT) =
1 AEFLUX(ILAT,IMLT)/AFLUX(ILAT,IMLT)
AEMEAN(ILAT,IMLT)=AEMEAN(ILAT,IMLT)*6.24E11
50 CONTINUE
40 CONTINUE

99 RETURN
END

-----
C
C *****
C FUNCTION EFUN(ICASE,KP,H,R0,H0,H1,S0,R1,S2)
C *****
C This function is called only by AURL2S() and this does not
```

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MSM76320
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MSM76360
MSM76370
MSM76380
MSM76390
MSM76400
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MSM76710
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MSM76750
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msml.for

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XLO=(ENERGY-HAFCHN(NCHNL))/(HAFCHN(NCHNL-1)-
2
HAFCHN(NCHNL))
C
48 CONTINUE
   XL1=1.-XLO
   XSTFLX=XLO*SATFLX(KK)+XL1*SATFLX(KK+1)
C
   DO 50 INO=1,LATDIM
   DO 60 JNO=1,LTDIM
     FLXNTR(INO,JNO,1)=FLUX(INO,JNO,KENERGY)
     FLXNTR(INO,JNO,2)=FLUX1(INO,JNO,KENERGY)
60 CONTINUE
50 CONTINUE
   FLUXT=G3NTRP(FLXNTR,LATDIM,LTDIM,2,BI,BJ,TMTRP1)
C
   FLUXT=FLUXT*1000.0
   IF(FLUXT.LE.0.0)THEN
     WRITE(6,*)' BAD FLUX VALUE CALCULATED IN SUBROUTINE OPTERR'
     WRITE(6,*)' UNABLE TO CONTINUE'
     WRITE(6,*)' VM, FLUX = ',CALVM,FLUXT
     STOP
   ENDIF
C
   WRITE(6,*) 'K=',KENERGY,' SAT FLUX=',XSTFLX,' MODEL FLUX=',
2 LOG10(FLUXT),' ALAM=',ALAM(KENERGY)
C
   IF(STNDEV(KENERGY).EQ.-1.0)THEN
     STNDEV(KENERGY)=(LOG10(FLUXT)-XSTFLX)**2
   ELSE
     STNDEV(KENERGY)=STNDEV(KENERGY)
1   +((LOG10(FLUXT)-XSTFLX)**2)
   ENDIF
C
   NPTS(KENERGY)=NPTS(KENERGY)+1
   COEF(KENERGY)=COEF(KENERGY)+(LOG10(FLUXT)-XSTFLX)
C
   WRITE(6,*)' NOCHNL,STNDEV,COEF,KENERGY ',NOCHNL-1,
C 1 STNDEV(KENERGY),COEF(KENERGY),KENERGY,FLUXT,XSTFLX
   ENDIF
45 CONTINUE
   XCHNCK=XCHNL
   IF(ISP.EQ.1) THEN
     READ(99,*,END=400)XCHNL,YEAR,DECDAY,LAT,LONG,ALT,MLT
   ELSE
     READ(98,*,END=400) XCHNL,YEAR,DECDAY,LAT,LONG,ALT,MLT
   END IF
C
   IF(XCHNCK.NE.XCHNL)THEN
     WRITE(6,*)' NUMBER OF SATELLITE ENERGY CHANNELS CHANGED IN'
     WRITE(6,*)' MID-RUN. UNABLE TO COMPUTE ERROR. RETURNING TO'
     WRITE(6,*)' MAIN PROGRAM.'
     RETURN
   ENDIF
   TIMCHK=TCONV2(YEAR,DECDAY,YRCHCK,DYCHCK)
   WRITE(6,*)' NPTS,TIMCHK,TIMTAG,ITM ',NPTS,TIMCHK,TIMTAG(ITM+1),
1 ITM
C
   IF(TIMCHK.LT.TIMTAG(ITM+1))GO TO 200
C
C COMPUTE STANDARD DEVIATION AND TIME SHIFT FOR THIS TIME INTERVAL
C
400 CONTINUE
C
   IF(ISP.EQ.NSP) THEN
MSM78700
MSM78710
MSM78720
MSM78730
MSM78740
MSM78750
MSM78760
MSM78770
MSM78780
MSM78790
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MSM78990
MSM79000
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MSM79190
MSM79200
MSM79210
MSM79220
MSM79230
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MSM79270
MSM79280
MSM79290
MSM79300
MSM79310
MSM79320
MSM79330
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```
DO 70 KENERGY=1, IEMAX
ENERGY=(ABS (ALAM (KENERGY)) *VMGEO) /1000.00
WRITE (6,*) ' KENERGY, STNDEV ', KENERGY, STNDEV (KENERGY)
IF (NPTS (KENERGY) .NE. 0) THEN
  STNDEV (KENERGY)=SQRT (STNDEV (KENERGY) /NPTS (KENERGY))
  WRITE (6,*) ' STANDARD DEVIATION (LOG10) = ', STNDEV (KENERGY),
1 ' FOR ENERGY ', ENERGY, ' (KEV)'
  COEF (KENERGY)=COEF (KENERGY) /NPTS (KENERGY)
  ERSHFT (KENERGY)=COEF (KENERGY)
  WRITE (6,*) ' PARALLEL SHIFT (LOG10) = ', COEF (KENERGY),
1 ' FOR ENERGY ', ENERGY, ' (KEV)'
  ELSE
  ERSHFT (KENERGY)=0.
  ENDIF
70 CONTINUE
C
C WRITE STANDARD DEVIATION AND SHIFT TO OUTPUT DATA SET
  IRDOUT=IREC+1
  WRITE (6,*) ' WRITING INTO SHFT FILE  IRDOUT=', IRDOUT,
2 ' IEMAX=', IEMAX, ' ERSHFT=', ERSHFT
  CALL WRTVEC (LUSHFT, IRDOUT, IEMAX, IEDIM, ALAM, THRSH, ERSHFT, IFLAV)
  END IF
C
30 CONTINUE
C
15 CONTINUE
C
  RETURN
  END
  SUBROUTINE WRTVEC (NOUNIT, IRDOUT, IEMAX, IEDIM, ALAM, THRSH,
1 ERSHFT, IFLAV)
C
C SUBROUTINE TO WRITE
C ALAMS, THRESHOLD ENERGIES, AND ERROR
C FOR EACH OF THE ENERGY CHANNELS IN THIS RUN
C
C
C DIMENSION ALAM (IEDIM), THRSH (IEDIM), ERSHFT (IEDIM), IFLAV (IEDIM)
C
C IRECL=4*IEDIM+1
C OPEN (UNIT=NOUNIT, ACCESS='DIRECT', RECL=IRECL, STATUS='UNKNOWN')
C
C WRITE THE INFORMATION
C
C WRITE (NOUNIT, REC=IRDOUT) IEMAX, ALAM, THRSH, ERSHFT, IFLAV
C
C CLOSE (NOUNIT)
C RETURN
C END
C
C FUNCTION CEXRAT (ISP, ENRG, RLOC, SSN, DKTIME, IRDK, INRGDK, ISOLDK,
2 IONDK)
C
C PROGRAMMER: R. W. SPIRO LAST UPDATE: 05.09.90
C
C PURPOSE: FUNCTION SUBPROGRAM TO RETURN CHARGE EXCHANGE LOSS RATE
C (SEC**(-1)) FOR IONS OF SPECIES ISP, ENERGY ENRG (EV) AT
C L=RLOC (RE) FOR SUNSPOT NUMBER SSN. THIS ROUTINE IS BASED
C ON A TABLE GENERATED BY JAMES BISHOP OF U. OF MICHIGAN.
C
C CALLING PARAMETERS
C ISP SPECIES IDENTIFIER
C ISP=2 FOR H+ IONS
C ISP=3 FOR O+ IONS
```

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MSM79400
MSM79410
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C      ENRG      ENERGY IN EV      MSM79980
C      RLOC      RADIAL LOCATION (RE)  MSM79990
C      SSN       SUNSPOT NUMBER      MSM80000
C      DKTIME    TABLE OF ION DECAY TIMES  MSM80010
C      IRDK      RADIAL DIMENSION OF DKTIME ARRAY  MSM80020
C      INRGDK    ENERGY DIMENSION OF DKTIME ARRAY  MSM80030
C      ISOLDK    SUNSPOT NUMBER DIMENSION OF DKTIME ARRAY  MSM80040
C      IONDK     NUMBER OF ION SPECIES IN DKTIME ARRAY  MSM80050
C
C      MSM80060
C      MSM80070
C      PARAMETER (IRSIZ=18, INRGSZ=13, ISOLSZ=2, IONSIZ=2)  MSM80080
C
C      DIMENSION DKTIME (IRDK, INRGDK, ISOLDK, IONDK)  MSM80090
C
C      DIMENSION ELGVEC (INRGSZ), RVEC (IRSIZ), SSNVEC (2)  MSM80100
C
C      DATA ELGVEC /2.50,2.75,3.00,3.25,3.50,3.75,4.00,  MSM80110
C      2          4.25,4.50,4.75,5.00,5.25,5.50/  MSM80120
C
C      DATA RVEC /1.50,2.00,2.50,3.00,  MSM80130
C      2          3.50,4.00,4.50,5.00,  MSM80140
C      3          5.50,6.00,6.50,7.00,  MSM80150
C      4          7.50,8.00,8.50,9.00,  MSM80160
C      5          9.50,10.00/  MSM80170
C
C      DATA SSNVEC /0.0,100./  MSM80180
C
C      MSM80190
C      MSM80200
C      MSM80210
C      MSM80220
C      MSM80230
C      MSM80240
C      MSM80250
C      CHECK DIMENSIONS  MSM80260
C
C      IF (IRSIZ.NE.IRDK.OR.INRGSZ.NE.INRGDK.OR.IONSIZ.NE.IONDK.OR.  MSM80270
C      2  ISOLSZ.NE.ISOLDK) THEN  MSM80280
C      WRITE (6,*) 'DIMENSION ERROR IN SUBROUTINE CEXRAT'  MSM80290
C      WRITE (6,*) 'IRDK,INRGDK,IONDK,ISOLDK',IRDK,INRGDK,IONDK,ISOLDK  MSM80300
C      WRITE (6,*) 'IRSIZ,INRGSZ,IONSIZ,ISOLSZ',IRSIZ,INRGSZ,IONSIZ,  MSM80310
C      2  ISOLSZ  MSM80320
C      WRITE (6,*) 'STOPPING PROGRAM IN CEXRAT'  MSM80330
C      STOP  MSM80340
C      END IF  MSM80350
C
C      MSM80360
C      WORK WITH LOG10 OF PARTICLE ENERGY  MSM80370
C      ENRGLG=ALOG10 (ENRG)  MSM80380
C
C      ISPNDX=ISP-1  MSM80390
C
C      FIND BR FOR INTERPOLATION  MSM80400
C      IF (RLOC.LE.RVEC (1)) THEN  MSM80410
C      BR=1.  MSM80420
C      ELSE IF (RLOC.GT.RVEC (IRDK)) THEN  MSM80430
C      BR=IRDK  MSM80440
C      ELSE  MSM80450
C      DO 10 IR=1,IRDK-1  MSM80460
C      IF (RLOC.LE.RVEC (IR+1)) THEN  MSM80470
C      BR=IR+(RLOC-RVEC (IR))/(RVEC (IR+1)-RVEC (IR))  MSM80480
C      GO TO 20  MSM80490
C      END IF  MSM80500
C      10  CONTINUE  MSM80510
C
C      END IF  MSM80520
C
C      20  CONTINUE  MSM80530
C
C      MSM80540
C      MSM80550
C      MSM80560
C      MSM80570
C      MSM80580
C      MSM80590
C      20  CONTINUE  MSM80600
C
C      MSM80610
```

```
C
C FIND BNRG FOR INTERPOLATION
  IF (ENRGLG.LE.ELGVEC(1)) THEN
    BNRG=1.
  ELSE IF (ENRGLG.GT.ELGVEC(INRGDK)) THEN
    BNRG=INRGDK
  ELSE
    DO 30 INRG=1,INRGDK-1
      IF (ENRGLG.LE.ELGVEC(INRG+1)) THEN
        BNRG=INRG+(ENRGLG-ELGVEC(INRG))/(ELGVEC(INRG+1)-
2          ELGVEC(INRG))
          GO TO 40
        END IF
30 CONTINUE
C
  END IF
C
C
C 40 CONTINUE
C
C FIND BSSN FOR INTERPOLATION
  BSSN=1.+(SSN-SSNVEC(1))/(SSNVEC(2)-SSNVEC(1))
C
C DECAYT IS DECAY TIME IN SECONDS
  DECAYT=G3NTRP(DKTIME(1,1,1,ISPNDX),IRDK,INRGDK,ISOLDK,BR,BNRG,
2    BSSN)
C
  IF (ABS(DECAYT).LT.1.E-20) THEN
    WRITE(6,*) 'DECAYT IS LESS THAN 1.E-20 SEC IN CEXRAT'
    WRITE(6,*) 'DECAYT=',DECAYT,' BR=',BR,' BNRG=',BNRG,' BSSN=',
2    BSSN
    WRITE(6,*) 'ISP=',ISP,' ENRG=',ENRG,' RLOC=',RLOC,' SSN=',SSN
  END IF
C
C TO GET CHARGE EXCHANGE RATE (SEC**9-1) CEXRAT, INVERT DECAYT
C
  CEXRAT=1./DECAYT
C
C DEBUG 5.27.90
C WRITE(6,800) ISP,ENRG,ENRGLG,RLOC,SSN
800 FORMAT(1X,'ISP=',I2,' ENRG=',E12.4,' ENRGLG=',F7.4,' RLOC=',
2    F7.4,' SSN=',F7.4)
C WRITE(6,802) BR,BNRG,BSSN,DECAYT
802 FORMAT(1X,'BR=',F7.4,' BNRG=',F7.4,' BSSN=',F7.4,' DECAYT=',
2    1PE12.4)
C
C END DEBUG 5.27.90
C
C
C
C
C RETURN
C END
C SUBROUTINE READDK(IRDK,INRGDK,ISOLDK,IONDK,DKTIME)
C
C PURPOSE: SUBROUTINE TO READ ION CHARGE EXCHANGE DECAY TABLE
C FURNISHED BY JAMES BISHOP OF UNIV. OF MICHIGAN
C
C LAST UPDATE: 05.10.90
C
C COMMON LUNIT CONTAINS LOGICAL UNIT NUMBERS FOR INPUT AND OUTPUT
COMMON /LUNIT/LUERR,LUPIEN,LUCORD,LUPRNT,LUIDAT,LUHDYE,
1    LUDK,LUFLXB,LUEBEG,LUSHFT,LUPIFX,LUEAVG,LUFLSM,LUFLX,
2    LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
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MSM81150
MSM81160
MSM81170
MSM81180
MSM81190
MSM81200
MSM81210
MSM81220
MSM81230
MSM81240
MSM81250
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3      LUCOLT, LUBNDL, LUPDAT, LUVN, LUVS, LIONEG, LIONNO, LUENCH
C
C      DIMENSION DKTIME (IRDK, INRGDK, ISOLDK, IONDK)
C
C      READ (LUDK, 800) DKTIME
800  FORMAT (8 (1X, 1PE9.3))
C
C      RETURN
C      END
C      SUBROUTINE FLX2ET (LATDIM, LTDIM, IEDIM, IEMAX, ITMDIM, ITM, IFLAV,
2      ALAM, ALMDEL, BNDLOC, VM, FLUX, ETA)
C
C      PURPOSE:  CONVERT FROM PARTICLE FLUX (PARTICLES/CM**2/S) TO
C      INVARIANT FLUX ETA
C
C      INPUT CALLING PARAMETERS
C      LATDIM      NUMBER OF LATITUDINAL GRID POINTS
C      LTDIM      NUMBER OF LONGITUDINAL GRID POINTS
C      IEDIM      MAXIMUM NUMBER OF MODEL ENERGY CHANNELS
C      IEMAX      ACTUAL NUMBER OF MODEL ENERGY CHANNELS
C      ITMDIM     MAXIMUM TIME DEPTH
C      ITM        TIME LABEL
C      IFLAV      VECTOR GIVING CHARGE AND MASS SPECIES OF PARTICLES
C      ALAM       ENERGY INVARIANT VECTOR
C      ALMDEL     ENERGY CHANNEL DIFFERENCE VECTOR
C      BNDLOC     BOUNDARY LOCATION ARRAY
C      VM        FLUX TUBE VOLUME** (-2/3)
C      FLUX      PARTICLE NUMBER FLUX
C
C      OUTPUT PARAMETERS
C      ETA       INVARIANT NUMBER FLUX (PARTICLES/UNIT MAGNETIC FLUX)
C
C      DIMENSION IFLAV (IEDIM), ALAM (IEDIM), ALMDEL (IEDIM)
C      DIMENSION VM (LATDIM, LTDIM, ITMDIM), FLUX (LATDIM, LTDIM, IEDIM)
C      DIMENSION ETA (LATDIM, LTDIM, IEDIM), BNDLOC (LTDIM, ITMDIM)
C
C      DO 10 IE=1, IEMAX
C      IF (IFLAV (IE) .EQ. 2) ATOMWT=1.
C      IF (IFLAV (IE) .EQ. 3) ATOMWT=16.
C
C      DO 20 J=1, LTDIM
C      IB=IFIX (BNDLOC (J, ITM))
C
C      DO 30 I=IB, LATDIM
C      IF (IFLAV (IE) .EQ. 1) THEN
C      ETA (I, J, IE) =FLUX (I, J, IE) *ALMDEL (IE) /7.392E-16/
2      SQRT (ABS (ALAM (IE))) /VM (I, J, ITM)
C      ELSE
C      ETA (I, J, IE) =FLUX (I, J, IE) *ALMDEL (IE) *SQRT (ATOMWT) /
2      1.731E-17/SQRT (ABS (ALAM (IE))) /VM (I, J, ITM)
C      END IF
C      30  CONTINUE
C
C      DO 35 I=1, IB-1
C      ETA (I, J, IE) =ETA (IB, J, IE)
C      35  CONTINUE
C
C      20  CONTINUE
C
C      10  CONTINUE
```

MSM81260
MSM81270
MSM81280
MSM81290
MSM81300
MSM81310
MSM81320
MSM81330
MSM81340
MSM81350
MSM81360
MSM81370
MSM81380
MSM81390
MSM81400
MSM81410
MSM81420
MSM81430
MSM81440
MSM81450
MSM81460
MSM81470
MSM81480
MSM81490
MSM81500
MSM81510
MSM81520
MSM81530
MSM81540
MSM81550
MSM81560
MSM81570
MSM81580
MSM81590
MSM81600
MSM81610
MSM81620
MSM81630
MSM81640
MSM81650
MSM81660
MSM81670
MSM81680
MSM81690
MSM81700
MSM81710
MSM81720
MSM81730
MSM81740
MSM81750
MSM81760
MSM81770
MSM81780
MSM81790
MSM81800
MSM81810
MSM81820
MSM81830
MSM81840
MSM81850
MSM81860
MSM81870
MSM81880
MSM81890

BO346051.DAT;1	BO346061.DAT;1	BO346071.DAT;1	BO346081.DAT;1
BO346091.DAT;1	BO346101.DAT;1	BO346111.DAT;1	BO346121.DAT;1
BO346131.DAT;1	BO346141.DAT;1	BO346151.DAT;1	BO346161.DAT;1
BO347011.DAT;1	BO347021.DAT;1	BO347031.DAT;1	BO347041.DAT;1
BO347051.DAT;1	BO347061.DAT;1	BO347071.DAT;1	BO347081.DAT;1
BO347091.DAT;1	BO347101.DAT;1	BO347111.DAT;1	BO347121.DAT;1
BO347131.DAT;1	BO347141.DAT;1	BO347151.DAT;1	BO347161.DAT;1
BO351011.DAT;1	BO351021.DAT;1	BO351031.DAT;1	BO351041.DAT;1
BO351051.DAT;1	BO351061.DAT;1	BO351071.DAT;1	BO351081.DAT;1
BO351091.DAT;1	BO351101.DAT;1	BO351111.DAT;1	BO351121.DAT;1
BO351131.DAT;1	BO351141.DAT;1	BO351151.DAT;1	BO351161.DAT;1
BO352011.DAT;1	BO352021.DAT;1	BO352031.DAT;1	BO352041.DAT;1
BO352051.DAT;1	BO352061.DAT;1	BO352071.DAT;1	BO352081.DAT;1
BO352091.DAT;1	BO352101.DAT;1	BO352111.DAT;1	BO352121.DAT;1
BO352131.DAT;1	BO352141.DAT;1	BO352151.DAT;1	BO352161.DAT;1
BO353011.DAT;1	BO353021.DAT;1	BO353031.DAT;1	BO353041.DAT;1
BO353051.DAT;1	BO353061.DAT;1	BO353071.DAT;1	BO353081.DAT;1
BO353091.DAT;1	BO353101.DAT;1	BO353111.DAT;1	BO353121.DAT;1
BO353131.DAT;1	BO353141.DAT;1	BO353151.DAT;1	BO353161.DAT;1
BO354011.DAT;1	BO354021.DAT;1	BO354031.DAT;1	BO354041.DAT;1
BO354051.DAT;1	BO354061.DAT;1	BO354071.DAT;1	BO354081.DAT;1
BO354091.DAT;1	BO354101.DAT;1	BO354111.DAT;1	BO354121.DAT;1
BO354131.DAT;1	BO354141.DAT;1	BO354151.DAT;1	BO354161.DAT;1
BO355011.DAT;1	BO355021.DAT;1	BO355031.DAT;1	BO355041.DAT;1
BO355051.DAT;1	BO355061.DAT;1	BO355071.DAT;1	BO355081.DAT;1
BO355091.DAT;1	BO355101.DAT;1	BO355111.DAT;1	BO355121.DAT;1
BO355131.DAT;1	BO355141.DAT;1	BO355151.DAT;1	BO355161.DAT;1
BO356011.DAT;1	BO356021.DAT;1	BO356031.DAT;1	BO356041.DAT;1
BO356051.DAT;1	BO356061.DAT;1	BO356071.DAT;1	BO356081.DAT;1
BO356091.DAT;1	BO356101.DAT;1	BO356111.DAT;1	BO356121.DAT;1
BO356131.DAT;1	BO356141.DAT;1	BO356151.DAT;1	BO356161.DAT;1
BO357011.DAT;1	BO357021.DAT;1	BO357031.DAT;1	BO357041.DAT;1
BO357051.DAT;1	BO357061.DAT;1	BO357071.DAT;1	BO357081.DAT;1
BO357091.DAT;1	BO357101.DAT;1	BO357111.DAT;1	BO357121.DAT;1
BO357131.DAT;1	BO357141.DAT;1	BO357151.DAT;1	BO357161.DAT;1
DIRECTORY.LIS;1			

Total of 609 files.

Appendix C

Appendix C is attached separately as a computer listing.

Appendix D

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12:04:56

mapint.com

1

```
$define sys$input tt
!$define sys$output tt
$define bfield [-.bfields]
$define for008 msmout.dat
$define for014 ashift.dat
$define for015 aflux.dat
$define for016 avm.dat
$define for017 abndloc.dat
$define for018 axmin.dat
$define for019 aymin.dat
$define for020 azmin.dat
$define for044 aupdat.dat
$run mapint
```

90/06/30
12:04:14

1

mapint.for

```
PROGRAM MSMAP                                MAP00010
C      VERSION OF 4/23/90                      MAP00020
C      PROGRAMMED BY R. V. HILMER             MAP00030
C      REQUIRES LINKAGE WITH BFIELD MODEL SUBROUTINES, MAP00040
C      SUBROUTINES FNDBRK, AND B-MATRIX DATA FILES MAP00050
C      MAP00060
C      PURPOSE- THIS PROGRAM COLLECTS MAGNETOSPHERIC SPECIFICATION MAP00070
C      MODEL INPUTS AND AN ARBITRARY GSM STARTING POINT, MAP00080
C      VALIDATES THE INPUTS AND FINDS THE POINT ON THE MSM MAP00090
C      CALCULATION SURFACE WHICH IS MAGNETICALLY CONNECTED MAP00100
C      TO THE GSM STARTING POINT. MAP00110
C      IT THEN INTERPOLATES IN SPACE, TIME AND ENERGY TO MAP00120
C      GET THE FLUXES AT THE MAPPED POINT. MAP00130
C      VARIABLES- FTILT: DIPOLE TILT ANGLE (DEGREES, POSITIVE FOR MAP00140
C      NORTHERN HEMISPHERE SUMMER) MAP00150
C      FSTDFF: MAGNETOPOUSE STAND-OFF DISTANCE (RE) MAP00160
C      FDST: MAGNETIC ACTIVITY INDEX DST (NT) MAP00170
C      FEQEDG: DIPOLE LAT. OF MIDNIGHT EQUATORWARD DIFFUSE MAP00180
C      AURORA BOUNDARY (DEG). MAP00190
C      FCLPSE: MAGNETOTAIL FIELD COLLAPSE INDICATOR MAP00200
C      XSTRT,YSTRT,ZSTRT: MAGNETIC TRACING START POINT (GSM) MAP00210
C      IVALID: INDICATES IF INSERTED INPUTS ARE WITHIN VALID MAP00220
C      RANGES. (1 = YES, 0 = NO) MAP00230
C      XMAP,YMAP,ZMAP: MAGNETIC MAPPING POINT ON THE MSM MAP00240
C      COMPUTATIONAL SURFACE (GSM). MAP00250
C      SUBROUTINES-MAPTRK: DETERMINES THE MAGNETIC FIELD MAPPING MAP00260
C      CONNECTING AN ARBITRARY POINT IN SPACE TO THE MSM MAP00270
C      COMPUTATIONAL SURFACE. USES INTERPOLATION SCHEME MAP00280
C      INVOLVING PRECALCULATED INTERNAL MODEL PARAMETER MAP00290
C      SETS TO FIND THE MAPPING FOR ARBITRARY MSM INPUT. MAP00300
C      VALID: CHECKS TO SEE IF EXTERNAL INPUT PARAMETERS MAP00310
C      AND TRACING START POINT ARE VALID. MAP00320
C      READ3D: READS DATA FILES FOR FLUX CALCULATION. MAP00330
C      LOCATE: FINDS THE INTERPOLATED POINT ON A MAP00340
C      2-DIMENSIONAL GRID. MAP00350
C      CHECK: CHECKS THAT THE INPUT TIMES ARE REASONABLE. MAP00360
C      TCHECK: LOCATES THE 2 RECORDS WHICH SPAN THE TIME MAP00370
C      REQUESTED. MAP00380
C      RDVEC: READS THE HEADER VECTOR OF THE FLUX FILES MAP00390
C      SETALM: SETS UP THE INVARIANT ENERGY ARRAY MAP00400
C      FUNCTIONS: G3NTRP: 3-DIMENSIONAL INTERPOLATION ROUTINE MAP00410
C
C      PARAMETER (LATDIM=62,LTDIM=51,IEDIM=30,ITMDIM=50, NAUGEL=28) MAP00420
C      DIMENSION R(LATDIM,LTDIM),BNDLOC(LTDIM,2),P(LATDIM,LTDIM), MAP00430
1  VM(LATDIM,LTDIM,2),FLUX(LATDIM,LTDIM,IEDIM),ALAM(IEDIM), MAP00440
2  ALMDEL(IEDIM),ID(20),RID(20),THRSH(IEDIM),ERSHFT(IEDIM), MAP00450
3  XMIN(LATDIM,LTDIM,2),YMIN(LATDIM,LTDIM,2),ZMIN(LATDIM,LTDIM,2), MAP00460
4  AUGPAR(NAUGEL),AGPAR1(NAUGEL),FLUX1(LATDIM,LTDIM,IEDIM), MAP00470
5  ISTART(3),IFLAV(IEDIM),FLXOUT(2) MAP00480
C      CHARACTER*80 CHID MAP00490
C
C      PI=ATAN2(0.,-1.) MAP00500
C      MAP00510
C      THE INTERACTIVE PORTION OF THE PROGRAM CHECKS FOR CORRECT TIME MAP00520
C      ENTRIES THROUGH SUBROUTINE CHECK. MAP00530
C      MAP00540
100 WRITE(6,*)' ENTER LAST 2 DIGITS OF YEAR AND JULIAN DAY ' MAP00550
    READ(5,*)IYEAR,IDAY MAP00560
    WRITE(6,*)' ENTER HOUR, MINUTE, AND SECONDS ' MAP00570
    READ(5,*)IHOURL,MINUTE,ISCNDS MAP00580
    CALL CHECK(IYEAR,IDAY,IHOURL,MINUTE,ISCNDS,IFLAG) MAP00590
    IF (IFLAG.EQ. 1) THEN MAP00600
        WRITE(6,*) MAP00610
        WRITE(6,*)' INCORRECT INPUT. DO YOU WANT TO TRY AGAIN?' MAP00620
```

mapint.for

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C      WRITE(6,*) 'ALAM', ALAM, ' THRSH', THRSH, ' ERSHFT', ERSHFT, ' IFLAV', IFLAV

      CALL READ3D(15, 'FLUX ', IREC, LATDIM, LTDIM, IEMAX, ITMDIM, ID, RID,
1      CHID, FLUX)
      CALL READ3D(15, 'FLUX ', IREC+1, LATDIM, LTDIM, IEMAX, ITMDIM, ID,
1      RID, CHID, FLUX1)

      IF ((ID(8).NE.LATDIM).OR.(ID(9).NE.LTDIM)) THEN
      WRITE(6,*)
      WRITE(6,*) ' INCORRECT PARAMETERS FOR GRID-STOPPING PROGRAM'
      WRITE(6,*) ' ID(8) = ', ID(8), ' LATDIM = ', LATDIM
      WRITE(6,*) ' ID(9) = ', ID(9), ' LTDIM = ', LTDIM
      WRITE(6,*)
      STOP
      ENDIF
      CALL READ3D(16, 'VM ', IREC, LATDIM, LTDIM, 1, ITMDIM, ID, RID, CHID,
1      VM(1,1,1))
      CALL READ3D(16, 'VM ', IREC+1, LATDIM, LTDIM, 1, ITMDIM, ID, RID, CHID,
1      VM(1,1,2))
      CALL READ3D(17, 'BNDLOC', IREC, LTDIM, 1, 1, ITMDIM, ID, RID, CHID,
1      BNDLOC(1,1))
      CALL READ3D(17, 'BNDLOC', IREC+1, LTDIM, 1, 1, ITMDIM, ID, RID, CHID,
1      BNDLOC(1,2))
      CALL READ3D(18, 'XMIN ', IREC, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, XMIN(1,1,1))
      CALL READ3D(18, 'XMIN ', IREC+1, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, XMIN(1,1,2))
      CALL READ3D(19, 'YMIN ', IREC, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, YMIN(1,1,1))
      CALL READ3D(19, 'YMIN ', IREC+1, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, YMIN(1,1,2))
      CALL READ3D(20, 'ZMIN ', IREC, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, ZMIN(1,1,1))
      CALL READ3D(20, 'ZMIN ', IREC+1, LATDIM, LTDIM, 1, ITMDIM, ID, RID,
1      CHID, ZMIN(1,1,2))

C
C SET UP THE TIME INTERPOLATION FOR THE B-FIELD COMPONENTS AND
C CALCULATE RADIUS AND LOCAL TIME ARRAYS
C
      TIME=(FLOAT(IHOUR)*3600.0) + (FLOAT(MINUTE)*60.0) + FLOAT(ISCNDS)
      TIME1=(AUGPAR(3)*3600.0) + (AUGPAR(4)*60.0) + AUGPAR(5)
      TIME2=(AGPAR1(3)*3600.0) + (AGPAR1(4)*60.0) + AGPAR1(5)
      TIMTRP =((TIME-TIME1)/(TIME2-TIME1)) + 1.0
C      WRITE(6,*) 'TIME, TIME1, TIME2, TIMTRP ', TIME, TIME1, TIME2, TIMTRP
      DO 400 I=1, LATDIM
      DO 450 J=1, LTDIM
      XNTRP=G3NTRP(XMIN, LATDIM, LTDIM, 2, FLOAT(I), FLOAT(J), TIMTRP)
      YNTRP=G3NTRP(YMIN, LATDIM, LTDIM, 2, FLOAT(I), FLOAT(J), TIMTRP)
      ZNTRP=G3NTRP(ZMIN, LATDIM, LTDIM, 2, FLOAT(I), FLOAT(J), TIMTRP)
      R(I,J)=SQRT(XNTRP**2 + YNTRP**2 + ZNTRP**2)
      IF ((XNTRP.EQ.0.0).AND.(YNTRP.EQ.0.0)) THEN
      P(I,J)=0.0
      ELSE
      P(I,J)=ATAN2(YNTRP,XNTRP)
      IF(P(I,J).LT.0.0)P(I,J)=P(I,J)+ 2.0*PI
      ENDIF
450      CONTINUE
400      CONTINUE
C      WRITE(6,*) ' IREC ', IREC
C
C SET UP INVARIANT ARRAYS FOR THE FLUX CALCULATIONS
C
      CALL SETALM(ALAM, IEMAX, IEDIM, IFLAV, ALMDEL)
10      CONTINUE

```

MAP01310
MAP01320
MAP01330
MAP01340
MAP01350
MAP01360
MAP01370
MAP01380
MAP01390
MAP01400
MAP01410
MAP01420
MAP01430
MAP01440
MAP01450
MAP01460
MAP01470
MAP01480
MAP01490
MAP01500
MAP01510
MAP01520
MAP01530
MAP01540
MAP01550
MAP01560
MAP01570
MAP01580
MAP01590
MAP01600
MAP01610
MAP01620
MAP01630
MAP01640
MAP01650
MAP01660
MAP01670
MAP01680
MAP01690
MAP01700
MAP01710
MAP01720
MAP01730
MAP01740
MAP01750
MAP01760
MAP01770
MAP01780
MAP01790
MAP01800
MAP01810
MAP01820
MAP01830
MAP01840
MAP01850
MAP01860
MAP01870

mapint.for

```

WRITE(6,*)' ENTER 0 TO STOP, ANY OTHER NUMBER TO TRY AGAIN.'
READ(5,*) IANSW
WRITE(6,*)
IF(IANSW.EQ.0) STOP
GO TO 100
ENDIF
IREC=1
C
C THIS PORTION OF THE CODE SEARCHES THE OUTPUT DATA BASE TO FIND THE
C 2 TIMES CLOSEST TO THE INPUT TIME.
C
200 CALL READ3D(44,'UPDATE',IREC,NAUGEL,1,1,ITMDIM,ID,RID,CHID,
1 AUGPAR)
C WRITE(6,*)' IREC, ID ',IREC,ID
IF(IREC.EQ.1) THEN
  ISTART(1)=AUGPAR(1)
  ISTART(2)=AUGPAR(2)
  ISTART(3)=AUGPAR(3)*3600 + AUGPAR(4)*60 + AUGPAR(5)
  ITMMAX=ID(10)
  IEMAX=ID(9)
ENDIF
IF(IREC+1.GT.ITMMAX) THEN
  WRITE(6,*)
  WRITE(6,*)' END OF FILE ENCOUNTERED WITHOUT FINDING THE TIME',
1 ' YOU REQUESTED.'
  WRITE(6,*)' ENTER 0 TO STOP, ANY OTHER NUMBER TO TRY AGAIN.'
  READ(5,*) IANSW
  IF(IANSW.EQ.0) STOP
  GO TO 100
ENDIF
CALL READ3D(44,'UPDATE',IREC+1,NAUGEL,1,1,ITMDIM,ID,RID,CHID,
1 AGPAR1)
CALL TCHECK(IYEAR,IDAY,IHOUR,MINUTE,ISCNDS,AUGPAR,AGPAR1,
1 NAUGEL,IFLAG,ISTART)
IF(IFLAG.EQ.1) THEN
  IREC=IREC+1
  GO TO 200
ENDIF
C
C INPUT SATELLITE ENERGY IN KEV. THIS IS CHECK TO BE GREATER THAN 0
C AND CONVERTED TO INVARIANT ENERGY, ALAM, THE PROGRAMS BASIC
C ENERGY UNIT. ALSO PARTICLE TYPE IS REQUESTED AND CHECKED TO BE
C BETWEEN 1 AND 3 (1=ELECTRONS,2=H+,3=O+)
C
300 WRITE(6,*)' INPUT ENERGY (KEV) AND 1 FOR ELECTRONS, 2 FOR H+,'
WRITE(6,*)' OR 3 FOR O+'
READ(5,*) ENERGY,JFLAV
IF((JFLAV.LT.1).OR.(JFLAV.GT.3)) THEN
  WRITE(6,*)
  WRITE(6,*)' INCORRECT INPUT FOR PARTICLE TYPE. PLEASE RE-ENTER.'
  WRITE(6,*)
  GO TO 300
ENDIF
IF(ENERGY.LE.0) THEN
  WRITE(6,*)
  WRITE(6,*)' ENERGY LESS THAN 0. PLEASE RE-ENTER.'
  WRITE(6,*)
  GO TO 300
ENDIF
C
C READ INPUT FILES NEEDED FOR INTERPOLATING
C
CALL RDVEC (14,IREC,IEMAX,IEDIM,ALAM,THRSH,ERSHFT,IFLAV)

```

```

MAP00630
MAP00640
MAP00650
MAP00660
MAP00670
MAP00680
MAP00690
MAP00700
MAP00710
MAP00720
MAP00730
MAP00740
MAP00750
MAP00760
MAP00770
MAP00780
MAP00790
MAP00800
MAP00810
MAP00820
MAP00830
MAP00840
MAP00850
MAP00860
MAP00870
MAP00880
MAP00890
MAP00900
MAP00910
MAP00920
MAP00930
MAP00940
MAP00950
MAP00960
MAP00970
MAP00980
MAP00990
MAP01000
MAP01010
MAP01020
MAP01030
MAP01040
MAP01050
MAP01060
MAP01070
MAP01080
MAP01090
MAP01100
MAP01110
MAP01120
MAP01130
MAP01140
MAP01150
MAP01160
MAP01170
MAP01180
MAP01190
MAP01200
MAP01210
MAP01220
MAP01230
MAP01240
MAP01250

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mapint.for

5

```

                    ENDIF
550  CONTINUE
                    IF (XLO.EQ.-1.0) THEN
                        WRITE (6,*)
                        WRITE (6,*) ' ENERGY NOT CALCULATED FOR THIS POINT IN THIS RUN.'
                        WRITE (6,*)
                        WRITE (6,*) ' FOLLOWING ARE THE ENERGIES AND SPECIES FOR THIS RUN'
                        WRITE (6,*)
                        DO 475 IE=1,IEMAX
                            WRITE (6,*) ' ENERGY (KEV) = ',ABS (ALAM (IE)*CALVM)/1000.0,
1          ' SPECIES NUMBER = ',IFLAV (IE)
475  CONTINUE
                        WRITE (6,*) ' ENTER 0 TO STOP, ANY OTHER NUMBER TO TRY AGAIN'
                        READ (5,*) IANSW
                        IF (IANSW.EQ.0) STOP
                        WRITE (6,*)
                        GO TO 300
                    ENDIF
                    IF ((ALAM (IFIX (BK)) .LT. 0.0) .AND. (JFLAV.NE.1)) THEN
                        WRITE (6,*)
                        WRITE (6,*) ' PARTICLE TYPE AND INVARIANT ENERGY ARE INCORRECT.'
                        WRITE (6,*) ' ENTER 0 STOP, AND OTHER NUMBER TO CONTINUE.'
                        READ (5,*) IANSW
                        WRITE (6,*)
                        IF (IANSW.EQ.0) STOP
                        GO TO 300
                    ENDIF
C
C  INTERPOLATE FLUX ARRAYS IN SPACE, TIME AND ENERGY
C
C
                    FLXOUT (1)=G3NTRP (FLUX, LATDIM, LTDIM, IEMAX, BI, BJ, BK)
                    FLXOUT (2)=G3NTRP (FLUX1, LATDIM, LTDIM, IEMAX, BI, BJ, BK)
                    SATFLX=G3NTRP (FLXOUT, 2, 1, 1, TIMTRP, 1., 1.)
C          WRITE (6,*) ' BI, BJ, BK, TIMTRP, FLXOUT ', BI, BJ, BK, TIMTRP, FLXOUT
C
C  WRITE OUT FLUX, INCLUDING ERROR AND THRESHOLD IF AVAILABLE
C
                    ERROR=G3NTRP (ERSHFT, IEMAX, 1, 1, BK, 1., 1.)
                    WRITE (6,*)
                    WRITE (6,*) ' FLUX AT THE SATELLITE (LOG (#/CM2-S-KEV-STER)) = ',
1          SATFLX
                    WRITE (6,*)
                    IF (ERROR.NE.0.0) THEN
                        WRITE (6,*) ' THE ERROR BETWEEN THE MODEL OUTPUT AND SATELLITE '
                        WRITE (6,*) ' DATA IS ', ERROR
                        WRITE (6,*) ' PLEASE NOTE THAT THE ERROR WAS CALCULATED USING '
                        WRITE (6,*) ' DATA AT GEOSYNCHRONOUS ORBIT AND IS ONLY VALID FOR'
                        WRITE (6,*) ' POINTS AT 6.6 RE.'
                        WRITE (6,*)
                    ENDIF
                    THRSHK=G3NTRP (THRSH, IEMAX, 1, 1, BK, 1., 1.)
                    WRITE (6,*)
                    IF (THRSHK.NE.0.0) THEN
                        WRITE (6,*) ' THE PARTICLES USED IN THE FLUX CALCULATION WERE '
                        WRITE (6,*) ' ABOVE THE THRESHOLD LEVEL AND THE FULL-TRACEBACK'
                        WRITE (6,*) ' METHOD WAS NOT USED.'
                    ENDIF
C          WRITE (6,*) ' ERROR, THRSHK ', ERROR, THRSHK
                    WRITE (6,*)
500  WRITE (6,*) ' TRACE FROM ANOTHER STARTING POINT'
                    WRITE (6,*) ' WITH SAME TIME PARAMETERS?          (1 = YES)'
                    READ (5,*) KK
                    IF (KK.EQ.1) GOTO 300

```

MAP02520
MAP02530
MAP02540
MAP02550
MAP02560
MAP02570
MAP02580
MAP02590
MAP02600
MAP02610
MAP02620
MAP02630
MAP02640
MAP02650
MAP02660
MAP02670
MAP02680
MAP02690
MAP02700
MAP02710
MAP02720
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MAP02790
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MAP02890
MAP02900
MAP02910
MAP02920
MAP02930
MAP02940
MAP02950
MAP02960
MAP02970
MAP02980
MAP02990
MAP03000
MAP03010
MAP03020
MAP03030
MAP03040
MAP03050
MAP03060
MAP03070
MAP03080
MAP03090
MAP03100
MAP03110
MAP03120
MAP03130
MAP03140
MAP03150

```
C
C INPUT FOR SPATIAL COORDINATE OF SATELLITE
C
  FTILT=AUGPAR(23)
  FSTDF=AUGPAR(24)
  FDST=AUGPAR(7)
  FEQEDG=AUGPAR(8)
  FCLPSE=AUGPAR(15)
20 CONTINUE
  WRITE(6,*) 'ENTER SPATIAL POINT OF INTEREST IN GSM (RE): X,Y,Z'
  READ(5,*) XSTRT,YSTRT,ZSTRT
C   CHECK VALIDITY OF INPUT PARAMETERS AND TRACER START POINT
  CALL VALID(FTILT,FSTDF,FDST,FEQEDG,FCLPSE,XSTRT,YSTRT,ZSTRT,
1     IVALID)
  IF (IVALID.EQ.0) THEN
    WRITE(6,*) 'INVALID INPUT. TRY AGAIN? (0 = YES)'
    READ(5,*) KK
    IF (KK.EQ.0) GOTO 20
    STOP
  END IF
  CALL MAPTRK(FSTDF,FTILT,FEQEDG,FDST,FCLPSE,XSTRT,YSTRT,ZSTRT,
1     XMAP,YMAP,ZMAP)
  IF (ABS(XMAP).LT.1.0.AND.ABS(YMAP).LT.1.0.AND.ABS(ZMAP).LT.1.0)
1 GO TO 500
  WRITE(6,*)
  WRITE(6,*) 'INTERPOLATED MAPPING POINT: XGSM YGSM ZGSM'
  WRITE(6,*) XMAP,YMAP,ZMAP
  WRITE(6,*)
C
C CHECK THAT THE MAPPED POINT IS WITHIN THE BOUNDARY OF THE MODEL
C CALCULATION
C
  RTEST=SQRT(XMAP**2 + YMAP**2 + ZMAP**2)
  PTEST=ATAN2(YMAP,XMAP)
  IF (PTEST.GT.2.0*PI) PTEST=PTEST-(2.0*PI)
  IF (PTEST.LT.0.0) PTEST=PTEST + 2.0*PI
  CALL LOCATE(RTEST,PTEST,LATDIM,LTDIM,R,P,BI,BJ)
  JPLACE=IFIX(BJ)
  BNDY=G3NTRP(BNDLOC,LTDIM,2,1,BJ,TIMTRP,1.0)
  IPLACE=IFIX(BNDY)
  IF ((R(IPLACE,JPLACE).LT.RTEST)) THEN
    WRITE(6,*)
    WRITE(6,*) ' POINT MAPPED TO IS OUT OF THE BOUNDARY OF THE '
    WRITE(6,*) ' MSM CALCULATION REGION. '
    WRITE(6,*) ' BOUNDARY LOCATION ',R(IPLACE,JPLACE),' RE'
    WRITE(6,*) ' SATELLITE MAPS TO ',RTEST,' RE'
    WRITE(6,*)
    GO TO 500
  ENDIF
  CALVM=G3NTRP(VM,LATDIM,LTDIM,2,BI,BJ,TIMTRP)
  ALMCHK=(ENERGY/CALVM)*1000.0
C   WRITE(6,*) ' ENERGY,CALVM,ALMCHK',ENERGY,CALVM,ALMCHK
C   WRITE(6,*) ' VM(IFIX(BI,BJ)) ',VM(IFIX(BI),IFIX(BJ),1)
C
C CHECK TO SEE IF THE ENERGY AND SPECIES INPUT IS WITHIN OUR
C CALCULATED RANGE
C
  XLO=-1.0
  DO 550 IE=1,IEMAX-1
    IF ((IFLAV(IE).NE.JFLAV).AND.(IFLAV(IE+1).NE.JFLAV)) GO TO 550
    IF ((ALMCHK.GE.ABS(ALAM(IE))).AND.(ALMCHK.LE.ABS(ALAM(IE+1))))
1 .AND.(IFLAV(IE).EQ.IFLAV(IE+1))) THEN
      XLO=(ALMCHK-ABS(ALAM(IE)))/(ABS(ALAM(IE+1))-ABS(ALAM(IE)))
      BK=FLOAT(IE)+XLO
MAP01880
MAP01890
MAP01900
MAP01910
MAP01920
MAP01930
MAP01940
MAP01950
MAP01960
MAP01970
MAP01980
MAP01990
MAP02000
MAP02010
MAP02020
MAP02030
MAP02040
MAP02050
MAP02060
MAP02070
MAP02080
MAP02090
MAP02100
MAP02110
MAP02120
MAP02130
MAP02140
MAP02150
MAP02160
MAP02170
MAP02180
MAP02190
MAP02200
MAP02210
MAP02220
MAP02230
MAP02240
MAP02250
MAP02260
MAP02270
MAP02280
MAP02290
MAP02300
MAP02310
MAP02320
MAP02330
MAP02340
MAP02350
MAP02360
MAP02370
MAP02380
MAP02390
MAP02400
MAP02410
MAP02420
MAP02430
MAP02440
MAP02450
MAP02460
MAP02470
MAP02480
MAP02490
MAP02500
MAP02510
```

90/06/30
17:04:14

mapint.for

7

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C
C
C PURPOSE -DETERMINE THE MAGNETIC FIELD MAPPING CONNECTING AN MAP03800
C ARBITRARY POINT IN SPACE TO THE MSM COMPUTATIONAL MAP03810
C SURFACE (THE GSM EQUATORIAL PLANE FOR DIPOLE TILT ANGLEMAP03820
C SET EQUAL TO ZERO) MAPPINGS ARE DONE FROM A GIVEN POINTMAP03830
C TO A SURFACE FOR ALL MODELS IMMEDIATELY ADJACENT IN MAP03850
C THE MODELS EXTERNAL PARAMETER SPACE. (SEE OUTLINE OF MAP03860
C METHOD GIVEN IN MSM QUARTERLY REPORT NO. 11) MAP03870
C
C *** NOTE: PROCEDURE IS STOPPED IF AN OPEN FIELD-LINE IS FOUND MAP03880
C DURING ONE OF THE TRACES OR IF THERE ARE LESS THAN THE MAP03890
C MINIMUM NUMBER (8) OF ESTABLISHED MODELS REQUIRED FOR MAP03900
C A PROPER INTERPOLATION. MAP03910
C
C INPUT -FTILT: DIPOLE TILT ANGLE (DEGREES, POSITIVE FOR MAP03920
C NORTHERN HEMISPHERE SUMMER. MAP03930
C FSTDF: MAGNETO PAUSE STAND-OFF DISTANCE (RE) MAP03940
C FDST: MAGNETIC ACTIVITY DST (NT) MAP03950
C FEQEDG: DIPOLE LAT. OF MIDNIGHT EQUATORWARD DIFFUSE MAP03960
C AURORA BOUNDARY (DEG) MAP03970
C
C FCLPSE: MAGNETOTAIL FIELD COLLAPSE INDICATOR MAP03980
C XSTRT,YSTRT,ZSTRT: STARTING POINT FOR MAGNETIC FIELD MAP03990
C TRACES (GSM COORDINATES) MAP04000
C
C OUTPUT -XMAP,YMAP,ZMAP: INTERPOLATED MAPPING POSITION (GSM) MAP04010
C VARIABLES -XHIT,YHIT,ZHIT: MAPPING POINT OF INDIVIDUAL TRACES MAP04020
C IOPEN: OPEN/CLOSED FIELD-LINE INDICATOR 1 = OPEN MAP04030
C 0 = CLOSED MAP04040
C
C BFEFST: INDICATES IF B-FIELD MATRIX EXISTS MAP04050
C TPRM: MAGNETIC FIELD MODEL INTERNAL INPUT PARAMETERS MAP04060
C BFLIM: ESTABLISHED PARAMETERS WHICH BRACKET BFPAR MAP04070
C T: COEFFICIENTS FOR SINGLE LINEAR INTERPOLATION USED TO MAP04080
C CONSTRUCT VALUES OF VARIABLE COEFF. MAP04090
C
C BFPAR: THE INPUT PARAMETERS MAP04100
C COEFF: INTERPOLATION COEFFICIENT MAP04110
C
C ISWIT,STAND,TILT,HJNEAR,XNEAR,HJFRAC,DY,D,COLLAP,DELXC,MAP04120
C DYC,BRN,BRP,RN,RP: MAGNETIC FIELD MODEL INTERNAL MAP04130
C INPUTS (SEE SUBROUTINE BFIELD FOR DETAILS) MAP04140
C
C XMAX,YMAX,ZMAX: MAXIMUM VALUES OF XHIT,YHIT,ZHIT MAP04150
C XMIN,YMIN,ZMIN: MINIMUM VALUES OF XHIT,YHIT,ZHIT MAP04160
C XRANGE,YRANGE,ZRANGE: = MAXIMUM - MINIMUM OF ABOVE MAP04170
C
C SUBROUTINE-BFIELD: MAGNETIC FIELD MODEL POINT CALCULATIONS MAP04180
C BMNMAP: MAPS SINGLE FIELD LINE TO MINIMUM |B| SURFACE MAP04190
C GETIP: COLLECTS INTERNAL BFIELD MODEL INPUTS MAP04200
C FROM THE RESPECTIVE MATRICES FOR THE GROUP MAP04210
C OF MODELS IN CLOSEST PROXIMITY OF PARAMETER MAP04220
C SPACE TO THE MSM INPUTS. MAP04230
C MAP04240
C
C NOTE: THIS SUBROUTINE CONTAINS PARTS WHICH WERE ADAPTED DIRECTLY MAP04250
C FROM SUBROUTINE BTRACE AS PROGRAMMED BY R.W. SPIRO. THESE MAP04260
C INCLUDE THE MATRIX READING PROCEDURE, DEVELOPING THE PARAMETER MAP04270
C WEIGHTING COEFFICIENTS, AND THE FIVE DIMENSIONAL INTERPOLATION MAP04280
C SCHEME. MAP04290
C
C REFERENCE: MAP04300
C FIVE DIMENSIONAL INTERPOLATION IS BASED ON MULTILINEAR MAP04310
C INTERPOLATION SCHEME GIVEN BY PRESS ET AL. IN MAP04320
C NUMERICAL RECIPES, CAMBRIDGE UNIVERSITY PRESS, 1987,PP 95-97 MAP04330
C
C LOGICAL*1 BFEFST(2,2,2,2,2) MAP04340
C
C DIMENSION TPRM(14,2,2,2,2,2) MAP04350
C DIMENSION XHIT(2,2,2,2,2),YHIT(2,2,2,2,2),ZHIT(2,2,2,2,2) MAP04370
C DIMENSION BFLIM(2,5),BFPAR(5) MAP04380
C DIMENSION T(2,5),N(5) MAP04390
C
C SET UP BFPAR VECTOR FOR CALLING GETMAT MAP04400
C BFPAR(1)=FSTDF MAP04410
C MAP04420
C MAP04430
```

mapint.for

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WRITE(6,*) 'AGAIN WITH NEW TIME?'           (1 = YES)'
READ(5,*) KK
IF (KK.EQ.1) GOTO 100
C
STOP
END
C
C***** VALID
SUBROUTINE VALID(TILT,STDF,DST,EQBDY, COLLAP,XSTRT,YSTRT,ZSTRT,
1          IVALID)
C
C  PURPOSE- DETERMINE IF EXTERIOR MODEL INPUTS ARE WITHIN VALID
C           RANGES.
C  INPUT-   TILT:   DIPOLE TILT ANGLE (DEG)
C           STDF:   MAGNETOPOUSE STAND-OFF DISTANCE (RE)
C           DST:    MAGNETIC FIELD STRENGTH INDEX (NT)
C           EQBDY:  MIDNIGHT EQUATORWARD BOUNDARY OF DIFFUSE
C                   AURORA (DEGREES DIPOLE LATITUDE)
C           COLLAP: SUBSTORM MAGNETOTAIL FIELD COLLAPSE INDICATOR
C           XSTRT,YSTRT,ZSTRT: GSM STARTING POINT FOR B-FIELD TRACE
C  OUTPUT-  IVALID: INDICATOR OF PARAMETER SET VALIDITY
C           1 = VALID, 0 = INVALID
C  VARIABLE-DIST:  GEOCENTRIC DISTANCE TO TRACER STARTING POINT (RE)
C
C           SET MAXIMUM(MX) AND MINIMUM(MN) ACCEPTABLE PARAMETER VALUES
DATA TILTMX,TILTMN/35.00,-35.00/
DATA STDFMX,STDFMN/14.00,6.00/
DATA DSTMX,DSTMN/50.00,-400.00/
DATA EQBDYMX,EQBDYMN/69.30,49.47/
DATA COLLAPMX, COLLAPMN/1.00,0.00/
C
C  IVALID = 1
C  IF ((TILT.LT.TILTMN).OR.(TILT.GT.TILTMX)) THEN
C    IVALID = 0
C    WRITE(6,*) 'TILT VALUE',TILT,' IS OUT OF RANGE'
C  END IF
C  IF ((STDF.LT.STDFMN).OR.(STDF.GT.STDFMX)) THEN
C    IVALID = 0
C    WRITE(6,*) 'STAND-OFF VALUE',STDF,' IS OUT OF RANGE'
C  END IF
C  IF ((DST.LT.DSTMN).OR.(DST.GT.DSTMX)) THEN
C    IVALID = 0
C    WRITE(6,*) 'DST VALUE',DST,' IS OUT OF RANGE'
C  END IF
C  IF ((EQBDY.LT.EQBDYMN).OR.(EQBDY.GT.EQBDYMX)) THEN
C    IVALID = 0
C    WRITE(6,*) 'EQEDGE VALUE',EQBDY,' IS OUT OF RANGE'
C  END IF
C  IF ((COLLAP.LT.COLLAPMN).OR.(COLLAP.GT.COLLAPMX)) THEN
C    IVALID = 0
C    WRITE(6,*) 'COLLAPSE VALUE',COLLAP,' IS OUT OF RANGE'
C  END IF
C
C  DIST = SQRT(XSTRT**2 + YSTRT**2 + ZSTRT**2)
C  IF (DIST.LE.1.) THEN
C    IVALID = 0
C    WRITE(6,*) 'INVALID STARTING POINT FOR FIELD-LINE TRACE (<1 RE)'
C  END IF
C
C  RETURN
C  END
C***** MAPTRK
SUBROUTINE MAPTRK(FSTDF,FTILT,FEQEDG,FDST,FCLPSE,
1          XSTRT,YSTRT,ZSTRT,XMAP,YMAP,ZMAP)
MAP03160
MAP03170
MAP03180
MAP03190
MAP03200
MAP03210
MAP03220
MAP03230
MAP03240
MAP03250
MAP03260
MAP03270
MAP03280
MAP03290
MAP03300
MAP03310
MAP03320
MAP03330
MAP03340
MAP03350
MAP03360
MAP03370
MAP03380
MAP03390
MAP03400
MAP03410
MAP03420
MAP03430
MAP03440
MAP03450
MAP03460
MAP03470
MAP03480
MAP03490
MAP03500
MAP03510
MAP03520
MAP03530
MAP03540
MAP03550
MAP03560
MAP03570
MAP03580
MAP03590
MAP03600
MAP03610
MAP03620
MAP03630
MAP03640
MAP03650
MAP03660
MAP03670
MAP03680
MAP03690
MAP03700
MAP03710
MAP03720
MAP03730
MAP03740
MAP03750
MAP03760
MAP03770
MAP03780
MAP03790
```

```
BFPAR(2)=FTILT  
BFPAR(3)=FEQEDG  
BFPAR(4)=FDST  
BFPAR(5)=FCLPSE  
C  
C INITIALIZE "HIT" ARRAYS AND MAPPING RESULT  
  X = 1.  
  Y = 1.  
  Z = 1.  
  XMAP = 0.  
  YMAP = 0.  
  ZMAP = 0.  
  DO 15 I=1,2  
    DO 16 J=1,2  
      DO 17 K=1,2  
        DO 18 L=1,2  
          DO 19 M=1,2  
            XHIT(I,J,K,L,M) = 0.  
            YHIT(I,J,K,L,M) = 0.  
            ZHIT(I,J,K,L,M) = 0.  
          19 CONTINUE  
        18 CONTINUE  
      17 CONTINUE  
    16 CONTINUE  
  15 CONTINUE  
C  
C GET INTERNAL B-FIELD PARAMETERS  
  CALL GETIP(BFPAR,TPRM,BFLIM,BFEXST)  
C  
C SET UP WEIGHTING PARAMETERS FOR INTERPOLATION  
C  
  DO 10 II=1,5  
    T(2,II)=(BFPAR(II)-BFLIM(1,II))/(BFLIM(2,II)-BFLIM(1,II))  
    T(1,II)=1.-T(2,II)  
  10 CONTINUE  
C  
C FIND MINIMUM CROSSING POINT FOR EACH OF THE "CORNERS"  
DO 31 I = 1,2  
  DO 32 J = 1,2  
    DO 33 K = 1,2  
      DO 34 L = 1,2  
        DO 35 M = 1,2  
          IF (.NOT.BFEXST(I,J,K,L,M)) THEN  
            DO NOT ATTEMPT A FIELD-LINE TRACE  
            GOTO 36  
          END IF  
C  
C SET INTERNAL PARAMETERS  
  STAND = TPRM( 1,I,J,K,L,M)  
  TILT = TPRM( 2,I,J,K,L,M)  
  HJNEAR = TPRM( 3,I,J,K,L,M)  
  XNEAR = TPRM( 4,I,J,K,L,M)  
  HJFRAC = TPRM( 5,I,J,K,L,M)  
  DY = TPRM( 6,I,J,K,L,M)  
  D = TPRM( 7,I,J,K,L,M)  
  COLLAP = TPRM( 8,I,J,K,L,M)  
  DELXC = TPRM( 9,I,J,K,L,M)  
  DYC = TPRM(10,I,J,K,L,M)  
  BRN = TPRM(11,I,J,K,L,M)  
  BRP = TPRM(12,I,J,K,L,M)  
  RN = TPRM(13,I,J,K,L,M)  
  RP = TPRM(14,I,J,K,L,M)  
C  
C SET-UP BFIELD INTERNAL COEFFICIENTS AND TAIL CURRENTS  
  ISWIT = 0
```

MAP04440
MAP04450
MAP04460
MAP04470
MAP04480
MAP04490
MAP04500
MAP04510
MAP04520
MAP04530
MAP04540
MAP04550
MAP04560
MAP04570
MAP04580
MAP04590
MAP04600
MAP04610
MAP04620
MAP04630
MAP04640
MAP04650
MAP04660
MAP04670
MAP04680
MAP04690
MAP04700
MAP04710
MAP04720
MAP04730
MAP04740
MAP04750
MAP04760
MAP04770
MAP04780
MAP04790
MAP04800
MAP04810
MAP04820
MAP04830
MAP04840
MAP04850
MAP04860
MAP04870
MAP04880
MAP04890
MAP04900
MAP04910
MAP04920
MAP04930
MAP04940
MAP04950
MAP04960
MAP04970
MAP04980
MAP04990
MAP05000
MAP05010
MAP05020
MAP05030
MAP05040
MAP05050
MAP05060
MAP05070


```

                END IF
                END IF
C
                IF (ZHIT(N1,N2,N3,N4,N5).GT.ZMAX) THEN
                ZMAX = ZHIT(N1,N2,N3,N4,N5)
                ELSE
                IF (ZHIT(N1,N2,N3,N4,N5).LT.ZMIN) THEN
                ZMIN = ZHIT(N1,N2,N3,N4,N5)
                END IF
                END IF
                END IF
                CONTINUE
25          CONTINUE
24          CONTINUE
23          CONTINUE
22          CONTINUE
21          CONTINUE
XRANGE = XMAX - XMIN
YRANGE = YMAX - YMIN
ZRANGE = ZMAX - ZMIN
WRITE(6,*) 'MAPPING POINTS USED FOR INTERPOLATION WERE SPREAD:'
WRITE(6,*) XRANGE,'RE ALONG THE XGSM DIRECTION'
WRITE(6,*) YRANGE,'RE ALONG THE YGSM DIRECTION'
WRITE(6,*) ZRANGE,'RE ALONG THE ZGSM DIRECTION'
C
RETURN
END
C ***** GETIP *****
SUBROUTINE GETIP (BFPAR,TPRM,BFLIM,BFEXST)
C
C PURPOSE-   FIND THE MSM PARAMETER SETS WHICH LIE CLOSEST TO THE
C             INPUT PARAMETER SET AND LOAD THE B-FIELD MODEL
C             INTERNAL PARAMETERS FROM THE APPROPRIATE MATRICES TO
C             BE PASSED ON FOR MAGNETIC FIELD LINE TRACING PURPOSES
C INPUT-     BFPAR: MSM INPUTS
C OUTPUT-    TPRM: BFIELD MODEL INTERNAL INPUTS (14 FOR EACH)
C             BFLIM: VALUES FROM PARAMETER "GRID" WHICH BRACKET
C             THE VALUES OF BFPAR
C             BFEXST: INDICATES IF A BFIELD MODEL AS REPRESENTED
C             BY A MATRIX HAS BEEN LOADED.
C VARIABLES- BFNDX: INDEX ASSIGNED TO BFLIM VALUES
C             STNDPR,TILTPR,FINEDP,DSTPR,STCHPR: GRID VALUES OF THE
C             MSM INPUTS
C             MSTND,MTILT,MINED,MDST,MSTCH: NUMBER OF GRID POINTS
C             FOR EACH MSM INPUT
C             ICOUNT: NUMBER OF PARAMETER SETS LOADED.
C SUBROUTINES-FNDBRK: FINDS THE SET OF B-FIELD MODELS WHICH
C             BRACKET THE POINT OF INTEREST IN PARAMETER
C             SPACE.
C             LOADIP: LOADS INTERNAL B-FIELD PARAMETERS FROM MATRIX
C             FILES INTO VARIABLE TPRM.
C FUNCTIONS-MEXIST: INDICATES IF A BFIELD MODEL EXISTS
C
PARAMETER (IMSTND=5,IMTILT=5,IMINED=16,IMDST=8,IMSTCH=2)
C
LOGICAL MEXIST
INTEGER BFNDX(2,5)
LOGICAL*1 BFEXST(2,2,2,2,2)
C
DIMENSION STNDPR(IMSTND),TILTPR(IMTILT),FINEDP(IMINED)
DIMENSION DSTPR(IMDST),STCHPR(IMSTCH)
DIMENSION BFLIM(2,5),BFPAR(5)
DIMENSION TPRM(14,2,2,2,2,2)
DATA MSTND/IMSTND/
DATA MTILT/IMTILT/

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MAP05720
MAP05730
MAP05740
MAP05750
MAP05760
MAP05770
MAP05780
MAP05790
MAP05800
MAP05810
MAP05820
MAP05830
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MAP05850
MAP05860
MAP05870
MAP05880
MAP05890
MAP05900
MAP05910
MAP05920
MAP05930
MAP05940
MAP05950
MAP05960
MAP05970
MAP05980
MAP05990
MAP06000
MAP06010
MAP06020
MAP06030
MAP06040
MAP06050
MAP06060
MAP06070
MAP06080
MAP06090
MAP06100
MAP06120
MAP06130
MAP06140
MAP06150
MAP06160
MAP06170
MAP06200
MAP06210
MAP06220
MAP06230
MAP06240
MAP06110
MAP06250
MAP06260
MAP06270
MAP06290
MAP06300
MAP06310
MAP06320
MAP06330
MAP06340
MAP06350
MAP06360
MAP06370

	DATA MINED/IMINED/	MAP06380
	DATA MDST/IMDST/	MAP06390
	DATA MSTCH/IMSTCH/	MAP06400
C		MAP06410
	DATA STNDPR/6.0,8.0,10.0,12.0,14.0/	MAP06420
	DATA TILTPR/-35.0,-17.5,0.0,17.5,35.0/	MAP06430
	DATA FINEDP/49.47, 53.20, 55.89, 57.96, 59.60,	MAP06440
1	60.95, 62.06, 63.02, 63.99, 65.01,	MAP06450
2	65.91, 66.72, 67.45, 68.12, 68.73,	MAP06460
3	69.30/	MAP06470
	DATA DSTPR/-400.0, -300.0, -200.0, -150.0,	MAP06480
1	-100.0, -50.0, 0.0, 50.0/	MAP06490
	DATA STCHPR/0.0, 1.0/	MAP06500
C		
	EXTERNAL MEXIST	
C		MAP06510
	CALL FNDBRK(BFPAR(1), STNDPR, MSTND, BFNDX(1,1), BFNDX(2,1))	MAP06540
	CALL FNDBRK(BFPAR(2), TILTPR, MTILT, BFNDX(1,2), BFNDX(2,2))	MAP06550
	CALL FNDBRK(BFPAR(3), FINEDP, MINED, BFNDX(1,3), BFNDX(2,3))	MAP06560
	CALL FNDBRK(BFPAR(4), DSTPR, MDST, BFNDX(1,4), BFNDX(2,4))	MAP06570
	CALL FNDBRK(BFPAR(5), STCHPR, MSTCH, BFNDX(1,5), BFNDX(2,5))	MAP06580
C		MAP06590
	DO 5, I=1,2	MAP06600
	BFLIM(I,1) = STNDPR(BFNDX(I,1))	MAP06610
	BFLIM(I,2) = TILTPR(BFNDX(I,2))	MAP06620
	BFLIM(I,3) = FINEDP(BFNDX(I,3))	MAP06630
	BFLIM(I,4) = DSTPR(BFNDX(I,4))	MAP06640
	BFLIM(I,5) = STCHPR(BFNDX(I,5))	MAP06650
5	CONTINUE	MAP06660
C		MAP06670
	ICOUNT = 0	MAP06680
	DO 10, I=1,2	MAP06690
	DO 20, J=1,2	MAP06700
	DO 30, K=1,2	MAP06710
	DO 40, L=1,2	MAP06720
	DO 50, M=1,2	MAP06730
	IF (MEXIST(BFNDX(I,1), BFNDX(J,2), BFNDX(K,3),	MAP06740
1	BFNDX(L,4), BFNDX(M,5))) THEN	MAP06750
	CALL LOADIP(I, J, K, L, M, BFNDX, TPRM)	MAP06760
	BFEXST(I, J, K, L, M) = .TRUE.	MAP06770
	ICOUNT = ICOUNT + 1	MAP06780
	ELSE	MAP06790
	BFEXST(I, J, K, L, M) = .FALSE.	MAP06800
	ENDIF	MAP06810
50	CONTINUE	MAP06820
40	CONTINUE	MAP06830
30	CONTINUE	MAP06840
20	CONTINUE	MAP06850
10	CONTINUE	MAP06860
	IF (ICOUNT.LT.8) THEN	MAP06870
	WRITE(6,1000) ICOUNT	MAP06880
1000	FORMAT(1X,'ONLY',I3,' MODELS AVAILABLE (NEED 8 MINIMUM)')	MAP06890
	WRITE(6,*) 'B-FIELD TRACING INTERPOLATION PROCEDURE INVALIDATED'	MAP06900
	WRITE(6,*) 'EXITED FROM SUBROUTINE GETIP'	MAP06910
	RETURN	MAP06920
	END IF	MAP06930
C		MAP06940
	RETURN	MAP06950
	END	MAP06960
C		MAP06970
C	***** LOADIP *****	MAP06980
	SUBROUTINE LOADIP(I, J, K, L, M, BFNDX, TPRM)	MAP06990
C		MAP07000
C	PURPOSE-	MAP07010

mapint.for

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C THIS SUBROUTINE LOADS INTERNAL MODEL PARAMETERS FROM OFFLINE MAP07020
C B-SUPERMATRIX INTO THE TPRM MATRIX. A CHECK IS MADE TO MAP07030
C VERIFY THAT THE CORRECT PARAMETERS HAVE BEEN RETRIEVED. IF THIS MAP07040
C CHECK FAILS THE PROGRAM WILL STOP. THIS SUBROUTINE HAS THE SAME MAP07050
C BASIC STRUCTURE (AND READS FROM THE SAME DATA FILES) AS SUBROUTINE MAP07060
C LOADBM. ONE CALL PER MODEL. MAP07070
C INPUT- I,J,K,L,M: INDICES FOR MATRIX BFNDX MAP07080
C BFNDX: INDEX NUMBERS OF PARAMETERS USED TO IDENTIFY MAP07090
C INDIVIDUAL MATRICES. MAP07100
C OUTPUT- TPRM: INTERNAL B-FIELD PARAMETERS (14) FOR MAXIMUM OF 32 MAP07110
C DIFFERENT MODELS (2X2X2X2X2) MAP07120
C VARIABLES-IDF1-IDF6: MATRIX IDENTIFIERS MAP07130
C
C INTEGER BFNDX(2,5) MAP07150
C CHARACTER*32 FILNAM MAP07160
C
C DIMENSION TPRM(14,2,2,2,2,2) MAP07170
C
C WRITE (FILNAM,1000) BFNDX(J,2), BFNDX(I,1), BFNDX(L,4), MAP07190
C BFNDX(K,3), (3-BFNDX(M,5)) MAP07200
1000 FORMAT ('BFIELD:BO',I1,I1,I1,I2.2,I1,'.DAT') MAP07210
C MAP07220
C OPEN (UNIT=99,FILE=FILNAM,ERR=199,FORM='FORMATTED', MAP07230
C ACCESS='SEQUENTIAL') MAP07240
C MAP07250
C READ (99,800) IDF1,IDF2,IDF3,IDF4,IDF5,IDF6,TPRM( 1,I,J,K,L,M), MAP07270
C TPRM( 2,I,J,K,L,M),TPRM( 3,I,J,K,L,M),TPRM( 4,I,J,K,L,M), MAP07280
1 TPRM( 5,I,J,K,L,M),TPRM( 6,I,J,K,L,M),TPRM( 7,I,J,K,L,M), MAP07290
2 TPRM( 8,I,J,K,L,M),TPRM( 9,I,J,K,L,M),TPRM(10,I,J,K,L,M), MAP07300
3 TPRM(11,I,J,K,L,M),TPRM(12,I,J,K,L,M),TPRM(13,I,J,K,L,M), MAP07310
4 TPRM(14,I,J,K,L,M) MAP07320
5 800 FORMAT(3I1,I2.2,I1,I3,14F8.2) MAP07330
C MAP07340
C IF ((BFNDX(I,1).NE.IDF2).OR.(BFNDX(J,2).NE.IDF1).OR. MAP07350
C (BFNDX(K,3).NE.IDF4).OR.(BFNDX(L,4).NE.IDF3).OR. MAP07360
C ((3-BFNDX(M,5)).NE.IDF5).OR.(IDF6.NE.201)) THEN MAP07370
C WRITE (6,*) 'FILE ',FILNAM,' IS INCORRECT.' MAP07380
C STOP 'INCORRECT B-FIELD. STOPPING IN LOADIP.' MAP07390
C ENDIF MAP07400
C MAP07410
C CLOSE (99) MAP07420
C RETURN MAP07430
C MAP07440
C 199 CONTINUE MAP07450
C WRITE(6,*) 'STOPPING IN LOADIP. OPEN FAILED ON ',FILNAM MAP07460
C STOP 'STOPPING IN LOADBM. OPEN FAILED ON B-MATRIX.' MAP07470
C END MAP07480
C***** BMNMAP MAP07490
C SUBROUTINE BMNMAP(ISWIT,STAND,TILT,HJNEAR,XNEAR,HJFRAC,DY,D, MAP07500
C 1 COLLAP,DELXC,DYC,BRN,BRP,RN,RP,RADIUS,X,Y,Z, MAP07510
C 2 IOPEN,XHIT,YHIT,ZHIT) MAP07520
C MAP07530
C PURPOSE- MAGNETIC FIELD LINE MAPPING TO THE MINIMUM |B| SURFACEMAP07540
C OR THE MAGNETOPAUSE BOUNDARY, OPEN/CLOSED DETERMINED MAP07550
C INPUT- FIRST 15: BFIELD INPUT MAP07560
C RADIUS: MAGNETOTAIL RADIUS FOR DEFINING BOUNDARY MAP07570
C X,Y,Z,: GSM STARTING POINT OF TRACE MAP07580
C OUTPUT- IOPEN: DESIGNATES OPEN FIELD LINE = 1 MAP07590
C CLOSED FIELD LINE = 0 MAP07600
C XHIT,YHIT,ZHIT: LAST TRACE POINT. EITHER AT MSM MAP07610
C SURFACE WHEN FIELD LINE IS CLOSED OR AT A POINT MAP07620
C ON THE DEFINED MAGNETOPAUSE FOR OPEN LINES. MAP07630
C VARIABLE- ER,EP,H:ERROR,DIRECTION, AND INITIAL TRACE STEP SIZE MAP07640
C DX1,DY1,DZ1,BB: VECTOR INFORMATION FOR SUBROUT. TRAC MAP07650

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```

      YHIT = YA
      ZHIT = ZA
      GOTO 20
    END IF
  END IF
20  CONTINUE
C   START FULL TRACE OF A SINGLE FIELD-LINE
    CALL TRAC (ISWIT, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D, COLLAP,
1    DELXC, DYC, BRN, BRP, RN, RP, RADIUS, XA, YA, ZA, XN, YN, ZN)
    DIST = SQRT (YN**2 + ZN**2)
    XP = XN + BDIST
    DDAY = SQRT (XP**2 + YN**2 + ZN**2)
    IF ((XN.LT.(-50.)).OR.(DIST.GT.RADIUS)).OR.
1    ((XP.GE.0.).AND.(DDAY.GT.RADIUS))) THEN
C   TRACE HIT MAGNETOPAUSE OR FAR TAIL LIMIT (OPEN FIELD LINE)
    IOPEN = 1
    XHIT = XN
    YHIT = YN
    ZHIT = ZN
    WRITE (6,*) '*****'
    WRITE (6,*) 'OPEN FIELD-LINE HIT AT POINT: XGSM   YGSM   ZGSM'
    WRITE (6,*) XHIT, YHIT, ZHIT
    GOTO 20
  END IF
C
    CALL BFIELD (ISWIT, XN, YN, ZN, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D,
1    COLLAP, DELXC, DYC, BRN, BRP, RN, RP, RADIUS, BX, BY, BZ)
    BSIZE = SQRT (BX**2 + BY**2 + BZ**2)
    IF (BSIZE.LE.BMIN) THEN
C   CLOSER TO MINIMUM IN |B|
      BMIN = BSIZE
      XHIT = XN
      YHIT = YN
      ZHIT = ZN
      IOPEN = 0
    ELSE
C   PAST MINIMUM |B|, DONE
      GOTO 20
    END IF
C
    XA = XN
    YA = YN
    ZA = ZN
    GOTO 30
C
20  CONTINUE
    RETURN
  END
C***** TRAC
  SUBROUTINE TRAC (ISWIT, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D, COLLAP,
1  DELXC, DYC, BRN, BRP, RN, RP, RADIUS, XA, YA, ZA, XN, YN, ZN)
C
C  PURPOSE-   FINDS SUCCESSIVE STEP LOCATION IN A TRACE OF A VECTOR
C             FIELD, E.G., USED TO MAP MAGNETIC FIELD LINES.
C  INPUT-    FIRST 15 ARE BFIELD MODEL INPUTS (SUBROUTINE BFIELD)
C             XA, YA, ZA: GSM LOCATION OF START POINT OF VECTOR TRACE.
C  OUTPUT-   RADIUS: MAGNETOTAIL RADIUS (RE)
C             XN, YN, ZN: GSM LOCATION OF NEXT STEP IN VECTOR TRACE.
C  VARIABLES- H: STEP SIZE
C             EP: DIRECTION OF TRACE (+1. IS PARALLEL TO FIELD
C                VECTOR AND -1. IS ANTIPARALLEL TO SAME)
C             ER: ALLOWABLE DISTANCE ERROR LIMIT (RE)
C  SUBROUTINES-FUNC: PROVIDES VECTOR INFORMATION ABOUT THE BFIELD

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MAP08300
MAP08310
MAP08320
MAP08330
MAP08340
MAP08350
MAP08360
MAP08370
MAP08380
MAP08390
MAP08400
MAP08410
MAP08420
MAP08430
MAP08440
MAP08450
MAP08460
MAP08470
MAP08480
MAP08490
MAP08500
MAP08510
MAP08520
MAP08530
MAP08540
MAP08550
MAP08560
MAP08570
MAP08580
MAP08590
MAP08600
MAP08610
MAP08620
MAP08630
MAP08640
MAP08650
MAP08660
MAP08670
MAP08680
MAP08690
MAP08700
MAP08710
MAP08720
MAP08730
MAP08740
MAP08750
MAP08760
MAP08770
MAP08780
MAP08790
MAP08800
MAP08810
MAP08820
MAP08830
MAP08840
MAP08850
MAP08860
MAP08870
MAP08880
MAP08890
MAP08900
MAP08910
MAP08920
MAP08930

```

mapint.for

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COMMON/BSTEP/DX1,DY1,DZ1, BB, H, EP, ER
REAL DX1,DY1,DZ1, BB, H, EP, ER, XA, YA, ZA, XN, YN, ZN
C
CALL FUNC (ISWIT, XA, YA, ZA, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D,
1          COLLAP, DELXC, DYC, BRN, BRP, RN, RP, RADIUS, DX1, DY1, DZ1, BF1)
1  CONTINUE
   H1=H*EP
   H2=0.5*H1
C
   XN1=XA+H1*DX1
   YN1=YA+H1*DY1
   ZN1=ZA+H1*DZ1
   XN2=XA+H2*DX1
   YN2=YA+H2*DY1
   ZN2=ZA+H2*DZ1
C
CALL FUNC (ISWIT, XN2, YN2, ZN2, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D,
1          COLLAP, DELXC, DYC, BRN, BRP, RN, RP, RADIUS, DX2, DY2, DZ2, BF2)
1  XN3=XN2+H2*DX2
   YN3=YN2+H2*DY2
   ZN3=ZN2+H2*DZ2
C
   DELX=XN1-XN3
   DELY=YN1-YN3
   DELZ=ZN1-ZN3
   RTES1=DELX*DELX
   RTES2=DELY*DELY
   RTES3=DELZ*DELZ
   RTES=SQRT (RTES1+RTES2+RTES3)
C
   IF (RTES-ER) 4,4,2
4  CONTINUE
C
   XN=XN3-DELX
   YN=YN3-DELY
   ZN=ZN3-DELZ
   BB=BF2
   IF (RTES-(0.25*ER)) 7,6,6
7  H=2.*H
C ***LIMIT MAXIMUM STEP SIZE***
   IF (H.GT.(5.0)) THEN
     H = 5.0
   END IF
6  GOTO 5
C
2  CONTINUE
   H=0.5*H
   GOTO 1
C
5  CONTINUE
   RETURN
   END
C***** FUNC
SUBROUTINE FUNC (ISWIT, X, Y, Z, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY, D,
1          COLLAP, DELXC, DYC, BRN, BRP, RN, RP, RADIUS, DX, DYY, DZ, B)
C
C  PURPOSE-   PROVIDE VECTOR INFORMATION ABOUT A FUNCTION (BFIELD)
C  INPUT-     FIRST 18: BFIELD INPUTS
C  OUTPUT-    DX,DYY,DZ,B: VECTOR COMPONENT INFORMATION
C  SUBROUTINE-BFIELD: MAGNETIC FIELD MODEL
C
   BX = 0.
   BY = 0.
   BZ = 0.

```

MAP08940
MAP08950
MAP08960
MAP08970
MAP08980
MAP08990
MAP09000
MAP09010
MAP09020
MAP09030
MAP09040
MAP09050
MAP09060
MAP09070
MAP09080
MAP09090
MAP09100
MAP09110
MAP09120
MAP09130
MAP09140
MAP09150
MAP09160
MAP09170
MAP09180
MAP09190
MAP09200
MAP09210
MAP09220
MAP09230
MAP09240
MAP09250
MAP09260
MAP09270
MAP09280
MAP09290
MAP09300
MAP09310
MAP09320
MAP09330
MAP09340
MAP09350
MAP09360
MAP09370
MAP09380
MAP09390
MAP09400
MAP09410
MAP09420
MAP09430
MAP09440
MAP09450
MAP09460
MAP09470
MAP09480
MAP09490
MAP09500
MAP09510
MAP09520
MAP09530
MAP09540
MAP09550
MAP09560
MAP09570

mapint.for

```
CALL BFIELD (ISWIT,X,Y,Z,STAND,TILT,HJNEAR,XNEAR,HJFRAC,DY,D,  
1 COLLAP,DELXC,DYC,BRN,BRP,RN,RP,RADIUS,BX,BY,BZ) MAP09580  
C MAP09590  
B = SQRT(BX**2 + BY**2 + BZ**2) MAP09600  
DX = BX/B MAP09610  
DYY = BY/B MAP09620  
DZ = BZ/B MAP09630  
C MAP09640  
RETURN MAP09650  
END MAP09660  
SUBROUTINE CHECK (IYEAR, IDAY, IHOURL, MINUTE, ISCNDS, IFLAG) MAP09670  
C MAP09680  
C THIS SUBROUTINE CHECKS THAT THE INTERACTIVE INPUT IS WITHIN MAP09690  
C REASONABLE LIMITS. MAP09700  
C MAP09710  
IFLAG=0 MAP09720  
IF ((IYEAR.LT.0).OR.(IYEAR.GT.99)) THEN MAP09730  
WRITE(6,*)' INCORRECT INPUT FOR YEAR-MUST BE BETWEEN 0 AND 99' MAP09740  
IFLAG= 1 MAP09750  
RETURN MAP09760  
ENDIF MAP09770  
IF ((IDAY.LT.1).OR.(IDAY.GT.366)) THEN MAP09780  
WRITE(6,*)' INCORRECT INPUT FOR DAY-MUST BE BETWEEN 1 AND 366' MAP09790  
IFLAG= 1 MAP09800  
RETURN MAP09810  
ENDIF MAP09820  
IF ((IHOURL.LT.0).OR.(IHOURL.GT.24)) THEN MAP09830  
WRITE(6,*)' INCORRECT INPUT FOR HOUR-MUST BE BETWEEN 1 AND 24' MAP09840  
IFLAG=1 MAP09850  
RETURN MAP09860  
ENDIF MAP09870  
IF ((MINUTE.LT.0).OR.(MINUTE.GT.60)) THEN MAP09880  
WRITE(6,*)' INCORRECT INPUT FOR MINUTE-MUST BE BETWEEN 0 AND 60' MAP09890  
IFLAG= 1 MAP09900  
RETURN MAP09910  
ENDIF MAP09920  
IF ((ISCNDS.LT.0).OR.(ISCNDS.GT.60)) THEN MAP09930  
WRITE(6,*)' INCORRECT INPUT FOR SECONDS-MUST BE BETWEEN 0 AND 60' MAP09940  
IFLAG= 1 MAP09950  
RETURN MAP09960  
ENDIF MAP09970  
RETURN MAP09980  
END MAP09990  
SUBROUTINE TCHECK (IYEAR, IDAY, IHOURL, MINUTE, ISCNDS, AUGPAR, AGPAR1,  
1 NAUGEL, IFLAG, ISTART) MAP10000  
C MAP10010  
C THIS SUBROUTINE CHECKS TO FIND THE RECORD NUMBERS OF THE DATA MAP10020  
C FILES WHICH SPAN THE REQUESTED TIME. MAP10030  
C MAP10040  
DIMENSION AUGPAR (NAUGEL), AGPAR1 (NAUGEL), ISTART (3), ITIME (3) MAP10050  
IFLAG=0 MAP10060  
ITIME (1)=IYEAR MAP10070  
ITIME (2)=IDAY MAP10080  
ITIME (3)=IHOURL*3600 + MINUTE*60 + ISCNDS MAP10090  
TIMCHK=TCONV3 (ITIME, ISTART) MAP10100  
ITIME (1)=AUGPAR (1) MAP10110  
ITIME (2)=AUGPAR (2) MAP10120  
ITIME (3)=AUGPAR (3)*3600 + AUGPAR (4)*60 + AUGPAR (5) MAP10130  
TIMAUG=TCONV3 (ITIME, ISTART) MAP10140  
ITIME (1)=AGPAR1 (1) MAP10150  
ITIME (2)=AGPAR1 (2) MAP10160  
ITIME (3)=AGPAR1 (3)*3600 + AGPAR1 (4)*60 + AGPAR1 (5) MAP10170  
TIMAG1=TCONV3 (ITIME, ISTART) MAP10180  
IF ((TIMCHK.GE.TIMAUG).AND.(TIMCHK.LT.TIMAG1)) THEN MAP10190  
MAP10200  
MAP10210
```

```

IFLAG=0
ELSE
  IFLAG=1
ENDIF
RETURN
END
C ***** TCONV3 *****
C
C REAL FUNCTION TCONV3(ITIME, ISTART)
C
C THIS FUNCTION TAKES A START YEAR, START DAY, A CURRENT YEAR,
C A CURRENT DAY, AND A CURRENT SECOND.. IT PRODUCES
C A VALUE THAT IS THE SECONDS FROM THE START YEAR AND DAY.
C THIS VALUE IS RELATIVE TO MIDNIGHT OF THE START DAY.
C
C PARAMETER (IYR=1, IDY=2, ISEC=3)
C DIMENSION ITIME(3), ISTART(3)
C INTRINSIC REAL
C
C IF (ISTART(IYR).EQ.ITIME(IYR)) THEN
1   TEMP = REAL(ITIME(IDY) - ISTART(IDY))*86400.0 +
      REAL(ITIME(ISEC))
C ELSEIF (MOD(ISTART(IYR), 4).EQ.0) THEN
1   TEMP = REAL(ITIME(IDY) + 366 - ISTART(IDY))*86400.0 +
      REAL(ITIME(ISEC))
C ELSE
1   TEMP = REAL(ITIME(IDY) + 365 - ISTART(IDY))*86400.0 +
      REAL(ITIME(ISEC))
C ENDIF
C
C TCONV3 = TEMP
C
C RETURN
C END
C SUBROUTINE LOCATE (RVAL, PVAL, LATDIM, LTDIM, R, P, BI, BJ)
C
C PURPOSE: FIND GRID LOCATION (BI, BJ) OF PHYSICAL LOCATIONS GIVEN BY
C (RVAL, PVAL, LL)
C
C VERSION 1.00 DATE: 01.22.90
C
C INPUT:
C RVAL RADIAL DISTANCE (RE)
C PVAL HOUR ANGLE MEASURED EASTWARD FROM NOON (RADIAN)
C LATDIM NUMBER OF LATITUDINAL GRID PTS
C LTDIM MAX NUMBER OF LOCAL TIME GRID PTS (INCL WRAPAROUND)
C R RADIAL DISTANCE ARRAY (RE)
C P HOUR ANGLE ARRAY (RADIANS)
C
C OUTPUT:
C BI NON-INTEG I LOCATION OF (RVAL, XLT)
C BJ NON-INTEG J LOCATION OF (RVAL, XLT)
C
C PROGRAMMER: R.W. SPIRO
C
C DIMENSION R(LATDIM, LTDIM), P(LATDIM, LTDIM)

```

MAP10220
MAP10230
MAP10240
MAP10250
MAP10260
MAP10270
MAP10280
MAP10290
MAP10300
MAP10310
MAP10320
MAP10330
MAP10340
MAP10350
MAP10360
MAP10370
MAP10380
MAP10390
MAP10400
MAP10410
MAP10420
MAP10430
MAP10440
MAP10450
MAP10460
MAP10470
MAP10480
MAP10490
MAP10500
MAP10510
MAP10520
MAP10530
MAP10540
MAP10550
MAP10560
MAP10570
MAP10580
MAP10590
MAP10600
MAP10610
MAP10620
MAP10630
MAP10640
MAP10650
MAP10660
MAP10670
MAP10680
MAP10690
MAP10700
MAP10710
MAP10720
MAP10730
MAP10740
MAP10750
MAP10760
MAP10770
MAP10780
MAP10790
MAP10800
MAP10810
MAP10820
MAP10830
MAP10840
MAP10850

```
PI=ATAN2(0.,-1.)
C
C
C
C
C
C
C
C SEARCH GRID AND TRY TO LOCALIZE (RVAL,PVAL) WITHIN A GRID SQUARE
  DO 30 J=2,LTDIM-2
    JJ=J
C
    DO 40 I=2,LATDIM
      II=I
C
C GET PVAL,P(I,J), AND P(I,J+1) IN SAME MODULUS
  CALL PFIX(PVAL,P(I,J),P(I,J+1),P4,P5)
  WRITE(6,*) I,J,RVAL,R(I-1,J,LL),R(I,J,LL),PVAL,P4,P5
C
C      IF (RVAL.LE.R(I-1,J)
1         .AND.
2         RVAL.GT.R(I,J)
3         .AND.
4         PVAL.GE.P4
5         .AND.
6         PVAL.LT.P5)
7         THEN
8         GO TO 50
        END IF
C
40 CONTINUE
30 CONTINUE
C
  WRITE(6,*) 'STOPPING IN LOCATE'
  WRITE(6,*) 'UNABLE TO FIND (BI,BJ)'
  WRITE(6,*) 'RVAL= ',RVAL,' PVAL= ',PVAL
  STOP
C
C
50 CONTINUE
C
  DO 45 IK=2,LATDIM
    IIK=IK
    IF (RVAL.LE.R(IK-1,J+1).AND.RVAL.GT.R(IK,J+1)) GO TO 60
45 CONTINUE
C
  WRITE(6,*) 'STOPPING IN EFLOC'
  WRITE(6,*) 'UNABLE TO FIND (BI,BJ)'
  WRITE(6,*) 'RVAL= ',RVAL,' PVAL= ',PVAL
  STOP
C
60 CONTINUE
C
C
C COMPUTE COEFFICIENTS FOR INTERPOLATION
  F1=(RVAL-R(II-1,JJ))/(R(II,JJ)-R(II-1,JJ))+FLOAT(II-1)
  F2=(RVAL-R(IIK-1,JJ+1))/(R(IIK,JJ+1)-R(IIK-1,JJ+1))+
  2  FLOAT(IIK-1)
C
  CALL PFIX(XLT,P(II,JJ),P(IIK,JJ+1),P4,P5)
C
  BJ=(PVAL-P4)/(P5-P4)+FLOAT(JJ)
C
  IF (BJ.LT.1.) BJ=BJ+FLOAT(LTDIM-3)
```

```
MAP10860
MAP10870
MAP10880
MAP10890
MAP10900
MAP10910
MAP10920
MAP10930
MAP10940
MAP10950
MAP10960
MAP10970
MAP10980
MAP10990
MAP11000
MAP11010
MAP11020
MAP11030
MAP11040
MAP11050
MAP11060
MAP11070
MAP11080
MAP11090
MAP11100
MAP11110
MAP11120
MAP11130
MAP11140
MAP11150
MAP11160
MAP11170
MAP11180
MAP11190
MAP11200
MAP11210
MAP11220
MAP11230
MAP11240
MAP11250
MAP11260
MAP11270
MAP11280
MAP11290
MAP11300
MAP11310
MAP11320
MAP11330
MAP11340
MAP11350
MAP11360
MAP11370
MAP11380
MAP11390
MAP11400
MAP11410
MAP11420
MAP11430
MAP11440
MAP11450
MAP11460
MAP11470
MAP11480
MAP11490
```

90/06/30
12:04:14

19

mapint.for

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C      IF (BJ.GT.FLOAT(LTDIM)) BJ=BJ-FLOAT(LTDIM-3)
C
C      BI=F1+(BJ-FLOAT(JJ))*(F2-F1)/(FLOAT(JJ+1)-FLOAT(JJ))
C
C      RETURN
C      END
C
C      SUBROUTINE PFIX(P1,P2,P3,P4,P5)
C
C      PURPOSE:  SUBROUTINE TO ADJUST MODULUS OF P2 AND P3 TO MATCH P1.
C                ON OUTPUT P4 CORRESPONDS TO P2, P5 TO P3
C
C      VERSION 1.00                      DATE: 09.04.89
C
C      PROGRAMMER: R.W. SPIRO
C
C      PI=ATAN2(0.,-1.)
C
C      P4=P2
C      P5=P3
C
C      IF (ABS(P2-P3).GT.PI) THEN
C        IF (P2.LT.P3) THEN
C          P4=P2+2.*PI
C        ELSE
C          P5=P3+2.*PI
C        END IF
C
C        IF (P1.LT.PI) THEN
C          P4=P4-2.*PI
C          P5=P5-2.*PI
C        END IF
C
C      END IF
C
C      RETURN
C      END
C      FUNCTION G3NTRP(A,IMAX,JMAX,KMAX,BI,BJ,BK)
C
C      VERSION 1.00                      DATE: 01.11.88
C      1.01A                            02.02.89
C
C      PURPOSE:  FUNCTION SUBPROGRAM TO PERFORM A GENERAL 3-D LINEAR
C                INTERPOLATION OF ARRAY A(I,J,K) AT PT(BV(1),BV(2),BV(3))
C
C      INPUT:
C      A          3-D ARRAY TO BE INTERPOLATED
C                INTERPOLATE A
C
C      COMMON /LUNIT/LUERR,LUPPT,LUCORD,LUPRNT,LUIDAT,LUHDYE,
C 1      LSPARE,LUETAB,LUEBEG,LUPLEC,LUPION,LUEAVG,LUFLSM,LUETA,
C 2      LUEFLX,LUEFLD,LUBFLD,LUBMIN,LUXMIN,LUYMIN,LUZMIN,LUALOC,
C 3      LUCOLT,LUBNDL,LUPDAT,LUVN,LUVS,LIONEG,LIONNO,LUENCH
C      DIMENSION A(IMAX,JMAX,KMAX)
C      DIMENSION NDX(3),NDIM(3),BV(3),COEF(3,2)
C
C      PREPARE INDICES FOR INTERPOLATION
```

MAP11500
MAP11510
MAP11520
MAP11530
MAP11540
MAP11550
MAP11560
MAP11570
MAP11580
MAP11590
MAP11600
MAP11610
MAP11620
MAP11630
MAP11640
MAP11650
MAP11660
MAP11670
MAP11680
MAP11690
MAP11700
MAP11710
MAP11720
MAP11730
MAP11740
MAP11750
MAP11760
MAP11770
MAP11780
MAP11790
MAP11800
MAP11810
MAP11820
MAP11830
MAP11840
MAP11850
MAP11860
MAP11870
MAP11880
MAP11890
MAP11900
MAP11910
MAP11920
MAP11930
MAP11940
MAP11950
MAP11960
MAP11970
MAP11980
MAP11990
MAP12000
MAP12010
MAP12020
MAP12030
MAP12040
MAP12050
MAP12060
MAP12070
MAP12080
MAP12090
MAP12100
MAP12110
MAP12120
MAP12130

```
C
NDIM(1)=IMAX
NDIM(2)=JMAX
NDIM(3)=KMAX
BV(1)=BI
BV(2)=BJ
BV(3)=BK
DO 10 L=1,3
  NDX(L)=BV(L)
  IF (NDX(L).LT.1) NDX(L)=1
  IF (NDX(L).GT.NDIM(L)-1) NDX(L)=NDIM(L)-1
  IF (NDX(L).LE.0) NDX(L)=1
C
  FNDX=REAL(NDX(L))
  COEF(L,1)=1.-BV(L)+FNDX
  COEF(L,2)=BV(L)-FNDX
10 CONTINUE
C
C
G3NTRP=0.
KSTOP = MIN(KMAX,2)
JSTOP = MIN(JMAX,2)
DO 20 I=1,2
DO 20 J=1,JSTOP
DO 20 K=1,KSTOP
  G3NTRP=G3NTRP+
1      COEF(1,I)*COEF(2,J)*COEF(3,K)*A(NDX(1)+I-1,NDX(2)+J-1,
2      NDX(3)+K-1)
20 CONTINUE
RETURN
END
C
C
SUBROUTINE READ3D(LUN,FILNAM,LREC,IDIM,JDIM,KDIM,ITMDIM,ID,RID,
2      CHID,ARRAY)
C
PROGRAMMER: BOB SPIRO          DATE: 6/26/88
C
PURPOSE:  THIS SUBROUTINE READS A LOGICAL RECORD FROM THE
STANDARD MAGNETOSPHERIC SPECIFICATIONS MODEL FILE FORMAT.
C
CHARACTER CHID*80, FILNAM*6
C
  DIMENSION ARRAY(IDIM,JDIM,KDIM)
  DIMENSION ID(20),RID(20)
C
OPEN THE FILE
C
  IRECL = IDIM*JDIM + 2*80
  OPEN (UNIT=LUN,ACCESS='DIRECT',RECL=IRECL,STATUS='OLD')
C
  READ THE ARRAY
C
DO 10, K=1, KDIM
C
  CALCULATE THE RECORD NUMBER
C
  IREC = (LREC-1)*KDIM + K
  READ (LUN,REC=IREC) ID,RID,CHID,
2      ((ARRAY(I,J,K),I=1,IDIM),J=1,JDIM)
10 CONTINUE
C
CLOSE(LUN)
```

```
MAP12140
MAP12150
MAP12160
MAP12170
MAP12180
MAP12190
MAP12200
MAP12210
MAP12220
MAP12230
MAP12240
MAP12250
MAP12260
MAP12270
MAP12280
MAP12290
MAP12300
MAP12310
MAP12320
MAP12330
MAP12340
MAP12350
MAP12360
MAP12370
MAP12380
MAP12390
MAP12400
MAP12410
MAP12420
MAP12430
MAP12440
MAP12450
MAP12460
MAP12700
MAP12710
MAP12720
MAP12730
MAP12740
MAP12750
MAP12760
MAP12770
MAP12780
MAP12790
MAP12800
MAP12810
MAP12820
MAP12830
MAP12840
MAP12850
MAP12860
MAP12880
MAP12890
MAP12900
MAP12910
MAP12920
MAP12930
MAP12940
MAP12950
MAP12960
MAP12970
MAP12980
MAP12990
MAP13000
```

```

C          RETURN
C
C          END
C
C ***** FNDBRK *****
C          SUBROUTINE FNDBRK (PARVAL, PVALS, IPDIM, MIN, MAX)
C
C          THIS SUBROUTINE FINDS THE INDICES OF THE VALUES IN ARRAY
C          PVALS THAT BRACKET PARVAL.
C
C          BRYAN BALES          9/12/89
C
C          DIMENSION PVALS (IPDIM)
C
C          MIN = 0
C
C          10 CONTINUE
C             MIN = MIN + 1
C             MAX = MIN + 1
C          IF (PARVAL.LE.PVALS (MIN)) THEN
C             MAX = MIN
C          ELSEIF (PARVAL.GT.PVALS (MAX) .AND. MAX.EQ.IPDIM) THEN
C             MIN = MAX
C          IF (PARVAL.GT.PVALS (MAX) .AND. MAX.LT.IPDIM) THEN
C             GO TO 10
C          ENDIF
C
C          RETURN
C          END
C
C          LOGICAL FUNCTION MEXIST (MSTND, MTILT, MINED, MDST, MSTCH)
C
C          THIS FUNCTION CHECKS TO SEE IF A PARTICULAR B-FIELD IS
C          AVAILABLE.
C
C          CHARACTER*32 FILNAM
C          LOGICAL TEST
C
C          WRITE (FILNAM, 1000) MTILT, MSTND, MDST, MINED, (3-MSTCH)
1000  FORMAT (' BFIELD:BO', I1, I1, I1, I2.2, I1, ' .DAT' )
C
C          INQUIRE (FILE=FILNAM, EXIST=TEST)
C          MEXIST = TEST
C
C          RETURN
C          END
C
C          SUBROUTINE RDVEC (NOUNIT, IRDIN, IEMAX, IEDIM, ALAM, THRSH, ERSHFT, IFLAV)
C
C          THIS SUBROUTINE READS THE HEADER VECTOR FOR THE ETA FILES. THE
C          HEADER CONTAINS THE ALAM, THRESHOLD ENERGY, AND ERROR INFORMATION
C          FOR THIS RUN.
C
C          DIMENSION ALAM (IEDIM), THRSH (IEDIM), ERSHFT (IEDIM), IFLAV (IEDIM)
C
C          OPEN THE FILE
C
C          IRECL = 4*iedim + 1
C          OPEN (UNIT=NOUNIT, ACCESS='DIRECT', RECL=IRECL, STATUS='OLD')
C
C          READ VALUES
C          READ (NOUNIT, REC=IRDIN) IEMAX, ALAM, THRSH, ERSHFT, IFLAV

```

```

MAP13010
MAP13020
MAP13030
MAP13040
MAP13050
MAP13060
MAP13070
MAP13080
MAP13090
MAP13100
MAP13110
MAP13120
MAP13130
MAP13140
MAP13150
MAP13160
MAP13170
MAP13180
MAP13190
MAP13200
MAP13210
MAP13220
MAP13230
MAP13240
MAP13250
MAP13260
MAP13270
MAP13280
MAP13290
MAP13300
MAP13310
MAP13320
MAP14560
MAP14570
MAP14580
MAP14590
MAP14600
MAP14620
MAP14630

```

```
C
CLOSE (NOUNIT)
RETURN
END
SUBROUTINE SETALM(ALAM, IEMAX, IEDIM, IFLAV, ALMDEL)
C
C THIS SUBROUTINE READS THE NUMBER OF ENERGY CHANNELS AND THEIR
C ENERGIES AT GEOSYNCHRONOUS ORBIT AND CALCULATES THE ENERGY
C INVARIANTS NEEDED TO RUN THE PROGRAM.
C THE INPUT ENERGY IS IN EV AND MUST BE IN ASCENDING ORDER SO THAT THE
C ALMDEL VARIABLES CAN BE CORRECTLY CALCULATED.
C
C
C PARAMETER (VM6=7.0)
C
C DIMENSION ALAM(IEDIM)
C DIMENSION IFLAV(IEDIM)
C DIMENSION ALMDEL(IEDIM)
C DIMENSION NUM(3)
C
C DO 5 N=1, 3
C   NUM(N)=0
C 5 CONTINUE
C
C COMPUTE ALMDEL
C DO 20 IE=1, IEMAX
C   ISP=IFLAV (IE)
C   IF (NUM (ISP) .GE. 2) THEN
C     IF (IE.EQ.1.OR.IFLAV (IE-1) .NE. ISP) THEN
C       ALMMIN=0.
C     ELSE
C       ALMMIN= (ALAM (IE-1) +ALAM (IE)) /2.
C     END IF
C
C   IF (IE.EQ.IEMAX.OR.IFLAV (IE+1) .NE. ISP) THEN
C     ALMMAX=1.5*ALAM (IE) -.5*ALAM (IE-1)
C   ELSE
C     ALMMAX= (ALAM (IE) +ALAM (IE+1)) /2.
C   END IF
C
C   ALMDEL (IE) =ABS (ALMMAX) -ABS (ALMMIN)
C
C   END IF
C 20 CONTINUE
C
C RETURN
C END
SUBROUTINE BFIELD (ISWIT, X, Y, Z, STAND, TILT, HJNEAR, XNEAR, HJFRAC, DY,
1 D, COLLAP, DELXC, DYC, BRN, BRP, RN, RP, RADIUS,
2 BXTOT, BYTOT, BZTOT)
C
C
C PURPOSE- CALLS ALL OF THE MAGNETIC FIELD MODEL ROUTINES FOR A
C GIVEN POINT AND SUMS UP THE MAGNETIC FIELD VECTORS (NO
C CURRENT) CONTRIBUTIONS. THE THREE ROUTINES ARE BVOIGT,
C TAILC, AND RINGC, REPRESENTING A SHIELDED VACUUM DIPOLE,
C A TAIL CURRENT SYSTEM, AND A RING CURRENT SYSTEM, RESP.
C MUST CALL TWICE, BEGINNING WITH ISWIT=0, TO CALCULATE
C AND COLLECT CONSTANTS. THE THIRD AND HIGHER CALLS GIVE
C RESULTS FOR SINGLE POINTS X,Y,Z IN GSM COORDINATES.
C THE COUNTER ISWIT IS ADJUSTED INTERNALLY SO IT NEED ONLY
C BE SPECIFIED (=0) FOR THE FIRST CALL.
C INPUT- ISWIT: A COUNTER, VERY FIRST CALL MUST HAVE ISWIT=0
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MAP14650
MAP14660
MAP14670
MAP14680
MAP14690
MAP14700
MAP14710
MAP14720
MAP14730
MAP14740
MAP14750
MAP14760
MAP14770
MAP14780
MAP14790
MAP14800
MAP14810
MAP14820
MAP14830
MAP14840
MAP14850
MAP14860
MAP14870
MAP14880
MAP14890
MAP14900
MAP14910
MAP14920
MAP14930
MAP14940
MAP14950
MAP14960
MAP14970
MAP14980
MAP14990
MAP15000
MAP15010
MAP15020
MAP15030
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MAP15080
MAP15090
MAP15100
MAP15110
MAP15120
MAP15130
MAP15140
MAP15150
MAP15160
MAP15170
MAP15180
MAP15190
MAP15200
MAP15210
MAP15220
MAP15230
MAP15240
MAP15250
MAP15260
MAP15270
MAP15280
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mapint.for

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C      X,Y,Z: GSM COORDINATES IN EARTH RADII          MAP15290
C      STAND: STAND-OFF DISTANCE IN RE                MAP15300
C      TILT: DIPOLE TILT ANGLE IN DEGREES            MAP15310
C                                                    MAP15320
C      OUTPUT- BXTOT,BYTOT,BZTOT: MAGNETIC FIELD COMPONENTS IN GAMMA MAP15330
C      HJXS,HJYS,HJZS: CURRENT DENSITY COMPONENTS (AMPS/M**2) MAP15340
C      THE INPUT VARIABLES FOR SUBROUT. BVOIGT,TAILC, AND MAP15350
C      RINGC ARE EXPLAINED IN EACH RESPECTIVE SUBROUT. MAP15360
C                                                    MAP15370
C      VARIABLES--XNST,ZNST: XGSM AND ZGSM POSITIONS OF THE CURRENT SHEET MAP15380
C      IN THE NOON-MIDNIGHT MERIDIAN. SEGMENT        MAP15390
C      BOUNDAFORM XNST(I),ZNST(I)                   MAP15400
C      BNST: CURRENT STRENGTH AT POINT XNST(I),ZNST(I) ABOVE MAP15410
C      RADIUS: MAGNETOPOUSE RADIUS IN RE            MAP15420
C                                                    MAP15430
C      SUBROUTINES--GETRAD: CALCULATES RADIUS FROM STAND-OFF DISTANCE MAP15440
C      BVOIGT: FINDS VACUUM SHIELDED DIPOLE CONTRIBUTIONS MAP15450
C      ZPOS: CALCULATES COEFFICIENTS FOR PLACEMENT OF TAIL MAP15460
C      CURRENT SHEET                                MAP15470
C      SEGMNT: FINDS XNST,ZNST, AND BNST FOR NSTEP SEGMENTS MAP15480
C      (NOT CALLED IF HJNEAR = 0)                   MAP15490
C      TAILC: FINDS TAIL CURRENT SHEET CONTRIBUTIONS MAP15500
C      (NOT CALLED IF HJNEAR = 0.)                  MAP15510
C      RINGC: FINDS RING CURRENT SYSTEM CONTRIBUTIONS MAP15520
C      (NOT CALLED IF BRN = BRP = 0.)                MAP15530
C      TCOLLP: FINDS COLLAPSING TAIL CURRENT CONTRIBUTIONS MAP15540
C      (NOT CALLED IF COLLAP = 1.)                  MAP15550
C                                                    MAP15560
C      DIMENSION XNST(50),ZNST(50),BNST(50)         MAP15570
C                                                    MAP15580
C      FIRST CALL MUST HAVE ISWIT = 0                MAP15590
C      ISWIT = ISWIT + 1                              MAP15600
C      *** LIMIT MAX VALUE OF ISWIT TO 4 ***         MAP15610
C      IF (ISWIT.GT.3) THEN                           MAP15620
C      ISWIT = 4                                       MAP15630
C      END IF                                          MAP15640
C                                                    MAP15650
C      GET BVOIGT COEFFICIENTS                        MAP15660
C      IF (ISWIT.EQ.1) THEN                           MAP15670
C                                                    MAP15680
C      SET CONSTANTS FOR VACUUM VOIGT SHIELDED DIPOLE MODEL MAP15690
C      NO PENETRATION OF IMF                          MAP15700
C      ALFA = 1.00                                    MAP15710
C      CDIPOL = 0.0                                   MAP15720
C      CIMF = 0.0                                     MAP15730
C      BIMF = 0.0                                     MAP15740
C      BIMF = 0.0                                     MAP15750
C      DIR = 0.0                                      MAP15760
C                                                    MAP15770
C      ZERO QUANTITIES                                MAP15780
C      BXV = 0.                                       MAP15790
C      BYV = 0.                                       MAP15800
C      BZV = 0.                                       MAP15810
C      BXT = 0.                                       MAP15820
C      BYT = 0.                                       MAP15830
C      BZT = 0.                                       MAP15840
C      BXTC = 0.                                       MAP15850
C      BYTC = 0.                                       MAP15860
C      BZTC = 0.                                       MAP15870
C      BXR = 0.                                       MAP15880
C      BYR = 0.                                       MAP15890
C      BZR = 0.                                       MAP15900
C                                                    MAP15910
C      GET RADIUS FROM STAND                          MAP15920

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mapint.for

```

C      CALL GETRAD (STAND,RADIUS)
C      GET COEFFICIENTS FOR BVOIGT
C      CALL BVOIGT (STAND,RADIUS,TILT,ALFA,CDIPOL,CIMF,BIMF,DIR,
1      ISWIT,X,Y,Z,GARB1,GARB2,GARB3)
C      END IF
C
C      SET CONSTANTS IN BVOIGT,SET-UP TAIL CURRENT WITH POSITION
C      IF (ISWIT.EQ.2) THEN
C      CALL BVOIGT (STAND,RADIUS,TILT,ALFA,CDIPOL,CIMF,BIMF,DIR,
1      ISWIT,X,Y,Z,GARB1,GARB2,GARB3)
C      CALCULATE COEFFICIENTS FOR CURRENT SHEET POSITION
C      CALL ZPOS (ISWIT,TILT,X,Z)
C      ADVANCE ISWIT BECAUSE ZPOS CALLED NEXT IN SEGMNT
C      ISWIT = ISWIT + 1
C      CALCULATE SEGMENT BOUNDARIES AND CURRENT STRENGTHS
C      IF (HJNEAR.NE.0.) THEN
C      CALL SEGMNT (ISWIT,TILT,XNEAR,HJNEAR,HJFRAC,NSTEP,
1      XNST,ZNST,BNST)
C      END IF
C      END IF
C
C      GET POINT VALUES
C      IF (ISWIT.EQ.4) THEN
C      CALL BVOIGT (STAND,RADIUS,TILT,ALFA,CDIPOL,CIMF,BIMF,DIR,
1      ISWIT,X,Y,Z,BXV,BYV,BZV)
C      IF (HJNEAR.NE.0.) THEN
C      CALL TAILC (ISWIT,NSTEP,X,Y,Z,RADIUS,DY,D,XNST,ZNST,BNST,
1      BXT,BYT,BZT)
C      IF (COLLAP.NE.1.) THEN
C      CALL TCOLLP (ISWIT,NSTEP,X,Y,Z,RADIUS,DYC,D,XNST,ZNST,
1      BNST,COLLAP,DELXC,BXTC,BYTC,BZTC)
C      END IF
C      END IF
C      IF ((BRN.NE.0.).OR.(BRP.NE.0.)) THEN
C      CALL RINGC (X,Y,Z,TILT,BRN,BRP,RN,RP,BXR,BYR,BZR)
C      END IF
C
C      BXTOT = BXV + BXT + BXTC + BXR
C      BYTOT = BYV + BYT + BYTC + BYR
C      BZTOT = BZV + BZT + BZTC + BZR
C
C      END IF
C
C      RETURN
C      END
C***** GETRAD
C
C      SUBROUTINE GETRAD (STAND,RADIUS)
C
C      PURPOSE- GIVES MAGNETOTAIL RADIUS AS A FUNCTION OF THE STAND-OFF
C      DISTANCE.
C      INPUT- STAND: THE STAND-OFF DISTANCE (RE)
C      OUTPUT- RADIUS: OF THE MAGNETOTAIL (RE)
C      VARIABLES-A0,A1,A2: COEFFICIENTS
C      MAXRAD: UPPER LIMIT RADIUS ALLOWED
C      MINRAD: LOWER LIMIT RADIUS ALLOWED
C      MXSTND: UPPER LIMIT STAND-OFF DISTANCE
C      MNSTND: LOWER LIMIT STAND-OFF DISTANCE
C      NOTE: DERIVED BY MATCHING STAND-OFF DISTANCES 7,11,14 RE WITH
C      RADII 17,20,27 RE RESPECTIVELY
C
C      A0 = 29.1660
C      A1 = -3.3214

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MAP15930
MAP15940
MAP15950
MAP15960
MAP15970
MAP15980
MAP15990
MAP16000
MAP16010
MAP16020
MAP16030
MAP16040
MAP16050
MAP16060
MAP16070
MAP16080
MAP16090
MAP16100
MAP16110
MAP16120
MAP16130
MAP16140
MAP16150
MAP16160
MAP16170
MAP16180
MAP16190
MAP16200
MAP16210
MAP16220
MAP16230
MAP16240
MAP16250
MAP16260
MAP16270
MAP16280
MAP16290
MAP16300
MAP16310
MAP16320
MAP16330
MAP16340
MAP16350
MAP16360
MAP16370
MAP16380
MAP16390
MAP16400
MAP16410
MAP16420
MAP16430
MAP16440
MAP16450
MAP16460
MAP16470
MAP16480
MAP16490
MAP16500
MAP16510
MAP16520
MAP16530
MAP16540
MAP16550
MAP16560

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mapint.for

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A2 = 0.2262
MAXRAD = 27.
MINRAD = 17.
MXSTND = 14.
MNSTND = 7.
C
C
IF (STAND.GT.MXSTND) THEN
  RADIUS = MAXRAD
  STAND = MXSTND
C
ELSE
  IF (STAND.LT.MNSTND) THEN
    RADIUS = MINRAD
    STAND = MNSTND
C
  ELSE
    RADIUS = A0 + A1*STAND + A2*(STAND**2)
  END IF
END IF
C
RETURN
END
C***** TAILC
SUBROUTINE TAILC (ISWIT, NSTEP, XGSM, YGSM, ZGSM, RADIUS, DY, D, XNST, ZNST,
1          BNST, BX, BY, BZ)
C
C
C PURPOSE- CALCULATE THE MAGNETIC FIELD AND CURRENTS DUE TO A
C           CROSSTAIL CURRENT SHEET. MULTIPLE CURRENT SEGMENTS ARE
C           JOINED EDGE TO EDGE. THE CURRENT STRENGTH AND POSITION
C           AS A FUNCTION OF XGSM ARE ARBITRARY AND PROVIDED.
C           A YGSM DEPENDENCE IS ALSO INCLUDED. INSPIRATION FOR
C           THIS MODEL CAN BE FOUND IN
C           TSYGANENKO & USMANOV, PLANETARY AND SPACE SCIENCE,
C           VOL. 30, PP. 985-998, 1982
C
C INPUT-   ISWIT: COUNTER USED IN SUBROUT. ZPOS
C           NSTEP: NUMBER OF CURRENT SEGMENTS COMPRISING THE TAIL
C           XGSM, YGSM, ZGSM: THE GEOCENTRIC SOLAR MAGNETOSPHERIC
C                           COORDINATE (EARTH RADII)
C           NOTE: ALL REFERENCES TO DISTANCE ARE MADE IN EARTH
C           RADII IN THE GSM COORDINATE SYSTEM.
C           RADIUS: (RE) OF MAGNETOTAIL
C           DY: CHAR. WIDTH FOR Y DEPENDENCE OF BX AND BZ
C           D: HALF-WIDTH OF CURRENT FILAMENTS
C           XNST, ZNST: LOCATION OF CURRENT SHEET IN GSM X AND Z
C           BNST: CURRENT STRENGTH AT XNST, ZNST
C OUTPUT-  BX, BY, BZ MAGNETIC FIELD COMPONENTS IN GSM (GAMMAS)
C           HJX, HJY, HJZ CURRENT DENSITY IN GSM (AMPS/METER**2)
C
C VARIABLES- XN, XF: NEAR AND FAR EDGES OF A CURRENT SEGMENT
C            ZN, ZF: NEAR AND FAR ZGSM POSITION OF CURRENT SEGMENT
C            BN, BF: VALUES OF B AT XN AND XF (REALLY CURRENT STRENGTH)
C            DELX: STEP SIZE = (XN-XF)
C            FY: VALUE OF Y-DEPENDENT FUNCTION (SEE SUBROUT. YYY)
C            FYP: FIRST DERIVATIVE OF Y-DEPENDENT FUNCTION ABOVE
C            DELB: =(BN-BF)
C            DD: = DELB/DELX
C            SLOPE: SLOPE OF A SEGMENT =(ZF-ZN)/(XF-XN)
C            RADIUS: RADIUS OF MAGNETOTAIL IN RE
C            FACTJ: FACTOR TO GET CURRENT IN UNITS AMPS/METER**2
C                   = (1/MAGNETIC PERM)*(TESLA/GAMMA)*(RE/METER)
C                   = (1/(4*PI*1E-07))*(1E-09)*(1/(6.370E+06))
C                   = 1.249E-10
C            ALL OTHER VARIABLES ARE PRESENT FOR CONVENIENCE AND HAVE

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MAP16570
MAP16580
MAP16590
MAP16600
MAP16610
MAP16620
MAP16630
MAP16640
MAP16650
MAP16660
MAP16670
MAP16680
MAP16690
MAP16700
MAP16710
MAP16720
MAP16730
MAP16740
MAP16750
MAP16760
MAP16770
MAP16780
MAP16790
MAP16800
MAP16810
MAP16820
MAP16830
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MAP16890
MAP16900
MAP16910
MAP16920
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MAP16940
MAP16950
MAP16960
MAP16970
MAP16980
MAP16990
MAP17000
MAP17010
MAP17020
MAP17030
MAP17040
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MAP17060
MAP17070
MAP17080
MAP17090
MAP17100
MAP17110
MAP17120
MAP17130
MAP17140
MAP17150
MAP17160
MAP17170
MAP17180
MAP17190
MAP17200

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mapint.for

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C          NO PARTICULAR PHYSICAL MEANINGS IN MOST CASES.
C
C          SUBROUT.- YYY: RETURNS VALUE OF YGSM FUNCTIONAL DEPENDENCE AND THEM
C          FIRST DERIVATIVE W.R.T. YGSM AT A GIVEN YGSM
C
C          DIMENSION XNST(50), ZNST(50), BNST(50)
C          FACTJ = 1.249E-10
C
C          BX = 0.
C          BY = 0.
C          BZ = 0.
C
C          CALCULATE CONTRIBUTIONS FROM NSTEP CURRENT SEGMENTS TO B-FIELD
C          DO 10 N = 1, NSTEP
C
C             XN = XNST(N)
C             XF = XNST(N+1)
C             DELX = XN - XF
C             ZN = ZNST(N)
C             ZF = ZNST(N+1)
C             SLOPE = (ZF - ZN) / (XF - XN)
C
C             BN = BNST(N)
C             BF = BNST(N+1)
C             DELB = BN - BF
C
C             DD = DELB/DELX
C             QB = BN - DD*XN
C
C             CONSTANTS INVOLVED IN INTEGRATION: A,B,C ARE COMMON TO BOTH
C             THE BX AND BZ EXPRESSIONS, BY = 0
C
C             A = 1. + SLOPE**2
C             B = -2.*(XGSM + SLOPE*(ZGSM - ZN + SLOPE*XN))
C             C = XGSM**2 + (ZGSM - ZN + SLOPE*XN)**2 + D**2
C             BDX = -2.
C             BDZ = -2.*SLOPE
C             CDX = 2.*XGSM
C             CDZ = 2.*(ZGSM - ZN + SLOPE*XN)
C
C             TEST FOR PROPER INTEGRAL FORM, ONLY THE FORM FOR ABC > 0 HAVE
C             BEEN INCLUDED. NO EXCEPTIONS FOUND TO DATE
C
C             ABC = 4.*A*C - B**2
C             SABC = SQRT(ABC)
C             IF (ABC.LE.0.) THEN
C                 GOTO 15
C             END IF
C
C             SOME CONSTANTS FOR BX EXPRESSION
C
C             CMX = -SLOPE*DD
C             CNX = -SLOPE*QB + DD*(SLOPE*XN + ZGSM - ZN)
C             CPX = (SLOPE*XN + ZGSM - ZN)*QB
C
C             SOME CONSTANTS FOR BZ EXPRESSION
C
C             CMZ = DD
C             CNZ = BN - DD*(XN + XGSM)
C             CPZ = -XGSM*QB
C
C             SOME COMMON FACTORS FOR BOTH BX AND BZ

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MAP17210
MAP17220
MAP17230
MAP17240
MAP17250
MAP17260
MAP17270
MAP17280
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MAP17300
MAP17310
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MAP17340
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MAP17670
MAP17680
MAP17690
MAP17700
MAP17710
MAP17720
MAP17730
MAP17740
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MAP17760
MAP17770
MAP17780
MAP17790
MAP17800
MAP17810
MAP17820
MAP17830
MAP17840

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mapint.for

```

WLN = LOG((A*XN**2+B*XN+C)/(A*XF**2+B*XF+C))
WATAN = ATAN((2*A*XN+B)/SABC) - ATAN((2*A*XF+B)/SABC)
C
C   THE BX FUNCTION
C
CLNX = (A*CNX - B*CMX)/(2.*(A**2))
CTANX = (2.*A*(A*CPX-C*CMX) - B*(A*CNX-B*CMX))/((A**2)*SABC)
BX = BX + (CMX*DELX)/A + CLNX*WLN + CTANX*WATAN
C
C   THE BZ FUNCTION
C
CLNZ = (A*CNZ - B*CMZ)/(2.*(A**2))
CTANZ = (2.*A*(A*CPZ-C*CMZ) - B*(A*CNZ-B*CMZ))/((A**2)*SABC)
BZ = BZ + (CMZ*DELX)/A + CLNZ*WLN + CTANZ*WATAN
C
10  CONTINUE
C
C   GET YGSM DEPENDENCE AND FIRST DERIVATIVE
CALL YYY(YGSM,DY,RADIUS,FY,FYP)
C
C   NOW INCLUDE THE YGSM DEPENDENCE IN B-FIELD AND CURRENT
BX = BX*FY
BY = 0.
BZ = BZ*FY
GOTO 20
C
15  CONTINUE
WRITE(6,99)
99  FORMAT(1H1,'WRONG EQUATION USED, OUTPUT SET TO ZERO')
BX = 0.
BY = 0.
BZ = 0.
C
20  CONTINUE
RETURN
END
C
C***** HJSIZE
C
FUNCTION HJSIZE(X,XNEAR,HJNEAR,HJFRAC)
C
C   PURPOSE- CALCULATE RELATIVE CURRENT STRENGTH ALONG MIDNIGHT
C             MERIDIAN AT A GIVEN XGSM POSITION. FUNCTION IS ARBITRARY
C   INPUT-   X: XGSM POSITION
C             XNEAR: TAIL CURRENT INNER EDGE DISTANCE (NEG. TAILWARD)
C             HJNEAR: HJSIZE AT XNEAR
C             HJFRAC: FRACTION OF HJNEAR FOUND AT -100 RE
C   OUTPUT-  HJSIZE: STRENGTH OF CROSSTAIL CURRENT
C   VARIABLES-BFLAT: X POSITION WHERE HJSIZE LEVELS OFF TO CONSTANT REM
C             NOTE: BFLAT IS SET AT -100. RE, AN AD HOC VALUE
C             EXPON: EXPONENTIAL DECREASE OF CURRENT DENSITY
C
BFLAT = -100.
EXPON = LOG(HJFRAC)/(BFLAT - XNEAR)
IF (X.GT.XNEAR) THEN
  HJSIZE = 0.
  GOTO 10
END IF
C
IF (X.GT.(BFLAT)) THEN
  HJSIZE = HJNEAR*EXP(EXPON*(X - XNEAR))
ELSE
  HJSIZE = HJNEAR*HJFRAC
END IF

```

MAP17850
MAP17860
MAP17870
MAP17880
MAP17890
MAP17900
MAP17910
MAP17920
MAP17930
MAP17940
MAP17950
MAP17960
MAP17970
MAP17980
MAP17990
MAP18000
MAP18010
MAP18020
MAP18030
MAP18040
MAP18050
MAP18060
MAP18070
MAP18080
MAP18090
MAP18100
MAP18110
MAP18120
MAP18130
MAP18140
MAP18150
MAP18160
MAP18170
MAP18180
MAP18190
MAP18200
MAP18210
MAP18220
MAP18230
MAP18240
MAP18250
MAP18260
MAP18270
MAP18280
MAP18290
MAP18300
MAP18310
MAP18320
MAP18330
MAP18340
MAP18350
MAP18360
MAP18370
MAP18380
MAP18390
MAP18400
MAP18410
MAP18420
MAP18430
MAP18440
MAP18450
MAP18460
MAP18470
MAP18480

```

C
10 CONTINUE
RETURN
END
C
C***** ZPOS
C
SUBROUTINE ZPOS (ISWIT, TILT, XGSM, ZGSM)
C
C PURPOSE- CALCULATE ZGSM POSITION OF CURRENT SHEET IN
C MIDNIGHT MERIDIAN
C INPUT- TILT: DIPOLE TILT ANGLE
C ISWIT: COUNTER SO COEFFICIENTS ONLY CALCULATED ONCE
C XGSM: COORDINATE OF INTEREST
C OUTPUT- ZGSM: CURRENT SHEET ELEVATION W.R.T. THE XGSM AXIS
C VARIABLES- C1: XGSM WHERE CURVE LEVELS OFF, ZERO SLOPE
C C2: XGSM WHERE CURVE LEAVES XSM AXIS
C C3: ZGSM AT XGSM=C2
C C4: ZGSM AT XGSM>=C1
C C5: SLOPE OF XSM AXIS IN GSM FRAME AT C2
C RTILT: DIPOLE TILT IN RADIANS
C HINGE: CURRENT SHEET HINGE POSITION, SET = 9. RE
C AFTER GOSLING, JGR, 7093, 1986
C A0,A1,A2,A3: COEFFICIENTS OF POLYNOMIAL FIT
C Z = A0 + A1*X + A2*X**2 + A3*X**3
C
IF (ISWIT.LE.2) THEN
C CALCULATE COEFFICIENTS
HINGE = 9.
DEG = ACOS(-1.00)/180.
RTILT = DEG*TILT
C
C1 = 4. - HINGE*(1. + COS(RTILT))
C2 = -4.*COS(RTILT)
C3 = 4.*SIN(RTILT)
C4 = HINGE*SIN(RTILT)
C5 = -TAN(RTILT)
C
C Q1 = 3.*(C1**2)*C2 - C2**3
C Q2 = -2.*C1*C2 + C2**2
C Q3 = C2 - C1
C Q4 = C2**2 - C1**2
C
C A3 = (2.*(C4-C3)+C5*Q3)/(3.*Q3*Q4+2.*(Q1-2.*(C1**3)))
C A2 = (C5 - 3.*A3*Q4)/(2.*Q3)
C A1 = -2.*A2*C1 - 3.*A3*(C1**2)
C A0 = C3 - A2*Q2 + A3*Q1
END IF
C
C INSIDE CURVE LIMIT USE XSM AXIS
C IF (XGSM.GT.C2) THEN
C ZGSM = XGSM*C5
C END IF
C
C BETWEEN XGSM C2 AND C1, FITTED CURVE IS USED
C IF ((XGSM.LE.C2).AND.(XGSM.GE.C1)) THEN
C ZGSM = A0 + A1*XGSM + A2*(XGSM**2) + A3*(XGSM**3)
C END IF
C
C OUTSIDE CURVE LIMIT USE LINE PARALLEL TO XGSM AXIS
C IF (XGSM.LT.C1) THEN
C ZGSM = C4
C END IF
C

```

MAP18490
MAP18500
MAP18510
MAP18520
MAP18530
MAP18540
MAP18550
MAP18560
MAP18570
MAP18580
MAP18590
MAP18600
MAP18610
MAP18620
MAP18630
MAP18640
MAP18650
MAP18660
MAP18670
MAP18680
MAP18690
MAP18700
MAP18710
MAP18720
MAP18730
MAP18740
MAP18750
MAP18760
MAP18770
MAP18780
MAP18790
MAP18800
MAP18810
MAP18820
MAP18830
MAP18840
MAP18850
MAP18860
MAP18870
MAP18880
MAP18890
MAP18900
MAP18910
MAP18920
MAP18930
MAP18940
MAP18950
MAP18960
MAP18970
MAP18980
MAP18990
MAP19000
MAP19010
MAP19020
MAP19030
MAP19040
MAP19050
MAP19060
MAP19070
MAP19080
MAP19090
MAP19100
MAP19110
MAP19120

```

RETURN
END
C
C***** YYY
SUBROUTINE YYY(Y,DY,RAD,FY,FYP)
C
C PURPOSE- CALCULATE YGSM DEPENDENCE AND FIRST DERIVATIVE
C           FY = 0 AT Y = RADIUS
C INPUT-   Y: YGSM POSITION (EARTH RADII)
C           RAD: RADIUS OF MAGNETOTAIL
C           DY: CHARACTERISTIC WIDTH OF Y DEPENDENCE
C OUTPUT-  FY: FUNCTIONAL VALUE OF YGSM DEPENDENCE AT Y
C           FYP: FIRST DERIVATIVE OF FY W.R.T Y
C
C YEXP = -(Y/DY)**2
C IF (YEXP.LT.(-40.)) THEN
C   FY = 0.
C   FYP = 0.
C   GOTO 10
C END IF
C
C PI = ACOS(-1.00)
C CY = COS(PI*Y/(2.*RAD))
C SY = SIN(PI*Y/(2.*RAD))
C
C FY = CY*EXP(-(Y/DY)**2)
C FYP = (-2.*Y*CY/(DY**2) - PI*SY/(2.*RAD))*EXP(-(Y/DY)**2)
10 CONTINUE
C
C RETURN
C END
C***** RINGC
C
C SUBROUTINE RINGC(XGSM,YGSM,ZGSM,TILT,BRN,BRP,RN,RP,
1 BXGSM,BYGSM,BZGSM)
C
C PURPOSE- CALCULATE MAGNETIC FIELD AND CURRENT COMPONENTS OF RING
C           CURRENT TILTED WITH THE DIPOLE
C INPUT-   XGSM,YGSM,ZGSM: GSM COORDINATES IN RE
C           TILT: TILT IN DEGREES OF CENTRAL AXIS OF RINGS, ALIGNED
C                   WITH DIPOLE AXIS. POSITIVE FOR N. HEMISPHERE SUMM.
C           BRN: NEGATIVE BZ CONTRIBUTION FOR ZERO TILT AT (0,0,0)
C                   FROM THE WESTWARD CURRENT
C           BRP: POSITIVE BZ CONTRIBUTION FROM EASTWARD CURRENT
C           RN: CHARACTERISTIC RADIUS (IN RE) OF WESTWARD RING
C           RP: CHARACTERISTIC RADIUS (IN RE) OF EASTWARD RING
C           BXGSM,BYGSM,BZGSM: MAGNETIC FIELD COMPONENTS OF RING
C                   IN GAMMAS
C OUTPUT-  FACTJ: CONSTANT USED TO ADJUST UNITS OF CURRENT, SEE
C VARIABLES-BR: SUBROUT. TAILC FOR DERIVATION
C           RHO,PHI,Z: CYLINDRICAL COORDINATE SYSTEM
C SUBROUTINES- TRANS6: CHANGES GSM CARTESIAN TO SM CYLINDRICAL
C                   VTRAN6: CHANGES SM CYLINDRICAL VECTORS TO GSM SYSTEM
C
C           FACTOR TO MAKE CURRENT OUTPUT IN AMPS/M**2
C FACTJ = 1.249E-10
C PI = ACOS(-1.00)
C
C CHANGE GSM TO SM CYLINDRICAL COORDINATES
C CALL TRANS6(TILT,XGSM,YGSM,ZGSM,RHO,PHI,Z)
C
C SCALE FACTOR (PUT Z AND RHO INTO UNITS OF CHAR. RADII)

```

MAP19130
MAP19140
MAP19150
MAP19160
MAP19170
MAP19180
MAP19190
MAP19200
MAP19210
MAP19220
MAP19230
MAP19240
MAP19250
MAP19260
MAP19270
MAP19280
MAP19290
MAP19300
MAP19310
MAP19320
MAP19330
MAP19340
MAP19350
MAP19360
MAP19370
MAP19380
MAP19390
MAP19400
MAP19410
MAP19420
MAP19430
MAP19440
MAP19450
MAP19460
MAP19470
MAP19480
MAP19490
MAP19500
MAP19510
MAP19520
MAP19530
MAP19540
MAP19550
MAP19560
MAP19570
MAP19580
MAP19590
MAP19600
MAP19610
MAP19620
MAP19630
MAP19640
MAP19650
MAP19660
MAP19670
MAP19680
MAP19690
MAP19700
MAP19710
MAP19720
MAP19730
MAP19740
MAP19750
MAP19760

mapint.for

ZN = Z/RN
RHON = RHO/RN
ZP = Z/RP
RHOP = RHO/RP

C
C

COMMON FACTORS
AN = RHON**2 + ZN**2 + 4.
BN = 2.*(ZN**2) - (RHON**2) + 8.
AP = RHOP**2 + ZP**2 + 4.
BP = 2.*(ZP**2) - (RHOP**2) + 8.

C
C

CYLINDRICAL BFIELD
BRHO = 12.*BRN*RHON*ZN/SQRT(AN**5) + 12.*BRP*RHOP*ZP/SQRT(AP**5)
BPHI = 0.
BZ = 4.*BRN*BN/SQRT(AN**5) + 4.*BRP*BP/SQRT(AP**5)

C
C

CHANGE VECTOR QUANTITIES BACK TO GSM COORDINATES
CALL VTRAN6 (BRHO, BPHI, BZ, PHI, TILT, BXGSM, BYGSM, BZGSM)

C

RETURN
END

C
C

C***** TRANS6

SUBROUTINE TRANS6 (TILT, XGSM, YGSM, ZGSM, RHO, PHI, Z)

C
C
C
C
C
C
C
C

PURPOSE- CHANGE GSM CARTESIAN TO SM CYLINDRICAL COORDINATES
INPUT- TILT: DIPOLE TILT IN DEGREES
XGSM, YGSM, ZGSM: GSM COORDINATES
OUTPUT- RHO, PHI, Z: CYLINDRICAL COORDINATES OF SM SYSTEM
UNITS (RE, RADIANS, RE)
VARIABLES-RTILT: TILT ANGLE IN RADIANS

PI = ACOS(-1.00)
RTILT = TILT*(PI/180.)

C
C

CHANGE GSM TO SM COORDINATES
XSM = XGSM*COS(RTILT) - ZGSM*SIN(RTILT)
YSM = YGSM
ZSM = XGSM*SIN(RTILT) + ZGSM*COS(RTILT)

C

RHO = SQRT(XSM**2 + YSM**2)
IF (RHO.EQ.0.) THEN
RHO = 0.000001
END IF
PHI = ACOS(XSM/RHO)
IF (YSM.LT.0.) THEN
PHI = PHI + 2.*(PI - PHI)
END IF
Z = ZSM

C

RETURN
END

C

C***** VTRAN6

C

SUBROUTINE VTRAN6 (VRHO, VPHI, VZ, PHI, TILT, VXGSM, VYGSM, VZGSM)

C
C
C
C
C
C
C

PURPOSE- CHANGE VECTOR QUANTITIES OF SM CYLINDRICAL TO
VECTORS OF GSM COORDINATES
INPUT- VRHO, VPHI, VZ: RHO, PHI, Z VECTORS
PHI: ANGLE PHI IN RADIANS
TILT: DIPOLE TILT ANGLE IN DEGREES
OUTPUT- VXGSM, VYGSM, VZGSM: GSM VECTOR COMPONENTS

MAP19770
MAP19780
MAP19790
MAP19800
MAP19810
MAP19820
MAP19830
MAP19840
MAP19850
MAP19860
MAP19870
MAP19880
MAP19890
MAP19900
MAP19910
MAP19920
MAP19930
MAP19940
MAP19950
MAP19960
MAP19970
MAP19980
MAP19990
MAP20000
MAP20010
MAP20020
MAP20030
MAP20040
MAP20050
MAP20060
MAP20070
MAP20080
MAP20090
MAP20100
MAP20110
MAP20120
MAP20130
MAP20140
MAP20150
MAP20160
MAP20170
MAP20180
MAP20190
MAP20200
MAP20210
MAP20220
MAP20230
MAP20240
MAP20250
MAP20260
MAP20270
MAP20280
MAP20290
MAP20300
MAP20310
MAP20320
MAP20330
MAP20340
MAP20350
MAP20360
MAP20370
MAP20380
MAP20390
MAP20400

mapint.for

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C          VARIABLES-RTILT: DIPOLE TILT ANGLE IN RADIANS          MAP20410
C                                                                MAP20420
C          PI = ACOS(-1.00)                                       MAP20430
C          RTILT = TILT*(PI/180.)                                  MAP20440
C                                                                MAP20450
C          CHANGE CYLINDRICAL TO CARTESIAN (BOTH SM)             MAP20460
C          VXSM = VRHO*COS(PHI) - VPHI*SIN(PHI)                 MAP20470
C          VYSM = VRHO*SIN(PHI) + VPHI*COS(PHI)                 MAP20480
C          VZSM = VZ                                             MAP20490
C                                                                MAP20500
C          CHANGE SM TO GSM                                       MAP20510
C          VXGSM = VXSM*COS(RTILT) + VZSM*SIN(RTILT)            MAP20520
C          VYGSM = VYSM                                          MAP20530
C          VZGSM = -VXSM*SIN(RTILT) + VZSM*COS(RTILT)          MAP20540
C                                                                MAP20550
C          RETURN                                                MAP20560
C          END                                                    MAP20570
C                                                                MAP20580
C                                                                MAP20590
C***** TCOLLP                                                  MAP20600
C          SUBROUTINE TCOLLP (ISWIT,NSTEP,XGSM,YGSM,ZGSM,RADIUS,DYC,D, MAP20610
C          1          XNST,ZNST,BNST, COLLAP, DELXC, BX, BY, BZ)   MAP20620
C                                                                MAP20630
C                                                                MAP20640
C          ***** SPECIAL COLLAPSE OF TAIL SIMUALTION, INTRODUCES LESSER MAP20650
C          CURRENT IN OPPOSITE DIRECTION AT NEAR PART OF TAIL, ADDED TO MAP20660
C          REGULAR CURRENT.                                       MAP20670
C          *****                                               MAP20680
C          PURPOSE- CALCULATE THE MAGNETIC FIELD AND CURRENTS DUE TO A MAP20690
C          CROSSTAIL CURRENT SHEET. MULTIPLE CURRENT SEGMENTS ARE MAP20700
C          JOINED EDGE TO EDGE. THE CURRENT STRENGTH AND POSITION MAP20710
C          AS A FUNCTION OF XGSM ARE ARBITRARY AND PROVIDED.     MAP20720
C          A YGSM DEPENDENCE IS ALSO INCLUDED.                   MAP20730
C                                                                MAP20740
C          INPUT- ISWIT: COUNTER USED IN SUBROUT. ZPOS           MAP20750
C          NSTEP: NUMBER OF CURRENT SEGMENTS IN TAIL             MAP20760
C          XGSM,YGSM,ZGSM: THE GEOCENTRIC SOLAR MAGNETOSPHERIC MAP20770
C          COORDINATE (EARTH RADII)                               MAP20780
C          NOTE: ALL REFERENCES TO DISTANCE ARE MADE IN EARTHMAP20790
C          RADII IN THE GSM COORDINATE SYSTEM.                   MAP20800
C          DYC: CHAR. WIDTH FOR Y DEPENDENCE OF BX AND BZ       MAP20810
C          D: HALF-WIDTH OF CURRENT FILAMENTS                    MAP20820
C          XNST,ZNST: XGSM AND ZGSM POSITION OF CURRENT SHEET    MAP20830
C          BNST: CURRENT STRENGTH AT ANST,ZNST                   MAP20840
C          COLLAP: FRACTION OF AIL FIELD CURRENT LIET AT MIDNIGHT MAP20850
C          = 1. MEANS NO CHANGE, ORIGINAL TAIL ONLY              MAP20860
C          = 0. MEANS COMPLETE COLLAPSE AT INNER EDGE           MAP20870
C          DELXC: LENGTH OF INNER TAIL CURRENT SHEET (IN X) THAT ISMAP20880
C          DISRUPTED                                             MAP20890
C                                                                MAP20900
C          OUTPUT- BX,BY,BZ MAGNETIC FIELD COMPONENTS IN GSM (GAMMAS) MAP20910
C                                                                MAP20920
C          VARIABLES-XN,XF: NEAR AND FAR EDGES OF A CURRENT SEGMENT MAP20930
C          BN,BF: VALUES OF B AT XN AND XF (REALLY CURRENT STRENGTH)MAP20940
C          NSTEP: NUMBER OF CURRENT SEGMENTS IN TAIL WITHIN 100 RE MAP20950
C          DELX: STEP SIZE = (XN-XF)                              MAP20960
C          FY: VALUE OF Y-DEPENDENT FUNCTION (SEE SUBROUT. YYY ) MAP20970
C          FYP: FIRST DERIVATIVE OF Y-DEPENDENT FUNCTION ABOVE  MAP20980
C          DELB: =(BN-BF)                                         MAP20990
C          DD: = DELB/DELX                                         MAP21000
C          SLOPE: SLOPE OF A SEGMENT =(ZF-ZN)/(XF-XN)           MAP21010
C          = 1.249E-10                                            MAP21020
C          ALL OTHER VARIABLES ARE PRESENT FOR CONVENIENCE AND HAVEMAP21030
C          NO PARTICULAR PHYSICAL MEANINGS IN MOST CASES.     MAP21040

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mapint.for

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C      SOME CONSTANTS FOR BZ EXPRESSION
CMZ = DD
CNZ = BN - DD*(XN + XGSM)
CPZ = -XGSM*QB
MAP21690
MAP21700
MAP21710
MAP21720
MAP21730
MAP21740
MAP21750
MAP21760
MAP21770
MAP21780
MAP21790
C      SOME COMMON FACTORS FOR BOTH BX AND BZ
C
C      WLN = LOG((A*XN**2+B*XN+C)/(A*XF**2+B*XF+C))
WLN = LOG((A*XN**2+B*XN+C)/(A*XF**2+B*XF+C))
C      WATAN = ATAN((2*A*XN+B)/SABC) - ATAN((2*A*XF+B)/SABC)
WATAN = ATAN((2*A*XN+B)/SABC) - ATAN((2*A*XF+B)/SABC)
MAP21800
MAP21810
MAP21820
MAP21830
C      THE BX FUNCTION
C
C      CLNX = (A*CNX - B*CMX)/(2.*(A**2))
CLNX = (A*CNX - B*CMX)/(2.*(A**2))
C      CTANX = (2.*A*(A*CPX-C*CMX)-B*(A*CNX-B*CMX))/((A**2)*SABC)
CTANX = (2.*A*(A*CPX-C*CMX)-B*(A*CNX-B*CMX))/((A**2)*SABC)
C      BX = BX + (CMX*DELX)/A + CLNX*WLN + CTANX*WATAN
BX = BX + (CMX*DELX)/A + CLNX*WLN + CTANX*WATAN
MAP21840
MAP21850
MAP21860
MAP21870
MAP21880
MAP21890
C      THE BZ FUNCTION
C
C      CLNZ = (A*CNZ - B*CMZ)/(2.*(A**2))
CLNZ = (A*CNZ - B*CMZ)/(2.*(A**2))
C      CTANZ = (2.*A*(A*CPZ-C*CMZ)-B*(A*CNZ-B*CMZ))/((A**2)*SABC)
CTANZ = (2.*A*(A*CPZ-C*CMZ)-B*(A*CNZ-B*CMZ))/((A**2)*SABC)
C      BZ = BZ + (CMZ*DELX)/A + CLNZ*WLN + CTANZ*WATAN
BZ = BZ + (CMZ*DELX)/A + CLNZ*WLN + CTANZ*WATAN
MAP21900
MAP21910
MAP21920
MAP21930
MAP21940
MAP21950
MAP21960
MAP21970
MAP21980
MAP21990
MAP22000
MAP22010
MAP22020
MAP22030
MAP22040
MAP22050
MAP22060
MAP22070
MAP22080
MAP22090
MAP22100
MAP22110
MAP22120
MAP22130
MAP22140
MAP22150
MAP22160
MAP22170
MAP22180
MAP22190
MAP22200
MAP22210
MAP22220
MAP22230
MAP22240
MAP22250
MAP22260
MAP22270
MAP22280
MAP22290
MAP22300
MAP22310
MAP22320
10 CONTINUE
11 CONTINUE
C
C      USING SAME Y FUNCTION AS TAILC SUBROUT., BUT WITH DIFFERENT
C      DY VALUE (DYC HERE)
C      GET YGSM DEPENDENCE AND FIRST DERIVATIVE
C      CALL YYY(YGSM,DYC,RADIUS,FY,FYP)
C
C      NOW INCLUDE THE YGSM DEPENDENCE IN B-FIELD AND CURRENT
C      BX = BX*FY
C      BY = 0.
C      BZ = BZ*FY
C      GOTO 20
15 CONTINUE
WRITE(6,99)
99 FORMAT(1H1,'WRONG EQUATION USED, OUTPUT SET TO ZERO')
BX = 0.
BY = 0.
BZ = 0.
C
20 CONTINUE
RETURN
END
C***** SEGMENT
SUBROUTINE SEGMENT(ISWIT,TILT,XNEAR,HJNEAR,HJFRAC,NSTEP,XNST,
1 ZNST,BNST)
C
C      PURPOSE- FIND THE GSM X AND Z LOCATIONS OF THE SEGMENT BOUNDARIES
C      USED TO BUILD THE TAIL CURRENT. ALSO ASSIGN A CURRENT
C      STRENGTH FOR EACH POINT. THE INNER EDGE IS ABS(XNEAR)
C      AWAY FROM EARTH.
C
C      INPUT- ISWIT: COUNTER USED IN SUBROUT. ZPOS
C      TILT: DIPOLE TILT IN DEGREES
C      XNEAR: NEGATIVE DISTANCE TAILWARD, LOCATION OF INNER EDGE
C      HJNEAR: CURRENT STRENGTH AT INNER EDGE
C      HJFRAC: FRACTION OF HJNEAR REMAINING IN FAR TAIL
C      OUTPUT- NSTEP: NUMBER OF SEGMENTS USED TO BUILD THE TAIL CURRENT
C      XNST,ZNST: GSM X AND Z LOCATIONS SEGMENT BOUNDARIES
C      BNST: CURRENT STRENGTH AT (XNST,ZNST)
C      VARIABLES-FRAC: FRACTION OF DESIRED SEGMENT LENGTH
C      PI: JUST PI
C      RTILT: TILT ANGLE IN RADIAN

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mapint.for

C	XNGSM,ZNGSM: TEST XGSM AND ZGSM TO FIND INNER EDGE	MAP22330
C	SN: DISTANCE ALONG SHEET PLUS INNER EDGE DISTANCE	MAP22340
C	DELS: DESIRED SEGMENT LENGTH	MAP22350
C	DIST: TEST DISTANCE COMPARED TO DELS OR ABS(XNEAR)	MAP22360
C		MAP22370
C	SUBROUT.- ZPOS: FINDS ZGSM LOCATION OF CURRENT SHEET AT ANY XGSM	MAP22380
C	HJSIZE: FINDS CURRENT STRENGTH AT POINT ALONG SHEET	MAP22390
C		MAP22400
C	DIMENSION XNST(50),ZNST(50),BNST(50)	MAP22410
C		MAP22420
C	NSTEP = 16	MAP22430
C	TAIL IS 350 RE LONG, MADE OF 16 SEGMENTS OF VARYING LENGTHS	MAP22440
C	FRAC = 0.025	MAP22450
C	SET INNER EDGE POINT, ABS(XNEAR) IS DISTANCE FROM EARTH	MAP22460
C	IF (TILT.NE.0.) THEN	MAP22470
C	STEP ALONG XGSM AXIS UNTIL PROPER DISTANCE IS FOUND	MAP22480
C	PI = ACOS(-1.00)	MAP22490
C	RTILT = TILT*PI/180	MAP22500
C	XNGSM = 0.0	MAP22510
2	CONTINUE	MAP22520
C	XNGSM = XNGSM - 0.05	MAP22530
C	CALL ZPOS(ISWIT,TILT,XNGSM,ZNGSM)	MAP22540
C	DIST = SQRT(XNGSM**2 + ZNGSM**2)	MAP22550
C	SEE IF INNER EDGE IS AT PROPER DISTANCE FROM EARTH	MAP22560
C	IF (DIST.GE.ABS(XNEAR)) THEN	MAP22570
C	XNST(1) = XNGSM	MAP22580
C	ZNST(1) = ZNGSM	MAP22590
C	ELSE	MAP22600
C	GOTO 2	MAP22610
C	END IF	MAP22620
C	ELSE	MAP22630
C	TILT = 0	MAP22640
C	XNST(1) = XNEAR	MAP22650
C	ZNST(1) = 0.	MAP22660
C	END IF	MAP22670
C	SN = XNST(1)	MAP22680
C	BNST(1) = HJSIZE(SN,XNST(1),HJNEAR,HJFRAC)	MAP22690
C	GET OTHER SEGMENT BOUNDARY POINTS	MAP22700
C	DO 10 N = 1,NSTEP	MAP22710
C	I = N + 1	MAP22720
C	GET STEP SIZE	MAP22730
C	IF (N.LE.8) THEN	MAP22740
C	DELS = 2.0	MAP22750
C	ELSE	MAP22760
C	IF (N.LE.11) THEN	MAP22770
C	DELS = 5.	MAP22780
C	ELSE	MAP22790
C	IF (N.LE.14) THEN	MAP22800
C	DELS = 10.	MAP22810
C	ELSE	MAP22820
C	IF (N.EQ.15) THEN	MAP22830
C	DELS = 39.	MAP22840
C	END IF	MAP22850
C	END IF	MAP22860
C	END IF	MAP22870
C	END IF	MAP22880
C	IF (N.EQ.NSTEP) THEN	MAP22890
C	DELS = 250.	MAP22900
C	END IF	MAP22910
C		MAP22920
C	SN = SN - DELS	MAP22930
C	BNST(I) = HJSIZE(SN,XNST(1),HJNEAR,HJFRAC)	MAP22940
C	IF (TILT.NE.0.) THEN	MAP22950
C	IF (I.GT.2) THEN	MAP22960

mapint.for

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C      IF (ZNST(I-1).EQ.ZNST(I-2)) THEN
C          NOW IN FLAT PART OF CURRENT SHEET
C          XNST(I) = XNST(I-1) - DELS
C          ZNST(I) = ZNST(I-1)
C          GOTO 9
C      END IF
C      END IF
C      XNST(I) = XNST(I-1)
5      CONTINUE
C      XNST(I) = XNST(I) - FRAC*DELS
C      CALL ZPOS(ISWIT,TILT,XNST(I),ZNST(I))
C      DIST = SQRT((XNST(I)-XNST(I-1))**2+(ZNST(I)-ZNST(I-1))**2)
C      IF (DIST.GE.DELS) THEN
C          THEN NEXT SEGMENT BOUNDARY IS FOUND
C          GOTO 9
C      ELSE
C          ADD ANOTHER PIECE
C          GOTO 5
C      END IF
C      ELSE
C          TILT IS ZERO
C          XNST(I) = SN
C          ZNST(I) = 0.
C      END IF
9      CONTINUE
10     CONTINUE
      RETURN
      END
C *****: BVOIGT
      SUBROUTINE BVOIGT(STAND,RADIUS,TILT,ALFA,CDIPOL,CIMF,BIMF,DIR,
1         ISWIT,X,Y,Z,BX,BY,BZ)
C
C PURPOSE- COMPUTES THREE COMPONENTS OF THE VECTOR MAGNETIC FIELD
C           AT ANY POINT. POINTS OUTSIDE OF THE MAGNETOPAUSE WILL
C           ONLY RETURN NONZERO FIELDS IF INTERCONNECTION IS ALLOWED
C           WITH THE IMF.
C
C INPUT-   STAND, THE SUBSOLAR STAND-OFF DISTANCE (IN EARTH RADII)
C           RADIUS, RADIUS OF THE MAGNETOTAIL (IN EARTH RADII)
C           TILT, DIPOLE TILT ANGLE (IN DEGREES)
C           TILT>0 INDICATES NORTHERN HEMISPHERE SUMMER
C           ALFA, PARAMETER INDICATING PLASMA CONTENT OF TAIL,
C           = 1.0 MEANS VACUUM, = 0.0 MEANS HARRIS SHEET
C           CDIPOL, FRACTION OF DIPOLE FIELD ALLOWED TO PENETRATE
C           OUT THROUGH THE MAGNETOPAUSE
C           CIMF, FRACTION OF THE INTERPLANETARY FIELD ALLOWED TO
C           PENETRATE IN THROUGH THE MAGNETOPAUSE
C           BIMF, MAGNITUDE OF THE INTERPLANETARY MAGNETIC FIELD
C           (IN GAMMA)
C           DIR, DIRECTION OF IMF, 0 DEGREES IS NORTH, 90 DEGREES
C           IS ANTISUNWARD
C           ISWIT, INDICATES THE PROCEDURE TO FOLLOW ON THIS CALL
C           BFIELD IS CALLED THREE TIMES WITH ISWIT = 1,2
C           THEN EITHER 3 OR 4
C           *****ALTERED SO >2 GIVES GSM RESULT 10/11/87
C           = 1 GENERAL COEFFICIENTS ARE FOUND TO REPRESENT
C           THE MAGNETIC FIELD WITH LEGENDRE AND BESSEL
C           SERIES
C           = 2 CONSTANTS SPECIFY THE CONFIGURATION DESIRED
C           ARE CALCULATED AND STORED, I.E. TILT
C           = 3 CALCULATES FIELD COMPONENTS, INPUT AND OUTPUT
C           ARE IN THE SM (SOLAR MAGNETOSPHERIC) SYSTEM
C           = 4 SAME AS 3 BUT GSM COORDINATES ARE USED
C           X,Y,Z CARTESIAN COORDINATE IN EITHER SM OR GSM SYSTEM

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MAP22970
MAP22980
MAP22990
MAP23000
MAP23010
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MAP23570
MAP23580
MAP23590
MAP23600

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mapint.for

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C
C OUTPUT- BX,BY,BZ MAGNETIC FIELD VECTOR IN CARTESIAN SYSTEM MAP23610
C ACCORDING TO CHOICE ISWIT=3 OR 4. (IN GAMMA) MAP23620
C MAP23630
C MAP23640
C MAP23650
C VARIABLES- NDIM NUMBER OF GRID POINTS TO BE USED FOR INTEGRATION MAP23660
C TO OBTAIN SERIES COEFFICIENTS MAP23670
C NELE NUMBER OF ITERATIONS TO BE MADE BETWEEN SPHERICAL MAP23680
C AND CYLINDRICAL COEFFICIENT CALCULATIONS. MAP23690
C BEX DISTANCE BETWEEN SPHERE CENTER AND EARTH MAP23700
C XD,YD,ZD CARTESIAN COORDINATES IN DIPOLE SYSTEM, XD IS MAP23710
C PERPEND. TO DIPOLE MOMENT POINTING ANTISUNWARD MAP23720
C HXD,HYD,HZD MAGNETIC FIELD COMPONENTS IN DIPOLE SYSTEM MAP23730
C XM,YM,ZM EARTH CENTERED CARTESIAN SYSTEM, XM POINTS ANTI- MAP23740
C SUNWARD, PARALLEL TO THE TAIL AXIS (CALLED THE M MAP23750
C SYSTEM) MAP23760
C HXM,HYM,HZM MAGNETIC FIELD COMPONENTS ON M SYSTEM MAP23770
C SNPS,CSPS SIN AND COS OF THE DIPOLE TILT ANGLE MAP23780
C MAP23790
C REFERENCES- MAP23800
C MAP23810
C REF1: VOIGT,G.-H., A MATHEMATICAL MAGNETOSPHERIC MAP23820
C FIELD MODEL WITH INDEPENDENT PHYSICAL PARAMETERS, PLANETARY MAP23830
C AND SPACE SCIENCE, VOL. 29, 1-20,1981 MAP23840
C MAP23850
C REF2: ABRAMOWITZ AND STEGUN,EDS., HANDBOOK OF MAP23860
C MATHEMATICAL FUNCTIONS, U.S. NATIONAL BUREAU OF STANDARDS, MAP23870
C DOVER, NEW YORK, (1965) MAP23880
C MAP23890
C REF3: JAHNKE-EMDE-LOSCH, TABLES OF HIGHER MAP23900
C FUNCTIONS, 6TH EDITION(REVISED), NEW YORK, (1960) MAP23910
C MAP23920
C REF4: VOIGT PH.D. THESIS MAP23930
C MAP23940
C COORDINATE SYSTEMS- MAP23950
C MAP23960
C GSM GEOCENTRIC SOLAR MAGNETOSPHERIC - EARTH CENTERED MAP23970
C MAP23980
C XGSM : FROM EARTH TO SUN MAP23990
C YGSM : PERPENDICULAR TO EARTH'S DIPOLE, POINTING MAP24000
C TOWARDS DUSK MAP24010
C ZGSM : SAME SENSE AS NORTHERN MAGNETIC POLE MAP24020
C DIPOLE CONTAINED WITHIN X-Z PLANE MAP24030
C MAP24040
C SM SOLAR MAGNETIC - EARTH CENTERED MAP24050
C MAP24060
C XSM : TOWARD SUN BUT NOT DIRECTLY UNLESS TILT ZERO MAP24070
C YSM = YGSM MAP24080
C ZSM : PARALLEL TO NORTH MAGNETIC POLE MAP24090
C MAP24100
C M THE M SYSTEM (XM,YM,ZM) - EARTH CENTERED MAP24110
C MAP24120
C XM = -XGSM MAP24130
C YM = -YGSM MAP24140
C ZM = ZGSM MAP24150
C MAP24160
C V THE V SYSTEM (XV,YV,ZV) - SPHERE CENTERED MAP24170
C MAP24180
C XV = ZGSM MAP24190
C YV = YGSM MAP24200
C ZV = -XGSM - B WHERE B = (TAIL RADIUS)-(STAND-OFF) MAP24210
C MAP24220
C D THE D SYSTEM (XD,YD,ZD) - EARTH CENTERED MAP24230
C MAP24240

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C          XD = -XSM          MAP24250
C          YD = -YSM = -YGSM  MAP24260
C          ZD = ZSM          MAP24270
C                                     MAP24280
C          SPHERICAL SYSTEM   (R, THETA, PHI) - SPHERE CENTERED  MAP24290
C                                     MAP24300
C          R : DISTANCE FROM ORIGIN (XV, YV, ZV) = (0, 0, 0)      MAP24310
C          THETA : ANGLE BETWEEN ZV AND VECTOR R                 MAP24320
C          PHI : ANGLE BETWEEN XV AND COMPONENT OF VECTOR R      MAP24330
C                   IN THE XV-YV PLANE                          MAP24340
C                                     MAP24350
C          CYLINDRICAL SYSTEM (RHO, PHI, Z) - SPHERE CENTERED  MAP24360
C                                     MAP24370
C          RHO : RADIAL DISTANCE FROM ZV AXIS                    MAP24380
C          PHI : ANGLE BETWEEN XV-ZV PLANE AND VECTOR RHO      MAP24390
C                   (SAME AS PHI OF SPHERICAL)                 MAP24400
C          Z = ZV                                               MAP24410
C                                     MAP24420
C          COMMON /BLOCK1/ BEX, R, Q, PI, PSI                   MAP24430
C          COMMON /BLOCK3/ H0, ALFB, N                         MAP24440
C          COMMON /BLOCK5/ CSPH, SNPH, QCS, QSN, CSPS, SNPS    MAP24450
C          COMMON /BLOCK6/ CT, ST                             MAP24460
C          COMMON /FIMF/ HIMF, CD, CI, XI                     MAP24470
C                                     MAP24480
C          ALFB = ALFA                                         MAP24490
C                                     MAP24500
C          R = RADIUS                                          MAP24510
C          CD = CDIPOL                                         MAP24520
C          CI = CIMF                                           MAP24530
C          HIMF = BIMF                                         MAP24540
C          XI = DIR                                            MAP24550
C                                     MAP24560
C                                     MAP24570
C          IF (ISWIT.EQ.1) THEN                                MAP24580
C              GET COEFFICIENTS FOR SPHERICAL AND BESSEL HARMONICS  MAP24590
C              BEX = RADIUS - STAND                            MAP24600
C              NDIM = 101                                       MAP24610
C              NELE = 4                                         MAP24620
C              CALL COEFFS (NDIM, NELE)                        MAP24630
C          END IF                                             MAP24640
C                                     MAP24650
C          IF (ISWIT.EQ.2) THEN                                MAP24660
C              SET CONSTANTS, SPECIFY TILT WHICH WAS PRESET IN COEFFS  MAP24670
C              NOTE THAT SIGN OF TILT ANGLE IS BEING SWITCH      MAP24680
C              TI = - TILT                                       MAP24690
C              CALL CONST(TI)                                    MAP24700
C          END IF                                             MAP24710
C                                     MAP24720
C          SM COORDINATE OPTION CUTOFF FOR NOW EVERYTHING IN GSM  MAP24730
C          IF (ISWIT.EQ.3) THEN                                MAP24740
C              GET BFIELD AT POINT USING SM COORDINATE SYSTEM    MAP24750
C              TRANSFORM SM TO DIPOLE SYSTEM, XD IS PERPENDICULAR  MAP24760
C              TO DIPOLE MOMENT POINTING OPPOSITE XSM          MAP24770
C          CCC          XD = - X                                MAP24780
C          CCC          YD = - Y                                MAP24790
C          CCC          ZD = + Z                                MAP24800
C                                     MAP24810
C              TRANSFORM DIPOLE TO M SYSTEM, XM ANTISOLAR      MAP24820
C          CCC          CALL TRANS4 (XD, YD, ZD, XM, YM, ZM)      MAP24830
C                                     MAP24840
C              GET FIELD COMPONENTS AT XM, YM, ZM              MAP24850
C          CCC          CALL BTOTAL (XM, YM, ZM, HXM, HYM, HZM)  MAP24860
C                                     MAP24870
C          CCC          TRANSFORM FIELD COMPONENTS BACK TO DIPOLE SYSTEM  MAP24880
C                                     MAP24890
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mapint.for

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CCC      HXD = HXM*CSPS - HZM*SNPS
CCC      HYD = HYM
CCC      HZD = HXM*SNPS + HZM*CSPS
C
C          OUTPUT IN SM COORDINATES (GAMMAS)
CCC      BX = - HXD
CCC      BY = - HYD
CCC      BZ = + HZD
C
CCC      END IF
C
C          ALL CALLS WITH ISWIT > 2 GIVE POINT RESULT IN GSM COORDINATES
C          IF (ISWIT.GT.2) THEN
C              GET BFIELD AT POINT USING GSM COORDINATE SYSTEM
C              XM = - X
C              YM = - Y
C              ZM = + Z
C
C              GET BFIELD COMPONENTS AT XM, YM, ZM
C              CALL BTOTAL(XM, YM, ZM, HXM, HYM, HZM)
C
C              OUTPUT IN GSM COORDINATES (GAMMAS)
C              BX = - HXM
C              BY = - HYM
C              BZ = + HZM
C
C          END IF
C          RETURN
C          END
C *****:      COEFFS
C          SUBROUTINE COEFFS (NDIM, NELE)
C
C          PURPOSE- CALCULATE COEFFICIENTS
C          INPUT- NDIM, NUMBER OF GRID POINTS FOR NUMERICAL INTEGRATION
C              NELE, NUMBER OF INTERATIONS TO OBTAIN COEFFICIENTS
C
C              FILL COMMON BLOCK SITES WITH BESSEL ROOTS AND VALUES
C          CALL ZERO
C
C          DO 10 KSA = 1, NELE
C              GET COEFFICIENTS OF LEGENDRE POLYNOMIALS
C              CALL SPHRCO (NDIM, KSA)
C              GET COEFFICIENTS OF BESSEL SERIES
C              CALL TAILCO (NDIM)
10      CONTINUE
C
C          RETURN
C          END
C *****:      CONST
C          SUBROUTINE CONST (TI)
C
C          PURPOSE- PROVIDE CONSTANTS (TO COMMON BLOCKS)
C          INPUT- TI, DIPOLE TILT ANGLE IN DEGREES
C              TI>0 INDICATES NORTHERN HEMISPHERE WINTER
C              R, RADIUS OF TAIL (FROM BLOCK 1) IN EARTH RADII
C          OUTPUT- Q, RATIO OF DIPOLE MOMENT/(RADIUS**3) IN GAMMA
C              PSI, DIPOLE TILT ANGLE IN RADIANS
C              PI, RADIAN EQUIVALENT OF 180 DEGREES
C              SNPS AND CSPS, SIN AND COS OF PSI
C          VARIABLES- DM, DIPOLE MOMENT IN GAMMA*(METERS**3)
C              RE, EARTH RADIUS, METERS
C
C          COMMON /BLOCK1/ BEX, R, Q, PI, PSI

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MAP24890
MAP24900
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COMMON /BLOCK5/ CSPH,SNPH,QCS,QSN,CSPS,SNPS
COMMON /BLOCK6/ CT, ST
C
C   PI = ACOS(-1.00)
C
C   DM = 7.951E+24
C   RE = 6.37104E+06
C   ZA = R*RE
C   Q  = DM/(ZA**3)
C
C   PSI = (PI*TI)/180.0
C   CSPPS = COS(PSI)
C   SNPS = SIN(PSI)
C
C   RETURN
C   END
C *****: BTOTAL
C   SUBROUTINE BTOTAL(XM,YM,ZM,HXM,HYM,HZM)
C
C   PURPOSE- GET FIELD COMPONENTS USING PREDETERMINED COEFFICIENTS
C   INPUT-   XM,YM,ZM M COORDINATES
C   OUTPUT-  HXM,HYM,HZM FIELD COMPONENTS IN M SYSTEM IN GAMMAS
C
C   COMMON /BLOCK1/ BEX,R,Q,PI,PSI
C   COMMON /BLOCK5/CSPH,SNPH,QCS,QSN,CSPS,SNPS
C   COMMON /BLOCK6/ CT, ST
C
C           TRANSFORM M TO SPHERICAL COORDINATES RR,T,PHI
C           TWO STEP TRANSFORM BECAUSE ZV IS NEEDED BELOW IN 'IF'
C   CALL TRANS5(XM,YM,ZM,XV,YV,ZV,D1,D2,D3)
C   CALL TRANS3(XV,YV,ZV,RR,T,PHI)
C
C   IF(ZV.LT.0.0) THEN
C           GET FIELD FROM DAYSIDE OF SPHERE ZV<0
C           CALL DAYTOT(RR,T,PHI,HR,HT,HP)
C           TRANSFORM TO CARTESIAN ZV DOWN TAIL
C           CALL BTRAN1(HR,HT,HP,HXV,HYV,HZV)
C   ELSE
C           GET FIELD FROM NIGHTSIDE OF SPHERE ZV>0
C           RRZ = SQRT(XV*XV + YV*YV)
C           CALL TAILTO(RRZ,PHI,ZV,HR,HP,HZ)
C           TRANSFORM TO CARTESIAN ZV DOWN TAIL
C           CALL BTRAN2(HR,HZ,HP,HXV,HYV,HZV)
C   END IF
C
C           TRANSFORM BACK TO M SYSTEM FOR OUTPUT
C   HXM = + HZV
C   HYM = - HYV
C   HZM = + HXV
C
C   RETURN
C   END
C *****: TRANS4
C   SUBROUTINE TRANS4(XD,YD,ZD,XM,YM,ZM)
C
C   PURPOSE- TRANSFORM DIPOLE TO M COORDINATES
C   INPUT-   XD,YD,ZD DIPOLE COORDINATES, ZD NORTH, XD TAILWARD
C   OUTPUT-  XM,YM,ZM M COORDINATES, XM IS ANTISUNWARD
C   VARIABLES- SNPS AND CSPPS, SIN AND COS OF DIPOLE TILT ANGLE
C
C   COMMON /BLOCK5/CSPH,SNPH,QCS,QSN,CSPS,SNPS
C
C   XM = ZD*SNPS + XD*CSPPS
C   YM = YD
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MAP25530
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MAP26150
MAP26160

mapint.for

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ZM = ZD*CSPS - XD*SNPS
C
RETURN
END
C *****: SPHRCO
SUBROUTINE SPHRCO (NDIM, KSA)
C
C PURPOSE- CALCULATE COEFFICIENTS FOR LEGENDRE POLYNOMIALS
C INPUT- NDIM, NUMBER OF GRID POINTS FOR NUMERICAL INTEGRATION
C GRID POINTS ARE ON SPHERE SURFACE FROM THETA 0 TO
C 180 AND PHI=0, THETA=0 POINTS DOWN TAIL
C KSA, ITERATION LEVEL
C OUTPUT- G1,G0, COEFFICIENTS FOR TILT 0 AND 90 DEGREES RESPECT.
C CONTAIN ALL EXCEPT ANGULAR AND LEGENDRE FUNCTIONS
C SEE EQ. 5.2.3 REF4 FOR GENERAL EXPRESSIONS
C VARIABLES- Q, RATIO OF DIPOLE MOMENT/RADIUS**3
C R, RADIUS OF TAIL AND SPHERE
C B, = R - STANDOFF DISTANCE
C N, ORDER OF LEGENDRE POLYNOMIAL
C TI, DIPOLE TILT ANGLE
C HS, GRID SIZE
C Y1,Y0, INTEGRAND FOR 0 AND 90 DEGREE CASES
C Z1,Z0, RESULT OF INTEGRALS FOR 0 AND 90 DEGREE CASES
C
COMMON /BLOCK9/ X(1001),Y1(1001),Y0(1001),Z1(1001),Z0(1001), HS
COMMON /CHABLO/ G1(20), G0(20)
COMMON /BLOCK1/ B,R,Q,PI,PSI
C
C
IF (KSA.EQ.1) THEN
C COEFFICIENTS ARE ANALYTIC, 5.11 AND 5.12 REF1
TI = 0.0
CALL CONST(TI)
G1(1) = - 2. * Q
G0(1) = - 2. * Q
EP = +1.0
RRP = 1.0
RP = B/R
C
DO 1 N = 2, 20
EP = -EP
RRP = RRP * RP
G1(N) = - Q * EP * FLOAT(N+1) * RRP
G0(N) = - Q * EP * FLOAT(N*(N+1)) * RRP
1 CONTINUE
ELSE
C NUMERICAL INTEGRATION REQUIRED FOR KSA>1
C GET RADIAL COMPONENT OF DIPOLE PLUS TAIL SOLUTION
C ON GRID
CALL BRDIP(NDIM)
DO 3 N = 1, 20
C FORM INTEGRANDS Y1 AND Y0
CALL FUN1(N,NDIM)
C INTEGRATE, RESULTS Z1 AND Z0
CALL INTEGR(HS,Y1,Z1,NDIM)
CALL INTEGR(HS,Y0,Z0,NDIM)
ZFE = FLOAT(2*N+1)
FN = FLOAT(N)
C FORM COEFFICIENTS 5.2.3 REF4
G1(N) = 0.5 * ZFE / (FN*(FN+1.)) * Z1(NDIM)
G0(N) = 0.5 * ZFE * Z0(NDIM)
3 CONTINUE
END IF
C

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MAP26170
MAP26180
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MAP26690
MAP26700
MAP26710
MAP26720
MAP26730
MAP26740
MAP26750
MAP26760
MAP26770
MAP26780
MAP26790
MAP26800

mapint.for

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RETURN MAP26810
END MAP26820
C *****: DAYTOT MAP26830
SUBROUTINE DAYTOT(RR,T,PHI,HR,HT,HP) MAP26840
C MAP26850
C PURPOSE- CALCULATE TOTAL FIELD OF DAYSIDE HALF OF SPHERE ZV<0 MAP26860
C INPUT- RR,T,PHI SPHERICAL COORDINATES OF INTEREST MAP26870
C OUTPUT- HR,HT,HP FIELD COMPONENTS IN SPHERICAL SYSTEM MAP26880
C VARIABLES- CDIPOL, FRAC. OF DIPOLE PENETRATING OUT OF MAGNETOPAUSE MAP26890
C CIMF, FRAC. OF IMF PENETRATING INTO MAGNETOPAUSE MAP26900
C MAP26910
COMMON /BLOCK1/ B, R, Q, PI, PSI MAP26920
COMMON /FIMF/ HIMF, CDIPOL, CIMF, XI MAP26930
C MAP26940
CD = (1.- CDIPOL) MAP26950
CF = (1.- CIMF) MAP26960
C MAP26970
IF(RR.LE.R) THEN MAP26980
C GET FIELD INSIDE SPHERE MAP26990
C DIPOLE FIELD MAP27000
CALL BDIP (RR,HR1,HT1,HP1) MAP27010
C CHAPMAN-FERRARO DUE TO DIPOLE MAP27020
CALL CFDSPH(RR,HR2,HT2,HP2) MAP27030
C TAIL SOLUTION, DAYSIDE INFLUENCE MAP27040
CALL BTASPH (RR,HR3,HT3,HP3) MAP27050
C IMF FIELD MAP27060
CALL BIMF (HIMF,XI,D1,D2,D3,D4, HR5,HT5,HP5, D5,D6,D7) MAP27070
C MAP27080
EQ. 3.22 INTERNAL FIELD REF1 MAP27090
HR = HR1 + CD * (HR2 + HR3) + CIMF * HR5 MAP27100
HT = HT1 + CD * (HT2 + HT3) + CIMF * HT5 MAP27110
HP = HP1 + CD * (HP2 + HP3) + CIMF * HP5 MAP27120
ELSE MAP27130
C GET FIELD OUTSIDE SPHERE MAP27140
C DIPOLE FIELD MAP27150
CALL BDIP (RR,HR1,HT1,HP1) MAP27160
C CHAPMAN-FERRARO DUE TO IMF MAP27170
CALL CFISPH(RR,HR2,HT2,HP2) MAP27180
C IMF FIELD MAP27190
CALL BIMF (HIMF,XI,D1,D2,D3,D4, HR5,HT5,HP5, D5,D6,D7) MAP27200
C MAP27210
EQ. 3.23 EXTERNAL FIELD REF1 MAP27220
HR = HR5 + CF * HR2 + CDIPOL * HR1 MAP27230
HT = HT5 + CF * HT2 + CDIPOL * HT1 MAP27240
HP = HP5 + CF * HP2 + CDIPOL * HP1 MAP27250
END IF MAP27260
RETURN MAP27270
END MAP27280
C *****: TAILTO MAP27290
SUBROUTINE TAILTO(RR,PHI,Z,HR,HP,HZ) MAP27300
C MAP27310
C PURPOSE- CALCULATE TOTAL FIELD OF CYLINDER PORTION FOR ZV>0 MAP27320
C INPUT- RR,PHI,Z, CYLINDRICAL COORDINATES MAP27330
C OUTPUT- HR,HP,HZ, FIELD COMPONENTS IN CYLINDRICAL SYSTEM MAP27340
C VARIABLES- CDIPOL, FRAC. OF DIPOLE PENETRATING OUT OF MAGNETOPAUSE MAP27350
C CIMF, FRAC. OF IMF PENETRATING IN THROUGH MAGNETOPAUSE MAP27360
C SNPH,CSPH, SIN AND COS OF PHI MAP27370
C MAP27380
COMMON /BLOCK1/ BEX,R,Q,PI,PSI MAP27390
COMMON /BLOCK5/ CSPH,SNPH,QCS,QSN,CSPS,SNPS MAP27400
COMMON /BLOCK6/ CT, ST MAP27410
COMMON /FIMF/ HIMF, CDIPOL, CIMF, XI MAP27420
C MAP27430
CD = (1.- CDIPOL) MAP27440
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mapint for

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C      CF = (1.- CIMF)
C
C      IF (RR.LE.R) THEN
C          GET FIELD INSIDE CYLINDER
C          RRR = SQRT(RR*RR + Z*Z)
C          DIPOLE FIELD
C          CALL BDIP (RRR,HR1,HT1,HP1)
C          TRANSFORM SPHERICAL TO CARTESIAN, HZV DOWN TAIL
C          CALL BTRAN1 (HR1,HT1,HP1, HXV,HYV,HZV)
C          TRANSFORM CARTEIAN TO CYLINDRICAL
C          HR1 = HXV * CSPH + HYV * SNPH
C          HP1 = HYV * CSPH - HXV * SNPH
C          HZ1 = HZV
C          TOTAL TAIL FIELD SOLUTION
C          CALL BTATA (Z,RR,HR2,HZ2,HP2)
C          CHAPMAN-FERRARO = TOTAL FIELD - DIPOLE FIELD
C          HR2 = HR2 - HR1
C          HP2 = HP2 - HP1
C          HZ2 = HZ2 - HZ1
C          GET IMF FIELD
C          CALL BIMF (HIMF,XI, D1,D2,D3,D4,D5,D6,D7, HR5,HZ5,HP5)
C          SUM OF INTERNAL FIELDS, 3.22 REF1
C          HR = HR1 + CD * HR2 + CIMF * HR5
C          HZ = HZ1 + CD * HZ2 + CIMF * HZ5
C          HP = HP1 + CD * HP2 + CIMF * HP5
C      ELSE
C          GET FIELD OUTSIDE OF CYLINDER
C          RRR = SQRT(RR*RR + Z*Z)
C          DIPOLE FIELD
C          CALL BDIP (RRR,HR1,HT1,HP1)
C          TRANSFORM SPHERICAL TO CARTESIAN, HZV DOWN TAIL
C          CALL BTRAN1 (HR1,HT1,HP1, HXV,HYV,HZV)
C          TRANSFORM CARTESIAN TO CYLINDRICAL
C          HR1 = HXV * CSPH + HYV * SNPH
C          HP1 = HYV * CSPH - HXV * SNPH
C          HZ1 = HZV
C          CHAPMAN-FERRARO DUE TO IMF
C          CALL CFITA (RR,HR2,HZ2,HP2)
C          IMF FIELD
C          CALL BIMF (HIMF,XI, D1,D2,D3,D4,D5,D6,D7, HR5,HZ5,HP5)
C          SUM OF EXTERNAL FIELDS USING 3.23 REF1
C          HR = HR5 + CF * HR2 + CDIPOL * HR1
C          HZ = HZ5 + CF * HZ2 + CDIPOL * HZ1
C          HP = HP5 + CF * HP2 + CDIPOL * HP1
C      END IF
C      RETURN
C      END
C *****:      BTRAN1
C      SUBROUTINE BTRAN1 (HRV,HTV,HPV,HXV,HYV,HZV)
C
C      PURPOSE-  CHANGES FIELD COMPONENTS FROM SPHERICAL TO CARTESIAN
C                HZV POINTS DOWN TAIL AXIS, =0 TO SPHERE CENTER
C      INPUT-    HRV,HTV,HPV, SPHERICAL COMPONENTS
C      OUTPUT-   HXV,HYV,HZV, CARTESIAN COMPONENTS
C      VARIABLES- ST,CT, SIN AND COS OF THETA
C                CP,SP, COS AND SIN OF PHI
C
C      COMMON /BLOCK5/ CP,SP,QCS,QSN,CSPS,SNPS
C      COMMON /BLOCK6/ CT, ST
C
C      HXV = HRV*ST*CP + HTV*CT*CP - HPV*SP
C      HYV = HRV*ST*SP + HTV*CT*SP + HPV*CP
C      HZV = HRV*CT - HTV*ST

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MAP27450
MAP27460
MAP27470
MAP27480
MAP27490
MAP27500
MAP27510
MAP27520
MAP27530
MAP27540
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MAP27580
MAP27590
MAP27600
MAP27610
MAP27620
MAP27630
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MAP27680
MAP27690
MAP27700
MAP27710
MAP27720
MAP27730
MAP27740
MAP27750
MAP27760
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MAP27810
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MAP27900
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MAP27970
MAP27980
MAP27990
MAP28000
MAP28010
MAP28020
MAP28030
MAP28040
MAP28050
MAP28060
MAP28070
MAP28080

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mapint.for

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RETURN
END
C *****: TAILCO
SUBROUTINE TAILCO (NDIM)
C
C PURPOSE- NUMERICAL CALCULATION OF FOURIER-BESSEL COEFFICIENTS
C INPUT- NDIM, NUMBER OF GRID POINTS ALONG CYLINDER CAP AT
C THETA=90 DEGREES FOR INTEGRATION
C OUTPUT- AX, BX FOURIER-BESSEL COEFFICIENTS WITH MODIFICATIONS
C TO BE USEFUL IN FINAL EXPRESSION 6.4 REF1
C VARIABLES- BE, BO BESSEL FUNCTIONS J1 AND J0 WITH ARGUMENTS THAT
C ARE ROOTS OF DERIVATIVES OF THE BESSEL FUNCTIONS
C SEE 5.21 AND 5.22 REF1
C Z1, Z0 RESULTS OF INTEGRATION FOR 0 AND 90 DEGREES CASES
C ZE, Z0 ZEROS OF DERIVATIVES OF J1 AND J0
C Q, DIPOLE MOMENT/ (RADIUS**3)
C
COMMON /BLOCK9/ X(1001), Y1(1001), Y0(1001), Z1(1001), Z0(1001), HS
COMMON /BLOCK1/ B, R, Q, PI, PSI
COMMON /BLOCK2/ ZE(20), AX(20), ZO(20), BX(20)
COMMON /BLOCK7/ BE(20), BO(20)
C
C GENERATE POTENTIAL ON CYLINDER HEAD= CHAP-FERR + DIPOLE
CALL TAPOT (NDIM)
C GENERATE COEFFICIENTS FOR N ORDERS
DO 1 N = 1, 20
C FORM INTEGRANDS Y1 AND Y0
CALL FUN2 (N, NDIM)
C DO INTEGRATIONS FOR BOTH TILT CASES, RESULT Z1, Z0
CALL INTEGR (HS, Y1, Z1, NDIM)
CALL INTEGR (HS, Y0, Z0, NDIM)
C PREPARE SOME BESSEL FACTORS
BX0 = BE (N) * BE (N)
BY0 = BO (N) * BO (N)
ZEX = ZE (N) * ZE (N)
C COEFFICIENTS A AND B OF 5.24 AND 5.25 REF1
AX (N) = Z1 (NDIM) * ZEX / (BX0 * (ZEX-1.))
BX (N) = Z0 (NDIM) / (BY0)
C MODIFY COEFFICIENTS TO SUIT EXPRESSION 6.4 REF1
AX (N) = AX (N) * ZE (N) * Q
BX (N) = BX (N) * ZO (N) * 2. * Q
1 CONTINUE
C
RETURN
END
C *****: TRANS3
SUBROUTINE TRANS3 (XV, YV, ZV, RR, T, PHI)
C
C PURPOSE- CHANGE CARTESIAN TO SPHERICAL AND FORM TRIG. FUNCTIONS
C FOR COMMON BLOCKS
C INPUT- XV, YV, ZV CARTESIAN WITH ZV DOWN TAIL
C OUTPUT- RR, T, PHI SPHERICAL COORDINATES
C VARIABLES- Q, RATIO DIPOLE MOMENT/ (RADIUS**3)
C
COMMON /BLOCK1/ BEX, R, Q, PI, PSI
COMMON /BLOCK5/ CSPH, SNPH, QCS, QSN, CSPS, SNPS
COMMON /BLOCK6/ CT, ST
C
RR = SQRT (XV*XV + YV*YV + ZV*ZV)
PHI = ATAN3 (YV, XV)
T = ATAN3 (SQRT (XV*XV+YV*YV), ZV)
C
CT = COS (T)
ST = SIN (T)

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MAP28090
MAP28100
MAP28110
MAP28120
MAP28130
MAP28140
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MAP28220
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MAP28280
MAP28290
MAP28300
MAP28310
MAP28320
MAP28330
MAP28340
MAP28350
MAP28360
MAP28370
MAP28380
MAP28390
MAP28400
MAP28410
MAP28420
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MAP28450
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MAP28660
MAP28670
MAP28680
MAP28690
MAP28700
MAP28710
MAP28720

mapint.for

CSPH = COS(PHI)
SNPH = SIN(PHI)
QCS = Q*CSPH
QSN = Q*SNPH

C

RETURN
END

C *****: TRANS5
SUBROUTINE TRANS5(XM,YM,ZM, XV,YV,ZV, XGSE,YGSE,ZGSE)

C

PURPOSE- TRANSFORM M TO SPHERICAL AND GSE SYSTEM
C INPUT- XM,YM,ZM THE M SYSTEM, EARTH CENTERED, XM DOWN TAIL
C OUTPUT- XV,YV,ZV CARTESIAN, SPHERE CENTERED, ZV DOWN TAIL
C XGSE,YGSE,ZGSE, GSE SYSTEM
C VARIABLES- BEX, = RADIUS - STAND-OFF DISTANCE

C

COMMON /BLOCK1/ BEX,R,Q,PI,PSI
XV = ZM
YV = -YM
ZV = XM - BEX

C

XGSE = - XM
YGSE = -YM
ZGSE =+ ZM

C

RETURN
END

C *****: ZERO
SUBROUTINE ZERO

C

PURPOSE- FILL COMMON BLOCKS WITH ZEROS OF BESSELS AND FUNCTION
C VALUES AT ZEROS
C INPUT- SOURCE IS TABLE 9.5 REF2
C ZE, ZEROS OF J1'(XI)
C ZO, ZEROS OF JO'(YI)
C BE, BESSEL VALUE J1(XI)
C BO, BESEL VALUE JO(YI)

C

COMMON /BLOCK2/ ZE(20),AX(20),ZO(20),BX(20)
COMMON /BLOCK7/ BE(20),BO(20)

C

C

C

ZEROS J1'(XI) = 0.0

C

ZE(1)= 1.84118
ZE(2)= 5.33144
ZE(3)= 8.53632
ZE(4)= 11.70600
ZE(5)= 14.86359
ZE(6)= 18.01553
ZE(7)= 21.16437
ZE(8)= 24.31133
ZE(9)= 27.45705
ZE(10)= 30.60192
ZE(11)= 33.74618
ZE(12)= 36.88999
ZE(13)= 40.03344
ZE(14)= 43.17663
ZE(15)= 46.31960
ZE(16)= 49.46239
ZE(17)= 52.60504
ZE(18)= 55.74757
ZE(19)= 58.89000
ZE(20)= 62.03235

MAP28730
MAP28740
MAP28750
MAP28760
MAP28770
MAP28780
MAP28790
MAP28800
MAP28810
MAP28820
MAP28830
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MAP28990
MAP29000
MAP29010
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MAP29030
MAP29040
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MAP29060
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MAP29090
MAP29100
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MAP29210
MAP29220
MAP29230
MAP29240
MAP29250
MAP29260
MAP29270
MAP29280
MAP29290
MAP29300
MAP29310
MAP29320
MAP29330
MAP29340
MAP29350
MAP29360

mapint.for

C
C
C
C

ZEROS J0'(YI) = 0.0

- ZO(1) = 3.8317059702
- ZO(2) = 7.0155866698
- ZO(3) = 10.1734681351
- ZO(4) = 13.3236919363
- ZO(5) = 16.4706300509
- ZO(6) = 19.6158585105
- ZO(7) = 22.7600843806
- ZO(8) = 25.9036720876
- ZO(9) = 29.0468285349
- ZO(10) = 32.1896799110
- ZO(11) = 35.3323075501
- ZO(12) = 38.4747662348
- ZO(13) = 41.6170942128
- ZO(14) = 44.7593189977
- ZO(15) = 47.9014608872
- ZO(16) = 51.0435351836
- ZO(17) = 54.1855536411
- ZO(18) = 57.3275254379
- ZO(19) = 60.4694578453
- ZO(20) = 63.61141

C
C
C
C

BE(I) = J1(XI) BESSELS EVALUATED AT XI'S OF ABOVE

- BE(1) = +0.58187
- BE(2) = -0.34613
- BE(3) = +0.27330
- BE(4) = -0.23330
- BE(5) = +0.20701
- BE(6) = -0.18802
- BE(7) = +0.17346
- BE(8) = -0.16184
- BE(9) = +0.15228
- BE(10) = -0.14424
- BE(11) = +0.13736
- BE(12) = -0.13137
- BE(13) = +0.12611
- BE(14) = -0.12143
- BE(15) = +0.11724
- BE(16) = -0.11345
- BE(17) = +0.11001
- BE(18) = -0.10687
- BE(19) = +0.10397
- BE(20) = -0.10131

C
C
C
C

BO(I) = J0(YI) BESSELS EVALUATED AT YI'S OF ABOVE

- BO(1) = -0.4027593957
- BO(2) = +0.3001157525
- BO(3) = -0.2497048871
- BO(4) = +0.2183594072
- BO(5) = -0.1964653715
- BO(6) = +0.1800633753
- BO(7) = -0.1671846005
- BO(8) = +0.1567249836
- BO(9) = -0.1480111100
- BO(10) = +0.1406057982
- BO(11) = -0.1342112403
- BO(12) = +0.1286166221

- MAP29370
- MAP29380
- MAP29390
- MAP29400
- MAP29410
- MAP29420
- MAP29430
- MAP29440
- MAP29450
- MAP29460
- MAP29470
- MAP29480
- MAP29490
- MAP29500
- MAP29510
- MAP29520
- MAP29530
- MAP29540
- MAP29550
- MAP29560
- MAP29570
- MAP29580
- MAP29590
- MAP29600
- MAP29610
- MAP29620
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- MAP29690
- MAP29700
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- MAP29900
- MAP29910
- MAP29920
- MAP29930
- MAP29940
- MAP29950
- MAP29960
- MAP29970
- MAP29980
- MAP29990
- MAP30000

mapint.for

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BO(13) = -0.1236679608
BO(14) = +0.1192498120
BO(15) = -0.1152736941
BO(16) = +0.1116704969
BO(17) = -0.1083853489
BO(18) = +0.1053740554
BO(19) = -0.1026005671
BO(20) = +0.1000
C
C
RETURN
END
C *****: BIMF
SUBROUTINE BIMF(HIMF,XI, HXM,HZM, HXV,HZV, HR,HT,HP, HRHO,HZ,HPHI)
C
C PURPOSE- DETERMINE IMF CONTRIBUTION IN CARTESIAN M AND V, SPHER,
C AND CYLINDRICAL COORDINATES
C NO Y COMPONENT INCLUDED
C INPUT- HIMF, MAGNITUDE OF IMF (GAMMA)
C XI, DIRECTION OF IMF, 0 DEGREES IS NORTHWARD, 90 ANTISUN
C OUTPUT- HXM,HZM FIELD VALUES IN M SYSTEM, HXM DOWN TAIL
C HXV,HZV FIELD VALUES IN V SYSTEM, HZV DOWN TAIL
C HR,HT,HP " " " SPHERICAL
C HRHO,HZ,HPHI " " CYLINDRICAL
C VARIABLES- ST,CT SIN AND COS OF THETA
C SNPH,CSPH SIN AND COS OF PHI
C
COMMON /BLOCK5/CSPH,SNPH,QCS,QSN,CSPS,SNPS
COMMON /BLOCK6/ CT, ST
C DEGREES TO RADIANS
AXI = XI*3.1415926535/180.0
C M SYSTEM
HXM = HIMF * SIN(AXI)
HXM = HIMF * COS(AXI)
C V SYSTEM
HXV = HZM
HZV = HXM
C SPHERICAL SYSTEM
HR = + HXV*ST*CSPH + HZV*CT
HT = + HXV*CT*CSPH - HZV*ST
HP = - HXV*SNPH
C CYLINDRICAL SYSTEM
HRHO = + HXV * CSPH
HPHI = + HP
HZ = + HZV
C
RETURN
END
C *****: CFDSPH
SUBROUTINE CFDSPH(RR,HR,HT,HP)
C
C PURPOSE- CALCULATE FIELD OF CHAPMAN-FERRARO CURRENTS FOR
C SHIELDING DIPOLE ONLY IN SPHERE. SUMMATION OF FIELD DUE
C TO POTENTIAL 5.11 REF1
C NOTE: RECURRENCE RELATIONS JAHNKE-EMDE NORMALIZED, REF3
C INPUT- RR, RADIAL LOCATION
C OUTPUT- HR,HT,HP SPHERICAL FIELD COMPONENTS, 5.2.13 REF4
C VARIABLES- GAM1,GAMO LEGENDRE POLYNOMIAL COEFFICIENTS FROM SPHRCO
C PN, LEGENDRE POLYNOMIAL M=0
C CPN, DERIVATIVE OF PN W.R.T. ARGUMENT COS(THETA)
C TPN, DERIVATIVE OF PN W.R.T. THETA
C PNM, LEGENDRE POLYNOMIAL M=1
C TPNM, DERIVATIVE OF PNM W.R.T. THETA
C SPNM, QUOTIENT PN/SIN(THETA)

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MAP30010
MAP30020
MAP30030
MAP30040
MAP30050
MAP30060
MAP30070
MAP30080
MAP30090
MAP30100
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MAP30210
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MAP30350
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MAP30370
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MAP30390
MAP30400
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MAP30420
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MAP30450
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MAP30500
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MAP30550
MAP30560
MAP30570
MAP30580
MAP30590
MAP30600
MAP30610
MAP30620
MAP30630
MAP30640

mapint.for

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C          31,C1 SIN AND COS OF THETA
C
DIMENSION PN(20), CPN(20), TPN(20)
DIMENSION PNM(20), TPNM(20), SPNM(20)
COMMON /CHABLO/ GAM1(20), GAM0(20)
C
COMMON /BLOCK1/ B,R,Q,PI,PSI
COMMON /BLOCK5/ CSPH, SNPH, QCS, QSN, CSPS, SNPS
COMMON /BLOCK6/ C1, S1
C
D = 1.0E-03
C
C2 = C1*C1 - S1*S1
S2 = 2.*S1*C1
C
PN(1) = C1
PN(2) = 0.25*(3.*C2+1.)
CPN(1) = 1.0
CPN(2) = 3.*C1
C
DO 1 N=3,20
  FN = FLOAT(N)
  ZFE = 2.*FN - 1.0
  PN(N) = (1./FN) * (ZFE*C1*PN(N-1) - (FN-1.)*PN(N-2))
  CPN(N) = ZFE*PN(N-1) + CPN(N-2)
1 CONTINUE
C
DO 2 N=1,20
  FN = FLOAT(N)
  TPN(N) = - S1*CPN(N)
  PNM(N) = - TPN(N)
  SPNM(N) = + CPN(N)
  TPNM(N) = FN*(FN+1.)*PN(N) - C1*CPN(N)
2 CONTINUE
C
HR1 = GAM1(1) * PNM(1)
HR2 = GAM0(1) * PN(1)
HT1 = GAM1(1) * TPNM(1)
HT2 = GAM0(1) * TPN(1)
HP = GAM1(1) * SPNM(1)
C
RP = 0.0
IF(RR.GT.D) RP = (RR/R)
RRP = 1.0
C
DO 3 N=2,20
  FN = FLOAT(N)
C
  RRP = RRP * RP
C
  GAMA = GAM1(N) * RRP
  GAMB = GAM0(N) * RRP
C
  1 AND 2 INDICATE TERMS MEANT FOR 0 AND 90 DEGREE CASES
  HR1 = HR1 + GAMA * PNM(N)
  HR2 = HR2 + GAMB * PN(N)
C
  HT1 = HT1 + GAMA * TPNM(N) / FN
  HT2 = HT2 + GAMB * TPN(N) / FN
C
  HP = HP + GAMA * SPNM(N) / FN
C
3 CONTINUE
C

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MAP30650
MAP30660
MAP30670
MAP30680
MAP30690
MAP30700
MAP30710
MAP30720
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MAP31190
MAP31200
MAP31210
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MAP31230
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MAP31250
MAP31260
MAP31270
MAP31280

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mapint.for

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C          EACH PART RELATING TO TILT CASES IS COMBINED WITH
C          FUNCTIONS OF 5.9 REF1
HR = - (HR1 * CSPH * CSPS + HR2 * SNPS)
HT = - (HT1 * CSPH * CSPS + HT2 * SNPS)
HP = + HP * SNPH * CSPS
C
C          RETURN
C          END
C *****: CFISPH
C          SUBROUTINE CFISPH(RR,HR,HT,HP)
C
C          PURPOSE- CALCULATE CHAPMAN-FERRARO FIELD OUTSIDE SHERE DUE TO IMF
C                   USING 5.15 REF1
C          INPUT-   RR, RADIAL COORDINATE
C          OUTPUT-  HR,HT,HP CHAP-FERR FIELD COMPONENTS IN SPHERICAL SYSTEM
C          VARIABLES- HR3,HT3,HP3 IMF FIELD COMPONENTS FROM SUBROUT. BIMF
C
C          COMMON /BLOCK1/ BEX, R, Q, PI, PSI
C          COMMON /FIMF/ HIMF, CDIPOL, CIMF, XI
C
C          GET IMF FIELD COMPONENTS
C          CALL BIMF(HIMF,XI, D1,D2,D3,D4, HR3,HT3,HP3, D5,D6,D7)
C          TRANSFORM COMPONENTS TO SPHERICAL SYSTEM
C          FR = R/RR
C          FR = FR*FR*FR
C
C          HR = - HR3 * FR
C          HT = + 0.5 * HT3 * FR
C          HP = + 0.5 * HP3 * FR
C
C          RETURN
C          END
C *****: BDIP
C          SUBROUTINE BDIP(RR,HR,HT,HP)
C
C          PURPOSE- CALCULATE EXPLICIT COMPONENTS OF DIPOLE USING SPHERICAL
C                   EQUIVALENT OF 5.6 REF1 FOR POTENTIAL
C          INPUT-   RR, RADIAL COORDINATE LOCATION
C          OUTPUT-  HR,HT,HP DIPOLE FIELD IN SPHERICAL SYSTEM (GAMMA)
C          VARIABLES- C1,S1 COS AND SIN OF THETA
C                   R, RADIUS OF SPHERE AND TAIL
C                   B, = R - STANDOFF DISTANCE
C                   SNPS,CSPS SIN AND COS OF PSI, THE DIPOLE TILT ANGLE
C
C          COMMON /BLOCK1/ B,R,Q,PI,PSI
C          COMMON /BLOCK5/CSPH,SNPH,QCS,QSN,CSPS,SNPS
C          COMMON /BLOCK6/ C1, S1
C
C          R3 = R**3
C
C          A = QCS*R3
C          AA = QSN*R3
C
C          V = ((RR*RR) + (B*B) + (2.*B*RR*C1))
C
C          AV = ABS(V)
C          SV = SIGN(1.0,V)
C
C          W3 = SQRT(AV**3)
C          W4 = SQRT(AV**5)
C
C          W1 = W3 * SV

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MAP31290
MAP31300
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MAP31900
MAP31910
MAP31920

mapint.for

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C      W2 = W4 * SV
C
C      F1 = 2.*RR*B*S1
C      G1 = 2.*RR + 2.*B*C1
C      E1 = 1.5*RR*G1/W2
C      E2 = 1.5*F1/W2
C
C      HR1 = A*CSPS*S1*(1./W1 - E1)
C      HR2 = Q*R3*C1*SNPS*(1./W1 - E1)
C      HR3 = -Q*R3*B*SNPS*3.*(RR+ B*C1)/W2
C
C      HT1 = A*CSPS*(C1/W1 + S1*E2)
C      HT2 = Q*R3*SNPS*(C1*E2 - S1/W1)
C      HT3 = Q*R3*B*SNPS*(3.*B*S1/W2)
C
C      HP = -AA*CSPS/W1
C
C      HR = HR1 + HR2 + HR3
C      HT = HT1 + HT2 + HT3
C      HP = HP
C
C      RETURN
C      END
C *****:      FUN1
C      SUBROUTINE FUN1(N,NDIM)
C
C      PURPOSE-   FORM INTEGRAND FOR COEFFICIENT CALCULATIONS AT EACH OF
C                  NDIM STEPS FOR A CERTAIN ORDER OF LEGENDRE POLYNOMIAL
C      INPUT-     N, ORDER OF LEGENDRE POLYNOMIAL
C                  NDIM, NUMBER OF GRID POINTS USED FOR INTEGRATION
C      OUTPUT-    Y1,Y0 VALUE OF INTEGRAND FOR CASES 0 AND 90 DEGREES RESP
C      VARIABLES- PNM, LEGENDRE POLYNOMIAL M=1
C                  PN, LEGENDRE POLYNOMIAL M=0
C                  ST, SIN(T) LAST VALUE COMES FROM SUBROUT. LEGEN
C
C      COMMON /LEG1/ PN(20), PNM(20), CPN(20)
C      COMMON /BLOCK8/ W1(1001),W0(1001)
C      COMMON /BLOCK9/ X(1001),Y1(1001),Y0(1001),Z1(1001),Z0(1001), HS
C      COMMON /BLOCK6/ CT, ST
C
C      DO 1 I = 1, NDIM
C          X(I) IS THETA, GENERATES LEGENDRE POLYNOMIAL TERMS
C          CALL LEGEN(X(I),N)
C
C          D = 1.0E-20
C
C          IF (ABS(W1(I)).LT.D) W1(I) = 0.0
C          IF (ABS(W0(I)).LT.D) W0(I) = 0.0
C          IF (ABS(PNM(N)).LT.D) PNM(N) = 0.0
C          IF (ABS(PN(N)).LT.D) PN(N) = 0.0
C          IF (ABS(ST).LT.D) ST = 0.0
C
C          NDIM INTEGRANDS FOR EACH ORDER TO GET COEFFICIENTS
C          5.2.3 REF4
C          Y1(I) = W1(I) * PNM(N) * ST
C          Y0(I) = W0(I) * PN(N) * ST
C
C      1 CONTINUE
C
C      RETURN
C      END
C *****:      BRDIP

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MAP31930
MAP31940
MAP31950
MAP31960
MAP31970
MAP31980
MAP31990
MAP32000
MAP32010
MAP32020
MAP32030
MAP32040
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MAP32550
MAP32560

mapint.for

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SUBROUTINE BRDIP (NDIM)
C
C
C PURPOSE- GENERATE RADIAL COMPONENTS OF DIPOLE FIELD ON GRID FOR
C           TILT 0 AND 90 DEGREES
C INPUT-   NDIM, NUMBER OF GRID POINTS AT RADIUS=R ALONG CURVE
C           THETA=0 TO 180 DEGREES TO BE USED FOR INTEGRATION
C OUTPUT-  W1,W0 RADIAL COMPONENTS OF DIPOLE, INTO BLOCK 8
C VARIABLES- KDIM, NUMBER OF THE GRID POINT SEPARATING DAY AND NIGHT-
C             SIDE OF SPHERE
C           R, RADIUS OF SHPERE AND TAIL
C           Q, RATIO DIPOLE MOMENT/(R**3)
C           SNPH,CSPH SIN AND COS OF PHI
C           QSN,QCS =Q*SNPH AND =Q*CSPH RESPECTIVELY
C           X(I), THETA VALUES OF GRID POINTS
C           HS, GRID POINT SPACING
C
COMMON /BLOCK8/ W1(1001),W0(1001)
COMMON /BLOCK9/ X(1001), Y1(1001),Y0(1001),Z1(1001),Z0(1001), HS
COMMON /BLOCK1/ B,R,Q,PI,PSI
COMMON /BLOCK5/ CSPH,SNPH,QCS,QSN,CSPS,SNPS
COMMON /BLOCK6/ CT,ST
COMMON /BLOCK3/ H0,ALFA,KSWIT
C
C KDIM = (NDIM-1)/2
C
C           PHI = 0 DEGREES FOR THIS SUBROUT.
CSPH = 1.0
SNPH = 0.0
QCS = Q
QSN = 0.0
C
C           GENERATE GRID POINTS
X(1) = 0.0
HS = PI/FLOAT(NDIM-1)
DO 1 I = 2, NDIM
    X(I) = FLOAT(I-1) * HS
1 CONTINUE
C
C           GET COMPONENTS FOR TILT=0 DEGREES
TI = 0.0
CALL CONST(TI)
C
DO 4 I = 1, NDIM
C
    CT = COS(X(I))
    ST = SIN(X(I))
C
    RRDIP = R
C           GET RADIAL COMPONENT OF DIPOLE AT SPHERE RADIUS
    CALL BDIP(RRDIP,HR,HT,HP)
    W1(I) = HR
C
    IF (I.LE.KDIM) THEN
C           LOCATION IS NIGHTSIDE, CHANGE TO CYLINDRICAL
        RHO= R * ST
        Z = R * CT
C           GET CYLINDER SOLUTION
        CALL VACTA(Z,RHO,HR,HZ,HP)
        HR = HR * ST + HZ * CT
C           CYLINDER SOLUTION HAS DIPOLE + CHAP-FERR 5.16 REF1
        W1(I) = W1(I) - HR
    ELSE
C           LOCATION IS DAYSIDE OF SPHERE

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C      RRSHE = R
C      DAYSIDE FIELD RESULTING FROM TAIL SOLUTION
C      CALL BTASPH(RRSHE,HR,HT,HP)
C      DIPOLE PLUS DAYSIDE TAIL SOLUTION GIVES DAYSIDE
C      FIELD, 5.1 REF1
C      W1(I) = W1(I) + HR
C      END IF
4     CONTINUE
C
C      GENERATE COMPONENTS FOR TILT=90 DEGREES
C      (SAME PROCEDURE AS ABOVE FOR TILT=0 DEGREES)
C      TI = 90.0
C      CALL CONST(TI)
C
C      DO 7 I = 1, NDIM
C
C      CT = COS(X(I))
C      ST = SIN(X(I))
C
C      RRDIP = R
C      CALL BDIP(RRDIP,HR,HT,HP)
C      W0(I) = HR
C
C      IF (I.LE.KDIM) THEN
C      RHO= R * ST
C      Z = R * CT
C      CALL VACTA(Z,RHO,HR,HZ,HP)
C      HR = HR * ST + HZ * CT
C      W0(I) = W0(I) - HR
C      ELSE
C      RRSHE = R
C      CALL BTASPH(RRSHE,HR,HT,HP)
C      W0(I) = W0(I) + HR
C      END IF
7     CONTINUE
C
C      RETURN
C      END
C *****: INTEGR
C      SUBROUTINE INTEGR(H,Y,Z,NDIM)
C
C      PURPOSE- GENERAL INTEGRATION ROUTINE
C      INPUT- H, GRID SIZE
C      Y, INTEGRAND, FROM FUN1 OR FUN2 SUBROUT.
C      NDIM, NUMBER OF GRID POINTS USED
C      OUTPUT- Z INTEGRAL RESULT OF FUNCTION Y FROM ZERO TO NDIM*H
C      (USED TO FILL Z1 AND Z0 OF BLOCK 9)
C
C      DIMENSION Y(NDIM), Z(NDIM)
C
C      HT=.3333333*H
C      IF (NDIM-5) 7,8,1
C
C      NDIM IS GREATER THAN 5. PREPARATIONS OF INTEGRATION LOOP
1     SUM1=Y(2)+Y(2)
C      SUM1=SUM1+SUM1
C      SUM1=HT*(Y(1)+SUM1+Y(3))
C      AUX1=Y(4)+Y(4)
C      AUX1=AUX1+AUX1
C      AUX1=SUM1+HT*(Y(3)+AUX1+Y(5))
C      AUX2=HT*(Y(1)+3.875*(Y(2)+Y(5))+2.625*(Y(3)+Y(4))+Y(6))

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MAP33210
MAP33220
MAP33230
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MAP33250
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MAP33740
MAP33750
MAP33760
MAP33770
MAP33780
MAP33790
MAP33800
MAP33810
MAP33820
MAP33830
MAP33840

SUM2=Y (5) +Y (5)	MAP33850
SUM2=SUM2+SUM2	MAP33860
SUM2=AUX2-HT* (Y (4) +SUM2+Y (6))	MAP33870
Z (1) =0.	MAP33880
AUX=Y (3) +Y (3)	MAP33890
AUX=AUX+AUX	MAP33900
Z (2) =SUM2-HT* (Y (2) +AUX+Y (4))	MAP33910
Z (3) =SUM1	MAP33920
Z (4) =SUM2	MAP33930
IF (NDIM-6) 5, 5, 2	MAP33940
C	MAP33950
C INTEGRATION LOOP	MAP33960
2 DO 4 I=7,NDIM,2	MAP33970
SUM1=AUX1	MAP33980
SUM2=AUX2	MAP33990
AUX1=Y (I-1) +Y (I-1)	MAP34000
AUX1=AUX1+AUX1	MAP34010
AUX1=SUM1+HT* (Y (I-2) +AUX1+Y (I))	MAP34020
Z (I-2) =SUM1	MAP34030
IF (I-NDIM) 3, 6, 6	MAP34040
3 AUX2=Y (I) +Y (I)	MAP34050
AUX2=AUX2+AUX2	MAP34060
AUX2=SUM2+HT* (Y (I-1) +AUX2+Y (I+1))	MAP34070
4 Z (I-1) =SUM2	MAP34080
5 Z (NDIM-1) =AUX1	MAP34090
Z (NDIM) =AUX2	MAP34100
RETURN	MAP34110
6 Z (NDIM-1) =SUM2	MAP34120
Z (NDIM) =AUX1	MAP34130
RETURN	MAP34140
C END OF INTEGRATION LOOP	MAP34150
C	MAP34160
7 IF (NDIM-3) 12, 11, 8	MAP34170
C	MAP34180
C NDIM IS EQUAL TO 4 OR 5	MAP34190
8 SUM2=1.125*HT* (Y (1) +Y (2) +Y (2) +Y (2) +Y (3) +Y (3) +Y (3) +Y (4))	MAP34200
SUM1=Y (2) +Y (2)	MAP34210
SUM1=SUM1+SUM1	MAP34220
SUM1=HT* (Y (1) +SUM1+Y (3))	MAP34230
Z (1) =0.	MAP34240
AUX1=Y (3) +Y (3)	MAP34250
AUX1=AUX1+AUX1	MAP34260
Z (2) =SUM2-HT* (Y (2) +AUX1+Y (4))	MAP34270
IF (NDIM-5) 10, 9, 9	MAP34280
9 AUX1=Y (4) +Y (4)	MAP34290
AUX1=AUX1+AUX1	MAP34300
Z (5) =SUM1+HT* (Y (3) +AUX1+Y (5))	MAP34310
10 Z (3) =SUM1	MAP34320
Z (4) =SUM2	MAP34330
RETURN	MAP34340
C	MAP34350
C NDIM IS EQUAL TO 3	MAP34360
11 SUM1=HT* (1.25*Y (1) +Y (2) +Y (2) -.25*Y (3))	MAP34370
SUM2=Y (2) +Y (2)	MAP34380
SUM2=SUM2+SUM2	MAP34390
Z (3) =HT* (Y (1) +SUM2+Y (3))	MAP34400
Z (1) =0.	MAP34410
Z (2) =SUM1	MAP34420
12 RETURN	MAP34430
END	MAP34440
C *****: BTRAN2	MAP34450
SUBROUTINE BTRAN2 (HRV, HZV, HPV, HXV, HYV, HZVV)	MAP34460
C	MAP34470
C PURPOSE- CHANGE FIELD COMPONENTS FROM CYLINDRICAL TO CARTESIAN	MAP34480

mapint.for

```

B0 = 1.0
B1 = 0.0
B2 = 0.0
TB0 = 1.0
TB1 = 0.0
IF (ABS (RHO) .GE.1.0E-06) THEN
  B0 = BFJ0 (ARX)
  B1 = BFJ1 (ARX)
  B2 = BFJ2 (B1, B0, ARX)
  TB0 = BFJ0 (TARX)
  TB1 = BFJ1 (TARX)
END IF
HHR = HHR + (B0-B2)*EX
HHP = HHP + (B0+B2)*EX
HHZ = HHZ + 2.0*B1*EX
C
  THR = THR + TB1*TEX
  THZ = THZ + TB0*TEX
C
C
C 100 CONTINUE
C
HHR = HHR*CSPPS*CSPH
HHP = HHP*CSPPS*SNPH
HHZ = HHZ*CSPPS*CSPH
THR = THR*SNPS
THZ = THZ*SNPS
C
C
HHR = - HHR + THR
HHP = + HHP
HHZ = - HHZ - THZ
C
  OUTPUT IN SPHERICAL COORDINATES
HR = HHR*ST + HHZ*CT
HT = HHR*CT - HHZ*ST
H2 = HHP
C
  RETURN
  END
C *****: ATAN3
  FUNCTION ATAN3 (Y, X)
C
  PI = 3.1415926535
  ATAN3 = 0.00
  IF ((X.NE.0.0).OR.(Y.NE.0.0)) ATAN3 = ATAN2 (Y, X)
C
  RETURN
  END
C *****: BFJ0
  FUNCTION BFJ0 (X)
C
  PURPOSE- CALCULATE BESSEL FUNCTION J0 (X)
  USING 9.4.1 AND 9.4.3 OF REF2 TO ORDER 12 APPROXIMATION
C
  INPUT- X, ARGUMENT OF THE BESSEL FUNCTION
C
  OUTPUT- BFJ0 (X), =J0 (X)
C
  DATA A1/-2.2499997/, A2/1.2656208/, A3/-0.3163866/, A4/0.0444479/,
1 A5/-0.0039444/, A6/0.00021/, B0/0.79788456/, B1/-0.0000077/,
2 B2/-0.0055274/, B3/-0.00009512/, B4/0.00137237/, B5/-0.00072805/,
3 B6/0.00014476/, C0/-0.78539816/, C1/-0.04166397/, C2/-0.00003954/,
4 C3/0.00262573/, C4/-0.00054125/, C5/-0.00029333/, C6/0.00013558/
C
  X0=ABS (X)
  T=X0/3.0

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MAP35130
MAP35140
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MAP35700
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MAP35740
MAP35750
MAP35760

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C
  IF (T.LT.1.0) THEN
C
    USE EQ. 9.4.1
    T=T*T
    H1=1.0+T*(A1+T*(A2+T*(A3+T*(A4+T*(A5+T*A6))))
    BFJ0=H1
  ELSE
C
    USE EQ. 9.4.3
    T=1.0/T
    H2 =B0+T*(B1+T*(B2+T*(B3+T*(B4+T*(B5+T*B6))))
    H3=X0+C0+T*(C1+T*(C2+T*(C3+T*(C4+T*(C5+T*C6))))
    BFJ0=H2*COS(H3)/SQRT(X0)
  END IF
  RETURN
  END
C *****:      BFJ1
  FUNCTION BFJ1(X)
C
C  PURPOSE-   CALCULATE BESSEL FUNCTION J1(X)
C             USING 9.4.4 AND 9.4.6 REF2 TO ORDER 12 APPROXIMATION
C  INPUT-    X, ARGUMENT OF BESSEL FUNCTION
C  OUTPUT-   BFJ1, BESSEL FUNCTION J1(X)
C
  DATA A1/-.56249985/,
1  A2/.21093573/,A3/-.03954289/,A4/.00443319/,A5/-.00031761/,
2  A6/.00001109/,B0/.79788456/,B1/.00000156/,B2/.01659667/,
3  B3/.00017105/,B4/-.00249511/,B5/.00113653/,B6/-.00020033/,
4  C0/-2.35619449/,C1/.12499612/,C2/.0000565/,C3/-.00637879/,
5  C4/.00074348/,C5/.00079824/,C6/-.00029166/
C
  X0=ABS(X)
  X1=SIGN(1.0,X)
  T=X0/3.0
C
  IF (T.LT.1.0) THEN
C
    USE 9.4.4
    T=T*T
    H1=0.5+T*(A1+T*(A2+T*(A3+T*(A4+T*(A5+T*A6))))
    BFJ1=X*H1
  ELSE
C
    USE 9.4.6
    T=1.0/T
    H2=B0+T*(B1+T*(B2+T*(B3+T*(B4+T*(B5+T*B6))))
    H3=X0+C0+T*(C1+T*(C2+T*(C3+T*(C4+T*(C5+T*C6))))
    BFJ1=X1*H2*COS(H3)/SQRT(X0)
  END IF
  RETURN
  END
C *****:      BFJ2
  FUNCTION BFJ2(B1,B0,X)
C
C  PURPOSE-   CALCULATE BESSEL FUNCTION J2(X) USING 9.1.27 REF2
C  INPUT-    B1, J1(X) BESSEL FROM FUNCTION BFJ1
C             B0, J0(X) BESSEL FROM FUNCTION BFJ0
C             X, ARGUMENT OF BESSEL FUNCTIONS
C  OUTPUT-   BFJ2, BESSEL J2(X)
C
  BFJ2 = 0.0
  IF(X.GT.0.0) THEN
    BFJ2 = (2./X) * B1 - B0
  END IF
C
  RETURN
  END

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MAP35770
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 MAP36140
 MAP36150
 MAP36160
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 MAP36250
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 MAP36290
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 MAP36310
 MAP36320
 MAP36330
 MAP36340
 MAP36350
 MAP36360
 MAP36370
 MAP36380
 MAP36390
 MAP36400

mapint.for

```

C *****: CFITA
SUBROUTINE CFITA(RR,HR,HZ,HP)
C
C PURPOSE- CALCULATE CHAPMAN-FERRARO FIELD OF IMF OUTSIDE CYLINDER
C INPUT- RR RHO IN CYLINDRICAL COORDINATES
C OUTPUT- HR,HZ,HP CYLINDRICAL FIELD COMPONENTS
C VARIABLES- HIMF, STRENGTH OF IMF FIELD
C XI, IMF ANGLE
C R, RADIUS OF MAGNETOPAUSE SPHERE AND TAIL
C
COMMON /BLOCK1/ BEX, R, Q, PI, PSI
COMMON /FIMF/ HIMF, CDIPOL, CIMF, XI
C
C GET IMF FIELD COMPONENTS
CALL BIMF(HIMF,XI, D1,D2,D3,D4,D5,D6,D7, HR3,HZ3,HP3)
C
FR = R/RR
FR = FR*FR*FR
C
C COMPONENTS DERIVED FROM 5.30 REF1
HR = - HR3 * FR
HZ = + 0.5 * HZ3 * FR
HP = + 0.5 * HP3 * FR
C
RETURN
END
C *****: FUN2
SUBROUTINE FUN2(N,NDIM)
C
C PURPOSE- CALCULATE INTEGRAND FOR FOURIER-BESSEL INTEGRALS. ONE
C FOR EACH OF NDIM GRID POINTS. DONE FOR TILT 0 AND 90 DEG
C INPUT- N, ORDER OF BESSEL FUNCTION
C NDIM, NUMBER OF GRID POINTS
C OUTPUT- Y1,Y0 INTEGRANDS FOR TILT 0, 90 DEGREES, 5.24,5.25 REF1
C OUTPUT TO BLOCK 9
C VARIABLES- ZE, ZEROS OF DERIVATIVES OF BESSEL J1
C ZO, " " " " " J0
C X, RADIAL VALUES OF GRID POINTS
C R, RADIUS OF TAIL CYLINDER
C
COMMON /BLOCK8/ W1(1001),W0(1001)
COMMON /BLOCK9/ X(1001),Y1(1001),Y0(1001),Z1(1001),Z0(1001), HS
COMMON /BLOCK1/ B ,R, Q, PI, PSI
COMMON /BLOCK2/ ZE(20), AX(20), ZO(20), BX(20)
C
C DO 1 I = 1, NDIM
C ARGUMENTS OF BESSELS
ARX = ZE(N) * X(I) / R
TARX = ZO(N) * X(I) / R
C SET BESSEL VALUES FOR VERY SMALL ARGUMENTS
B1 = 0.0
B0 = 1.0
IF(ABS(X(I)).GE.1.0E-06) THEN
C GET BESSEL FUNCTION VALUES J1 AND J0
B1 = BFJ1(ARX)
B0 = BFJ0(TARX)
END IF
C INTEGRANDS OF 5.24 AND 5.25 REF1
Y1(I) = X(I) * W1(I) * B1
Y0(I) = X(I) * W0(I) * B0
1 CONTINUE
C
C

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MAP36410
MAP36420
MAP36430
MAP36440
MAP36450
MAP36460
MAP36470
MAP36480
MAP36490
MAP36500
MAP36510
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MAP36580
MAP36590
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MAP36690
MAP36700
MAP36710
MAP36720
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MAP36750
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MAP36790
MAP36800
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MAP36900
MAP36910
MAP36920
MAP36930
MAP36940
MAP36950
MAP36960
MAP36970
MAP36980
MAP36990
MAP37000
MAP37010
MAP37020
MAP37030
MAP37040

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RETURN
END
C *****: LEGEN
SUBROUTINE LEGEN(T,NE)
C
C PURPOSE- CALCULATE LEGENDRE POLYNOMIAL TERMS
C INPUT- T, THETA OF SPHERICAL SYSTEM
C NE, ORDER OF LEGENDRE POLYNOMIAL
C OUTPUT- PN, LEGENDRE POLYNOMIAL TERMS M=0
C PN, DERIVATIVE OF PN W.R.T. COS(T)
C PNM, LEGENDRE POLYNOMIAL TERMS M=1
C
COMMON /LEG1/ PN(20), PNM(20), CPN(20)
COMMON /BLOCK6/ C1, S1
C
C1 = COS(T)
S1 = SIN(T)
C
C2 = C1*C1 - S1*S1
S2 = 2.*S1*C1
C
PN(1) = C1
PN(2) = 0.25*(3.*C2+1.)
C
CPN(1) = 1.0
CPN(2) = 3.*C1
C
PNM(1) = + S1 * CPN(1)
PNM(2) = + S1 * CPN(2)
C
C
IF (NE.LT.3) RETURN
IF (NE.EQ.3) NELE= 4
IF (NE.GT.3) NELE= NE
C
DO 1 N=3,NELE
FN = FLOAT(N)
ZFE = 2.*FN - 1.0
C RECCURRENCE RELATION FROM REF3 JAHNKE-EMDE NORMALIZED
PN(N) = (1./FN) * (ZFE*C1*PN(N-1) - (FN-1.)*PN(N-2))
CPN(N) = ZFE*PN(N-1) + CPN(N-2)
PNM(N) = + S1*CPN(N)
1 CONTINUE
C
C
RETURN
END
C *****: BTATA
SUBROUTINE BTATA(Z,RHO,HHR,HHZ,HHP)
C
C PURPOSE- CALCULATE COMPONENTS OF TAILFIELD SOLUTION FOR ZV>0
C INCLUDING STRETCH,SUMMARIES 6.3 AND 6.4 REF1
C INPUT- Z,RHO CYLINDRICAL COORDINATES
C OUTPUT- HHR,HHZ,HHP CYLINDRICAL FIELD COMPONENTS
C VARIABLES- ALFA, PLASMA CONTENT STRETCH PARAMETER
C SNPH,CSPH SIN AND COS OF PHI, A CYLINDRICAL COORDINATE
C SNPS,CSPS SIN AND COS OF PSI, THE DIPOLE TILT ANGLE
C AX,BX COEFFICIENTS FOR FOURIER-BESSEL SERIES
C R, RADIUS OF TAIL
C ZE,ZO ZEROS OF BESSEL FUNCTION DERIVATIVES 5.25 REF1
C
COMMON /BLOCK1/ B,R,Q,PI,PSI
COMMON /BLOCK2/ ZE(20),AX(20),ZO(20),BX(20)
COMMON /BLOCK5/CSPH,SNPH,QCS,QSN,CSPS,SNPS

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MAP37050
MAP37060
MAP37070
MAP37080
MAP37090
MAP37100
MAP37110
MAP37120
MAP37130
MAP37140
MAP37150
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MAP37180
MAP37190
MAP37200
MAP37210
MAP37220
MAP37230
MAP37240
MAP37250
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MAP37280
MAP37290
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MAP37390
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MAP37410
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MAP37450
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MAP37470
MAP37480
MAP37490
MAP37500
MAP37510
MAP37520
MAP37530
MAP37540
MAP37550
MAP37560
MAP37570
MAP37580
MAP37590
MAP37600
MAP37610
MAP37620
MAP37630
MAP37640
MAP37650
MAP37660
MAP37670
MAP37680

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```
COMMON /BLOCK6/ CT,ST
COMMON /BLOCK3/ H0,ALFA,KSWIT

C
HHR = 0.0
HHZ = 0.0
HHP = 0.0
THR = 0.0
THZ = 0.0
D = 1.0E-02

C
IF (ABS (ALFA) .LT. 1.0E-06) THEN
  ALFA = 1.0E-06
END IF

C
FL = 0.5 * (1.-ALFA)

C
C
DO 100 I = 1,15
  ARGUMENTS OF BESSEL FUNCTIONS
  ARX = ZE(I)/R*RHO
  TARX = ZO(I)/R*RHO

  ARZ = ZE(I)/R*Z
  TARZ = ZO(I)/R*Z

  FLZX = ALFA * ARZ
  FLZY = ALFA * TARZ

  EX = 0.0
  TEX = 0.0
  IF ((ARZ.LT.170.) .AND. (TARZ.LT.170.)) THEN
    EX = EXP(-ARZ)
    TEX = EXP(-TARZ)

  EX = EX * FL * AX(I)
  TEX = TEX * FL * BX(I)
  END IF

  FLEX = 0.0
  FLEY = 0.0
  IF ((FLZX.LT.170.) .AND. (FLZY.LT.170.)) THEN
    FLEX = EXP(-FLZX)
    FLEY = EXP(-FLZY)
  END IF

  FLEX = FLEX * ALFA * AX(I)
  FLEY = FLEY * ALFA * BX(I)

  B0 = 1.0
  B1 = 0.0
  B2 = 0.0
  TB0 = 1.0
  TB1 = 0.0

  IF (ABS (RHO) .GE. 1.0E-06) THEN
    GET BESSEL FUNCTION
    B0 = BFJ0 (ARX)
    B1 = BFJ1 (ARX)
    B2 = BFJ2 (B1,B0,ARX)
    TB0 = BFJ0 (TARX)
    TB1 = BFJ1 (TARX)
  END IF

  HHR = HHR + (B0-B2) * (FLEX + EX)
```

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MAP37690
MAP37700
MAP37710
MAP37720
MAP37730
MAP37740
MAP37750
MAP37760
MAP37770
MAP37780
MAP37790
MAP37800
MAP37810
MAP37820
MAP37830
MAP37840
MAP37850
MAP37860
MAP37870
MAP37880
MAP37890
MAP37900
MAP37910
MAP37920
MAP37930
MAP37940
MAP37950
MAP37960
MAP37970
MAP37980
MAP37990
MAP38000
MAP38010
MAP38020
MAP38030
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MAP38060
MAP38070
MAP38080
MAP38090
MAP38100
MAP38110
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MAP38140
MAP38150
MAP38160
MAP38170
MAP38180
MAP38190
MAP38200
MAP38210
MAP38220
MAP38230
MAP38240
MAP38250
MAP38260
MAP38270
MAP38280
MAP38290
MAP38300
MAP38310
MAP38320
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mapint.for

```

HHP = HHP + (B0+B2) * (FLEX + EX)
HHZ = HHZ + 2.*B1 * (FLEX/ALFA + EX)
C
THR = THR + TB1 * (FLEY + TEX)
THZ = THZ + TB0 * (FLEY/ALFA + TEX)
C
100 CONTINUE
C      SUPERPOSITION OF 0 AND 90 DEGREE TILT CASES
HHR = HHR*CSPS*CSPH
HHP = HHP*CSPS*SNPH
HHZ = HHZ*CSPS*CSPH
THR = THR*SNPS
THZ = THZ*SNPS
C
C
HHR = +HHR -THR
HHP = -HHP
HHZ = -HHZ -THZ
C
RETURN
END
C *****: VACTA
SUBROUTINE VACTA(Z,RR,HHR,HHZ,HHP)
C
C PURPOSE- CALCULATE NIGHTSIDE (ZV>0) VACUUM FIELD COMPONENTS OF
C           TAIL SOLUTION FROM POTENTIAL 5.26 REF1. SOLUTION
C           INCLUDES DIPOLE PLUS CHAPMAN-FERRARO. FIRST CALLED ON
C           SECOND ITERATION AS FIRST ITER. HAS ANALYTIC COEFFICIENTS
C INPUT-    Z,RR Z AND RHO OF CYLINDRICAL SYSTEM
C OUTPUT-   HHR,HHZ,HHP FIELD COMPONENTS IN CYLINDRICAL SYSTEM
C VARIABLES- ZE,ZO ZEROS OF DERIVATIVES OF BESSELS J1 AND J0
C           AX,BX COEFFICIENTS OF FOURIER-BESSEL SERIES FROM TAILCOM
C           5.24 AND 5.25 REF1
C           R, RADIUS OF TAIL
C           SNPS,CSPS SIN AND COS OF PSI, THE DIPOLE TILT ANGLE
C           SNPH,SNPH SIN AND COS OF PHI, A CYLINDRICAL COORDINATE
C
COMMON /BLOCK1/ B,R,Q,PI,PSI
COMMON /BLOCK2/ ZE(20),AX(20),ZO(20),BX(20)
COMMON /BLOCK5/ CSPH,SNPH,QCS,QSN,CSPS,SNPS
COMMON /BLOCK6/ CT,ST
C
HHR = 0.0
HHZ = 0.0
HHP = 0.0
THR = 0.0
THZ = 0.0
D = 1.0E-02
C
C
DO 100 I = 1,15
C      ARGUMENTS FOR BESSEL FUNCTIONS
ARX = ZE(I)/R*RR
ARZ = ZE(I)/R*Z
TARX = ZO(I)/R*RR
TARZ = ZO(I)/R*Z
C
EX = 0.0
TEX = 0.0
C
IF ((ARZ.LT.170.).AND.(TARZ.LT.170.)) THEN
EX = EXP(-ARZ)
EX = EX*AX(I)

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MAP38330
MAP38340
MAP38350
MAP38360
MAP38370
MAP38380
MAP38390
MAP38400
MAP38410
MAP38420
MAP38430
MAP38440
MAP38450
MAP38460
MAP38470
MAP38480
MAP38490
MAP38500
MAP38510
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MAP38580
MAP38590
MAP38600
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MAP38670
MAP38680
MAP38690
MAP38700
MAP38710
MAP38720
MAP38730
MAP38740
MAP38750
MAP38760
MAP38770
MAP38780
MAP38790
MAP38800
MAP38810
MAP38820
MAP38830
MAP38840
MAP38850
MAP38860
MAP38870
MAP38880
MAP38890
MAP38900
MAP38910
MAP38920
MAP38930
MAP38940
MAP38950
MAP38960

```

TEX = EXP(-TARZ)
TEX = TEX*BX(I)
END IF
C
B0 = 1.0
B1 = 0.0
B2 = 0.0
TB0 = 1.0
TB1 = 0.0
C
IF (ABS(RR) .GE. 1.0E-06) THEN
  B0 = BFJ0(ARX)
  B1 = BFJ1(ARX)
  B2 = BFJ2(B1,B0,ARX)
  TB0 = BFJ0(TARX)
  TB1 = BFJ1(TARX)
END IF
C
HHR = HHR + (B0-B2)*EX
HHP = HHP + (B0+B2)*EX
HHZ = HHZ + 2.0*B1*EX
C
THR = THR + TB1*TEX
THZ = THZ + TB0*TEX
C
100 CONTINUE
C
SUPERIMPOSE 0 AND 90 DEGREE TILT CASES
HHR = HHR*CSPS*CSPH
HHP = HHP*CSPS*SNPH
HHZ = HHZ*CSPS*CSPH
THR = THR*SNPS
THZ = THZ*SNPS
C
C
HHR = +HHR -THR
HHP = -HHP
HHZ = -HHZ -THZ
C
RETURN
END
C *****: TAPOT
SUBROUTINE TAPOT(NDIM)
C
C PURPOSE- GET SUM OF CHAPMAN-FERRARO AND DIPOLE POTENTIALS AT NDIM
C LOCATIONS ON THE CYLINDER CAP ZV=0
C INPUT- NDIM, NUMBER OF GRID POINTS FOR INTEGRATION
C OUTPUT- W1,W0 SUM OF POTENTIALS FOR TILTS 0 AND 90 DEGREE
C OUTPUT IS POTENTIAL*(1/DIPOLE MOMENT0
C VARIABLES- HS, GRID SIZE
C R, RADIUS OF TAIL
C X, RADIAL POSITIONS OF GRID POINTS
C
COMMON /BLOCK8/ W1(1001),W0(1001)
COMMON /BLOCK9/ X(1001),Y1(1001),Y0(1001),Z1(1001),Z0(1001), HS
COMMON /BLOCK1/ B, R, Q, PI, PSI
C
C GENERATE GRID POINTS ON CYLINDER CAP
X(1) = 0.0
HS = R/FLOAT(NDIM-1)
DO 1 I = 2, NDIM
  X(I) = FLOAT(I-1) * HS
1 CONTINUE
C
C GET POTENTIALS OF CHAPMAN-FERRARO TILT 0 AND 90 DEGREES

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MAP38970
MAP38980
MAP38990
MAP39000
MAP39010
MAP39020
MAP39030
MAP39040
MAP39050
MAP39060
MAP39070
MAP39080
MAP39090
MAP39100
MAP39110
MAP39120
MAP39130
MAP39140
MAP39150
MAP39160
MAP39170
MAP39180
MAP39190
MAP39200
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MAP39400
MAP39410
MAP39420
MAP39430
MAP39440
MAP39450
MAP39460
MAP39470
MAP39480
MAP39490
MAP39500
MAP39510
MAP39520
MAP39530
MAP39540
MAP39550
MAP39560
MAP39570
MAP39580
MAP39590
MAP39600

mapint.for

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C          EQ. 5.18-5.20 REF1
DO 2 I = 1, NDIM
  CALL CFPOT(X(I),POT1,POT0)
  W1(I) = POT1
  W0(I) = POT0
2 CONTINUE
C
C          GET POTENTIALS OF DIPOLE,TILT 0 AND 90 DEGREES 5.17 REF1
DO 3 I = 1, NDIM
  CALL DIPOT(X(I),POT1,POT0)
  W1(I) = W1(I) + POT1
  W0(I) = W0(I) + POT0
3 CONTINUE
C
C          RETURN
END
C *****: CFPOT
  SUBROUTINE CFPOT(RR,POT1,POT0)
C
C PURPOSE- CALCULATE CHAPMAN-FERRARO POTENTIAL FOR A POINT AT THE
C           CYLINDER LID, ZV=0. USES 5.11 WITH THETA=90 DEGREES,
C           EQUIVALENT TO 5.18-5.20 REF1. BOTH TILT CASES 0 AND 90
C           DEGREES DONE.
C INPUT-   RR, RHO IN CYLINDRICAL, DISTANCE FROM TAIL AXIS
C OUTPUT-  POT1, POTENTIAL FOR 0 DEGREE TILT CASE
C           POT0, POTENTIAL FOR 90 DEGREE TILT CASE
C           OUTPUT IS ACTUALLY POTENTIAL*(-1/DIPOLE MOMENT)
C VARIABLES- QR, DIPOLE MOMENT
C            P1,PO LEGENDRE POLYNOMIAL TERMS FOR M=1 AND 0, RESPECT.
C            G1,G0 COEFFICIENTS OF LEGENDRE TERMS, M=1 AND 0 RESPECT.
C            R, RADIUS OF TAIL
C
COMMON /BLOCK1/ B, R, Q, PI, PSI
COMMON /CHABLO/ G1(20), G0(20)
C
DIMENSION P0(21), P1(21)
C
C          LEGENDRE TERMS WITH THETA=90 DEGREES
P0(2) = - 0.5
P1(1) = + 1.0
P1(3) = 3.*P0(2)
C
C
DO 1 NY = 2, 10
  EVERY OTHER TERM IS ZERO, RECURRENCE RELATION USED
  SUBROUT. LEGEN NOT CALLED
  ZFNY = 2.*FLOAT(NY)
  FAKNY = (ZFNY-1.)/ZFNY
  P0(2*NY) = - P0(2*NY-2) * FAKNY
  P1(2*NY+1) = + (ZFNY+1.) * P0(2*NY)
1 CONTINUE
C
C          TILT = 0 DEGREES CASE
RRP = RR
RP = (RR*RR)/(R*R)
C
POT1 = G1(1) * P1(1) * RRP
C
DO 2 NY = 1, 9
  ZFE = FLOAT(2*NY+1)
  RRP = RRP * RP
  POT1 = POT1 + G1(2*NY+1) * P1(2*NY+1) * RRP / ZFE
2 CONTINUE

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MAP39610
MAP39620
MAP39630
MAP39640
MAP39650
MAP39660
MAP39670
MAP39680
MAP39690
MAP39700
MAP39710
MAP39720
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MAP39740
MAP39750
MAP39760
MAP39770
MAP39780
MAP39790
MAP39800
MAP39810
MAP39820
MAP39830
MAP39840
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MAP39870
MAP39880
MAP39890
MAP39900
MAP39910
MAP39920
MAP39930
MAP39940
MAP39950
MAP39960
MAP39970
MAP39980
MAP39990
MAP40000
MAP40010
MAP40020
MAP40030
MAP40040
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MAP40070
MAP40080
MAP40090
MAP40100
MAP40110
MAP40120
MAP40130
MAP40140
MAP40150
MAP40160
MAP40170
MAP40180
MAP40190
MAP40200
MAP40210
MAP40220
MAP40230
MAP40240

```
C      QR = Q * (R**3)
      POT1 = -POT1/QR
C
C      TILT = 90 DEGREE CASE
C      RRP = R
      RP = (RR*RR)/(R*R)
C
C      POT0 = 0.0
C
      DO 3 NY = 1, 10
        ZFE = FLOAT(2*NY)
        RRP = RRP * RP
        POT0 = POT0 + G0(2*NY) * P0(2*NY) * RRP / ZFE
3     CONTINUE
C
      QR = Q * (R**3)
      POT0 = -POT0/QR
C
      RETURN
      END
C *****:      DIPOT
      SUBROUTINE DIPOT(RR,POT1,POT2)
C
C PURPOSE-  CALCULATE DIPOLE POTENTIAL AT LID OF CYLINDER USING 5.17
C           REF1 FOR TILT 0 AND 90 DEGREE CASES
C INPUT-    RR, RHO IN CYLINDRICAL, DISTANCE FROM TAIL AXIS
C           B, = RADIUS MINUS STAND-OFF DISTANCE
C OUTPUT-   POT1,POT2 DIPOLE POTENTIAL FOR TILT 0 AND 90 DEGREES
C           OUTPUT IS POTENTIAL*(-1/DIPOLE MOMENT)
C
      COMMON /BLOCK1/ B, R, Q, PI, PSI
C
      RRB = SQRT(RR*RR + B*B)
      RRB = RRB**3
C
      POT1 = + RR / RRB
      POT2 = + B / RRB
C
      RETURN
      END
```

MAP40250
MAP40260
MAP40270
MAP40280
MAP40290
MAP40300
MAP40310
MAP40320
MAP40330
MAP40340
MAP40350
MAP40360
MAP40370
MAP40380
MAP40390
MAP40400
MAP40410
MAP40420
MAP40430
MAP40440
MAP40450
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MAP40470
MAP40480
MAP40490
MAP40500
MAP40510
MAP40520
MAP40530
MAP40540
MAP40550
MAP40560
MAP40570
MAP40580
MAP40590
MAP40600
MAP40610
MAP40620
MAP40630
MAP40640
MAP40650

Appendix E

MSM Reference List: Correlation Studies

Compiled by R. V. Hilmer. Reference numbers correspond to the numbers on associated source chart. Note that "*author" means copy available

<u>No.</u>	<u>First Author</u>	<u>Source</u>
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		Kp	Dst	AE	ap	Bx	By	Bz(Bs)	Bz*Bz
1	Stand-Off	390 1020 1030	420 1020 1180	8)	940			388	
2	Cusp Latitude	630 790	630 840 850	300 310 630 1300				200 220 300 310 630 690 850 1070 1080 1177 1300	
3	Plasma Sheet	460 710 780							
4	Plasmopause	320 330 700 1060 1220	320						
5	PC Latitudes	340 380 410 420 500 1175	10 1120 1130	380 382 775		80 830	80 830	80 380 382 530 590 830	530
6	PC Potential	530 540 670 700 970 1175		970 1110		427	427	427 970 1110 1175	427
7	PC Precipitation	290 495 502		768 775		975	290 975	290 495 768	
8	Kp	XXXXXXXXXXXX XXXXXXXXXXXX					880	170 560	170 1090
9	Dst		XXXXXXXXXXXX XXXXXXXXXXXX					250 600 610 660 900 920 1040	
10	AE		40	XXXXXXXXXX XXXXXXXXXX		600 220	800 880	100 130 140 450 490 600 800 820	490
11	AL					220	510 890	510 600 610 900	740
12	AU					220		600 610	740
13	Ap	560			XXXXX XXX			370 490	490
14	Am								740
15	N(S W Density)	980	980					980	980
16	Tail Lobe Ener. D.	1010						260 270 283	520
17	U(magn. ener. dis.)		60					140	
18	Delta B(magn)		1190						

	B Var.	Tilt	SW(T)	SW(deg)	PC Lat	SORT
1					1020	a
2		200				b
3						d
4						e
5	960	420				f
6						g
7			975			h
8	150 560		170			i
9						j
10	490			800		k
11	740 750 890	90 890	750	740 750		l
12	740 750	90	750	740 750		m
13	490 620					n
14	740 750		750	740 750		o
15	980					q
16						r
17						s
18						u