# 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 |
| 5 | 0 | 28/02/2017 |
| 6 | 0 | 31/07/2020 |

**MAGLIB**

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# Table of contents

# 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 6.0**

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:

- testchp20
- testgrad20
- testdgn95_20
- testsolter20

**Revision 5.0**

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:

- testchp15
- testgrad15
- testdgn95_15
- testsolter15

**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'

# 2. 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.

# 3. GENERATING AND USING MAGLIB LIBRARY UNDER UNIX/LINUX SYSTEM

## 3.1 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 makefiles.
- 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_<compiler>**
where **<compiler>** could be gfortran, g77 or f77

## 3.2 GENERATING USER'S PROGRAMS

The user's programs and associated makefile and file 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**

A directory called “test” is installed. It contains "src", "bin", "gen" and "results" directories.

- The "src" directory contains all the source code files of the user’s programs.
- The "gen" directory contains the makefiles.
- The "bin" directory is empty; it will contain the binary executables user’s programs after make file is performed.
- The "results" directory contains file of results as obtained and validated by the CNES.

Before performing the makefile, be sure to check these three environment variables in the Makefile_<compiler> file :

- REP_BIN_TEST : the target directory in which you want to create the executables
- REP_SRC_TEST : the source directory which contains the source code
- REP_LIB : the source directory in which you’ve previously created the maglib

To perform the makefile, the commands are:

**cd gen**
**make -f Makefile_<compiler>**
where **<compiler>** could be gfortran, g77 or f77

**NOTE**: If you want to add new programs, you must add the source code in the directory defined by the REP_SRC_TEST variable.

# 4. STARTING ROUTINES AND COORDINATE TRANSFORMATIONS

## 4.1 TESTCOORD

**Purpose:**

This program performs coordinate transformations for each month in year 2022. 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 $1^{st}$ to December 2024 the $31^{st}$ (**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 = 2022, month = 1, day = 21, hours = 0, minutes = 0, seconds = 0
($0 \leq$ hours $\leq 12$, 3 hours step), ($1 \leq$ month $\leq 12$, 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 2022   1   21    0    0    0  tilt -22.020  gsm  -6.629  -5.175   2.069 gse  -6.629  -4.004   3.876
date 2022   1   21    3    0    0  tilt -27.864  gsm  -2.028  -7.457   3.908 gse  -2.028  -5.893   6.013
date 2022   1   21    6    0    0  tilt -28.887  gsm   2.764  -4.940   6.554 gse   2.764  -3.729   7.311
date 2022   1   21    9    0    0  tilt -24.365  gsm   4.943   0.744   7.072 gse   4.943   1.221   7.005
date 2022   1   21   12    0    0  tilt -17.266  gsm   3.232   5.746   5.615 gse   3.232   6.060   5.276
date 2022   1   21   15    0    0  tilt -11.733  gsm  -1.366   7.442   4.213 gse  -1.366   7.954   3.141
date 2022   1   21   18    0    0  tilt -10.757  gsm  -6.158   5.110   3.312 gse  -6.158   5.799   1.858
date 2022   1   21   21    0    0  tilt -14.848  gsm  -8.337   0.014   2.345 gse  -8.337   0.859   2.182
date 2022   1   21   24    0    0  tilt -21.788  gsm  -6.623  -5.172   2.094 gse  -6.623  -3.968   3.923
date 2022   2   21    0    0    0  tilt -12.739  gsm  -6.121  -5.266   3.131 gse  -6.121  -2.971   5.358
```

**Remarks:**

One must have xgsm = xgse.

**Called routines:**

valfix    inigeom    geogsm    geose

## 4.2 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 1$^{st}$ to December 2024 the 31$^{st}$.

- Calculation of all the rotation matrices and of the different angles used in all the calculation routines for all epochs from January 2000 the 1$^{st}$ to December 2024 the 31$^{st}$ (**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 = 2022, 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  2022   3  21  12   0   0

alfagd,tetdipd,phidipd,alfasd,deltasd,tiltd   358.988   9.301 -72.663   0.782   0.339   2.817

   rgdip  0.2941 -0.9420 -0.1616  0.9546  0.2980  0.0000  0.0482 -0.1543  0.9869
    rgsm  0.9983  0.0389 -0.0426 -0.0318  0.9873  0.1559  0.0482 -0.1543  0.9869
   rggsm  0.9995  0.0313  0.0059 -0.0318  0.9873  0.1559 -0.0010 -0.1560  0.9878
     rig  0.9998 -0.0177  0.0000  0.0177  0.9998  0.0000  0.0000  0.0000  1.0000
   rigsm  0.9999  0.0136  0.0059 -0.0144  0.9877  0.1559 -0.0037 -0.1560  0.9878
    rgse  0.9995  0.0313  0.0059 -0.0311  0.9170  0.3977  0.0070 -0.3977  0.9175
    rism  0.9989  0.0213 -0.0426 -0.0144  0.9877  0.1559  0.0454 -0.1551  0.9869
    rise  0.9999  0.0136  0.0059 -0.0149  0.9174  0.3977  0.0000 -0.3977  0.9175

     geog. coord.    -6.400   -1.696    0.098
     gse   coord.    -6.449   -1.317    0.719
     gsm   coord.    -6.449   -1.455    0.368
     sm    coord.    -6.460   -1.455    0.050
```

**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 |

## 4.3 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 2024 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 = 2022, 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 2022 3 21 12 0 0

alfagd,tetdipd,phidipd,alfasd,deltasd,tiltd 358.988 9.301 -72.663 0.782 0.339 2.817

```
  rgdip  0.2941 -0.9420 -0.1616  0.9546  0.2980  0.0000  0.0482 -0.1543  0.9869
   rgsm  0.9983  0.0389 -0.0426 -0.0318  0.9873  0.1559  0.0482 -0.1543  0.9869
  rggsm  0.9995  0.0313  0.0059 -0.0318  0.9873  0.1559 -0.0010 -0.1560  0.9878
  rigsm  0.9999  0.0136  0.0059 -0.0149  0.9174  0.3977  0.0000 -0.3977  0.9175
 rsmgsm  0.9988  0.0000  0.0491  0.0000  1.0000  0.0000 -0.0491  0.0000  0.9988
    rig  0.9998 -0.0177  0.0000  0.0177  0.9998  0.0000  0.0000  0.0000  1.0000
   rgse  0.9995  0.0313  0.0059 -0.0311  0.9170  0.3977  0.0070 -0.3977  0.9175
   rism  0.9989  0.0213 -0.0426 -0.0144  0.9877  0.1559  0.0454 -0.1551  0.9869
   rise  0.9999  0.0136  0.0059 -0.0149  0.9174  0.3977  0.0000 -0.3977  0.9175
```

```
geog. coord.   -6.400   -1.696   0.098
gse   coord.   -6.449   -1.317   0.719
gsm   coord.   -6.449   -1.455   0.368
sm    coord.   -6.460   -1.455   0.050
```

**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 |

## 4.4 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).

Example:

| 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

## 4.5 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 = 2020.0,

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   2020.00     2.300     0.698     1.222

    rgvdh  -0.947257  0.319872  0.019634
    rgvdh  -0.233177 -0.729958  0.642488
    rgvdh   0.219846  0.604023  0.766044


    rvdhg  -0.947257 -0.233177  0.219846
    rvdhg   0.319872 -0.729958  0.604023
    rvdhg   0.019634  0.642488  0.766044
```

**Remarks:**

**Called routines:**

valfix rovdh

# 5. BOUNDARIES AND REGIONS

## 5.1 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

## 5.2 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: $1 \leq$ isw $\leq 5$,
the x, y and z solar magnetospheric coordinates (Re):
$20 \leq$ xgsm $\leq -37$ (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.

<u>Example:</u>

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

## 5.3 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

## 5.4 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

## 5.5 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 ≤ phido ≤ 360 (30 deg step),
the geocentric colatitude (deg): 0 ≤ 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

# 6. MAGNETIC FIELD MODELS

## 6.1 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:

Example:

```
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** and **chp00** routines must be identical.

**Called routines:**

valfix dgrf00 chp00

## 6.2 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:

Example:

| | | | | | |
|---|---|---|---|---|---|
| re | thetd | phid | dgrf05: br1nt | bt1nt | bp1nt |
| re | thetd | phid | chp05: br2nt | bt2nt | bp2nt |
| 1.20 | 10.00 | 10.00 | -32954.9727453 | -3730.1140133 | -392.7118347 |
| 1.20 | 10.00 | 10.00 | -32954.9727453 | -3730.1140133 | -392.7118347 |
| 1.20 | 40.00 | 10.00 | -25510.9744475 | -12017.4256468 | -157.1569314 |
| 1.20 | 40.00 | 10.00 | -25510.9744475 | -12017.4256468 | -157.1569314 |
| 1.20 | 70.00 | 10.00 | -8002.0096469 | -18313.0395626 | -470.3616956 |
| 1.20 | 70.00 | 10.00 | -8002.0096469 | -18313.0395626 | -470.3616956 |

| | | | | | |
|---|---|---|---|---|---|
| 1.20 | 100.00 | 10.00 | 11015.6850808 | -12941.8662194 | -1706.7112442 |
| 1.20 | 100.00 | 10.00 | 11015.6850808 | -12941.8662194 | -1706.7112442 |
| | | | | | |
| 1.20 | 10.00 | 40.00 | -33276.2389494 | -3495.3469113 | 478.4311880 |
| 1.20 | 10.00 | 40.00 | -33276.2389494 | -3495.3469113 | 478.4311880 |

**Remarks:**

The results of **dgrf05** and **chp05** routines must be identical.

**Called routines:**

valfix dgrf05 chp05

## 6.3 TESTCHP10

**Purpose:**

This program calculates the original internal magnetic field with the coefficients from DGRF10 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 **dgrf10** 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 **dgrf10** 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 | dgrf10: | br1nt | bt1nt | bp1nt |
| re | thetd | phid | chp10: | br2nt | bt2nt | bp2nt |
| 1.20 | 10.00 | 10.00 | -32977.7066979 | | -3710.9640526 | -242.9083917 |
| 1.20 | 10.00 | 10.00 | -32977.7066979 | | -3710.9640526 | -242.9083917 |
| 1.20 | 40.00 | 10.00 | -25555.2494160 | | -12036.2912999 | -4.2705249 |
| 1.20 | 40.00 | 10.00 | -25555.2494160 | | -12036.2912999 | -4.2705249 |
| 1.20 | 70.00 | 10.00 | -7969.3512308 | | -18358.1053157 | -306.2826074 |
| 1.20 | 70.00 | 10.00 | -7969.3512308 | | -18358.1053157 | -306.2826074 |

| | | | | | |
|---|---|---|---|---|---|
| 1.20 | 100.00 | 10.00 | 11069.2761793 | -12892.9071370 | -1555.1452334 |
| 1.20 | 100.00 | 10.00 | 11069.2761793 | -12892.9071370 | -1555.1452334 |
| | | | | | |
| 1.20 | 10.00 | 40.00 | -33317.4909586 | -3412.3607249 | 586.8695509 |
| 1.20 | 10.00 | 40.00 | -33317.4909586 | -3412.3607249 | 586.8695509 |

**Remarks:**

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

**Called routines:**

valfix dgrf10 chp10

## 6.4 TESTCHP15

**Purpose:**

This program calculates the original internal magnetic field with the coefficients from DGRF15 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 2015 coefficients with routines **dgrf15** and **chp15**.

**Input data:**

*Data set in the program:*

the calculation date: tm = 2020.,
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 **dgrf15** 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 **chp15** routine:

Example:

```
re  thetd phid dgrf15:    br1nt         bt1nt         bp1nt
re  thetd phid chp15:     br2nt         bt2nt         bp2nt

1.20  10.00  10.00    -33047.1689281   -3662.5875032     -82.6579951
1.20  10.00  10.00    -33047.1689281   -3662.5875032     -82.6579951

1.20  40.00  10.00    -25654.4417604  -12049.0145770     163.3891501
1.20  40.00  10.00    -25654.4417604  -12049.0145770     163.3891501

1.20  70.00  10.00     -7997.5538870  -18400.4549649    -127.5880611
1.20  70.00  10.00     -7997.5538870  -18400.4549649    -127.5880611

1.20 100.00  10.00     11042.5184021  -12858.5556903   -1396.0175187
1.20 100.00  10.00     11042.5184021  -12858.5556903   -1396.0175187
```

| | | | | | |
|---|---|---|---|---|---|
| 1.20 | 10.00 | 40.00 | -33408.8257391 | -3296.1957081 | 689.9418838 |
| 1.20 | 10.00 | 40.00 | -33408.8257391 | -3296.1957081 | 689.9418838 |

**Remarks:**

The results of **dgrf15** and **chp15** routines must be identical.

**Called routines:**

valfix dgrf15 chp15

## 6.5 TESTCHP20

**Purpose:**

This program calculates the original internal magnetic field with the coefficients from IGRF20 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 2020 coefficients with routines **igrf20** and **chp20**.

**Input data:**

*Data set in the program:*

the calculation date: tm = 2025.,
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 **igrf20** 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 **chp20** routine:

Example:

```
re  thetd phid igrf20:     br1nt          bt1nt          bp1nt
re  thetd phid chp20:       br2nt          bt2nt          bp2nt

1.20  10.00  10.00    -33135.0453883   -3602.1782778      75.1623100
1.20  10.00  10.00    -33135.0453883   -3602.1782778      75.1623100

1.20  40.00  10.00    -25779.2322411  -12058.4982412     334.5302521
1.20  40.00  10.00    -25779.2322411  -12058.4982412     334.5302521

1.20  70.00  10.00     -8063.2656623  -18436.0221585      49.7326116
1.20  70.00  10.00     -8063.2656623  -18436.0221585      49.7326116

1.20 100.00  10.00     10970.7081557  -12837.7203237   -1250.7590054
1.20 100.00  10.00     10970.7081557  -12837.7203237   -1250.7590054
```

| | | | | | |
|---|---|---|---|---|---|
| 1.20 | 10.00 | 40.00 | -33517.8137178 | -3169.6231339 | 784.5570586 |
| 1.20 | 10.00 | 40.00 | -33517.8137178 | -3169.6231339 | 784.5570586 |

**Remarks:**

The results of **igrf20** and **chp20** routines must be identical.

**Called routines:**

valfix igrf20 chp20

## 6.6 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 = 2000.,
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:

<u>Example:</u>

| 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 results of **dgrf95** and **chp95** routines must be identical.

**Called routines:**

valfix dgrf95 chp95

## 6.7 TESTDGN95_20

**Purpose:**

This program calculates the magnetic field for several epochs between 1995 and 2020 with two different routines: **chp95_20** and **igrf95_20.**

**Input data:**

*Data set in the program:*

the calculation date: 1997 ≤ tm ≤ 2019 (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_20** routine,
the results of **igrf95_20** routine.

Example:

```
1997.0


 re   thet  phi   chp95_20 results (br bt bp)      igrf95_20 results (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
```

2019.0

| re | thet | phi | chp95_20 results (br bt bp) | | | igrf95_20 results (br bt bp) | | |
|---|---|---|---|---|---|---|---|---|
| 1.2 | 2.0 | 20.0 | -33852.8 | -1276.0 | -106.1 | -33852.8 | -1276.0 | -106.1 |
| 1.2 | 4.0 | 20.0 | -33717.3 | -1875.4 | -21.3 | -33717.3 | -1875.4 | -21.3 |
| 1.2 | 6.0 | 20.0 | -33549.2 | -2466.3 | 57.3 | -33549.2 | -2466.3 | 57.3 |
| 1.2 | 8.0 | 20.0 | -33349.8 | -3049.2 | 129.4 | -33349.8 | -3049.2 | 129.4 |
| 1.2 | 2.0 | 40.0 | -33889.5 | -1219.9 | 184.2 | -33889.5 | -1219.9 | 184.2 |
| 1.2 | 4.0 | 40.0 | -33801.1 | -1743.6 | 318.1 | -33801.1 | -1743.6 | 318.1 |
| 1.2 | 6.0 | 40.0 | -33688.8 | -2267.3 | 444.1 | -33688.8 | -2267.3 | 444.1 |
| 1.2 | 8.0 | 40.0 | -33552.4 | -2792.2 | 561.4 | -33552.4 | -2792.2 | 561.4 |
| 1.2 | 2.0 | 60.0 | -33934.0 | -1067.5 | 403.1 | -33934.0 | -1067.5 | 403.1 |
| 1.2 | 4.0 | 60.0 | -33903.0 | -1502.8 | 522.8 | -33903.0 | -1502.8 | 522.8 |
| 1.2 | 6.0 | 60.0 | -33860.0 | -1946.6 | 636.5 | -33860.0 | -1946.6 | 636.5 |
| 1.2 | 8.0 | 60.0 | -33803.0 | -2401.5 | 743.6 | -33803.0 | -2401.5 | 743.6 |

**Remarks:**

The results of **chp95_20** and **igrf95_20** 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_20** and **igrf95_20** must be identical.

**Called routines:**

valfix chp95_20 igrf95_20

## 6.8 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 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

## 6.9 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 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

## 6.10 TESTDIPEX2

**Purpose:**

This program calculates the tilted eccentered dipole using the coefficients of the DGRF 2015 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 2015 given by IAGA:

g10 = -0.2944146,
g11 = -0.0150177,
h11 = +0.0479599,
g20 = -0.0244588,
g21 = +0.0301220,
h21 = -0.0284541,
g22 = +0.0167635,
h22 = -0.0064217.

*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).

<u>Example:</u>

```
ginc10,tetdip,phidip   0.29867313   9.68694657 -72.61307838

Coordinates of the eccentered coordinate system:
x0,y0,z0  -485.9601  -276.4988   141.6524
```

**Called routines:**

valfix incline

## 6.11 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.

<u>Example:</u>

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 |

**Called routines:**

valfix grad00 igrf00

## 6.12 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.

<u>Example:</u>

year, rre, thetd, phid 2005.10 1.20 45.00 130.00

ANALYTIC CALCULATION grad05
br, bt, bp -25965.56 14436.09 -1371.00

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 70905.58287 | 35797.94433 | 7973.40517 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28521.44060 | -18568.13832 | 543.15900 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5796.21266 | -585.37456 | -107.02246 |

ANALYTIC CALCULATION dgrf05
br, bt, bp -25965.56 -14436.09 -1371.00

NUMERICAL CALCULATION dgrf05

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 70905.56988 | 35797.93840 | 7973.40279 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28521.44257 | -18568.13763 | 543.15946 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5796.21284 | -585.37454 | -107.02198 |

**Called routines:**

valfix grad05 dgrf05

## 6.13 TESTGRAD10

**Purpose:**

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the IGRF 2010 model, using **grad10** and **dgrf10** 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 **dgrf10** routine.

<u>Example:</u>

year, rre, thetd, phid   2010.10   1.20   45.00   130.00

ANALYTIC CALCULATION GRAD10
br, bt, bp  -26038.31 -14389.14  -1406.64

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 70962.39022 | 35676.55754 | 8006.05455 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28422.72971 | -18587.05799 | 460.45540 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5798.71610 | -669.05532 | -72.16247 |

ANALYTIC CALCULATION DGRF10
br, bt, bp -26038.31 -14389.14 -1406.64

NUMERICAL CALCULATION dgrf10

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 70962.37736 | 35676.55163 | 8006.05219 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28422.73187 | -18587.05747 | 460.45586 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5798.71642 | -669.05522 | -72.16200 |

**Called routines:**

valfix grad10 dgrf10

## 6.14 TESTGRAD15

**Purpose:**

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the DGRF 2015 model, using **grad15** and **dgrf15** routines.

**Input data:**

*Data set in the program:*

the calculation date (years): year = 2015.1,
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 **grad15** 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 **dgrf15** routine.

<u>Example:</u>

```
year, rre, thetd, phid     2015.10      1.20     45.00    130.00


          ANALYTIC CALCULATION GRAD15
          br, bt, bp   -26165.35 -14318.79  -1463.18

gradb(1,1),gradb(2,1),gradb(3,1)    71216.09752    35455.68665     8109.87973
gradb(1,2),gradb(2,2),gradb(3,2)    28228.03548   -18688.98092      330.28998
gradb(1,3),gradb(2,3),gradb(3,3)     5846.83719     -801.07366      -85.44550

          ANALYTIC CALCULATION DGRF15
          br, bt, bp   -26165.35 -14318.79  -1463.18
```

NUMERICAL CALCULATION dgrf15

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 71216.08458 | 35455.68092 | 8109.87735 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28228.03775 | -18688.98028 | 330.29041 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5846.83707 | -801.07351 | -85.44502 |

**Called routines:**

valfix    grad15    dgrf15

## 6.15 TESTGRAD20

**Purpose:**

Calculation of the magnetic field components and the nine associated gradients with the coefficients of the IGRF 2020 model, using **grad20** and **igrf20** routines.

**Input data:**

*Data set in the program:*

the calculation date (years): year = 2020.1,
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 **grad20** 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 **igrf20** routine.

Example:

```
 year, rre, thetd, phid     2020.10      1.20     45.00    130.00

        ANALYTIC CALCULATION GRAD20
         br, bt, bp   -26292.21 -14285.44  -1559.79

gradb(1,1),gradb(2,1),gradb(3,1)    71496.96520    35362.96617     8343.58506
gradb(1,2),gradb(2,2),gradb(3,2)    28150.11987   -18831.35630      249.25845
gradb(1,3),gradb(2,3),gradb(3,3)     5976.83073     -926.68363      -67.27358

        ANALYTIC CALCULATION IGRF20
         br, bt, bp   -26292.21 -14285.44  -1559.79
```

NUMERICAL CALCULATION igrf20

| | | | |
|---|---|---|---|
| gradb(1,1),gradb(2,1),gradb(3,1) | 71496.95215 | 35362.96035 | 8343.58267 |
| gradb(1,2),gradb(2,2),gradb(3,2) | 28150.12199 | -18831.35558 | 249.25889 |
| gradb(1,3),gradb(2,3),gradb(3,3) | 5976.83095 | -926.68346 | -67.27311 |

**Called routines:**

valfix    grad20    igrf20

## 6.16 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.

<u>Example:</u>

```
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 |

**Called routines:**

valfix grad95 dgrf95

## 6.17 TESTKK97

**Purpose:**

This program calculates the magnetic field with the Kosik 97 model for various geomagnetic activity Kp index $\{1 \leq Kp < 6\}$ 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:**

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

## 6.18 TESTMF75

**Purpose:**

This program calculates the magnetic field with the Mead Fairfield 75 external field model for different Kp indexes $\{1 \le Kp < 4\}$ 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:**

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

## 6.19 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.

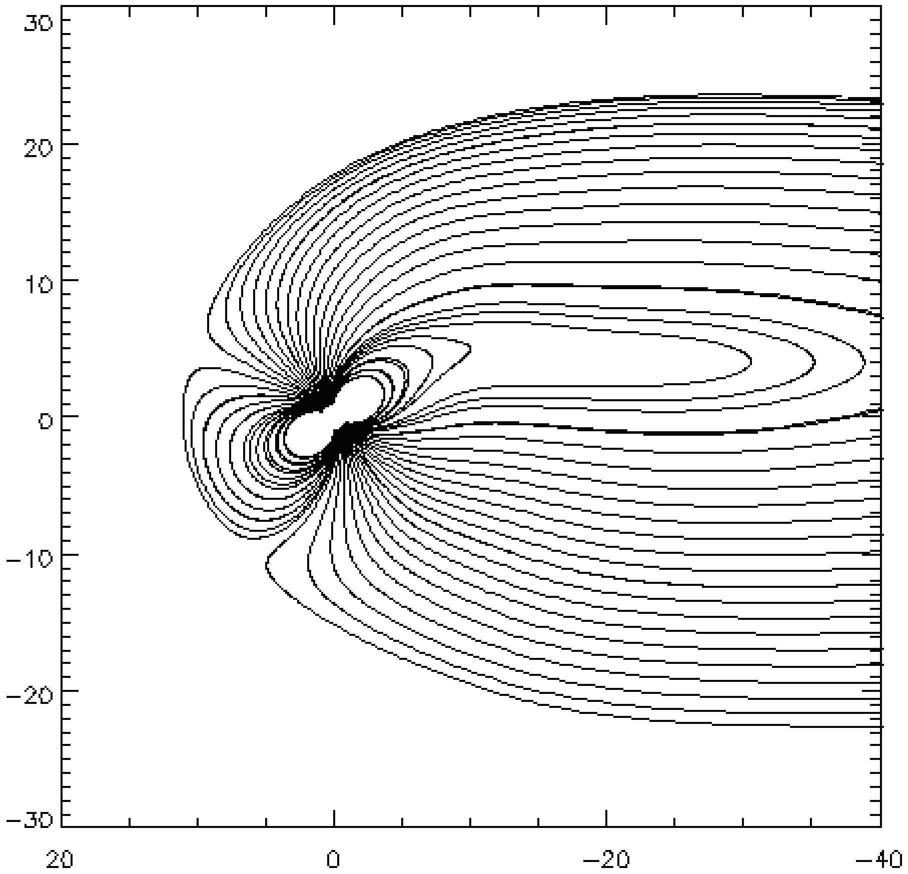
It uses the two files of results.

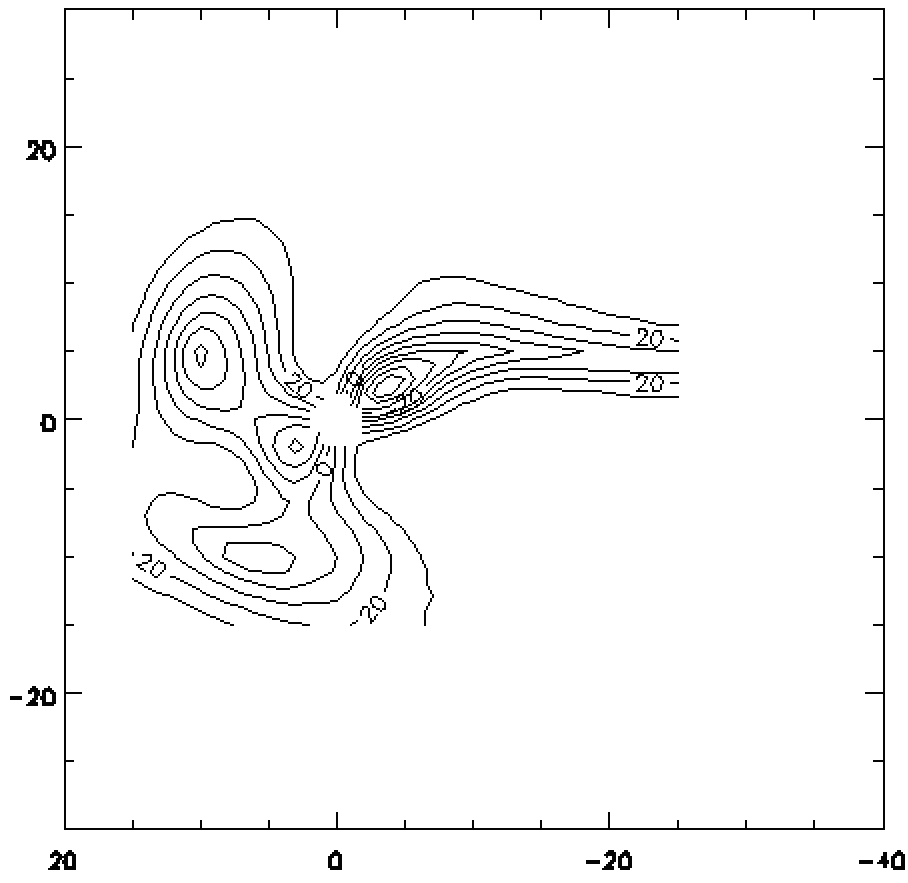
To use this program you need a WAVE license.

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

**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

## 6.20 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 $\leq 6$ (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:**

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

## 6.21 TESTVS

**Purpose:**

This program calculates the secular variations for DGRF15, CHP15.

**Input data:**

None.

**Output data:**

The file of results contains for the models CHP15: the secular variations of the coefficients in their order of appearance in the table lgt.

The file of results contains for the models DGRF15: the secular variations of the coefficients in their order of appearance in the matrix lgt written line by line.

Example 1 : secular variations for CHP15

```
k,1,dgg   2   1    7332.0
k,l,dgg   2   2   10174.0
k,l,dgg   2   2  -28698.0
k,1,dgg   3   1  -10744.0
k,l,dgg   3   2   -6040.0
k,l,dgg   3   2  -29238.0
k,l,dgg   3   3     130.0
k,l,dgg   3   3  -18486.0
k,1,dgg   4   1    2574.0
k,l,dgg   4   2   -5788.0
k,l,dgg   4   2    6638.0
k,l,dgg   4   3    2070.0
k,l,dgg   4   3    -628.0
k,l,dgg   4   4  -11198.0
k,l,dgg   4   4    -940.0
k,1,dgg   5   1    -884.0
k,l,dgg   5   2    -836.0
k,l,dgg   5   2    -328.0
k,l,dgg   5   3   -6838.0
```

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

```
data lgt/
  >  7332,10174,-28698,-10744,-6040,-29238,130,-18486,2574,-5788,6638,2070,-628,
  > -11198,-940,-884,-836,-328,-6838,…
```

Example 2: secular variations for DGRF15

```
n , m, dg, lg2, lg1    1    1       0.0      10.0     100.0
n , m, dg, lg2, lg1    1    2  -28698.0   46525.0  479599.0
n , m, dg, lg2, lg1    1    3  -29238.0  -29916.0 -284541.0
n , m, dg, lg2, lg1    1    4    6638.0    -821.0  -11529.0
n , m, dg, lg2, lg1    1    5    -328.0    2819.0   28354.0
n , m, dg, lg2, lg1    1    6     144.0     477.0    4698.0
n , m, dg, lg2, lg1    1    7     302.0    -191.0   -2061.0
n , m, dg, lg2, lg1    1    8     554.0    -515.0   -5427.0
n , m, dg, lg2, lg1    1    9    -328.0      84.0    1004.0
n , m, dg, lg2, lg1    1   10    -326.0    -234.0   -2177.0
n , m, dg, lg2, lg1    1   11      24.0      34.0     328.0
n , m, dg, lg2, lg1    1   12       0.0       0.0       0.0
n , m, dg, lg2, lg1    1   13     -24.0     -12.0    -108.0
n , m, dg, lg2, lg1    1   14      -4.0      -9.0     -88.0
n , m, dg, lg2, lg1    2    1    7332.0 -294048.0-2944146.0
n , m, dg, lg2, lg1    2    2   10174.0  -14509.0 -150177.0
n , m, dg, lg2, lg1    2    3  -18486.0   -7346.0  -64217.0
n , m, dg, lg2, lg1    2    4    -628.0    2419.0   24504.0
n , m, dg, lg2, lg1    2    5    6006.0   -1584.0  -18843.0
n , m, dg, lg2, lg1    2    6    2264.0    2083.0   19698.0
n , m, dg, lg2, lg1    2    7   -1640.0     251.0    3330.0
n , m, dg, lg2, lg1    2    8     526.0    -169.0   -1953.0
n , m, dg, lg2, lg1    2    9     592.0    -153.0   -1826.0
n , m, dg, lg2, lg1    2   10      48.0     110.0    1076.0
n , m, dg, lg2, lg1    2   11      40.0      -2.0     -40.0
n , m, dg, lg2, lg1    2   12      78.0      25.0     211.0
n , m, dg, lg2, lg1    2   13      26.0       5.0      37.0
n , m, dg, lg2, lg1    2   14      22.0       6.0      49.0
```

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

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000.0 | -28698 | -29238 | 6638 | -328 | 144 | 302 | 554 | -328 | -326 | 24 | 0 | -24 | -4 |
| 7332 | 10174 | -18486 | -628 | 6006 | 2264 | -1640 | 0526 | 0592 | 48 | 40 | 78 | 26 | 22 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

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,
 &          7332,-10744,2574,…
 &        -28698,10174,-6040,…
 &        -29238,-18486,130,…

 &       -4, 22, …………..…/
```

14 lines

14 columns

**Remarks:**

None.

**Called routines:**

vs_chp vs_igrf

# 7. MAGNETOSPHERIC PHYSICS CALCULATIONS

## 7.1 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, DGRF 2010, DGRF 2015 or IGRF 2020) 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 ≤ thetd ≤ 6 (step 2 deg),
the geocentric longitude (deg): 20 ≤ 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 = DGRF10, 5 = DGRF15, 6 = IGRF20),
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 02 15 11 30 00
magin, magout, indgm, indval
4 2 1 3

| Rre | thetd | phid | bxgsm | bygsm | bzgsm |
|---|---|---|---|---|---|
| Rre | thetd | phid | bxse | byse | bzse |
| | | | | | |
| 1.20 | 2.00 | 20.00 | 5074.423 | -6498.443 | -32862.395 |
| 1.20 | 2.00 | 20.00 | 5074.423 | -12004.273 | -31274.018 |
| | | | | | |
| 1.20 | 4.00 | 20.00 | 3296.142 | -6701.072 | -32927.484 |
| 1.20 | 4.00 | 20.00 | 3296.142 | -12215.031 | -31303.619 |
| | | | | | |
| 1.20 | 6.00 | 20.00 | 1523.660 | -6885.249 | -32876.754 |
| 1.20 | 6.00 | 20.00 | 1523.660 | -12387.867 | -31222.242 |
| | | | | | |
| 1.20 | 8.00 | 20.00 | -236.346 | -7050.566 | -32712.468 |
| 1.20 | 8.00 | 20.00 | -236.346 | -12522.765 | -31032.183 |

**Remarks:**

The file of results corresponds to a test done for a date equal to 2012 02 15 11 30 00 and for magin, magout, indgm and indval = 4, 2, 1, 3.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF05, 4 = DGRF10, 5 = IGRF15

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 ≤ indval ≤ 5 and 1 ≤ Kp ≤ 5

**Called routines:**

valfix inigeom bgsm

## 7.2 TESTCORGM

**Purpose:**

This program calculates the corrected geomagnetic coordinates, latitude and longitude taking in account the internal magnetic field (dipole, DGRF 00, DGRF 05, DGRF 10, DGRF 15 or IGRF 20) 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 = DGRF10, 5 = DGRF15, 6 = IGRF20),
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 02 15 11 30 00
magin, magout, indgm, indval
4 2 1 3

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  31.667  19.582
n,r,theta,phi   5   1.162  31.667  19.582
n,r,theta,phi   6   1.322  34.302  19.465
n,r,theta,phi   7   1.322  34.302  19.465
n,r,theta,phi   8   1.480  36.886  19.496
n,r,theta,phi   9   1.635  39.426  19.639
n,r,theta,phi  10   1.787  41.919  19.826
 …
n,r,theta,phi  25   3.494  78.840  24.169
n,r,theta,phi  26   3.534  81.507  24.516
n,r,theta,phi  27   3.559  84.197  24.871
n,r,theta,phi  28   3.567  86.898  25.234
n,r,theta,phi  29   3.559  89.597  25.604
```

points of the field line in dipole coordinates

```
n,rd,thetad,phid   1   1.000  30.878 109.293
n,rd,thetad,phid   2   1.000  30.878 109.293
n,rd,thetad,phid   3   1.000  30.878 109.293
n,rd,thetad,phid   4   1.162  33.335 107.299
…
n,rd,thetad,phid  28   3.567  88.242  98.027
n,rd,thetad,phid  29   3.559  90.966  97.934
```

corrected geomagnetic colatitude 31.987

corrected geomagnetic latitude 58.013

corrected geomagnetic longitude 97.966

**Remarks:**

The file of results corresponds to a test done for a date equal to 2013 02 15 11 30 00 and for magin, magout, indgm and indval = 4, 2, 1, 3.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF00, 3 = DGRF05, 4 = DGRF10, 5 = DGRF15, 6 = IGRF20.

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 = 91.053.

**Called routines:**

valfix inigeom corgm tradeg

## 7.3 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 = DGRF 2010, 5 = DGRF 2015, 6 = IGRF 2020
  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 = DGRF10, 5 = DGRF15, 6 = IGRF20),
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 02 15 11 30 00
magin, magout, indgm, indval
4 2 1 3

```
thet phi  southern conjugate point (dipole field):   147.556   52.109
thet phi  southern conjugate point (total field):    146.307   53.352

thet phi  southern conjugate point (dipole field):   142.771   65.057
thet phi  southern conjugate point (total field):    142.062   66.704

thet phi  southern conjugate point (dipole field):   139.035   77.709
thet phi  southern conjugate point (total field):    138.852   80.061

thet phi  southern conjugate point (dipole field):   136.509   90.276
thet phi  southern conjugate point (total field):    136.664   93.431

thet phi  southern conjugate point (dipole field):   135.302  102.835
thet phi  southern conjugate point (total field):    135.462  106.894

thet phi  southern conjugate point (dipole field):   135.465  115.396
thet phi  southern conjugate point (total field):    135.102  120.302
```

**Remarks:**

The file of results corresponds to a test done for a date equal to 2012 02 15 11 30 00 and for magin, magout, indgm and indval = 4, 2, 1, 3.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4 = DGRF 2010, 5 = DGRF 2015, 6 = IGRF 2020

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

## 7.4 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 = DGRF2010,
  5 = DGRF2015, 6 = IGRF2020
  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 ≤ 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 = DGRF2010, 5 = DGRF2015, 5 = IGRF2020),
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
2017 02 15 11 30 00
magin, magout, indgm, indval
4 2 1 3

```
field line tracing down to equator

n,tr,tthetd,tphid    1    1.000   29.000   20.000
n,tr,tthetd,tphid    2    1.238   32.921   19.519
n,tr,tthetd,tphid    3    1.471   36.748   19.508
n,tr,tthetd,tphid    4    1.699   40.469   19.706
n,tr,tthetd,tphid    5    1.921   44.099   20.006
n,tr,tthetd,tphid    6    2.136   47.663   20.362
n,tr,tthetd,tphid    7    2.345   51.186   20.748
n,tr,tthetd,tphid    8    2.544   54.692   21.154
n,tr,tthetd,tphid    9    2.825   59.971   21.788
n,tr,tthetd,tphid   10    3.076   65.339   22.448
n,tr,tthetd,tphid   11    3.288   70.856   23.137
n,tr,tthetd,tphid   12    3.449   76.558   23.860
n,tr,tthetd,tphid   13    3.545   82.428   24.622
n,tr,tthetd,tphid   14    3.566   88.387   25.422
n,tr,tthetd,tphid   15    3.507   94.307   26.260

req,theteqd,phieqd,equatorial conjugate   3.566  88.387  25.422
```

**Remarks:**

The file of results corresponds to a test done for a date equal to 2012 02 15 11 30 00 and for magin, magout, indgm and indval = 4, 2, 1, 3.

magin: internal magnetic field model: 1 = dipole, 2 = DGRF 00, 3 = DGRF 05, 4 = DGRF2010, 5 = DGRF2015, 6 = IGRF2020

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

## 7.5 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 = DGRF2010,
  5 = DGRF2015, 6 = IGRF2020
  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 = DGRF2010, 5 = DGRF2015, 6 = IGRF2020),
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 02 15 11 30 00
magin,magout,indgm,indval
4 2 1 3

```
thet phi  southern conjugate point (dipole field):   144.742   50.574
thet phi  southern conjugate point (total field):    143.200   47.979

thet phi  southern conjugate point (dipole field):   139.559   63.903
thet phi  southern conjugate point (total field):    139.520   62.740

thet phi  southern conjugate point (dipole field):   135.488   76.901
thet phi  southern conjugate point (total field):    136.674   77.316

thet phi  southern conjugate point (dipole field):   132.721   89.806
thet phi  southern conjugate point (total field):    134.690   91.815

thet phi  southern conjugate point (dipole field):   131.394  102.705
thet phi  southern conjugate point (total field):    133.537  106.461

thet phi  southern conjugate point (dipole field):   131.575  115.607
thet phi  southern conjugate point (total field):    133.011  121.030

thet phi  southern conjugate point (dipole field):   133.253  128.504
thet phi  southern conjugate point (total field):    133.114  134.733

thet phi  southern conjugate point (dipole field):   136.345  141.419
thet phi  southern conjugate point (total field):    134.305  147.093
```

**Remarks:**

The file of results corresponds to a test done for a date equal to 2012 02 15 11 30 00 and for magin, magout, indgm and indval = 4, 2, 1, 3.

magin: internal magnetic field model:
1 = dipole, 2 = DGRF 2000, 3 = DGRF 2005, 4 = DGRF2010, 5 = DGRF2015, 6 = IGRF2020

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    pconjr    tradeg

## 7.6 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 = DGRF2010,
  5 = DGRF2015, 6 = IGRF2020
  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 = 2022, month = 3, day = 21, hours = 12, minutes = 0, seconds = 0,

the internal magnetic field is igrf 2020: magin = 6
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 ≤ 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    25.89    78.67
rre,thetd,phid,flg,xlamb    1.20    10.00    10.00    22.00    77.69
rre,thetd,phid,flg,xlamb    1.20    10.00    20.00    19.29    76.84
rre,thetd,phid,flg,xlamb    1.20    10.00    30.00    17.34    76.10
rre,thetd,phid,flg,xlamb    1.20    10.00    40.00    15.90    75.48
rre,thetd,phid,flg,xlamb    1.20    10.00    50.00    14.84    74.96
rre,thetd,phid,flg,xlamb    1.20    10.00    60.00    14.05    74.53
rre,thetd,phid,flg,xlamb    1.20    10.00    70.00    13.47    74.19
rre,thetd,phid,flg,xlamb    1.20    10.00    80.00    13.05    73.93
rre,thetd,phid,flg,xlamb    1.20    10.00    90.00    12.75    73.74
rre,thetd,phid,flg,xlamb    1.20    10.00   100.00    12.57    73.62
```

**Remarks:**

None.

**Called routines:**

valfix            inigeom            dlgalp

## 7.7 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 = DGRF2010, 5 = DGRF2015, 6 = IGRF2020
  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 = 2022, month = 3, day = 21, hours = 12, minutes = 0, seconds = 0,
the internal magnetic field is igrf 20: magin = 6,
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    25.77    78.64
rre,thetd,phid,flg,xlamb     1.20    10.00    10.00    21.92    77.67
rre,thetd,phid,flg,xlamb     1.20    10.00    20.00    19.22    76.81
rre,thetd,phid,flg,xlamb     1.20    10.00    30.00    17.27    76.08
rre,thetd,phid,flg,xlamb     1.20    10.00    40.00    15.85    75.45
rre,thetd,phid,flg,xlamb     1.20    10.00    50.00    14.80    74.93
rre,thetd,phid,flg,xlamb     1.20    10.00    60.00    14.02    74.51
rre,thetd,phid,flg,xlamb     1.20    10.00    70.00    13.44    74.17
rre,thetd,phid,flg,xlamb     1.20    10.00    80.00    13.02    73.91
rre,thetd,phid,flg,xlamb     1.20    10.00    90.00    12.73    73.72
rre,thetd,phid,flg,xlamb     1.20    10.00   100.00    12.55    73.60
```

**Remarks:**

None.

**Called routines:**

valfix        inigeom        flgalp

## 7.8 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:**

None.

**Called routines:**

valfix inigeom julg tgeogr

## 7.9 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): $29 \leq$ thetd $\leq 55$ (2 deg step),
the geomagnetic local time (hours): $1 \leq$ tgmleq $\leq 22$ (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:**

None.

**Called routines:**

valfix mcilwe

# 8. ASTRONOMY AND CELESTIAL MECHANICS

## 8.1 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
($0 \leq$ hours $\leq 23$, 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:**

None.

**Called routines:**

valfix solter00

## 8.2 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 $1^{st}$ to December 2009 the $31^{st}$.

**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 | 10.2401 | -71.8222 | 0.4736 | 0.2053 |
| 208.6930 | 10.2401 | -71.8222 | 0.5115 | 0.2218 |
| 223.7341 | 10.2401 | -71.8222 | 0.5495 | 0.2382 |
| 238.7752 | 10.2401 | -71.8222 | 0.5875 | 0.2547 |
| 253.8162 | 10.2401 | -71.8222 | 0.6254 | 0.2711 |
| 268.8573 | 10.2401 | -71.8222 | 0.6634 | 0.2876 |
| 283.8984 | 10.2401 | -71.8222 | 0.7014 | 0.3041 |
| 298.9395 | 10.2401 | -71.8222 | 0.7393 | 0.3205 |
| 313.9805 | 10.2401 | -71.8222 | 0.7773 | 0.3370 |
| 329.0216 | 10.2401 | -71.8222 | 0.8153 | 0.3534 |
| 344.0627 | 10.2401 | -71.8222 | 0.8532 | 0.3699 |
| 359.1037 | 10.2401 | -71.8222 | 0.8912 | 0.3863 |
| 14.1448 | 10.2401 | -71.8222 | 0.9291 | 0.4028 |
| 29.1859 | 10.2401 | -71.8222 | 0.9671 | 0.4193 |
| 44.2269 | 10.2401 | -71.8222 | 1.0051 | 0.4357 |
| 59.2680 | 10.2401 | -71.8222 | 1.0430 | 0.4522 |
| 74.3091 | 10.2401 | -71.8222 | 1.0810 | 0.4686 |
| 89.3501 | 10.2401 | -71.8222 | 1.1189 | 0.4851 |
| 104.3912 | 10.2401 | -71.8222 | 1.1569 | 0.5015 |
| 119.4323 | 10.2401 | -71.8222 | 1.1949 | 0.5180 |
| 134.4733 | 10.2401 | -71.8222 | 1.2328 | 0.5344 |
| 149.5144 | 10.2401 | -71.8222 | 1.2708 | 0.5509 |
| 164.5555 | 10.2401 | -71.8222 | 1.3087 | 0.5673 |

**Remarks:**

None.

**Called routines:**

valfix solter05

## 8.3 TESTSOLTER10

**Purpose:**

This program calculates the position of the Sun, and the dipole orientation for all between 2010 and 2015.

- 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 1$^{st}$ to December 2014 the 31$^{st}$.

**Input data:**

*Data set in the program*:

the initial calculation date: year = 2010, 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 | 9.9712 | -72.2280 | 0.2805 | 0.1216 |
| 208.4851 | 9.9712 | -72.2280 | 0.3184 | 0.1380 |
| 223.5261 | 9.9712 | -72.2280 | 0.3564 | 0.1545 |
| 238.5672 | 9.9712 | -72.2280 | 0.3944 | 0.1710 |
| 253.6083 | 9.9712 | -72.2280 | 0.4324 | 0.1874 |
| 268.6494 | 9.9712 | -72.2280 | 0.4703 | 0.2039 |
| 283.6904 | 9.9712 | -72.2280 | 0.5083 | 0.2204 |
| 298.7315 | 9.9712 | -72.2280 | 0.5463 | 0.2368 |
| 313.7726 | 9.9712 | -72.2280 | 0.5842 | 0.2533 |
| 328.8136 | 9.9712 | -72.2280 | 0.6222 | 0.2697 |
| 343.8547 | 9.9712 | -72.2280 | 0.6602 | 0.2862 |
| 358.8958 | 9.9712 | -72.2280 | 0.6981 | 0.3027 |
| 13.9368 | 9.9712 | -72.2280 | 0.7361 | 0.3191 |
| 28.9779 | 9.9712 | -72.2280 | 0.7741 | 0.3356 |
| 44.0190 | 9.9712 | -72.2280 | 0.8120 | 0.3520 |
| 59.0600 | 9.9712 | -72.2280 | 0.8500 | 0.3685 |
| 74.1011 | 9.9712 | -72.2280 | 0.8880 | 0.3849 |
| 89.1422 | 9.9712 | -72.2280 | 0.9259 | 0.4014 |
| 104.1832 | 9.9712 | -72.2280 | 0.9639 | 0.4178 |
| 119.2243 | 9.9712 | -72.2280 | 1.0019 | 0.4343 |
| 134.2654 | 9.9712 | -72.2280 | 1.0398 | 0.4508 |
| 149.3065 | 9.9712 | -72.2280 | 1.0778 | 0.4672 |
| 164.3475 | 9.9712 | -72.2280 | 1.1157 | 0.4837 |
| 179.3886 | 9.9712 | -72.2280 | 1.1537 | 0.5001 |

**Remarks:**

None.

**Called routines:**

valfix solter10

## 8.4 TESTSOLTER15

**Purpose:**

This program calculates the position of the Sun, and the dipole orientation for all between 2015 and 2020.

- 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 (**solter15**).

These calculations are done for all epochs from January 2015 the 1st to December 2019 the 31st.

**Input data:**

*Data set in the program*:

the initial calculation date: year = 2015, 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 |
|---|---|---|---|---|
| 193.2360 | 9.7652 | -73.8533 | 0.0873 | 0.0378 |
| 208.2771 | 9.7652 | -73.8533 | 0.1253 | 0.0543 |
| 223.3182 | 9.7652 | -73.8533 | 0.1633 | 0.0708 |
| 238.3592 | 9.7652 | -73.8533 | 0.2012 | 0.0872 |
| 253.4003 | 9.7652 | -73.8533 | 0.2392 | 0.1037 |
| 268.4414 | 9.7652 | -73.8533 | 0.2772 | 0.1202 |
| 283.4825 | 9.7652 | -73.8533 | 0.3152 | 0.1366 |
| 298.5235 | 9.7652 | -73.8533 | 0.3532 | 0.1531 |
| 313.5646 | 9.7652 | -73.8533 | 0.3911 | 0.1696 |
| 328.6057 | 9.7652 | -73.8533 | 0.4291 | 0.1860 |
| 343.6467 | 9.7652 | -73.8533 | 0.4671 | 0.2025 |
| 358.6878 | 9.7652 | -73.8533 | 0.5051 | 0.2189 |
| 13.7289 | 9.7652 | -73.8533 | 0.5430 | 0.2354 |
| 28.7699 | 9.7652 | -73.8533 | 0.5810 | 0.2519 |
| 43.8110 | 9.7652 | -73.8533 | 0.6190 | 0.2683 |
| 58.8521 | 9.7652 | -73.8533 | 0.6569 | 0.2848 |
| 73.8931 | 9.7652 | -73.8533 | 0.6949 | 0.3012 |
| 88.9342 | 9.7652 | -73.8533 | 0.7329 | 0.3177 |
| 103.9753 | 9.7652 | -73.8533 | 0.7708 | 0.3342 |
| 119.0163 | 9.7652 | -73.8533 | 0.8088 | 0.3506 |
| 134.0574 | 9.7652 | -73.8533 | 0.8468 | 0.3671 |
| 149.0985 | 9.7652 | -73.8533 | 0.8847 | 0.3835 |
| 164.1396 | 9.7652 | -73.8533 | 0.9227 | 0.4000 |
| 179.1806 | 9.7652 | -73.8533 | 0.9607 | 0.4164 |

**Remarks:**

None.

**Called routines:**

valfix solter15

## 8.5 TESTSOLTER20

**Purpose:**

This program calculates the position of the Sun, and the dipole orientation for all between 2020 and 2025.

- 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 (**solter20**).

These calculations are done for all epochs from January 2020 the 1$^{st}$ to December 2024 the 31$^{st}$.

**Input data:**

*Data set in the program*:

the initial calculation date: year = 2020, 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 |
|---|---|---|---|---|
| 194.0137 | 9.3997 | -72.6780 | 0.8056 | 0.3492 |
| 209.0548 | 9.3997 | -72.6780 | 0.8435 | 0.3657 |
| 224.0959 | 9.3997 | -72.6780 | 0.8815 | 0.3821 |
| 239.1369 | 9.3997 | -72.6780 | 0.9195 | 0.3986 |
| 254.1780 | 9.3997 | -72.6780 | 0.9574 | 0.4150 |
| 269.2191 | 9.3997 | -72.6780 | 0.9954 | 0.4315 |
| 284.2601 | 9.3997 | -72.6780 | 1.0334 | 0.4479 |
| 299.3012 | 9.3997 | -72.6780 | 1.0713 | 0.4644 |
| 314.3423 | 9.3997 | -72.6780 | 1.1093 | 0.4808 |
| 329.3833 | 9.3997 | -72.6780 | 1.1473 | 0.4973 |
| 344.4244 | 9.3997 | -72.6780 | 1.1852 | 0.5137 |
| 359.4655 | 9.3997 | -72.6780 | 1.2232 | 0.5302 |
| 14.5065 | 9.3997 | -72.6780 | 1.2612 | 0.5466 |
| 29.5476 | 9.3997 | -72.6780 | 1.2991 | 0.5631 |
| 44.5887 | 9.3997 | -72.6780 | 1.3371 | 0.5795 |
| 59.6298 | 9.3997 | -72.6780 | 1.3750 | 0.5960 |
| 74.6708 | 9.3997 | -72.6780 | 1.4130 | 0.6124 |
| 89.7119 | 9.3997 | -72.6780 | 1.4509 | 0.6289 |
| 104.7530 | 9.3997 | -72.6780 | 1.4889 | 0.6453 |
| 119.7940 | 9.3997 | -72.6780 | 1.5269 | 0.6618 |
| 134.8351 | 9.3997 | -72.6780 | 1.5648 | 0.6782 |
| 149.8762 | 9.3997 | -72.6780 | 1.6028 | 0.6947 |
| 164.9172 | 9.3997 | -72.6780 | 1.6407 | 0.7111 |
| 179.9583 | 9.3997 | -72.6780 | 1.6787 | 0.7276 |

**Remarks:**

None.

**Called routines:**

valfix solter20

## 8.6 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 $1^{st}$ to December 1999 the $31^{st}$.

**Input data:**

*Data set in the program*:

the initial date: year = 1970, month = 6, day = 6, hours = 6, minutes = 6, seconds = 6 ($1970 \le$ year $\le 1999$, 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

## 8.7 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 $1^{st}$ to December 1969 the $31^{st}$.

**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 | phididp |
|---|---|---|---|---|---|---|---|
| 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

# 9. CONTROL ROUTINES FOR DATES AND PARAMETERS

## 9.1 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 = DGRF2010, 5 = DGRF2015, 6 = IGRF2020)
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.

Example:

```
calendar date                              : 2012  2 15 11 30  0
magin,magout,indgm,indval                  : 4 2 1 3
calculation distance unit (0=Km , 1=earth radii) : 1
r tetha phi                                :   5.000  30.000  20.000

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

**Remarks:**

None.

**Called routines:**

valfix ctrlpar

## 9.2 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:**

None.

**Called routines:**

datjhms        calendg          julg