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MAGLIB

USER'S MANUAL OF MAGLIB LIBRARY:

GEOGRAPHIC, GEOPHYSICS AND GEOMAGNETIC CALCULATION

ROUTINES

PLASMA-LO-MAGLIB-00066-CN

VERSION	REVISION	DATE
1	0	23/11/1998
1	1	10/11/2000
2	0	24/10/2001
2	1	08/01/2003
3	0	01/01/2007
4	0	01/12/2010

MAGLIB

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1. INTRODUCTION

This document describes a set of 40 programs delivered jointly with the maglib library.
The maglib library provides geographic, geophysics and geomagnetic calculation routines. These routines are described in the document: "MAGLIB - Reference Manual of MAGLIB Library: Geographic, Geophysics and Geomagnetic Calculation Modules". The programs described in this document give examples of how to use these routines.

The MAGLIB library and the users programs are coded in fortran77.

Revision 4.0

The test routines have been updated according to the changes in the internal magnetic field models and epochs. New test routines have been introduced to test the new calculations:

- testchp10
- testgrad10
- testdgn95_10
- 'testsolter10'

- rename test'solter' to 'testsolter00'
- rename 'testsoltern' to 'testsolter05'

3. USER PROGRAMS

Maglib library is delivered with 40 user programs:

- starting routines and coordinate transformations,
- boundaries and regions,
- magnetic field models,
- magnetospheric physics calculations,
- astronomy and celestial mechanics,
- control and date routines.

Several user programs use both the date calculation routines and the mathematics routines.

Each user program is delivered with:

- source code,
- associated makefile,
- file of results.

2. GENERATING AND USING MAGLIB LIBRARY UNDER UNIX SYSTEM

2.1 GENERATING MAGLIB LIBRARY

The maglib routines and the associated makefile and directories are compressed in a "tar" type file named :

00064.tar

We recommend to create a "maglib" dedicated directory. Then you shall copy the 00064.tar file into this directory before you uncompress it.

To uncompress this file the command is:

tar xvf 00064.tar

The "src", "bin", "gen" and "lib" directories are installed.

- The "src" directory contains all the source code files of the maglib routines.
- The "gen" directory contains the makefile named "Makefile".
- The "bin" directory is empty ; it will contain the object files after make file is performed.
- The "lib" directory is empty ; it will contain the maglib library named "maglib.a" after make file is performed.

To perform the makefile, the commands are:

cd gen
make -f Makefile_f77

Nota: if you want to use the GNU compiler, use "Makefile_**g**77" instead of "Makefile_**f**77".

2.2 GENERATING USER'S PROGRAMS

The user's programs and associated makefiles and files of results are compressed in a "tar" type file named:

00065.tar

We recommend to copy the 00065.tar file into the maglib dedicated directory before you uncompress it.

To uncompress this file the command is:

tar xvf 00065.tar

The "test" directory is installed. It contains all the useful files.
The file named "**make_tests.sh**" performs all the makefiles for each user's program.

The MAGLIBHOME variable shall be set:

in cshell: **setenv MAGLIBHOME "access path to maglib.a"**

in kshell: **export MAGLIBHOME="access path to maglib.a"**

To perform all makefiles the command is:

./**make_test.sh**

To perform a specific makefile the command is:

./**make_test.sh <module>**

Example:
./make_test chp00

NOTE: If you want to add a new module, you must add it
in the variable script: 'DEFAULT_MODULES'

EXAMPLE OF A MAKEFILE LINKING maglib.a LIBRARY:

```
#
# --------------------------------------------------------------------
#
#PRO MAGLIB
#
#VER 99.03.31 - v 1.0
#AUT CISI
#
#ROL Compilation file
#ROL         - System: UNIX
#ROL         - Creating the user's program: testxxx
#
#HST version 1.0 - 99.03.31 - creation
#
# --------------------------------------------------------------------
#
# $Header$
#
#   ========================
#FON Path and name of the library
#   ========================
#
LIB_MAGLIB = $(MAGLIBHOME)/maglib.a
#
#==================================
#FON Compilation of the source file and linking
#==================================
#
all:
	f77 -g testxxx.f $(LIB_MAGLIB) -lm -o testxxx
```

3. STARTING ROUTINES AND COORDINATE TRANSFORMATIONS

3.1 TESTCOORD

Purpose:

This program performs coordinate transformations for each month in year 2012. It calculates the solar magnetospheric (GSM) and the solar ecliptic (GSE) coordinates.

- Calculation of all the rotation matrices and of the different angles used in all the calculation routines for all epochs from January 2000 the 1st to December 2014 the 31st (**inigeom**).
- Transformation of the geocentric components of a vector into solar magnetospheric components (**geogsm**).
- Transformation of the geocentric components of a vector into solar ecliptic components (**geose**).

Input data:

Data set in the program:

the initial calculation date: year = 2012, month = 1, day = 21, hours = 0, minutes = 0, seconds = 0
($0 \leq$ hours ≤ 12, 3 hours step), ($1 \leq$ month ≤ 12, 1 month step),

the x, y and z geocentric coordinates: xg = 5.0 Re, yg = 5.0 Re, zg = 5.0 Re.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

a header line giving the x, y and z coordinates in the geocentric system,

a line for each input:

the calculation date (year, month, day, hours, minutes and seconds),
tilt angle (deg),
the x, y and z coordinates in the solar magnetospheric system (Re),
the x, y and z coordinates in the solar ecliptic system (Re).

Example:

xg,yg,zg 5.000 5.000 5.000

date	2012	1	21	0	0	0	tilt	-22.304	gsm	-6.633	-5.196	2.001	gse	-6.633	-4.024	3.849
date	2012	1	21	3	0	0	tilt	-28.489	gsm	-2.034	-7.477	3.867	gse	-2.034	-5.915	5.989
date	2012	1	21	6	0	0	tilt	-29.536	gsm	2.753	-4.910	6.581	gse	2.753	-3.751	7.304
date	2012	1	21	9	0	0	tilt	-24.697	gsm	4.927	0.822	7.074	gse	4.927	1.203	7.020
date	2012	1	21	12	0	0	tilt	-17.172	gsm	3.215	5.804	5.566	gse	3.215	6.045	5.303
date	2012	1	21	15	0	0	tilt	-11.348	gsm	-1.381	7.459	4.179	gse	-1.381	7.942	3.165
date	2012	1	21	18	0	0	tilt	-10.358	gsm	-6.168	5.096	3.314	gse	-6.168	5.786	1.864
date	2012	1	21	21	0	0	tilt	-14.718	gsm	-8.342	-0.009	2.326	gse	-8.342	0.843	2.167
date	2012	1	21	24	0	0	tilt	-22.075	gsm	-6.627	-5.194	2.027	gse	-6.627	-3.988	3.896
date	2012	2	21	0	0	0	tilt	-13.102	gsm	-6.137	-5.291	3.057	gse	-6.137	-2.986	5.331

Remarks:

The file of results is named rescoord.

One must have xgsm = xgse.

Called routines:

valfix inigeom geogsm geose

3.2 TESTINIGE

Purpose:

This program calculates all the transformation matrices for several epochs. It also calculates the different angles: tilt angle, orientation of the dipole axis, right ascension and declination of the Sun. Then it transforms the geocentric coordinates into solar ecliptic (GSE), solar magnetospheric (GSM) and solar magnetic (SM) coordinates.
These calculations are done for all epochs from January 2000 the 1st to December 2014 the 31st.

- Calculation of all the rotation matrices and of the different angles used in all the calculation routines for all epochs from January 2000 the 1st to December 2014 the 31st (**inigeom**).
- Transformation of the geocentric components of a vector into solar ecliptic components (**geose**).
- Transformation of the geocentric components of a vector into solar magnetospheric components (**geogsm**).
- Transformation of the geocentric components of a vector into solar magnetic components (**geosm**).

Input data:

Data set in the program:

the initial calculation date: year = 2012, month = 3, day = 21, hours = 12, minutes = 0, seconds = 0
(3 ≤ month ≤ 12, 3 months step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the calculation date (year, month, day, hours, minutes and seconds),
different calculated angles (deg),
a set of various transformation matrices,
the x, y and z coordinates in the solar ecliptic system (Re),
the x, y and z coordinates in the solar magnetospheric system (Re),
the x, y and z coordinates in the solar magnetic system (Re).

Example:

year,month,day,hours,min,sec 2012 3 21 12 0 0

alfagd,tetdipd,phidipd,alfasd,deltasd,tiltd 359.404 9.858 -72.395 1.168 0.506 3.178

rgdip	0.2980	-0.9391	-0.1712	0.9532	0.3024	0.0000	0.0518	-0.1632	0.9852
rgsm	0.9982	0.0399	-0.0459	-0.0318	0.9858	0.1649	0.0518	-0.1632	0.9852
rggsm	0.9995	0.0308	0.0088	-0.0318	0.9858	0.1649	-0.0036	-0.1651	0.9863
rig	0.9999	-0.0104	0.0000	0.0104	0.9999	0.0000	0.0000	0.0000	1.0000
rigsm	0.9998	0.0204	0.0088	-0.0216	0.9861	0.1649	-0.0053	-0.1651	0.9863
rgse	0.9995	0.0308	0.0088	-0.0317	0.9170	0.3977	0.0041	-0.3977	0.9175
rism	0.9985	0.0295	-0.0459	-0.0216	0.9861	0.1649	0.0501	-0.1637	0.9852
rise	0.9998	0.0204	0.0088	-0.0222	0.9173	0.3977	0.0000	-0.3978	0.9175

geog. coord.	-6.400	-1.696	0.098
gse coord.	-6.448	-1.313	0.738
gsm coord.	-6.448	-1.452	0.400
sm coord.	-6.460	-1.452	0.042

Remarks:

The different angles given (in degrees) in the file of results are:

alfagd	right ascension of Greenwich
tetdipd	geocentric colatitude of the point where the dipole cuts the northern hemisphere
phidipd	geocentric longitude of the point where the dipole cuts the northern hemisphere
alfasd	declination of the Sun
deltasd	right ascension of the Sun
tiltd	tilt angle between the solar magnetic equator and the geomagnetic equator

The transformation matrices given in the file of results are:

rgdip	transformation matrix (3,3) from the geocentric coordinate system into the dipolar coordinate system
rgsm	transformation matrix (3,3) from the geocentric coordinate system into the solar magnetic coordinate system
rggsm	transformation matrix (3,3) from the geocentric coordinate system into the solar magnetospheric coordinate system
rig	transformation matrix (3,3) from the inertial coordinate system into the geocentric coordinate system
rigsm	transformation matrix (3,3) from the inertial coordinate system into the solar magnetospheric coordinate system
rgse	transformation matrix (3,3) from the geocentric coordinate system into the solar ecliptic coordinate system
rism	transformation matrix (3,3) from the inertial coordinate system into the solar magnetic coordinate system
rise	transformation matrix (3,3) from the inertial coordinate system into the solar ecliptic coordinate system

One must have:
xgsm = xgse
ygsm = ysm

Called routines:

valfix	inigeom	promat	geose	geogsm	geosm

3.3 TESTINIGE1

Purpose:

This program calculates all the transformation matrices for the magnetospheric physics calculation of the CLUSTER spacecraft. It also calculates the different angles: tilt angle, orientation of the dipole axis, right ascension and declination of the Sun. Then it transforms the geocentric coordinates into solar ecliptic (GSE), solar magnetospheric (GSM) and solar magnetic (SM) coordinates.
These calculations are done for all epochs from January 2000 the 1st to December 2014 the 31st.

- Calculation of all the rotation matrices and of the different angles used in all the calculation routines specific for CLUSTER spacecraft (**inigeo1**).
- Transformation of the geocentric components of a vector into solar ecliptic components (**geose**).
- Transformation of the geocentric components of a vector into solar magnetospheric components (**geogsm**).
- Transformation of the geocentric components of a vector into solar magnetic components (**geosm**).

Input data:

Data set in the program:

the initial calculation date: year = 2012, month = 3, day = 21, hours = 12, minutes = 0, seconds = 0
(3 ≤ month ≤ 12, 1 month step),

the x, y and z geocentric coordinates: xg = -6.4 Re, yg = -1.696 Re, zg = 0.098 Re.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the calculation date (year, month, day, hours, minutes and seconds),
different calculated angles (deg),
a set of various transformation matrices,
the x, y and z coordinates in the solar ecliptic system (Re),
the x, y and z coordinates in the solar magnetospheric system (Re),
the x, y and z coordinates in the solar magnetic system (Re).

Example:

year,month,day,hours,min,sec 2012 3 21 12 0 0

alfagd,tetdipd,phidipd,alfasd,deltasd,tiltd 359.404 9.858 -72.395 1.168 0.506 3.178

rgdip	0.2980	-0.9391	-0.1712	0.9532	0.3024	0.0000	0.0518	-0.1632	0.9852
rgsm	0.9982	0.0399	-0.0459	-0.0318	0.9858	0.1649	0.0518	-0.1632	0.9852
rggsm	0.9995	0.0308	0.0088	-0.0318	0.9858	0.1649	-0.0036	-0.1651	0.9863
rigsm	0.9998	0.0204	0.0088	-0.0222	0.9173	0.3977	0.0000	-0.3978	0.9175
rsmgsm	0.9985	0.0000	0.0554	0.0000	1.0000	0.0000	-0.0554	0.0000	0.9985
rig	0.9999	-0.0104	0.0000	0.0104	0.9999	0.0000	0.0000	0.0000	1.0000
rgse	0.9995	0.0308	0.0088	-0.0317	0.9170	0.3977	0.0041	-0.3977	0.9175
rism	0.9985	0.0295	-0.0459	-0.0216	0.9861	0.1649	0.0501	-0.1637	0.9852
rise	0.9998	0.0204	0.0088	-0.0222	0.9173	0.3977	0.0000	-0.3978	0.9175

geog. coord.	-6.400	-1.696	0.098
gse coord.	-6.448	-1.313	0.738
gsm coord.	-6.448	-1.452	0.400
sm coord.	-6.460	-1.452	0.042

Remarks:

The different angles given (in deg) in the file of results are:

alfagd	right ascension of Greenwich
tetdipd	geocentric colatitude of the point where the dipole cuts the northern hemisphere
phidipd	geocentric longitude of the point where the dipole cuts the northern hemisphere
alfasd	declination of the Sun
deltasd	right ascension of the Sun
tiltd	tilt angle between the solar magnetic equator and the geomagnetic equator

The transformation matrices given in the file of results are:

rgdip	transformation matrix (3,3) from the geocentric coordinate system into the dipolar coordinate system
rgsm	transformation matrix (3,3) from the geocentric coordinate system into the solar magnetic coordinate system
rggsm	transformation matrix (3,3) from the geocentric coordinate system into the solar magnetospheric coordinate system
rig	transformation matrix (3,3) from the inertial coordinate system into the geocentric coordinate system
rigsm	transformation matrix (3,3) from the inertial coordinate system into the solar magnetospheric coordinate system
rgse	transformation matrix (3,3) from the geocentric coordinate system into the solar ecliptic coordinate system
rism	transformation matrix (3,3) from the inertial coordinate system into the solar magnetic coordinate system
rise	transformation matrix (3,3) from the inertial coordinate system into the solar ecliptic coordinate system

Called routines:

valfix	inigeo1	promat	geose	geogsm	geosm

3.4 TESTINIGV

Purpose:

This program calculates all the transformation matrices for epochs between 1945 and 2000.
It uses the DGRF field modulus form 1945 to 2000.

- Calculation of the different angles: tilt angle, orientation of the dipole axis, right ascension and declination of the Sun used in all the calculation routines (**inigeomv**).

Input data:

Data set in the program:

the initial calculation date: year = 1945, month = 6, day = 6, hours = 6, minutes = 6, seconds = 6
(1945 ≤ year < 2000, 1 year step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the calculation date (year, month, day, hours, minutes and seconds),
the geocentric colatitude and longitude of the spacecraft (deg).

<u>Example:</u>

year	month	day	hours	minutes	seconds	tetdipd	phidipd
1959	6	6	6	6	6	11.50	-69.44
1960	6	6	6	6	6	11.49	-69.51
1961	6	6	6	6	6	11.48	-69.58
1962	6	6	6	6	6	11.48	-69.66
1963	6	6	6	6	6	11.47	-69.74
1964	6	6	6	6	6	11.47	-69.81
1965	6	6	6	6	6	11.46	-69.89
1966	6	6	6	6	6	11.45	-69.95
1967	6	6	6	6	6	11.44	-70.01
1968	6	6	6	6	6	11.43	-70.08
1969	6	6	6	6	6	11.41	-70.14
1970	6	6	6	6	6	11.40	-70.21

Remarks:

Called routines:

valfix inigeomv

3.5 TESTVDH

Purpose:

This program transforms the geocentric coordinates into field coordinates.

- Calculation of all the transformation matrix from the geocentric coordinate system into the field coordinate system and the inverse matrix (**rovdh**).

Input data:

Data set in the program:

the calculation date: year = 2010.0,

the geocentric radial distance: re = 2.3 Re,
the geocentric longitude: thetr = 40. deg,
the geocentric colatitude: phir = 70. deg .

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the input data,
the transformation matrix from geocentric coordinates to field coordinates,
the transformation matrix from field coordinates to geocentric coordinates.

<u>Example:</u>

```
year rre thetr phir   2010.00     2.300     0.698     1.222

rgvdh           -0.949171    0.313767    0.024998
rgvdh           -0.225260   -0.732603    0.642301
rgvdh            0.219846    0.604023    0.766044

rvdhg           -0.949171   -0.225260    0.219846
rvdhg            0.313767   -0.732603    0.604023
rvdhg            0.024998    0.642301    0.766044
```

Remarks:

Called routines:

valfix rovdh

4. BOUNDARIES AND REGIONS

4.1 TESTDIST

Purpose:

This program calculates the distance to the Shabansky type magnetopause.

- Calculation of the distance of the spacecraft to the magnetopause region as defined by the Shabansky type parabola (**ddparab**).

Input data:

Data set in the program:

the subsolar distance: rb = 11 Re,
the x, y and z solar magnetospheric coordinates (Re):
15 < xgsm < -25 (2 Re step), ygsm = 0, 20 < zgsm < -20 (2 Re step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:
an array giving for each value of the x (lines) and z (columns) coordinates in the solar magnetospheric system (xgsm and zgsm), the values of the distance to the Shabansky type parabola magnetopause, negative inside, positive outside for each of the 21 values of xgsm (Re).

<u>Example:</u>

	15.0	13.0	11.0	9.0	7.0	5.0	3.0	1.0	-1.0	-3.0	-5.0	-7.0	-9.0	-11.0	-13.0	-15.0	-17.0	-19.0	-21.0	-23.0	-25.0
20.0	13.1	11.7	10.3	9.0	7.8	6.5	5.4	4.2	3.1	2.1	1.1	0.1	-0.9	-1.8	-2.7	-3.5	-4.4	-5.2	-6.0	-6.8	-7.6
18.0	11.7	10.3	8.9	7.5	6.2	4.9	3.7	2.6	1.5	0.4	-0.7	-1.7	-2.6	-3.6	-4.5	-5.4	-6.2	-7.0	-7.9	-8.6	-9.4
16.0	10.4	8.9	7.4	6.0	4.7	3.4	2.1	0.9	-0.2	-1.3	-2.4	-3.4	-4.4	-5.3	-6.3	-7.2	-8.0	-8.9	-9.7-	-10.5	-11.3
14.0	9.1	7.6	6.1	4.6	3.2	1.9	0.6	-0.7	-1.8	-3.0	-4.1	-5.1	-6.1	-7.1	-8.0	-8.9	-9.8	-10.7	-11.5	-12.3	-13.1
12.0	8.0	6.3	4.7	3.2	1.8	0.4	-1.0	-2.2	-3.5	-4.6	-5.8	-6.8	-7.9	-8.8	-9.8	-10.7	-11.6	-12.5	-13.3	-14.2	-14.9
10.0	6.9	5.2	3.5	1.9	0.4	-1.1	-2.5	-3.8	-5.1	-6.3	-7.4	-8.5	-9.6	-10.6	-11.6	-12.5	-13.4	-14.3	-15.1	-16.0	-16.8
8.0	5.9	4.2	2.4	0.7	-0.9	-2.4	-3.9	-5.3	-6.6	-7.9	-9.1	-10.2	-11.3	-12.3	-13.3	-14.3	-15.2	-16.1	-17.0	-17.8	-18.6
6.0	5.1	3.3	1.5	-0.3	-2.0	-3.7	-5.2	-6.7	-8.1	-9.4	-10.7	-11.8	-13.0	-14.0	-15.1	-16.0	-17.0	-17.9	-18.8	-19.6	-20.4
4.0	4.5	2.6	0.7	-1.2	-3.0	-4.8	-6.5	-8.1	-9.5	-10.9	-12.2	-13.5	-14.6	-15.7	-16.8	-17.8	-18.7	-19.7	-20.6	-21.4	-22.3
2.0	4.1	2.2	0.2	-1.8	-3.7	-5.6	-7.5	-9.2	-10.9	-12.4	-13.8	-15.1	-16.3	-17.4	-18.5	-19.5	-20.5	-21.4	-22.4	-23.2	-24.1
0.0	4.0	2.0	0.0	-2.0	-4.0	-6.0	-8.0	-10.0	-12.0	-13.7	-15.2	-16.6	-17.9	-19.1	-20.2	-21.2	-22.2	-23.2	-24.1	-25.0	-25.9
-2.0	4.1	2.2	0.2	-1.8	-3.7	-5.6	-7.5	-9.2	-10.9	-12.4	-13.8	-15.1	-16.3	-17.4	-18.5	-19.5	-20.5	-21.4	-22.4	-23.2	-24.1
-4.0	4.5	2.6	0.7	-1.2	-3.0	-4.8	-6.5	-8.1	-9.5	-10.9	-12.2	-13.5	-14.6	-15.7	-16.8	-17.8	-18.7	-19.7	-20.6	-21.4	-22.3
-6.0	5.1	3.3	1.5	-0.3	-2.0	-3.7	-5.2	-6.7	-8.1	-9.4	-10.7	-11.8	-13.0	-14.0	-15.1	-16.0	-17.0	-17.9	-18.8	-19.6	-20.4
-8.0	5.9	4.2	2.4	0.7	-0.9	-2.4	-3.9	-5.3	-6.6	-7.9	-9.1	-10.2	-11.3	-12.3	-13.3	-14.3	-15.2	-16.1	-17.0	-17.8	-18.6
-10.0	6.9	5.2	3.5	1.9	0.4	-1.1	-2.5	-3.8	-5.1	-6.3	-7.4	-8.5	-9.6	-10.6	-11.6	-12.5	-13.4	-14.3	-15.1	-16.0	-16.8
-12.0	8.0	6.3	4.7	3.2	1.8	0.4	-1.0	-2.2	-3.5	-4.6	-5.8	-6.8	-7.9	-8.8	-9.8	-10.7	-11.6	-12.5	-13.3	-14.2	-14.9
-14.0	9.1	7.6	6.1	4.6	3.2	1.9	0.6	-0.7	-1.8	-3.0	-4.1	-5.1	-6.1	-7.1	-8.0	-8.9	-9.8	-10.7	-11.5	-12.3	-13.1
-16.0	10.4	8.9	7.4	6.0	4.7	3.4	2.1	0.9	-0.2	-1.3	-2.4	-3.4	-4.4	-5.3	-6.3	-7.2	-8.0	-8.9	-9.7	-10.5	-11.3
-18.0	11.7	10.3	8.9	7.5	6.2	4.9	3.7	2.6	1.5	0.4	-0.7	-1.7	-2.6	-3.6	-4.5	-5.4	-6.2	-7.0	-7.9	-8.6	-9.4
-20.0	13.1	11.7	10.3	9.0	7.8	6.5	5.4	4.2	3.1	2.1	1.1	0.1	-0.9	-1.8	-2.7	-3.5	-4.4	-5.2	-6.0	-6.8	-7.6

Remarks:

Called routines:

valfix ddparab

4.2 TESTDIST2

Purpose:

This program calculates the distance of a spacecraft to several boundaries for CLUSTER spacecraft (Whisper experiment).

–Calculation of all the rotation matrices and of the different angles used in all the
–calculation routines specific for CLUSTER spacecraft (**inigeo1**).
- Transformation of the solar magnetospheric components of a vector into geocentric components (**gsmgeo**).
- Transformation of the geocentric coordinates of a point into spherical coordinates (**carsp**).
- Transformation of the geocentric components of a vector into solar ecliptic components (**geose**).
- Transformation of the geocentric components of a vector into solar magnetic components (**geosm**).
- Calculation of the distances from the spacecraft to several boundaries (**clusdis**).

Input data:

Data set in the program:

the year = 2002.,
the solar wind variability index: 1≤ isw ≤ 5,
the x, y and z solar magnetospheric coordinates (Re):
20 ≤ xgsm ≤-37 (3 Re step), ygsm = 0.1 . xgsm, zgsm = 0.1 . xgsm.

Parameters given by the user:

the name of the file of results.
the calculation date (year, month, day, hours, minutes and seconds).

Output data:

The file of results contains for each solar wind variability index value:

for each input:

the x, y and z coordinates in the solar magnetospheric system (Re),
the x, y and z coordinates in the solar magnetic system (Re),
the x, y and z coordinates in the solar ecliptic system (Re),
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the distances to 6 boundaries.

Example:

Date month day hour min sec
2000 3 21 12 0 0
solar wind isw 1

new point

xgsm,ygsm,zgsm	20.00	2.00	2.00
xsm,ysm,zsm	19.84	2.00	3.20
xse,yse,zse	20.00	2.41	1.48
xg,yg,zg	19.92	2.24	2.48
rre,thed,phid	20.20	82.94	6.41
dischap,dismp,disbwsh	999.00	7.65	2.70
dznsh,dzpshn,dzpshs	999.00	999.00	999.00

new point

xgsm,ygsm,zgsm	17.00	1.70	1.70
xsm,ysm,zsm	16.87	1.70	2.72
xse,yse,zse	17.00	2.05	1.26
xg,yg,zg	16.93	1.90	2.11
rre,thed,phid	17.17	82.94	6.41
dischap,dismp,disbwsh	999.00	4.62	-0.33
dznsh,dzpshn,dzpshs	999.00	999.00	999.00

Remarks:

The file of results corresponds to a test done for a date equal to 2000 3 21 12 0 0.
The different distances given (in Re) in the file of results are:

dischap	distance to the plasmasphere
dismp	distance to the magnetopause, negative inside, positive outside
disbwsh	distance to the bow shock, negative inside, positive outside
dznsh	distance to the neutral sheet, negative below, positive above
dzpshn	distance to the southern plasmasheet
dzpshs	distance to the northern plasmasheet

Called routines:

valfix inigeo1 gsmgeo carsp geose geosm
clusdis

4.3 TESTOLSDON

Purpose:

This program looks for the Olson's data by interpolation of a given tilt angle.

- Looking for the Olson's data by interpolation of the tilt angle (**olsdon**).
- Calculation of the time zone which includes the given point (**calphi**).
- Calculation of the distances to the magnetosphere and of the x solar ecliptic coordinates of the two meridians which border the time zone (**caltheta**).

Input data:

Data set in the program:

the tilt angle (degrees) = 22.,
the x, y and z solar ecliptic coordinates (Re):
xgse = 5., ygse = 3., zgse = 6..

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

The input data:

the x, y and z coordinates in the solar ecliptic system (Re),
the right ascension of Greenwich (deg),

The output data:

the Olson's data for the given point (tens of Re),
the corrected component in the solar ecliptic system,
the geocentric colatitude and longitude (deg),
the number of the time zone,
the geocentric colatitude of the two meridians (deg),
the Olson's data corresponding to both meridians (Re).

Example:

xgse ygse zgse rogse 5.00 3.00 6.00 6.708

trc

1.0473	1.0905	1.1243	1.1661	1.2166	1.2699	1.3453	1.0739	1.5192	2.1494	3.3317	6.2843
1.0473	1.0897	1.1253	1.1718	1.2186	1.2725	1.3512	1.0929	1.5373	2.1668	3.3397	6.3027
1.0473	1.0872	1.1272	1.1862	1.2235	1.2791	1.3675	1.1505	1.5907	2.2179	3.3631	6.3564
1.0473	1.0824	1.1272	1.2018	1.2276	1.2872	1.3900	1.2471	1.6757	2.2972	3.4004	6.4412
1.0473	1.0749	1.1208	1.2054	1.2261	1.2936	1.4130	1.3782	1.7843	2.3952	3.4509	6.5536
1.0473	1.0640	1.1042	1.1822	1.2155	1.2966	1.4324	1.5284	1.9021	2.4997	3.5144	6.6918
1.0473	1.0501	1.0762	1.1243	1.1945	1.2971	1.4477	1.6690	2.0105	2.5965	3.5902	6.8529
1.0473	1.0344	1.0385	1.0392	1.1656	1.2952	1.4615	1.7678	2.0927	2.6746	3.6761	7.0312
1.0473	1.0178	0.9967	0.9457	1.1307	1.2910	1.4738	1.8106	2.1403	2.7278	3.7669	7.2164
1.0473	1.0022	0.9569	0.8620	1.0970	1.2835	1.4815	1.8093	2.1576	2.7573	3.8541	7.3921
1.0473	0.9897	0.9249	0.7994	1.0680	1.2748	1.4839	1.7872	2.1564	2.7693	3.9273	7.5380
1.0473	0.9815	0.9042	0.7616	1.0487	1.2680	1.4833	1.7657	2.1496	2.7722	3.9762	7.6348
1.0473	0.9785	0.8971	0.7491	1.0420	1.2655	1.4827	1.7572	2.1462	2.7722	3.9933	7.6686

rgsa thetd phid 8.367 55.170 60.886

ival phi1 phi2 11 60.000 75.000

tro1

0.0000	2.5616	4.6244	5.6523	9.2488	12.3140	14.8386	17.2634	18.6753	19.5818	19.6367	19.5097

tro2

0.0000	2.5403	4.5210	5.3852	9.0818	12.2477	14.8326	17.0554	18.6159	19.6024	19.8811	19.7602

Remarks:

The file of results is named resolsdon.

Called routines:

valfix olsdon calphi caltheta

4.4 TESTRAD

Purpose:

This program calculates the position of a spacecraft in the magnetosphere using points on a line. This calculation is done for a spacecraft in an outbound trajectory.

- Calculation of all the rotation matrices and the different angles used in all the routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Determination of the region of the magnetosphere where is located the spacecraft. The near Earth region is divided in 15 regions, including the solar wind. The spacecraft geomagnetic local time, the Mac Ilwain L parameter and the geomagnetic parameters are calculated. The coordinates in several systems are also calculated (**posmag**).

Input data:

Data set in the program:

the external magnetic field is Tsyganenko 1989: magout = 2,
the spacecraft orbit type is far from Earth: apogee > 8 Re: isatex = 1.

The calculation is performed from the geocentric radial distance (rrmago) given by the user.
This value is increased 20 times by 1 Re steps.

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the initial geocentric radial distance of the spacecraft (Re),
the geocentric colatitude of the spacecraft (deg),
the geocentric longitude of the spacecraft (deg).

Output data:

The file of results contains a line for each input:

the geocentric radial distance (Re), the geocentric colatitude and longitude of the spacecraft (deg),
the geomagnetic local time of the spacecraft (hours and fractions),
the Mac Ilwain L parameter (calculated using Galperin's method),
the invariant latitude (deg),
the geomagnetic local time of the conjugate point in the same hemisphere (hours and fractions),
the geomagnetic latitude of the conjugate point on Earth (deg),
the geomagnetic longitude of the conjugate point on Earth (deg),
an array of 15 indexes indicating the location of the spacecraft in each region.

Example:

Year, month, day, hour, min, sec : 2012 3 01 0 0 0

geog. et geoph. parameters		regions	
rrmag	2.00	polar cap	0
thetdo	30.00	aurora oval	0
phido	30.00	cusp	0
tgl	2.70	diffuse aurora region	1
flg	6.07	Van Allen belt L = 6	0
xlamb	66.05	plasmapshere	0
tglc	3.25	neutral sheet	0
clatgm	65.88	plasmasheet	0
clongm	125.65	magnetosphere	1
		magnetopause	0
		magnetosheath	0
		bow shock	0
		solar wind	0
		shade of Earth	0
		Van Allen Belt L = 3.5	0

Remarks:

The file of results corresponds to a test done for a date equal to 2012 03 01 0 0 0, a geocentric radial distance equal to 2 Re, a geocentric colatitude and a geocentric longitude both equal to 30 deg.

The 15 indexes indicating the location of the spacecraft in each region are:
1: polar cap region,
2: aurora oval region,
3: cusp region,
4: diffuse aurora region,
5: Van Allen belt region for xbelt = 6. Re,
6: plasmasphere region,
7: neutral sheet region,
8: plasmasheet region,
9: magnetosphere region,
10: magnetopause region,
11: magnetosheath region,
12: bow shock region,
13: solar wind region,
14: shade of Earth,
15: Van Allen belt region for xbelt = 3.5 Re.

index value:
1 = spacecraft belongs to the region,
0 = spacecraft doesn't belong to the region,

Called routines:

valfix inigeom posmag

4.5 TESTSPH

Purpose:

This program calculates the position of a spacecraft in the magnetosphere using points on a circle. This calculation is done for a spacecraft close to earth.

- Calculation of all the rotation matrices and of the different angles used in all the routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Determination of the region of the magnetosphere where is located the spacecraft. The near Earth region is divided in 15 regions, including the solar wind. The spacecraft geomagnetic local time, the Mac Ilwain L parameter and the geomagnetic parameters are calculated. The coordinates in several systems are also calculated (**posmag**).

Input data:

Data set in the program:

the external magnetic field Tsyganenko 1989: magout = 2,
the spacecraft orbit type close to Earth: apogee < 8 Re: isatex = 0,
the geocentric longitude (deg): $0 \leq$ phido ≤ 360 (30 deg step),
the geocentric colatitude (deg): $0 \leq$ thetdo ≤ 85 (5 deg step).

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the geocentric radial distance of the spacecraft (Re).

Output data:

The file of results contains a line for each input:

- The geocentric radial distance (Re), geocentric colatitude and longitude of the spacecraft (deg)
- The geomagnetic local time of the spacecraft (hours and fractions)
- the Mac Ilwain L parameter (calculated using Galperin's method)
- The invariant latitude (deg)
- The geomagnetic local time of the conjugate point in the same hemisphere (hours and fractions)
- The geomagnetic latitude of the conjugate point on Earth (deg)
- The geomagnetic longitude of the conjugate point on Earth (deg)
- An array of 15 indexes indicating the location of the spacecraft in each region.

Example:

year month day hour min sec: 2012 3 1 0 0 0

geog. et geoph. parameters		regions	
rrmag	3.00	polar cap	1
thetdo	0.00	aurora oval	0
phido	0.00	cusp	0
tgl	6.87	diffuse aurora region	0
flg	87.02	Van Allen belt L = 6	0
xlamb	83.85	plasmasphere	0
tglc	7.28	neutral sheet	0
clatgm	81.59	plasmasheet	0
clongm	186.17	magnetosphere	1
		magnetopause	0
		magnetosheath	0
		bow shock	0
		solar wind	0
		shade of Earth	0
		Van Allen Belt L = 3.5	0

Remarks:

The file of results corresponds to a test done for a date equal to 2012 3 1 0 0 0 and a initial geocentric radial distance equal to 3 Re.

The 15 indexes indicating the location of the spacecraft in each region are:
1: polar cap region,
2: aurora oval region,
3: cusp region,
4: diffuse aurora region,
5: Van Allen belt region for xbelt = 6. Re,
6: plasmasphere region,
7: neutral sheet region,
8: plasmasheet region,
9: magnetosphere region,
10: magnetopause region,
11: magnetosheath region,
12: bow shock region,
13: solar wind region,
14: shade of Earth region,
15: Van Allen belt region for xbelt = 3.5 Re.

index value:
1 = spacecraft belongs to the region,
0 = spacecraft doesn't belong to the region.

Called routines:

valfix inigeom posmag

5. MAGNETIC FIELD MODELS

5.1 TESTCHP00

Purpose:

This program calculates the original internal magnetic field with the coefficients from DGRF 2000 model with two different routines. The coefficients are stored differently in the memory and errors in the coefficients can be detected.

Calculation of the internal magnetic field using IGRF 2000 coefficients with routines **dgrf00** and **chp00**.

Input data:

Data set in the program:

the calculation date: tm = 2005.,
the geocentric radial distance: re = 1.2 Re,
the geocentric longitude (deg): 10 ≤ phid ≤ 100 (30 deg step),
the geocentric colatitude (deg): 10 ≤ thetd ≤ 100 (30 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains two lines for each input:

on the first line the results of **dgrf00** routine:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg), the geomagnetic field radial component, positive outwards (nanoteslas), the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas), the magnetic field eastward component, positive eastwards (nanoteslas).

on the second line the same results for **chp00** routine:

<u>Example:</u>

```
re        thetd      phid       dgrf00:  br1nt          bt1nt         bp1nt
re        thetd      phid       chp00:   br2nt          bt2nt         bp2nt

1.20      10.00      10.00        -32914.4037650   -3737.9325888   -520.6600259
1.20      10.00      10.00        -32914.4037650   -3737.9325888   -520.6600259

1.20      40.00      10.00        -25465.5738039  -11992.7870210   -292.6406514
1.20      40.00      10.00        -25465.5738039  -11992.7870210   -292.6406514
```

1.20	70.00	10.00	-8043.4560750	-18257.0175497	-623.9896090
1.20	70.00	10.00	-8043.4560750	-18257.0175497	-623.9896090
1.20	100.00	10.00	10924.8589876	-12985.9452105	-1854.0597484
1.20	100.00	10.00	10924.8589876	-12985.9452105	-1854.0597484
1.20	10.00	40.00	-33221.1787410	-3557.4545614	387.5247008
1.20	10.00	40.00	-33221.1787410	-3557.4545614	387.5247008

Remarks:

The results of **dgrf00** et **chp00** routines must be identical.

Called routines:

valfix dgrf00 chp00

5.2 TESTCHP05

Purpose:

This program calculates the original internal magnetic field with the coefficients from DGRF 05 model with two different routines. The coefficients are stored differently in the memory and errors in the coefficients can be detected.

Calculation of the internal magnetic field using IGRF 2005 coefficients with routines **dgrf05 and chp05**.

Input data:

Data set in the program:

the calculation date: tm = 2010.,
the geocentric radial distance: re = 1.2 Re,
the geocentric longitude (deg): 10 ≤ phid ≤ 100 (30 deg step),
the geocentric colatitude (deg): 10 ≤ thetd ≤ 100 (30 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains two lines for each input:

on the first line the results of **dgrf05** routine:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

on the second line the same results for **chp05** routine:

<u>Example:</u>

re	thetd	phid	dgrf00: br1nt	bt1nt	bp1nt
re	thetd	phid	chp00: br2nt	bt2nt	bp2nt
1.20	10.00	10.00	-32956.5650494	-3730.9650771	-394.2004950
1.20	10.00	10.00	-32956.5650494	-3730.9650771	-394.2004950
1.20	40.00	10.00	-25510.6767654	-12018.3849802	-158.0076885
1.20	40.00	10.00	-25510.6767654	-12018.3849802	-158.0076885
1.20	70.00	10.00	-8000.4384622	-18313.8978005	-471.1200358
1.20	70.00	10.00	-8000.4384622	-18313.8978005	-471.1200358

1.20	100.00	10.00	11018.9175206	-12942.0158435	-1706.6577621
1.20	100.00	10.00	11018.9175206	-12942.0158435	-1706.6577621
1.20	10.00	40.00	-33277.1726422	-3496.9043459	477.2525913
1.20	10.00	40.00	-33277.1726422	-3496.9043459	477.2525913

Remarks:

The file of results is named reschp05.
The results of **dgrf05** et **chp05** routines must be identical.

Called routines:

valfix dgrf05 chp05

5.3 TESTCHP10

Purpose:

This program calculates the original internal magnetic field with the coefficients from IGRF10 model with two different routines. The coefficients are stored differently in the memory and errors in the coefficients can be detected.

Calculation of the internal magnetic field using IGRF 2010 coefficients with routines **igrf10** and **chp10**.

Input data:

Data set in the program:

the calculation date: tm = 2015.,
the geocentric radial distance: re = 1.2 Re,
the geocentric longitude (deg): 10 ≤ phid ≤ 100 (30 deg step),
the geocentric colatitude (deg): 10 ≤ thetd ≤ 100 (30 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains two lines for each input:

on the first line the results of **igrf10** routine:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

on the second line the same results for **chp10** routine:

Example:

re	thetd	phid	dgrf00:	br1nt	bt1nt	bp1nt
re	thetd	phid	chp00:	br2nt	bt2nt	bp2nt
1.20	10.00	10.00		-32987.9347280	-3721.8927027	-263.1330326
1.20	10.00	10.00		-32987.9347280	-3721.8927027	-263.1330326
1.20	40.00	10.00		-25550.5975294	-12041.3611423	-14.8237260
1.20	40.00	10.00		-25550.5975294	-12041.3611423	-14.8237260
1.20	70.00	10.00		-7962.4799538	-18367.0227973	-307.2977968
1.20	70.00	10.00		-7962.4799538	-18367.0227973	-307.2977968

1.20	100.00	10.00	11102.5921233	-12899.3166577	-1549.8579046
1.20	100.00	10.00	11102.5921233	-12899.3166577	-1549.8579046
1.20	10.00	40.00	-33322.5822236	-3431.9007017	571.9900176
1.20	10.00	40.00	-33322.5822236	-3431.9007017	571.9900176

Remarks:

The results of **igrf10** et **chp10** routines must be identical.

Called routines:

valfix igrf10 chp10

5.4 TESTCHP95

Purpose:

This program calculates the original internal magnetic field with the coefficients from DGRF95 model with two different routines. The coefficients are stored differently in the memory and errors in the coefficients can be detected.

Calculation of the internal magnetic field using DGRF 1995 coefficients with routines **dgrf95** and **chp95**.

Input data:

Data set in the program:

the calculation date: tm = 1998.,
the geocentric radial distance: re = 1.2 Re,
the geocentric longitude (deg): 20 ≤ phid ≤ 60 (20 deg step),
the geocentric colatitude (deg): 2 ≤ thetd ≤ 8 (2 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains two lines for each input:

on the first line the results of **dgrf95** routine:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

on the second line the same results for **chp95** routine:

Example:

re	thetd	phid	dgrf00:	br1nt	bt1nt	bp1nt
re	thetd	phid	chp00:	br2nt	bt2nt	bp2nt
1.20	2.00	20.00		-33712.8575418	-1431.2769421	-613.3577108
1.20	2.00	20.00		-33712.8575418	-1431.2769421	-613.3577108
1.20	4.00	20.00		-33560.4570547	-2034.7081261	-521.4136887
1.20	4.00	20.00		-33560.4570547	-2034.7081261	-521.4136887
1.20	6.00	20.00		-33374.8184083	-2627.8526710	-436.9545123

1.20	6.00	20.00	-33374.8184083	-2627.8526710	-436.9545123
1.20	8.00	20.00	-33157.5285601	-3211.0922604	-360.1179538
1.20	8.00	20.00	-33157.5285601	-3211.0922604	-360.1179538
1.20	2.00	40.00	-33739.1592801	-1533.3434835	-231.7561363
1.20	2.00	40.00	-33739.1592801	-1533.3434835	-231.7561363

Remarks:

The file of results is named reschp95.
The results of **dgrf95** et **chp95** routines must be identical.

Called routines:

valfix dgrf95 chp95

5.5 TESTDGN95_10

Purpose:

This program calculates the magnetic field for several epochs between 1995 and 2010 with two different routines: **chp95_10** and **igrf95_10.**

Input data:

Data set in the program:

the calculation date: 1997 ≤ tm ≤ 2009 (1 year step),
the geocentric radial distance: re = 1.2 Re,
the geocentric colatitude (deg): 2 ≤ thet ≤ 8 (2 deg step),
the geocentric longitude (deg): 20 ≤ phi ≤ 60 (20 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each calculation date:

a header line giving the calculation year,

for each input:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the results of **chp95_10** routine,
the results of **igrf95_10** routine.

<u>Example:</u>

1997.0

			chp70_95 results			dgrf70_95 results		
re	thet	phi	br	bt	bp	br	bt	bp
1.2	2.0	20.0	-33701.5	-1448.5	-681.9	-33701.5	-1448.5	-681.9
1.2	4.0	20.0	-33546.8	-2053.1	-589.2	-33546.8	-2053.1	-589.2
1.2	6.0	20.0	-33358.8	-2647.0	-504.1	-33358.8	-2647.0	-504.1
1.2	8.0	20.0	-33139.0	-3230.8	-426.8	-33139.0	-3230.8	-426.8
1.2	2.0	40.0	-33726.7	-1572.2	-289.3	-33726.7	-1572.2	-289.3
1.2	4.0	40.0	-33609.4	-2092.5	-137.6	-33609.4	-2092.5	-137.6
1.2	6.0	40.0	-33468.9	-2612.3	4.1	-33468.9	-2612.3	4.1
1.2	8.0	40.0	-33304.7	-3132.9	135.0	-33304.7	-3132.9	135.0
1.2	2.0	60.0	-33763.4	-1552.4	82.6	-33763.4	-1552.4	82.6
1.2	4.0	60.0	-33698.4	-1971.0	222.6	-33698.4	-1971.0	222.6
1.2	6.0	60.0	-33624.0	-2399.6	355.4	-33624.0	-2399.6	355.4
1.2	8.0	60.0	-33537.6	-2841.1	480.0	-33537.6	-2841.1	480.0

Remarks:

The file of results is named resdgn.

The results of **chp95_10**and **igrf95_10** routine are:

the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

The results of **chp95_10** and **igrf95_10** must be identical.

Called routines:

valfix chp95_10 igrf95_10

5.6 TESTDGN

Purpose:

This program calculates the magnetic field for several epochs between 1970 and 1995 with two different routines: **chp70_95** and **dgrf70_95**.

Input data:

Data set in the program:

the calculation date: 1970 ≤ tm ≤ 1995 (5 years step),
the geocentric radial distance: re = 1.2 Re,
the geocentric colatitude (deg): 2 ≤ thet ≤ 8 (2 deg step),
the geocentric longitude (deg): 20 ≤ phi ≤ 60 (20 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each calculation date:

a header line giving the calculation year,

for each input:
the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the results of **chp70_95** routine,
the results of **dgrf70_95** routine.

Example:

1990.0

			chp70_95 results			dgrf70_95 results		
re	thet	phi	br	bt	bp	br	bt	bp
1.2	2.0	20.0	-33735.8	-1482.4	-807.4	-33735.8	-1482.4	-807.4
1.2	4.0	20.0	-33574.9	-2091.4	-713.1	-33574.9	-2091.4	-713.1
1.2	6.0	20.0	-33379.9	-2688.8	-626.7	-33379.9	-2688.8	-626.7
1.2	8.0	20.0	-33152.7	-3274.9	-548.6	-33152.7	-3274.9	-548.6
1.2	2.0	40.0	-33759.8	-1645.7	-394.9	-33759.8	-1645.7	-394.9
1.2	4.0	40.0	-33635.5	-2168.5	-239.3	-33635.5	-2168.5	-239.3
1.2	6.0	40.0	-33487.4	-2690.5	-94.4	-33487.4	-2690.5	-94.4
1.2	8.0	40.0	-33315.2	-3212.7	39.1	-33315.2	-3212.7	39.1
1.2	2.0	60.0	-33796.3	-1655.9	8.0	-33796.3	-1655.9	8.0
1.2	4.0	60.0	-33724.4	-2074.5	152.3	-33724.4	-2074.5	152.3
1.2	6.0	60.0	-33642.8	-2503.3	288.8	-33642.8	-2503.3	288.8
1.2	8.0	60.0	-33548.9	-2944.9	416.4	-33548.9	-2944.9	416.4

Remarks:

The file of results is named resdgn.

The results of **chp70_95** and **dgrf70_95** routine are:

the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

The results of **chp70_95** and **dgrf70_95** must be identical.

Called routines:

valfix chp70_95 dgrf70_95

5.7 TESTDGN2

Purpose:

This program calculates the magnetic field for all epochs between 1945 and 1970 with two different routines: **chp45_70** and **dgrf45_70**.

Input data:

Data set in the program:

the calculation date (years): 1945 ≤. tm ≤ 1965 (5 years step),
the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude (deg): 2 ≤ thet ≤ 8 (2 deg step),
the geocentric longitude (deg): 20 ≤ phi ≤ 60 (20 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each input:

a header line giving the calculation year,

for each calculation step:
the geocentric radial distance, the geocentric colatitude and longitude (Re),
the results of **chp45_70** routine,
the results of **dgrf45_70** routine.

Example:

1945.0

				chp45_70 results			dgrf45_70 results	
re	thet	phi	br	bt	bp	br	bt	bp
1.2	2.0	20.0	-33502.8	-1680.7	-1155.2	-33502.8	-1680.7	-1155.2
1.2	4.0	20.0	-33308.4	-2278.1	-1070.7	-33308.4	-2278.1	-1070.7
1.2	6.0	20.0	-33081.9	-2861.0	-994.6	-33081.9	-2861.0	-994.6
1.2	8.0	20.0	-32825.6	-3430.2	-927.2	-32825.6	-3430.2	-927.2
1.2	2.0	40.0	-33525.8	-1951.2	-643.2	-33525.8	-1951.2	-643.2
1.2	4.0	40.0	-33366.4	-2466.9	-489.8	-33366.4	-2466.9	-489.8
1.2	6.0	40.0	-33184.4	-2979.3	-347.7	-33184.4	-2979.3	-347.7
1.2	8.0	40.0	-32980.2	-3489.6	-217.7	-32980.2	-3489.6	-217.7
1.2	2.0	60.0	-33565.6	-2025.2	-110.7	-33565.6	-2025.2	-110.7
1.2	4.0	60.0	-33461.7	-2435.4	39.7	-33461.7	-2435.4	39.7
1.2	6.0	60.0	-33348.8	-2854.4	181.2	-33348.8	-2854.4	181.2
1.2	8.0	60.0	-33224.5	-3284.3	313.0	-33224.5	-3284.3	313.0

Remarks:

The file of results is named resdgn.

The results of **chp45_70** and **dgrf45_70** routine are:

the geomagnetic field radial component, positive outwards (nanoteslas),
the geomagnetic field tangential component along the meridian, positive southwards (nanoteslas),
the magnetic field eastward component, positive eastwards (nanoteslas).

The results of **chp45_70** and **dgrf45_70** must be identical.

Called routines:

valfix chp45_70 dgrf45_70

5.8 TESTDIPEX2

Purpose:

This program calculates the tilted eccentered dipole using the coefficients of the DGRF 2005 magnetic field model.
See Technical Note: DGA/T/TI/MS/AM 97-155 (Kosik, 1997).

Calculation of the coefficient ginc10 of the tilted dipole and its orientation.

Calculation of the eccentered coordinate system linked to this tilted dipole.

Input data:

Data set in the program:

the components of the magnetic field DGRF 2005 given by IAGA:

g10 = -0.2955463,
g11 = -0.0166905,
h11 = +0.0507799,
g20 = -0.0233724,
g21 = +0.0304769,
h21 = -0.0259450,
g22 = +0.0165776,
h22 = -0.0051543.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

on the first line:

the tilted dipole coefficient (ginc10),
the geocentric colatitude and longitude of the point where the dipole cuts the northern hemisphere (deg).

on the second line:

the displacement along x, y, and z in cartesian coordinates (Re).

Example:

```
ginc10    tetdip    phidip    0.30034112 10.25169607    -71.80517450
```

Coordinates of the eccentered coordinate system:

```
x0        y0        z0        -456.6831    -281.7856    129.1980
```

Remarks:

The file of results is named resdipex2.

Called routines:

valfix incline

5.9 TESTGRAD00

Purpose:

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the IGRF 2000 model, using **grad00** and **dgrf00** routines.

Input data:

Data set in the program:

the calculation date (years): year = 2000.1,
the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude: thet = 45 deg,
the geocentric longitude: phid = 130 deg.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the input data,

the results from **grad00** routine:
the radial component of the magnetic field (nanoteslas),
the tangential component of the magnetic field along the meridian, positive downwards (nanoteslas),
the azimuthal component of the magnetic field, positive eastwards (nanoteslas),
the nine gradients,

the results are in units of Earth radii,

the same results from **dgrf00** routine.

Example:

```
year, rre, thetd, phid     2000.10      1.20     45.00    130.00

ANALYTIC CALCULATION grad00
br, bt, bp   -25942.51 -14453.50  -1342.54

gradb(1,1),gradb(2,1),gradb(3,1)        71043.07885      35810.60285      7959.71373
gradb(1,2),gradb(2,2),gradb(3,2)        28519.22195     -18647.40740       582.65939
gradb(1,3),gradb(2,3),gradb(3,3)         5804.71859       -537.32007      -187.93059

ANALYTIC CALCULATION dgrf00
br, bt, bp   -25942.51 -14453.50  -1342.54
```

NUMERICAL CALCULATION dgrf00

gradb(1,1),gradb(2,1),gradb(3,1)	71043.06576	35810.59709	7959.71134
gradb(1,2),gradb(2,2),gradb(3,2)	28519.22409	-18647.40674	582.65984
gradb(1,3),gradb(2,3),gradb(3,3)	5804.71843	-537.31996	-187.93011

Remarks:

The file of results is named resgrad00.

Called routines:

valfix grad00 igrf00

5.10 TESTGRAD05

Purpose:

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the IGRF 2005 model, using **grad05** and **dgrf05** routines.

Input data:

Data set in the program:

the calculation date (years): year = 2005.1,

the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude: thet = 45 deg,
the geocentric longitude: phid = 130 deg.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the input data,

the results from **grad05** routine:
- the radial component of the magnetic field (nanoteslas),
- the tangential component of the magnetic field along the meridian, positive downwards (nanoteslas),
- the azimuthal component of the magnetic field, positive eastwards (nanoteslas),
- the nine gradients,

the results are in units of Earth radii,

the same results from **dgrf05** routine.

Example:

year, rre, thetd, phid 2005.10 1.20 45.00 130.00

ANALYTIC CALCULATION grad05
br, bt, bp -25965.54 -14436.10 -1370.98

gradb(1,1),gradb(2,1),gradb(3,1)	70905.53012	35797.97400	7973.34266
gradb(1,2),gradb(2,2),gradb(3,2)	28521.46625	-18568.11125	543.17664
gradb(1,3),gradb(2,3),gradb(3,3)	5796.17282	-585.34890	-107.01636

ANALYTIC CALCULATION dgrf05
br, bt, bp   -25965.54 -14436.10 -1370.98

NUMERICAL CALCULATION dgrf05

gradb(1,1),gradb(2,1),gradb(3,1)	70905.51724	35797.96805	7973.34027
gradb(1,2),gradb(2,2),gradb(3,2)	28521.46821	-18568.11074	543.17709
gradb(1,3),gradb(2,3),gradb(3,3)	5796.17303	-585.34878	-107.01590

Remarks:

The file of results is named resgrad05.

Called routines:

valfix   grad05   dgrf05

5.11 TESTGRAD10

Purpose:

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the IGRF 2010 model, using **grad10** and **igrf10** routines.

Input data:

Data set in the program:

the calculation date (years): year = 2010.1,
the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude: thet = 45 deg,
the geocentric longitude: phid = 130 deg.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the input data,

the results from **grad10** routine:
the radial component of the magnetic field (nanoteslas),
the tangential component of the magnetic field along the meridian, positive downwards (nanoteslas),
the azimuthal component of the magnetic field, positive eastwards (nanoteslas),
the nine gradients,

the results are in units of Earth radii,

the same results from **igrf10** routine.

Example:

```
year, rre, thetd, phid     2010.10     1.20     45.00    130.00

ANALYTIC CALCULATION grad10
br, bt, bp   -26036.50 -14389.96  -1405.39

gradb(1,1),gradb(2,1),gradb(3,1)      70956.36177     35679.50361     8001.70112
gradb(1,2),gradb(2,2),gradb(3,2)      28425.44169    -18584.07302      462.15941
gradb(1,3),gradb(2,3),gradb(3,3)       5795.90956      -666.96294      -71.13723
```

ANALYTIC CALCULATION igrf10
br, bt, bp   -26036.50 -14389.96 -1405.39

NUMERICAL CALCULATION igrf10

gradb(1,1),gradb(2,1),gradb(3,1)	70956.34908	35679.49778	8001.69876
gradb(1,2),gradb(2,2),gradb(3,2)	28425.44410	-18584.07224	462.15987
gradb(1,3),gradb(2,3),gradb(3,3)	5795.90997	-666.96282	-71.13675

Remarks:

The file of results is named resgrad10.

Called routines:

valfix   grad10   igrf10

5.12 TESTGRAD95

Purpose:

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the DGRF 1995 model, using **grad95** and **dgrf95** routines.

Input data:

Data set in the program:

the calculation date (years): year = 1996.0,
the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude: thet = 45 deg,
the geocentric longitude: phid = 130 deg.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the input data,

the results from grad95 routine:
the radial component of the magnetic field (nanoteslas),
the tangential component of the magnetic field along the meridian, positive downwards (nanoteslas),
the azimuthal component of the magnetic field, positive eastwards (nanoteslas),
the nine gradients,

the results are in units of Earth radii,

the same results from dgrf95 routine.

Example:

year, rre, thetd, phid 1996.00 1.20 45.00 130.00

ANALYTIC CALCULATION grad95
br, bt, bp -25869.97 -14496.34 -1318.10

gradb(1,1),gradb(2,1),gradb(3,1)	70912.87247	35918.44847	7925.41480
gradb(1,2),gradb(2,2),gradb(3,2)	28605.79655	-18628.37671	589.87344
gradb(1,3),gradb(2,3),gradb(3,3)	5792.89908	-514.93487	-163.18743

ANALYTIC CALCULATION dgrf95
br, bt, bp -25869.97 -14496.34 -1318.10

NUMERICAL CALCULATION dgrf95

gradb(1,1),gradb(2,1),gradb(3,1)	70912.85959	35918.44254	7925.41240
gradb(1,2),gradb(2,2),gradb(3,2)	28605.79845	-18628.37605	589.87392
gradb(1,3),gradb(2,3),gradb(3,3)	5792.89921	-514.93482	-163.18694

Remarks:

The file of results is named resgrad95.

Called routines:

valfix grad95 dgrf95

5.13 TESTKK97

Purpose:

This program calculates the magnetic field with the Kosik 97 model for various geomagnetic activity Kp index { $1 \leq Kp \square 6$ } using routine **kk97kp**.

Input data:

Data set in the program:

the tilt angle: tilt = 0.25 rad,

the x, y and z solar magnetospheric coordinates:
xgsm = 6 Re, ygsm = 4 Re, zgsm = 5 Re,

the geomagnetic index value: 1 ≤ indval ≤ 5.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each geomagnetic index value (1 to 5):
the geomagnetic index Kp,
the tilt angle (rad),
the x, y and z coordinates in the solar magnetospheric system (Re),
the magnetic field components in the solar magnetospheric system: bx, by and bz (nanoteslas).

Example:

indval	tilt	xgsm	ygsm	zgsm	bx	by	bz
1	0.250	-6.000	4.000	5.000	24.257	0.679	-27.033
2	0.250	-6.000	4.000	5.000	24.415	0.957	-24.437
3	0.250	-6.000	4.000	5.000	28.521	-0.198	-26.340
4	0.250	-6.000	4.000	5.000	31.259	0.561	-23.899
5	0.250	-6.000	4.000	5.000	47.754	-5.401	-39.186

Remarks:

The file of results is named reskk97.

indval: geomagnetic index value
indval = 1: Kp = 1- ,1+
indval = 2: Kp = 2- ,2+

indval = 3: Kp = 3- , 3 , 3+
indval = 4: Kp = 4- , 4 , 4+
indval = 5: Kp = 5-, 5+

Called routines:

valfix kk97kp

5.14 TESTMF75

Purpose:

This program calculates the magnetic field with the Mead Fairfield 75 external field model for different Kp indexes { $1 \leq Kp \square 4$ } using **mf75** routine.

Input data:

Data set in the program:

the tilt angle: tilt = 0.25 rad,

the x, y and z solar magnetospheric coordinates:
xgsm = 6 Re, ygsm = 4 Re, zgsm = 5 Re,

the geomagnetic index value: 1 ≤ indval ≤ 4.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each geomagnetic index value (1 to 5):
the geomagnetic index Kp,
thetilt angle (rad),
the, y and z coordinates in the solar magnetospheric system (Re),
the magnetic field components in the solar magnetospheric system: bx, by and bz (nanoteslas).

Example:

indval	tilt	xgsm	ygsm	zgsm	bx	by	bz
1	0.250	-6.000	4.000	5.000	21.805	-4.056	-5.084
2	0.250	-6.000	4.000	5.000	24.587	-4.770	-7.230
3	0.250	-6.000	4.000	5.000	33.499	-6.520	-11.447
4	0.250	-6.000	4.000	5.000	37.163	-7.458	-13.931

Remarks:

The file of results is named resmf75.

indval: geomagnetic index value
indval = 1: Kp = 1- ,1+
indval = 2: Kp = 2- ,2+
indval = 3: Kp = 3- , 3 , 3+

indval = 4: Kp = 4- , 4 , 4+
indval = 5: Kp = 5-, 5+

Called routines:

valfix mf75

5.15 TESTMODEL

Purpose:

This program works in magnetospheric solar coordinates in the noon-midnight plane. It traces the field lines and the ΔB contours for three different models: Tsyganenko 89 Kp, Tsyganenko 87 and Kosik 97.

- Transformation of the geocentric components of a vector into solar magnetospheric components (**geogsm**).
- Calculation of a level curve ΔB in the noon-midnight plane. The ΔB contours give the difference between the total magnetic field and the dipolar magnetic field (**dbtot**).

Input data:

Data set in the program:

the initial calculation step: dso = 0.02,

the minimum geocentric distance: rend = 1.0 Re,
the maximum geocentric distance: rmax = 200.0 Re.

The field lines are first calculated for a tracing towards the southern hemisphere (dir = +1.), then for a tracing towards the northern hemisphere (dir = -1.).

The tracing is performed in the noon-midnight meridian for geocentric latitudes between 0 deg - 30 deg and 180 deg - 150 deg with a 2 deg step.

The ΔB contours are calculated for -25 Re < xgsm < +15 Re and -15 Re < zgsm < +15 Re.

Parameters given by the user:

the magnetic field model: 1 = Tsyganenko 89 Kp, 2 = Tsyganenko 87 , 3 = Kosik 97,
tilt angle (deg),
the geomagnetic index value for Ae, Kp or Kosik97: indval = 1 to 6
(indval = 1 to 5 for Kosik97).

Output data:

The file of results named **reslign** contains:

for each calculation of a field line:

the number of calculated points.

for each calculated point:
the x, y and z coordinates of the point.

Example:

```
193
        0.574   0.000    0.819
        0.585   0.000    0.836
        0.602   0.000    0.860
        0.628   0.000    0.897
                  .
                  .
                  .
                  .
                  .
      -44.301   0.000   21.024
      -45.287   0.000   20.985
      -46.273   0.000   20.946
186
        0.602   0.000    0.799
        0.678   0.000    0.896
        0.754   0.000    0.993
```

The file of results named **resdb** contains:

for each calculation of a contour:
the contour value (nanoteslas).

This user's program is associated with a tracing program. "wlines.pro" which traces the contour lines and the magnetic field lines.

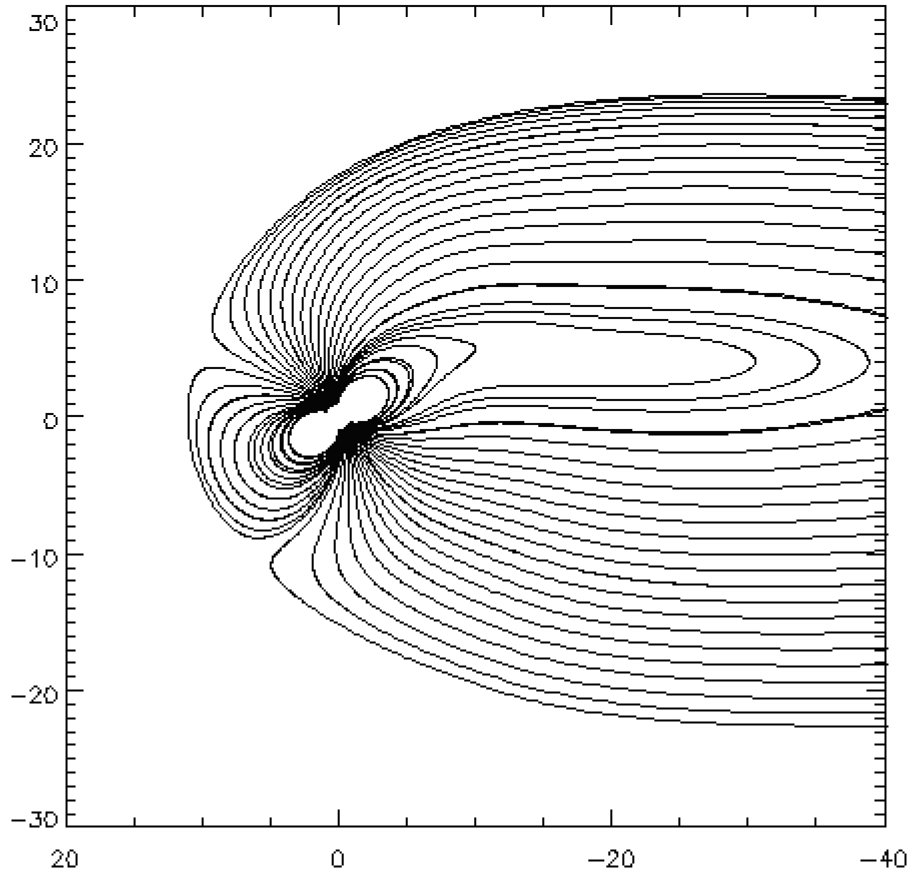
It uses the two files of results.

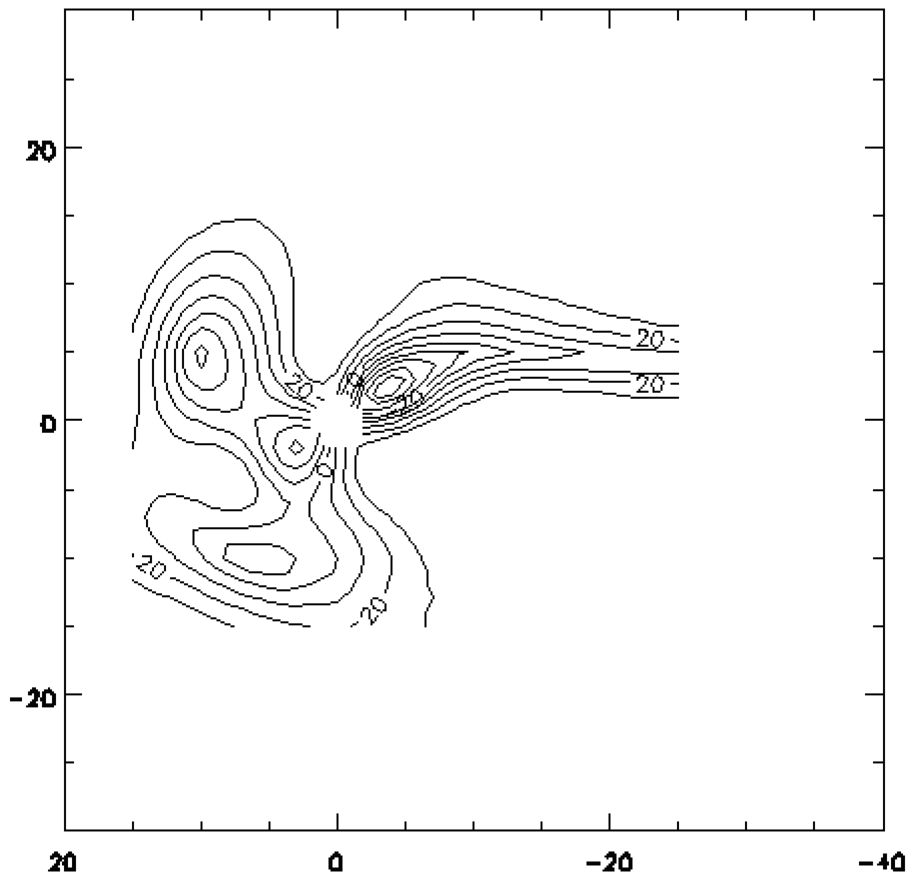
To use this program you need a WAVE license.

The commands are:

wave
.run wlines.pro
quit

Examples of the resulting tracing:


30
20
10
0
−10
−20
−30
20
0
−20
−40


20
0
−20
20
0
−20
−40
20
20
20
20
20

Remarks:

The file of results are named reslign and resdb.
The file of results correspond to a test done for Kosik 97 magnetic field model, a tilt angle of 35. deg and a geomagnetic index value of 1.

indval: goes from 1 to 6 for Tsyganenko 89 Kp and Tsyganenko 87 models and from 1 to 5 for Kosik 97 model.

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp = 0, 0+	Ae = 0 - 50
indval = 2: Kp = 1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp = 2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp = 3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp = 4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

indval: geomagnetic index value for Kosik97
indval = 1: Kp = 1- ,1+
indval = 2: Kp = 2- ,2+
indval = 3: Kp = 3- , 3 , 3+
indval = 4: Kp = 4- , 4 , 4+
indval = 5: Kp = 5-, 5+

Each contour gives the difference between the total magnetic field and the dipole magnetic field.

Called routines:

valfix geogsm dbtot spcar

5.16 TESTTSY

Purpose:

This program calculates the external magnetic field with the Tsyganenko models 1989 Kp and Ae.

- Calculation of the magnetospheric external field components depending on the tilt angle and the geomagnetic index value Kp (**ex89kp**).
- Calculation of the magnetospheric external field components depending on the tilt angle and the geomagnetic index value Ae (**ex89ae**).

Input data:

Data set in the program:

the tilt angle: tilt = 0.25 rad,

the x, y and z solar magnetospheric coordinates:
xgsm = 6 Re, ygsm = 4 Re, zgsm = 5 Re,

the geomagnetic index value for Ae or Kp: $1 \leq$ indval ≤ 6 (step is 1).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

for each geomagnetic index value (1 to 6) two lines giving:

the tilt angle (rad),
the x, y and z coordinates in the solar magnetospheric system (Re),
the x, y and z magnetic field components in the solar magnetospheric system (nanoteslas).

the first line gives the result for Kp geomagnetic indexes, the second one for Ae geomagnetic indexes.

Example:

tilt	xgsm	ygsm	zgsm	bx	by	bz
0.250	-6.000	4.000	5.000	15.017	-6.269	-15.258
0.250	-6.000	4.000	5.000	16.310	-6.944	-16.302
0.250	-6.000	4.000	5.000	19.138	-8.161	-18.650
0.250	-6.000	4.000	5.000	19.934	-8.885	-19.180
0.250	-6.000	4.000	5.000	23.427	-10.112	-21.184
0.250	-6.000	4.000	5.000	23.411	-10.172	-20.884
0.250	-6.000	4.000	5.000	28.446	-12.180	-23.559
0.250	-6.000	4.000	5.000	26.844	-11.232	-22.023
0.250	-6.000	4.000	5.000	34.286	-14.857	-27.265
0.250	-6.000	4.000	5.000	28.855	-12.994	-24.594
0.250	-6.000	4.000	5.000	43.541	-20.115	-32.393
0.250	-6.000	4.000	5.000	35.210	-15.808	-27.947

Remarks:

The file of results is named restsy.

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp = 0, 0+	Ae = 0 - 50
indval = 2: Kp = 1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp = 2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp = 3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp = 4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

Called routines:

valfix ex89kp ex89ae

5.17 TESTVS

Purpose:

This program calculates the secular variations for DGRF05, CHP05.

Input data:

None.

Output data:

The file of results contains for the models CHP05: the secular variations of the coefficients in their order of appearance in the table lgt.

The file of results contains for the models DGRF05: the secular variations of the coefficients in their order of appearance in the matrix lgt written line by line.

Example 1: secular variations for CHP05

k	l	dgg	2	1	11626.0
k	l	dgg	2	2	16630.0
k	l	dgg	2	2	-26578.0
k	l	dgg	3	1	-11872.0
k	l	dgg	3	2	-4338.0
k	l	dgg	3	2	-22640.0
k	l	dgg	3	3	2168.0
k	l	dgg	3	3	-11994.0
k	l	dgg	4	1	680.0
k	l	dgg	4	2	-4094.0
k	l	dgg	4	2	7672.0
k	l	dgg	4	3	-2938.0
k	l	dgg	4	3	-3604.0
k	l	dgg	4	4	-7662.0
k	l	dgg	4	4	-2416.0
k	l	dgg	5	1	-1590.0
k	l	dgg	5	2	2208.0
k	l	dgg	5	2	866.0
k	l	dgg	5	3	-8810.0
k	l	dgg	5	3	2806.0

The table lgt results from the sequential reading of the file above.

```
  data lgt/
> 11626,16630,-26578,-11872,-4338,-22640,2168,-11994,680,-4094,
> 7672,-2938,-3604,-7662,
> -2416,-1590,2208,866,-8810,2806,…
```

Example 2: secular variations for DGRF95

n m dg lg2 lg1	1	1	0.0	10.0	100.0
n m dg lg2 lg1	1	2	-26578.0	49451.0	507799.0
n m dg lg2 lg1	1	3	-22640.0	-27077.0	-259450.0
n m dg lg2 lg1	1	4	7672.0	-1605.0	-19886.0
n m dg lg2 lg1	1	5	866.0	2864.0	28207.0
n m dg lg2 lg1	1	6	396.0	447.0	4272.0
n m dg lg2 lg1	1	7	-94.0	-208.0	-2033.0
n m dg lg2 lg1	1	8	668.0	-578.0	-6114.0
n m dg lg2 lg1	1	9	-60.0	109.0	1120.0
n m dg lg2 lg1	1	10	-78.0	-205.0	-2011.0
n m dg lg2 lg1	1	11	122.0	28.0	219.0
n m dg lg2 lg1	1	12	-32.0	1.0	26.0
n m dg lg2 lg1	1	13	-50.0	-8.0	-55.0
n m dg lg2 lg1	1	14	-8.0	-8.0	-76.0
n m dg lg2 lg1	2	1	11626.0	-294965.0	-2955463.0
n m dg lg2 lg1	2	2	16630.0	-15859.0	-166905.0
n m dg lg2 lg1	2	3	-11994.0	-5754.0	-51543.0
n m dg lg2 lg1	2	4	-3604.0	2517.0	26972.0
n m dg lg2 lg1	2	5	2806.0	-2112.0	-22523.0
n m dg lg2 lg1	2	6	1730.0	1889.0	18025.0
n m dg lg2 lg1	2	7	-2110.0	442.0	5475.0
n m dg lg2 lg1	2	8	274.0	-212.0	-2257.0
n m dg lg2 lg1	2	9	176.0	-200.0	-2088.0
n m dg lg2 lg1	2	10	-218.0	116.0	1269.0
n m dg lg2 lg1	2	11	-40.0	-1.0	10.0
n m dg lg2 lg1	2	12	52.0	17.0	144.0
n m dg lg2 lg1	2	13	14.0	3.0	23.0
n m dg lg2 lg1	2	14	-6.0	3.0	33.0
n m dg lg2 lg1	3	1	-11872.0	-23966.0	-233724.0
n m dg lg2 lg1	3	2	-4338.0	30260.0	304769.0

Matrix created line by line obtained by the sequential reading of the file above:

1000.0	-26578.0	-22640.0	7672.0	866.0	396.0	-94.0	668.0	-60.0	-78.0	122.0	-32.0	-50.0	-8.0
11626.0	16630.0	-11994.0	-3604.0	2806.0	1730.0	-2110.0	274.0	176.0	-218.0	-40.0	52.0	14.0	-6.0
-11872.0	-4338.0												

1000 is the normalization coefficient i.e. each coefficient should be converted as a double precision number and divided by the value of the normalization coefficient.

The table lgt is constructed by reading this matrix column by column.

```
Data lgt/1000,
&        11626,-11872,680,…
&       -26578,16630,-4338,…
&       -22640,-11994,2168,…

&      -8, -6, ……………./
```

(14 lines; 14 columns)

Remarks:

None.

Called routines:

vs_chp   vs_igrf

6. MAGNETOSPHERIC PHYSICS CALCULATIONS

6.1 TESTBGSM

Purpose:

This program calculates the total magnetic as a sum of an internal magnetic field model and the external Tsyganenko model.

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Calculation of the total magnetic field as sum of the internal magnetic field (dipole, DGRF 2000, DGRF 2005 or IGRF 2010) and the external Tsyganenko fields 1987 and 1989, or Kosik 1997 in solar magnetic and solar ecliptic systems (**bgsm**).

Input data:

Data set in the program:

the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude (deg): $2 \leq$ thetd ≤ 6 (step 2 deg),
the geocentric longitude (deg): $20 \leq$ phid ≤ 60 (step 20 deg).

Parameters given by the user:

the name of the file of results,
the internal magnetic model field type (1 = dipole, 2 = DGRF00, 3= DGRF05, 4 = IGRF 10),
the external magnetic field (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field),
the geomagnetic index (1 = Kp, 2 = Ae),
the geomagnetic index value: (from 1 to 6),

the calculation date (year, month, day, hours, minutes and seconds).

Output data:

The file of results contains for each input:

the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
the x, y and z components of the magnetic field in the solar magnetospheric system (nanoteslas),
the x, y and z components of the magnetic field in the solar ecliptic system (nanoteslas).

Example:

iyear, imonth, iday, ihour, imin, isec
2012 3 1 0 0 0
magin, magout, indgm, indval
4 2 1 1

rre rre	thetd thetd	phid phid	bxgsm bxse	bygsm byse	bzgsm bzse
1.20	2.00	20.00	6746.068	6611.998	-32531.690
1.20	2.00	20.00	6746.068	-11606.061	-31101.908
1.20	4.00	20.00	8405.898	6947.605	-31947.754
1.20	4.00	20.00	8405.898	-11012.275	-30784.055
1.20	6.00	20.00	10019.461	7262.615	-31257.851
1.20	6.00	20.00	10019.461	-10379.886	-30365.388
1.20	8.00	20.00	11581.428	7556.151	-30466.543
1.20	8.00	20.00	11581.428	-9712.052	-29849.317

Remarks:

The file of results is named resbgsm.

The file of results corresponds to a test done for a date equal to 2012 3 1 0 0 0 and for magin, magout, indgm and indval = 4, 2, 1, 1.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF05, 4 = IGRF10

magout: external magnetic field model: 1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field.

indgm: geomagnetic index: 1 = Kp, 2 = Ae

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp =0, 0+	Ae = 0 - 50
indval = 2: Kp =1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp =2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp =3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp =4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

for Kosik 97 $1 \leq$ indval ≤ 5 and $1 \leq Kp \leq 5$

Called routines:

valfix inigeom bgsm

6.2 TESTCORGM

Purpose:

This program calculates the corrected geomagnetic coordinates, latitude and longitude taking in account the internal magnetic field (dipole, DGRF 00, DGRF 05, or IGRF10) and the external Tsyganenko field (Tsyganenko 1987 or Tsyganenko1989 or Kosik 1997) (**corgm**).

The calculations ends when the dipole geomagnetic equator is reached.

Input data:

Data set in the program:

the geocentric distance: rre = 1.0 Re,
the maximum geocentric distance: rmax = 200.0 Re,
the subsolar distance to the magnetopause: rb = 10.0 Re,
the geocentric colatitude (deg): 29 ≤ thetd ≤ 55 (2 deg step),
the geocentric longitude (deg): 20 ≤ phid ≤ 360 (20 deg step).

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the internal magnetic field model (1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4=IGRF10),
the external magnetic field model (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97),
the geomagnetic index type (1 = Kp, 2 = Ae),
the geomagnetic index value (from 1 to 6).

Output data:

The file of results contains for each input:

the points of the field in geocentric coordinates, for each point:
- the point number (Re),
- the geocentric radial distance, the geocentric colatitude and longitude (deg),

the points of the field in dipole coordinates, for each point:
- the point number,
- the geocentric radial distance (Re), the geocentric colatitude and longitude (deg),
- the corrected geomagnetic colatitude (deg),
- the corrected geomagnetic latitude (deg),
- the corrected geomagnetic longitude (deg).

Example:

iyear, imonth, iday, ihour, imin, isec
2012 3 1 0 0 0
magin, magout, indgm,
4 2 1 1

points of the field line in geocentric coordinates

n,r,theta,phi	1	1.000	29.000	20.000
n,r,theta,phi	2	1.000	29.000	20.000
n,r,theta,phi	3	1.000	29.000	20.000
n,r,theta,phi	4	1.162	31.674	19.656
n,r,theta,phi	5	1.162	31.674	19.656
n,r,theta,phi	6	1.321	34.315	19.601
n,r,theta,phi	7	1.321	34.315	19.601
n,r,theta,phi	8	1.478	36.903	19.685
n,r,theta,phi	9	1.633	39.446	19.874
n,r,theta,phi	10	1.785	41.941	20.100

n,r,theta,phi	25	3.504	78.605	24.725
n,r,theta,phi	26	3.547	81.246	25.086
n,r,theta,phi	27	3.573	83.913	25.456
n,r,theta,phi	28	3.582	86.593	25.835

points of the field line in dipole coordinates

n,rd,thetad,phid	1	1.000	30.905	109.379
n,rd,thetad,phid	2	1.000	30.905	109.379
n,rd,thetad,phid	3	1.000	30.905	109.379
n,rd,thetad,phid	4	1.162	33.371	107.406

n,rd,thetad,phid	29	3.574	90.723	98.205

corrected geomagnetic colatitude 31.914

corrected geomagnetic latitude 58.086

corrected geomagnetic longitude 98.226

Remarks:

The file of results is named rescorgm.

The file of results corresponds to a test done for a date equal to 2012 3 1 0 0 0 and for magin, magout, indgm and indval = 4, 2, 1, 1.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF00, 3 = DGRF05, 4 = IGRF10

magout: external magnetic field model: 1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97 field.

indgm: geomagnetic index: 1 = Kp, 2 = Ae indval: geomagnetic index value for Kp or Ae

indval = 1: Kp =0, 0+	Ae = 0 - 50
indval = 2: Kp = 1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp = 2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp = 3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp = 4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

for Kosik 97 1 ≤ indval ≤ 5 and 1 ≤ Kp ≤ 5

Last point: the dipole geomagnetic equator is reached, theta = 91.011.

Called routines:

valfix inigeom corgm tradeg

6.3 TESTDCONJ

Purpose:

This program calculates the field lines with the Merson algorithm with a great precision but is slow (Solving Ordinary differential equations by E. Hairer, SP P. Norsett, G. Wanner - Springer Verlag - p. 169, ref. 1).

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (inigeom).
- Calculation of the northern and southern conjugate points of a given point in the tilted dipole magnetic field (**conjdip**).
- Calculation of the conjugate point of a given point tacking in account a combination of the internal and the external fields (**dconjr**):
  magin: 1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF 2010
  magout: 0 = no external field, 1 = Tsyganenko 87, 2 = Tsyganenko 89, 3 = Kosik 97.

Input data:

Data set in the program:

the minimum geocentric distance: rend = 1.0 Re,
the maximum geocentric distance: rmax = 200.0 Re,
the subsolar distance to the magnetopause: rb = 10.0 Re,
the direction of the field lines: dir = -1.0 (lowest altitudes),
the departure point geocentric distance: rre = 1 Re,
the geocentric colatitude (deg): 29 ≤ thetd ≤ 55 (2 deg step),
the geocentric longitude (deg): 20 ≤ phid ≤ 360 (20 deg step).

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the internal magnetic field model (1 = dipole, 2 = DGRF 00, 3 = DGRF 05,
4 = IGRF10),
the external magnetic field model (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97 field),
the geomagnetic index type (1 = Kp, 2 = Ae),
the geomagnetic index value (from 1 to 6).

Output data:

The file of results contains for each input:

for each point of the field line:
the point number,
the geocentric colatitude and longitude of the point (deg).

Example:

iyear,imonth,iday,ihour,imin,isec
2012 3 1 0 0 0
magin,magout,indgm,indval
4 2 1 1

thet	phi	southern conjugate point (dipole field):	147.550	52.111
thet	phi	southern conjugate point (total field):	146.105	53.419
thet	phi	southern conjugate point (dipole field):	142.764	65.057
thet	phi	southern conjugate point (total field):	141.862	66.930
thet	phi	southern conjugate point (dipole field):	139.029	77.707
thet	phi	southern conjugate point (total field):	138.697	80.463
thet	phi	southern conjugate point (dipole field):	136.503	90.273
thet	phi	southern conjugate point (total field):	136.586	93.916
thet	phi	southern conjugate point (dipole field):	135.296	102.830
thet	phi	southern conjugate point (total field):	135.456	107.357
thet	phi	southern conjugate point (dipole field):	135.461	115.391
thet	phi	southern conjugate point (total field):	135.146	120.666

Remarks:
The file of results is named resdconj.

The file of results corresponds to a test done for a date equal to 2012 3 1 0 0 0 and for magin, magout, indgm and indval = 4, 2, 1,1.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4 = IGRF 2010

magout: external magnetic field model: 1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97.

indgm: geomagnetic index: 1 = Kp, 2 = Ae

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp = 0, 0+	Ae = 0 - 50
indval = 2: Kp = 1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp = 2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp = 3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp = 4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

for Kosik 97 1 ≤ indval ≤ 5 and 1 ≤ Kp ≤ 5

Called routines:

valfix inigeom conjdip dconjr tradeg

6.4 TESTECONJ

Purpose:

This program calculates the field tracing down to the equator, which corresponds to a minimum of the magnetic field (modulo the integration step).

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Calculation of the conjugate point of a given point taking in account a combination of the internal and the external fields (**econjr**):
  magin: 1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010
  magout: 0 = no external field, 1 = Tsyganenko 87, 2 = Tsyganenko 89, 3 = Kosik 97.

Input data:

Data set in the program:

the maximum geocentric distance: rmax = 200.0 Re,
the subsolar distance to the magnetopause: rb = 10.0 Re,
the direction of the field lines: dir = -1.0 (lowest altitudes),
the departure point geocentric distance: rre = 1 Re,
the geocentric colatitude (deg): $29 \leq$ thetd ≤ 55 (2 deg step),
the geocentric longitude (deg): $20 \leq$ phid ≤ 360 (20 deg step).

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the internal magnetic field model (1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4 = IGRF 10),
the external magnetic field model (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97 field),
the geomagnetic index type (1 = Kp, 2 = Ae).

Output data:

The file of results contains one line for each input:

for each point of the field line:
  the point number,
  the geocentric radial distance (Re), the geocentric colatitude and longitude (deg).

the geocentric radial distance (Re), the colatitude and the longitude of the equatorial conjugate point of minimum magnetic field in deg.

Example:

iyear,imonth,iday,ihour,imin,isec
2012 3 1 0 0 0
magin,magout,indgm,indval
4 2 1 1
field line tracing down to equator

n,tr,tthetd,tphid	1	1.000	29.000	20.000
n,tr,tthetd,tphid	2	1.238	32.924	19.524
n,tr,tthetd,tphid	3	1.471	36.754	19.516
n,tr,tthetd,tphid	4	1.699	40.478	19.716
n,tr,tthetd,tphid	5	1.921	44.111	20.017
n,tr,tthetd,tphid	6	2.136	47.675	20.373
n,tr,tthetd,tphid	7	2.345	51.194	20.758
n,tr,tthetd,tphid	8	2.545	54.690	21.161
n,tr,tthetd,tphid	9	2.826	59.940	21.788
n,tr,tthetd,tphid	10	3.080	65.256	22.438
n,tr,tthetd,tphid	11	3.297	70.703	23.114
n,tr,tthetd,tphid	12	3.465	76.327	23.826
n,tr,tthetd,tphid	13	3.568	82.133	24.580
n,tr,tthetd,tphid	14	3.592	88.044	25.381
n,tr,tthetd,tphid	15	3.533	93.915	26.223

req,theteqd,phieqd,equatorial conjugate 3.592 88.044 25.381

Remarks:

The file of results is named reseconj.

The file of results corresponds to a test done for a date equal to 2012 3 1 0 0 0 and for magin, magout, indgm and indval = 4, 2, 1,1.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4 = IGRF 10

magout: external magnetic field model: 1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97 field.

indgm: geomagnetic index: 1 = Kp, 2 = Ae

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp = 0, 0+	Ae = 0 - 50
indval = 2: Kp = 1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp = 2- , 2 , 2+	Ae = 100 - 150
indval = 4: Kp = 3- , 3 , 3+	Ae = 150 - 250
indval = 5: Kp = 4- , 4 , 4+	Ae = 250 - 400
indval = 6: Kp > 5	Ae ≥ 400

for Kosik 97 1 ≤ indval ≤ 5 and 1 ≤ Kp ≤ 5

Called routines:

valfix inigeom econjr tradeg

6.5 TESTPCONJ

Purpose:

This program calculates the field lines with a bootstrap algorithm using the internal and external fields with a fast algorithm with a fair precision.

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (inigeom).
- Calculation of the northern and southern conjugate points of a given point with a tilted dipole magnetic field (**conjdip**).
- Calculation of the conjugate point of a given point with a combination of the internal and the external fields and the different values of the geomagnetic indexes if any (**pconjr**):
  magin: 1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010
  magout: 0 = no external field, 1 = Tsyganenko 87, 2 = Tsyganenko 89, 3 = Kosik 97.

Input data:

Data set in the program:

the minimum geocentric distance: rend = 1.0 Re,
the maximum geocentric distance: rmax = 200.0 Re,
the subsolar distance to the magnetopause: rb = 10.0 Re,
the direction of the field lines: dir) = -1.0 (lowest altitudes),
the departure point geocentric distance: rre = 1.0 Re,
the geocentric colatitude (deg): 29 ≤ thetd ≤ 55 (2 deg step),
the geocentric longitude (deg): 20 ≤ phid ≤ 360 (20 deg step).

Parameters given by the user:

the name of the file of results,
the calculation date (year, month, day, hours, minutes and seconds),
the internal magnetic field type model (1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010),
the external magnetic field model (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97),
the geomagnetic index type (1 = Kp, 2 = Ae).

Output data:

The file of results contains for each input:

the geocentric colatitude and longitude of the dipolar southern conjugated point (deg) of the dipole field and the total field.

Example:
iyear,imonth,iday,ihour,imin,isec
2012 3 1 0 0 0
magin,magout,indgm,indval
4 2 1 1

thet phi southern conjugate point (dipole field):	144.735	50.577
thet phi southern conjugate point (total field):	143.060	48.024
thet phi southern conjugate point (dipole field):	139.553	63.903
thet phi southern conjugate point (total field):	139.384	62.880
thet phi southern conjugate point (dipole field):	135.482	76.900
thet phi southern conjugate point (total field):	136.563	77.576
thet phi southern conjugate point (dipole field):	132.715	89.803
thet phi southern conjugate point (total field):	134.626	92.152
thet phi southern conjugate point (dipole field):	131.389	102.700
thet phi southern conjugate point (total field):	133.526	106.782
thet phi southern conjugate point (dipole field):	131.570	115.602
thet phi southern conjugate point (total field):	133.035	121.263
thet phi southern conjugate point (dipole field):	133.249	128.498
thet phi southern conjugate point (total field):	133.151	134.873
thet phi southern conjugate point (dipole field):	136.343	141.412
thet phi southern conjugate point (total field):	134.346	147.176

Remarks:

The file of results is named respconj.

The file of results corresponds to a test done for a date equal to 2002 3 1 0 0 0 and for magin, magout, indgm and indval = 2, 2, 1,1.

magin: internal magnetic field model:
1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010

magout: external magnetic field model: 1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97.

indgm: geomagnetic index: 1 = Kp, 2 = Ae

indval: geomagnetic index value for Kp or Ae

indval = 1: Kp =0, 0+	Ae =0 - 50
indval = 2: Kp =1- , 1 , 1+	Ae = 50 - 100
indval = 3: Kp =2- , 2 , 2+	Ae =100 - 150
indval = 4: Kp =3- , 3 , 3+	Ae =150 - 250
indval = 5: Kp =4- , 4 , 4+	Ae =250 - 400
indval = 6: Kp > 5	Ae ≥ 400

for Kosik 97 $1 \leq indval \leq 5$ and $1 \leq Kp \leq 5$

Called routines:

valfix inigeom conjdip pconjr tradeg

6.6 TESTDLGALP

Purpose:

This program calculates the Galperin L parameter.

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Calculation of the Mac Ilwain L parameter according to the Y. Galperin's method. Invariant latitude is also calculated (**dlgalp**):
  magin: 1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010
  magout: 0 = no external field, 1 = Tsyganenko 87, 2 = Tsyganenko 89, 3 = Kosik 97.

Input data:

Data set in the program:

the calculation date: year = 2012, month = 3, day = 21, hours = 12, minutes = 0, seconds = 0,

the internal magnetic field is igrf 2010: magin = 4
the external magnetic field is Tsyganenko 1989: magout = 2,
the parameters ingeom and inval are set to 1,

the geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude (deg): $10 \leq$ thetd ≤ 28 (2 deg step),
the geocentric longitude (deg): $0 \leq$ phid ≤ 350 (20 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains one line for each input:

the geocentric radial distance (Re), colatitude and longitude (deg),
the Mac Ilwain L parameter,
the invariant latitude (rad).

Example:

rre,thetd,phid,flg,xlamb	1.20	10.00	0.00	26.24	78.74
rre,thetd,phid,flg,xlamb	1.20	10.00	10.00	22.29	77.77
rre,thetd,phid,flg,xlamb	1.20	10.00	20.00	19.52	76.92
rre,thetd,phid,flg,xlamb	1.20	10.00	30.00	17.53	76.18
rre,thetd,phid,flg,xlamb	1.20	10.00	40.00	16.07	75.56
rre,thetd,phid,flg,xlamb	1.20	10.00	50.00	14.99	75.03
rre,thetd,phid,flg,xlamb	1.20	10.00	60.00	14.19	74.60
rre,thetd,phid,flg,xlamb	1.20	10.00	70.00	13.60	74.27
rre,thetd,phid,flg,xlamb	1.20	10.00	80.00	13.16	74.00
rre,thetd,phid,flg,xlamb	1.20	10.00	90.00	12.85	73.80
rre,thetd,phid,flg,xlamb	1.20	10.00	100.00	12.66	73.68

Remarks:

The file of results is named resdlgalp.

Called routines:

valfix inigeom dlgalp

6.7 TESTFLGALP

Purpose:

This program calculates the Galperin L parameter.

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Calculation of the Mac Ilwain L parameter according to the Y. Galperin's method. Invariant latitude is also calculated (**flgalp**):
  magin: 1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010
  magout: 0 = no external field, 1 = Tsyganenko 87, 2 = Tsyganenko 89, 3 = Kosik 97.

Input data:

Data set in the program:

the calculation date: year = 2012, month = 3, day = 1, hours = 0, minutes = 0, seconds = 0,

the internal magnetic field is igrf 2010: magin = 4,
the external magnetic field is Tsyganenko 1989: magout = 2,
the parameters ingeom and inval are set to 1,
the departure point geocentric radial distance: rre = 1.2 Re,
the geocentric colatitude (deg): 10 ≤ thetd ≤ 28 (2 deg step),
the geocentric longitude (deg): 0 ≤ phid ≤ 350 (20 deg step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains one line for each input:

the geocentric radial distance (Re), colatitude and longitude (deg),
the Mac Ilwain L parameter,
the invariant latitude (rad).

Example:

rre,thetd,phid,flg,xlamb	1.20	10.00	0.00	26.15	78.72
rre,thetd,phid,flg,xlamb	1.20	10.00	10.00	22.22	77.75
rre,thetd,phid,flg,xlamb	1.20	10.00	20.00	19.47	76.90
rre,thetd,phid,flg,xlamb	1.20	10.00	30.00	17.48	76.16
rre,thetd,phid,flg,xlamb	1.20	10.00	40.00	16.04	75.54
rre,thetd,phid,flg,xlamb	1.20	10.00	50.00	14.97	75.02
rre,thetd,phid,flg,xlamb	1.20	10.00	60.00	14.17	74.59
rre,thetd,phid,flg,xlamb	1.20	10.00	70.00	13.57	74.25
rre,thetd,phid,flg,xlamb	1.20	10.00	80.00	13.14	73.98
rre,thetd,phid,flg,xlamb	1.20	10.00	90.00	12.84	73.79
rre,thetd,phid,flg,xlamb	1.20	10.00	100.00	12.65	73.67

Remarks:

The file of results is named resflgalp.

Called routines:

valfix inigeom flgalp

6.8 TESTGEOG

Purpose:

This program calculates the geographic quantities for a given date and given inertial components. 23 geographic quantities are calculated.

- Calculation of all the rotation matrices and the different angles used in all the calculation routines. These calculations are done for all epochs since 2000 (**inigeom**).
- Calculation of the geographic quantities and of all the magnetospheric local parameters (except magnetic field values) for a given set of orbital elements and a given date (**tgeogr**).

Input data:

Data set in the program:

the calculation date: year = 2002, month = 2, day = 2, hours = 2, minutes = 2, seconds = 2,
the orbit number: norb = 3,
the x, y and z inertial coordinates of the position:
xikm = 20000 km, yikm = 15000 km, zikm = 1000 km,
the x, y and z inertial coordinates of the velocity:
xivk = 3 km/s, yivk = 2 km/s, zivk = 1 km/s.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:
the calculation date (year, month, day, hours, minutes and seconds),
the CNES julian date,
the orbit number,
the x, y and z components of the position in the inertial coordinate system (km),
the x, y and z components of the velocity in the inertial coordinate system (km/s)
the geocentric (above geoid) altitude (km),
the geographic latitude and longitude (deg),
the geographic radial distance (Re),
the geocentric colatitude and longitude (deg),
the x, y and z coordinates in the solar ecliptic system (Re),
the x, y and z coordinates in the solar magnetospheric system (Re),
the geomagnetic latitude, longitude (deg) and local time (hours and fractions) of the spacecraft.

Example:

year,month,day,hours,min,sec	2002 2 2 2 2 2		
julian date	19025.084745		
orbit number	3		
xgkm,ygkm,zgkm	-14364.88	-20460.95	1000.00
vxgkm,vygkm,vzgkm	-3.72	-1.78	1.00
alt., lat. lon. geogr.	18641.87	0.04	4.10
rre, colat. long. geogr.	3.92	1.53	4.10
xgse,ygse,zgse coord. gse	0.47	3.81	-0.81
xgsm,ygsm, zgsm coord. gsm	0.47	3.80	0.84
lat, long, geom. tgml sat	0.15	5.34	17.23

Remarks:

The provided file of results is named resgeog.

Called routines:

valfix inigeom julg tgeogr

6.9 TESTILWE

Purpose:

This program calculates the electric field potential according to the Mac Ilwain model (**mcilwe**).

Input data:

Data set in the program:

the equatorial radius: req = 5, 7, 9 units of magnetic radius,
the geocentric colatitude (deg): 29 ≤ thetd ≤ 55 (2 deg step),
the geomagnetic local time (hours): 1 ≤ tgmleq ≤ 22 (3 hours step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each point:

the equatorial radius (units of magnetic radius),
the geomagnetic local time (hours and fractions),
the electric potential (kilovolts).

Example:

req	tgmleq	phikv
5.00	1.00	-6.3422
5.00	4.00	-6.9832
5.00	7.00	-8.2516
5.00	10.00	-9.4683
5.00	13.00	-10.6976
5.00	16.00	-11.4339
5.00	19.00	-11.5744
5.00	22.00	-10.8254
7.00	1.00	10.0351
7.00	4.00	2.8243
7.00	7.00	-1.6973
7.00	10.00	-4.6718
7.00	13.00	-6.9939
7.00	16.00	-8.8401
7.00	19.00	-9.3860
7.00	22.00	-8.1418
9.00	1.00	19.4198
9.00	4.00	8.5949
9.00	7.00	1.6427
9.00	10.00	-2.7847
9.00	13.00	-5.4454
9.00	16.00	-7.1363
9.00	19.00	-7.3890
9.00	22.00	-3.8806

Remarks:

The file of results is named resilwe.

Called routines:

valfix mcilwe

7. ASTRONOMY AND CELESTIAL MECHANICS

7.1 TESTSOLTER00

Purpose:

This program calculates the position of the Sun, and the dipole orientation for all epochs between 2000 and 2005.

- Calculation of the right ascension of Greenwich, the right ascension and the declination of the Sun ; calculation the geographic position of the point where the dipole cuts the northern hemisphere (**solter00**).

These calculations are done for all epochs from January 2000 the 1st to December 2004 the 31st.

Input data:

Data set in the program:

the initial calculation date: year = 2000, month = 3, day = 21, hours = 0, minutes = 0, seconds = 0
(0 ≤ hours ≤ 23, 1 hour step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the right ascension of Greenwich (deg),
the geocentric colatitude of the point where the dipole cuts the northern hemisphere (deg),
the geocentric longitude of the point where the dipole cuts the northern hemisphere (deg),
the right ascension and declination of the Sun (deg).

Example:

alfagd	tetdipd	phidipd	alfasd	deltasd
193.8599	10.4477	-71.5801	0.6666	0.2890
208.9010	10.4477	-71.5801	0.7046	0.3055
223.9421	10.4477	-71.5801	0.7426	0.3219
238.9831	10.4477	-71.5801	0.7805	0.3384
254.0242	10.4477	-71.5801	0.8185	0.3548
269.0653	10.4477	-71.5801	0.8564	0.3713
284.1064	10.4477	-71.5801	0.8944	0.3877
299.1474	10.4477	-71.5801	0.9324	0.4042
314.1885	10.4477	-71.5801	0.9703	0.4207
329.2296	10.4477	-71.5801	1.0083	0.4371
344.2706	10.4477	-71.5801	1.0462	0.4536
359.3117	10.4477	-71.5801	1.0842	0.4700
14.3528	10.4477	-71.5801	1.1221	0.4865
29.3938	10.4477	-71.5801	1.1601	0.5029
44.4349	10.4477	-71.5801	1.1981	0.5194
59.4760	10.4477	-71.5801	1.2360	0.5358
74.5170	10.4477	-71.5801	1.2740	0.5523
89.5581	10.4477	-71.5801	1.3119	0.5687
104.5992	10.4477	-71.5801	1.3499	0.5852
119.6402	10.4477	-71.5801	1.3878	0.6016
134.6813	10.4477	-71.5801	1.4258	0.6181
149.7224	10.4477	-71.5801	1.4637	0.6345
164.7635	10.4477	-71.5801	1.5017	0.6509

Remarks:

The file of results is named ressolter00.

Called routines:

valfix solter00

7.2 TESTSOLTER05

Purpose:

This program calculates the position of the Sun, and the dipole orientation for all between 2005 and 2010.

- Calculation of the right ascension of Greenwich, the right ascension and the declination of the Sun ; calculation the geographic position of the point where the dipole cuts the northern hemisphere (**soltern**).

These calculations are done for all epochs from January 2005 the 1st to December 2009 the 31st.

Input data:

Data set in the program:

the initial calculation date: year = 2005, month = 3, day = 21, hours = 0, minutes = 0, seconds = 0
(0 ≤ hours ≤ 23, 1 hour step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the right ascension of Greenwich (deg),
the geocentric colatitude of the point where the dipole cuts the northern hemisphere (deg),
the geocentric longitude of the point where the dipole cuts the northern hemisphere (deg),
the right ascension and declination of the Sun (deg).

Example:

alfagd	tetdipd	phidipd	alfasd	deltasd
193.6520	10.2402	-71.8226	0.4736	0.2053
208.6930	10.2402	-71.8226	0.5115	0.2218
223.7341	10.2402	-71.8226	0.5495	0.2382
238.7752	10.2402	-71.8226	0.5875	0.2547
253.8162	10.2402	-71.8226	0.6254	0.2711
268.8573	10.2402	-71.8226	0.6634	0.2876
283.8984	10.2402	-71.8226	0.7014	0.3041
298.9395	10.2402	-71.8226	0.7393	0.3205
313.9805	10.2402	-71.8226	0.7773	0.3370
329.0216	10.2402	-71.8226	0.8153	0.3534
344.0627	10.2402	-71.8226	0.8532	0.3699
359.1037	10.2402	-71.8226	0.8912	0.3863
14.1448	10.2402	-71.8226	0.9291	0.4028
29.1859	10.2402	-71.8226	0.9671	0.4193
44.2269	10.2402	-71.8226	1.0051	0.4357
59.2680	10.2402	-71.8226	1.0430	0.4522
74.3091	10.2402	-71.8226	1.0810	0.4686
89.3501	10.2402	-71.8226	1.1189	0.4851
104.3912	10.2402	-71.8226	1.1569	0.5015
119.4323	10.2402	-71.8226	1.1949	0.5180
134.4733	10.2402	-71.8226	1.2328	0.5344
149.5144	10.2402	-71.8226	1.2708	0.5509
164.5555	10.2402	-71.8226	1.3087	0.5673

Remarks:

The file of results is named ressoltern.

Called routines:

valfix solter05

7.3 TESTSOLTER10

Purpose:

This program calculates the position of the Sun, and the dipole orientation for all between 2005 and 2010.

- Calculation of the right ascension of Greenwich, the right ascension and the declination of the Sun ; calculation the geographic position of the point where the dipole cuts the northern hemisphere (**solter10**).

These calculations are done for all epochs from January 2010 the 1st to December 2014 the 31st.

Input data:

Data set in the program:

the initial calculation date: year = 2012, month = 3, day = 21, hours = 0, minutes = 0, seconds = 0
(0 ≤ hours ≤ 23, 1 hour step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains for each input:

the right ascension of Greenwich (deg),
the geocentric colatitude of the point where the dipole cuts the northern hemisphere (deg),
the geocentric longitude of the point where the dipole cuts the northern hemisphere (deg),
the right ascension and declination of the Sun (deg).

Example:

alfagd	tetdipd	phidipd	alfasd	deltasd
193.4440	9.9728	-72.2359	0.2805	0.1216
208.4851	9.9728	-72.2359	0.3184	0.1380
223.5261	9.9728	-72.2359	0.3564	0.1545
238.5672	9.9728	-72.2359	0.3944	0.1710
253.6083	9.9728	-72.2359	0.4324	0.1874
268.6494	9.9728	-72.2359	0.4703	0.2039
283.6904	9.9728	-72.2359	0.5083	0.2204
298.7315	9.9728	-72.2359	0.5463	0.2368
313.7726	9.9728	-72.2359	0.5842	0.2533
328.8136	9.9728	-72.2359	0.6222	0.2697
343.8547	9.9728	-72.2359	0.6602	0.2862
358.8958	9.9728	-72.2359	0.6981	0.3027
13.9368	9.9728	-72.2359	0.7361	0.3191
28.9779	9.9728	-72.2359	0.7741	0.3356
44.0190	9.9728	-72.2359	0.8120	0.3520
59.0600	9.9728	-72.2359	0.8500	0.3685
74.1011	9.9728	-72.2359	0.8880	0.3849
89.1422	9.9728	-72.2359	0.9259	0.4014
104.1832	9.9728	-72.2359	0.9639	0.4178
119.2243	9.9728	-72.2359	1.0019	0.4343
134.2654	9.9728	-72.2359	1.0398	0.4508
149.3065	9.9728	-72.2359	1.0778	0.4672
164.3475	9.9728	-72.2359	1.1157	0.4837
179.3886	9.9728	-72.2359	1.1537	0.5001

Remarks:

The file of results is named ressoltern.

Called routines:

valfix solter10

7.4 TESTSOLTV

Purpose:

This program calculates the position of the Sun, and the dipole orientation for all epochs between 1970 and 2000.

- Calculation of the right ascension of Greenwich, the right ascension and the declination of the Sun ; calculation the geographic position of the point where the dipole cuts the northern hemisphere (**solterv**).

These calculations are done for all epochs from January 1970 the 1st to December 1999 the 31st.

Input data:

Data set in the program:

the initial date: year = 1970, month = 6, day = 6, hours = 6, minutes = 6, seconds = 6 (1970 ≤ year ≤ 1999, 1 year step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains one line for each input:

the calculation date (year, month, day, hours, minutes and seconds),
the geocentric colatitude and longitude of the point where the dipole cuts the northern hemisphere (deg).

Example:

date						tetdipd	phidipd
1970	6	6	6	6	6	11.40	-70.21
1971	6	6	6	6	6	11.38	-70.26
1972	6	6	6	6	6	11.36	-70.32
1973	6	6	6	6	6	11.34	-70.38
1974	6	6	6	6	6	11.32	-70.44
1975	6	6	6	6	6	11.30	-70.50
1976	6	6	6	6	6	11.28	-70.56
1977	6	6	6	6	6	11.25	-70.61
1978	6	6	6	6	6	11.23	-70.67
1979	6	6	6	6	6	11.21	-70.73
1980	6	6	6	6	6	11.18	-70.77
1981	6	6	6	6	6	11.14	-70.80
1982	6	6	6	6	6	11.11	-70.83
1983	6	6	6	6	6	11.08	-70.85
1984	6	6	6	6	6	11.04	-70.88
1985	6	6	6	6	6	11.01	-70.92
1986	6	6	6	6	6	10.98	-70.96
1987	6	6	6	6	6	10.94	-71.01
1988	6	6	6	6	6	10.91	-71.06
1989	6	6	6	6	6	10.88	-71.10
1990	6	6	6	6	6	10.85	-71.15
1991	6	6	6	6	6	10.81	-71.21
1992	6	6	6	6	6	10.78	-71.27
1993	6	6	6	6	6	10.75	-71.32
1994	6	6	6	6	6	10.72	-71.38
1995	6	6	6	6	6	10.68	-71.42
1996	6	6	6	6	6	10.63	-71.46
1997	6	6	6	6	6	10.58	-71.49
1998	6	6	6	6	6	10.53	-71.52
1999	6	6	6	6	6	10.48	-71.55
2000	6	6	6	6	6	10.44	-71.59
2001	6	6	6	6	6	10.39	-71.64
2002	6	6	6	6	6	10.35	-71.69
2003	6	6	6	6	6	10.31	-71.73
2004	6	6	6	6	6	10.27	-71.78

Remarks:

The file of results is named ressoltv.

Called routines:

valfix solterv

7.5 TESTSOLTVO

Purpose:

This program calculates the position of the Sun, and the dipole orientation for all epochs between 1945 and 1970.

- Calculation of the right ascension of Greenwich, the right ascension and the declination of the Sun ; calculation the geographic position of the point where the dipole cuts the northern hemisphere (**soltervo**).

These calculations are done for all epochs from January 1945 the 1st to December 1969 the 31st.

Input data:

Data set in the program:

the initial date: year = 1945, month = 6, day = 6, hours = 6, minutes = 6, seconds = 6
(1945 ≤ year ≤ 1969, 1 year step).

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains one line for each input:

the calculation date (year, month, day, hours, minutes and seconds),
the geocentric colatitude and longitude of the point where the dipole cuts the northern hemisphere (deg).

Example:

date						tetdipd	phidipd
1945	6	6	6	6	6	11.53	-1.20
1946	6	6	6	6	6	11.53	-1.20
1947	6	6	6	6	6	11.53	-1.20
1948	6	6	6	6	6	11.53	-1.20
1949	6	6	6	6	6	11.53	-1.20
1950	6	6	6	6	6	11.53	-1.20
1951	6	6	6	6	6	11.54	-1.20
1952	6	6	6	6	6	11.54	-1.20
1953	6	6	6	6	6	11.54	-1.21
1954	6	6	6	6	6	11.54	-1.21
1955	6	6	6	6	6	11.53	-1.21
1956	6	6	6	6	6	11.52	-1.21
1957	6	6	6	6	6	11.51	-1.21

1958	6	6	6	6	6	11.51	-1.21
1959	6	6	6	6	6	11.50	-1.21
1960	6	6	6	6	6	11.49	-1.21
1961	6	6	6	6	6	11.48	-1.21
1962	6	6	6	6	6	11.48	-1.22
1963	6	6	6	6	6	11.47	-1.22
1964	6	6	6	6	6	11.47	-1.22
1965	6	6	6	6	6	11.46	-1.22
1966	6	6	6	6	6	11.45	-1.22
1967	6	6	6	6	6	11.44	-1.22
1968	6	6	6	6	6	11.43	-1.22
1969	6	6	6	6	6	11.41	-1.22

Remarks:

The file of results is named ressoltvo.

Called routines:

valfix soltervo

8. CONTROL ROUTINES FOR DATES AND PARAMETERS

8.1 TESTCTRL

Purpose:

This program controls the input data for calculation routines (**ctrlpar**).

Input data:

Parameters given by the user:

the name of the file of results,
the date type (0 = julian, 1 = calendar),
the julian date or gregorian date (year, month, day, hours, minutes and seconds),
the internal magnetic field type model
(1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = IGRF2010)
the external magnetic field model (1 = Tsyganenko 87 field, 2 = Tsyganenko 89 field, 3 = Kosik 97),
the geomagnetic index type (1 = Kp, 2 = Ae),
the geomagnetic index value (from 1 to 6),
the distance unit (0 = km, 1 = Re),
the geographic radial distance (depending on distance unit),
the geocentric colatitude and longitude (rad).

Output data:

The file of results contains:

the given parameters (julian or gregorian date, geomagnetic indexes, distance unit, geocentric radial distance, latitude and longitude),
the four validation codes (date, geomagnetic indexes, distance, position): 0 = OK, 1 = NON OK.

<u>Example:</u>

```
calendar date                              : 2007  3  1  0  0  0
magin,magout,indgm,indval                  : 4 2 1 1
calculation distance unit (0=Km , 1=earth radii) : 1
r tetha phi                                :   1.000  30.000  30.000

datation indexes distance position (0=OK, 1=KO)  : 0 0 0 0
```

Remarks:

The file of results is named resctrl.

Called routines:

valfix ctrlpar

8.2 TESTDATE

Purpose:

This program transforms a CNES julian date into a gregorian date and vice-versa.

- Transformation of a gregorian date into a CNES julian day (**julg**),
- Calculation of the days, hours, minutes and seconds from a number of seconds (**datjhms**).
- Transformation of a CNES julian day into a gregorian date (**calendg**).

Input data:

Data set in the program:

the calculation gregorian date: year = 1997, month = 3, day = 21, hours = 6, minutes = 30, seconds = 10.

Parameters given by the user:

the name of the file of results.

Output data:

The file of results contains:

the gregorian date (year, month, day, hours, minutes, and seconds),
CNES julian date.

Example:

iyear,imonth,iday,ihour,imin,isec:1997 3 21 6 30 10
julian date: 17246.270949

Remarks:

The file of results is named resdate.

Called routines:

datjhms calendg julg