

# IDL Geopack DLM

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## **Introduction:**

IDL Geopack DLM is a Dynamic Link Module (DLM) for the Interactive Data Language (IDL) by Research Systems, Inc. The DLM provides easy access to the GEOPACK library and magnetic field models by N. A. Tsyganenko et al. My only intellectual assets are in the interface itself, credits for the GEOPACK and magnetic field model codes go to the original authors. The interface allows calling of the GEOPACK functions, which are commonly used in geospace research, from the IDL command line without knowledge of Fortran or C. All commands behave like native IDL procedures.

## **Installation:**

The IDL Geopack DLM consists of the files `idl_geopack.dlm` and `idl_geopack.dll`. For installation, simply copy the above three files into the IDL executable directory, or into a directory in the search path of the IDL system variable `!DLM_PATH`. If the TS07 model is used, the environment variable `GEOPACK_TS07_PATH` must point to the path containing the TS07 model coefficients. This can be set in the OS or temporarily using the routine `GEOPACK_TS07_SETPATH`. The TS07 model coefficients consist of (a) the magnetotail coefficients contained in the file `TAIL_PAR.zip` in the “ts07 auxiliary files” subdirectory of this archive and (b) the dynamical model coefficients accessible at the NASA Space Physics Data Facility via the Uniform Resource Locator [https://spdf.gsfc.nasa.gov/pub/data/aaa\\_special-purpose-datasets/empirical-magnetic-field-modeling-database-with-TS07D-coefficients](https://spdf.gsfc.nasa.gov/pub/data/aaa_special-purpose-datasets/empirical-magnetic-field-modeling-database-with-TS07D-coefficients).

## **Implemented Procedures:**

### **Notes:**

- 1. Positional arguments in all Geopack routines may be given as vectors. Use this feature to avoid slow IDL loops.**
- 2. As of v9, both Geopack 2005 and 2008 are included. Unless otherwise noted, append “\_08” to the routine name to call version 2008.**

### **1. GEOPACK\_RECALC**

Description: Setup Geopack global variables.

Calling Sequence: `geopack_recalc(_08), year, doy, hour, min, sec`

or `geopack_recalc`, year, month, day, hour, min, sec, /date

Inputs: year, doy, hour, min, sec: Time of calculation.

Outputs: None.

Keywords: TILT: Named variable contains tilt angle upon return.

DATE: Use if month and day instead of doy is specified.

VGSE (08 only): Vector or scalar solar wind velocity.

## 2. GEOPACK\_IGRF\_GEO

Description: Calculate IGRF magnetic field in geographic coordinates.

Calling Sequence: `geopack_igrf_geo(_08)`, r, theta, phi, br, btheta, bphi.

Inputs: r: Distance from center of Earth in RE.

theta: colatitude in radians.

phi: Longitude in radians.

Outputs: br, btheta, bphi: Magnetic field in spherical coordinates.

Keywords: DEGREE: Specify if theta and phi are in degrees.

EPOCH: Specify epoch time for each computation.

## 3. GEOPACK\_DIP

Description: Calculate dipole magnetic field in GSM coordinates.

Calling Sequence: `geopack_dip(_08)`, x, y, z, bx, by, bz, tilt=tilt

Inputs: x, y, z: GSM coordinates in RE.

Outputs: bx, by, bz: Magnetic field in Cartesian coordinates.

Keywords: TILT: Specify dipole tilt angle manually.

EPOCH: Specify epoch time for each computation.

## 4. GEOPACK\_IGRF\_GSM, GEOPACK\_IGRF\_GSW\_08

Description: Calculate IGRF magnetic field in GSM coordinates.

Calling Sequence: `geopack_igrf_gsm`, x, y, z, bx, by, bz

`geopack_igrf_gsw_08`, x, y, z, bx, by, bz

Inputs: x, y, z: GSM coordinates in RE.

Outputs: bx, by, bz: Magnetic field in Cartesian coordinates.

Keywords: EPOCH: Specify epoch time for each computation.

#### 5. GEOPACK\_SPHCAR

Description: Convert between spherical and Cartesian coordinates.

Calling Sequence: `geopack_sphcar(_08), r, theta, phi, x, y, z, /to_rect`  
or `geopack_sphcar, x, y, z, r, theta, phi, /to_sphere`

Inputs: r, theta, phi: Location in spherical coordinates in radians, or  
x, y, z: Location in Cartesian coordinates.

Outputs: Complement to input.

Keywords: DEGREE: Specify degrees for input or output.

#### 6. GEOPACK\_BSPCAR

Description: Convert spherical vector components to Cartesian ones.

Calling Sequence: `geopack_bspicar(_08), theta, phi, br, btheta, bphi, bx, by, bz.`

Inputs: theta, phi: Colatitude and longitude in radians  
br, btheta, bphi: Vector in spherical coordinates.

Output: bx, by, bz: Vector in Cartesian coordinates.

Keywords: DEGREE: Specify for theta and phi in degrees.

#### 7. GEOPACK\_BCARSP

Description: Convert Cartesian vector components to spherical ones.

Calling Sequence: `geopack_bcarsp(_08), x, y, z, bx, by, bz, br, btheta, bphi.`

Inputs: x, y, z: Location in Cartesian coordinates.  
bx, by, bz: Vector in Cartesian coordinates.

Output: br, btheta, bphi: Vector in spherical coordinates.

## 8. GEOPACK\_CONV\_COORD

Description: Convert between a variety of commonly used coordinate systems.

Calling Sequence: `geopack_conv_coord(_08), s1, s2, s3, d1, d2, d3`.

Inputs: `s1, s2, s3`: Coordinates in system of origin.

Outputs: `d1, d2, d3`: Coordinates in target system.

Keywords: `FROM_GEO`: Specify source in geographic coordinates.

`FROM_MAG`: Specify source in geomagnetic coordinates.

`FROM_GEI`: Specify source in geocentric equatorial inertial coordinates.

`FROM_SM`: Specify source in solar magnetic coordinates.

`FROM_GSM`: Specify source in geocentric solar magnetospheric coordinates.

`FROM_GSE`: Specify source in geocentric solar ecliptic coordinates.

`FROM_GSW`: Specify source in geocentric solar magnetospheric coordinates (`GEOPACK_CONV_COORD_08` only).

`TO_GEO`: Specify destination in geographic coordinates.

`TO_MAG`: Specify destination in geomagnetic coordinates.

`TO_GEI`: Specify destination in geocentric equatorial inertial coordinates.

`TO_SM`: Specify destination in solar magnetic coordinates.

`TO_GSM`: Specify destination in geocentric solar magnetospheric coordinates.

`TO_GSE`: Specify destination in geocentric solar ecliptic coordinates.

`TO_GSW`: Specify destination in geocentric solar magnetospheric coordinates (`GEOPACK_CONV_COORD_08` only).

`EPOCH`: Specify epoch time for each computation.

## 9. GEOPACK\_TRACE

Description: Trace magnetic field line.

Calling Sequence: `geopack_trace(_08), xi, yi, zi, dir, par, xf, yf, zf`.

Inputs: `xi, yi, zi`: Initial GSM coordinates in RE.

`dir`: Trace direction: -1 for parallel to B vector, +1 for anti-parallel to B vector

`par`: ignored for dipole, `iopt=1,...,7` for T89, `parmod(10)` for T96, T01, and

T01S; see documentation of field models for details.

Outputs:

`xf, yf, zf`: Foot point of field line in GSM coordinates.

Keywords: `R0`: Minimum trace distance.

`RLIM`: Maximum trace distance.

`FLINE`: [`fldim`,3] array containing the field-line coordinates.

TILT: Specify dipole tilt angle in degrees.  
 IGRF: Specify IGRF internal magnetic field model.  
 T89: Specify T89 external magnetic field model.  
 T96: Specify T96 external magnetic field model.  
 T01: Specify T01 external magnetic field model.  
 TS04: Specify TS04 external magnetic field model.  
 TS07: Specify TS07 external magnetic field model.  
 STORM: Specify storm-time version of T01 external magnetic field model; use together with /T01.  
 NOBOUNDARY: Override boundary limits.  
 IOPGEN, IOPT, IOPB, IOPR (TS04 only): See TS04 Fortran code.  
 REFINE: Refined foot point locations using trace routine by Vassilis Angelopoulos.  
 EQUATOR (REFINE only): Trace to equatorial plane. The equator is defined as the location on the field line where the radial magnetic field component reverses sign.  
 IONOSPHERE (REFINE only): Trace to ionosphere.  
 EPOCH: Specify epoch time for each computation.  
 DSMAX (08 only): Upper limit on step size.  
 ERR (08 only): Permissible step error.

#### 10. GEOPACK\_T96\_MGNP

Description: Evaluate location relative to T96 model magnetopause.

Calling Sequence: `geopack_t96_mgnp(_08), xn_pd, vel, x_gsm, y_gsm, z_gsm, x_mgnp, y_mgnp, z_mgnp, dist, id`

Inputs/Outputs: `xn_pd`: Solar wind proton density or ram pressure for `vel`<0 or `vel`>0, respectively.  
`vel`: Solar wind velocity.  
`x, y, z`: GSM input coordinates.  
`x_mgnp, y_mgnp, z_mgnp`: GSM position of magnetopause location having the same tau coordinate as `x, y, z`.  
`dist`: Distance to magnetopause in units of  $R_E$ .  
`id`: Flag indicating `x, y, z` location inside (+1) or outside (-1) the magnetopause.

Keywords: None.

#### 11. GEOPACK\_SHUETAL\_MGNP

Description: Evaluate location relative to Shue et al. model magnetopause.

Calling Sequence: `geopack_shuetal_mgnp(_08), xn_pd, vel, bzimf, x_gsm, y_gsm, z_gsm, x_mgnp, y_mgnp, z_mgnp, dist, id`

Inputs/Outputs: `xn_pd`: Solar wind proton density or ram pressure for `vel>0` or `vel<0`, respectively.  
`vel`: Solar wind velocity.  
`bzimf`: Bz of the interplanetary magnetic field.  
`x`, `y`, `z`: GSM input coordinates.  
`x_mgnp`, `y_mgnp`, `z_mgnp`: GSM position of magnetopause location having the same tau coordinate as `x`, `y`, `z`.  
`dist`: Distance to magnetopause in units of  $R_E$ .  
`id`: Flag indicating `x`, `y`, `z` location inside (+1) or outside (-1) the magnetopause.

Keywords: None.

## 12. GEOPACK\_T89

Description: Calculate external magnetic field using T89c model.

Calling Sequence: `geopack_t89`, `iopt`, `x`, `y`, `z`, `bx`, `by`, `bz`, `tilt=tilt`

Inputs: `iopt=1,...,7`: T89 `iopt` parameter; see documentation of field model for details.  
`x`, `y`, `z`: GSM coordinates in  $R_E$ .

Outputs: `bx`, `by`, `bz`: External magnetic field in nT.

Keywords: TILT: Specify dipole tilt angle in degree.  
EPOCH: Specify epoch time for each computation.

## 13. GEOPACK\_T96

Description: Calculate external magnetic field using T96 model.

Calling Sequence: `geopack_t96`, `parmod`, `x`, `y`, `z`, `bx`, `by`, `bz`, `tilt=tilt`

Inputs: `parmod(10)`: T96 `parmod` array; see documentation of field model for details.  
`x`, `y`, `z`: GSM coordinates in  $R_E$ .

Outputs: `bx`, `by`, `bz`: External magnetic field in nT.

Keywords: TILT: Specify dipole tilt angle in degree.  
EPOCH: Specify epoch time for each computation.

## 14. GEOPACK\_T01

Description: Calculate external magnetic field using T01 model.

Calling Sequence: `geopack_t01, parmod, x, y, z, bx, by, bz, tilt=tilt`

Inputs: `parmod(10)`: T01 parmod array; see documentation of field model for details.  
`x, y, z`: GSM coordinates in RE.

Outputs: `bx, by, bz`: External magnetic field in nT.

Keywords: TILT: Specify dipole tilt angle in degree.  
STORM: Specify storm-time version of T01 external magnetic field model; use together with /T01.  
EPOCH: Specify epoch time for each computation.

#### 15. GEOPACK\_TS04

Description: Calculate external magnetic field using TS04 model.

Calling Sequence: `geopack_ts04, parmod, x, y, z, bx, by, bz, tilt=tilt`

Inputs: `parmod(10)`: TS04 parmod array; see documentation of field model for details.  
`x, y, z`: GSM coordinates in RE.

Outputs: `bx, by, bz`: External magnetic field in nT.

Keywords: TILT: Specify dipole tilt angle in degree.  
IOPGEN, IOPT, IOPB, IOPR: See TS04 Fortran code.  
EPOCH: Specify epoch time for each computation.

#### 16. GEOPACK\_TS07

Description: Calculate external magnetic field using TS07 model.

Calling Sequence: `geopack_ts07, parmod, x, y, z, bx, by, bz, tilt=tilt`

Inputs: `parmod(10)`: TS07 parmod array; see documentation of field model for details.  
`x, y, z`: GSM coordinates in RE.

Outputs: `bx, by, bz`: External magnetic field in nT.

Keywords: TILT: Specify dipole tilt angle in degree.  
IOPGEN: See TS07 Fortran code.  
EPOCH: Specify epoch time for each computation.

#### 17. GEOPACK\_TA15B

Description: Calculate external magnetic field using TA15B model.

Calling Sequence: `geopack_ta15b, parmod, x, y, z, bx, by, bz, tilt=tilt`

Inputs: `parmod(10)`: TA15B `parmod` array; see documentation of field model for details.

`x, y, z`: GSM coordinates in RE.

Outputs: `bx, by, bz`: External magnetic field in nT.

Keywords: `TILT`: Specify dipole tilt angle in degree.

`EPOCH`: Specify epoch time for each computation.

#### 18. `GEOPACK_TA15N`

Description: Calculate external magnetic field using TA15N model.

Calling Sequence: `geopack_ta15n, parmod, x, y, z, bx, by, bz, tilt=tilt`

Inputs: `parmod(10)`: TA15N `parmod` array; see documentation of field model for details.

`x, y, z`: GSM coordinates in RE.

Outputs: `bx, by, bz`: External magnetic field in nT.

Keywords: `TILT`: Specify dipole tilt angle in degree.

`EPOCH`: Specify epoch time for each computation.

#### 19. `GEOPACK_TS07_LOADCOEF`

Description: Load TS07 model coefficients.

Calling Sequence: `geopack_ts07_loadcoef, filename`

Inputs: `filename`: Name of TS07 model coefficients file, e.g., `Best_par_so_far.par`.

Outputs: None.

Keywords: `QUIET`: Suppress status message.

#### 20. `GEOPACK_TS07_SETPATH`

Description: Set path to TS07 model coefficients.

Calling Sequence: `geopack_ts07_setpath, path`



Inputs: path: Path to TS07 model coefficients.

Outputs: None.

Keywords: QUIET: Suppress status message.

## 21. GEOPACK\_GETB

Description: Calculate Boynton et al. (2011) index for TA15B model.

Calling Sequence: geopack\_getb, nsw, vsw, by, bz, bindex

Inputs: nsw: n-element array containing solar wind density [ $\text{cm}^{-3}$ ] in 5-minute intervals.

vsw: n-element array containing solar wind speed [km/s] in 5-minute intervals.

by: n-element array containing IMF By [nT] in 5-minute intervals.

bz: n-element array containing IMF Bz [nT] in 5-minute intervals.

Outputs: bindex: n-element array containing B index for each time step.

Keywords: None.

## 22. GEOPACK\_GETG

Description: Calculate G index for T01 model.

Calling Sequence: geopack\_getw, vsw, by, bz, gindex  
geopack\_getw, nsw, vsw, bz, gindex, /STORM

Inputs: nsw: n-element array containing solar wind density [ $\text{cm}^{-3}$ ] in 5-minute intervals.

vsw: n-element array containing solar wind speed [km/s] in 5-minute intervals.

by: n-element array containing IMF By [nT] in 5-minute intervals.

bz: n-element array containing IMF Bz [nT] in 5-minute intervals.

Outputs: w: n-by-2 element array containing G index for each time step.

Keywords: STORM: Specify storm-time version of T01 external magnetic field model; use together with /T01.

## 23. GEOPACK\_GETN

Description: Calculate Newell et al. (2007) index for TA15N model.

Calling Sequence: `geopack_getn`, `vsw`, `by`, `bz`, `nindex`

Inputs: `vsw`: n-element array containing solar wind speed [km/s] in 5-minute intervals.

by: n-element array containing IMF By [nT] in 5-minute intervals.

bz: n-element array containing IMF Bz [nT] in 5-minute intervals.

Outputs: `nindex`: n-element array containing B index for each time step.

Keywords: None.

#### 24. `GEOPACK_GETW`

Description: Calculate W index for TS04 model.

Calling Sequence: `geopack_getw`, `nsw`, `vsw`, `bz`, `windex`

Inputs: `nsw`: n-element array containing solar wind density [ $\text{cm}^{-3}$ ] in 5-minute intervals.

`vsw`: n-element array containing solar wind speed [km/s] in 5-minute intervals.

`bz`: n-element array containing IMF Bz [nT] in 5-minute intervals.

Outputs: `windex`: n-by-6 element array containing W parameters for each time step.

Keywords: None.

#### 25. `GEOPACK_EPOCH`

Description: Convert between UTC and CDF Epoch time formats.

Calling Sequence: `geopack_epoch`, `epoch`, `year`, [`month`, `day`, `hour`, `min`, `sec`, `msec`]

Inputs/Outputs: `epoch`: Scalar or n-element array of Epoch time.

year: Scalar or n-element array of year.

month: Scalar or n-element array of month.

day: Scalar or n-element array of day.

hour: Scalar or n-element array of hour.

min: Scalar or n-element array of minute.

sec: Scalar or n-element array of second.

msec: Scalar or n-element array of millisecond.

Keywords: `BREAKDOWN_EPOCH`: Convert from Epoch to UTC time format.

`COMPUTE_EPOCH`: Convert from UTC to Epoch time format.

## 26. GEOPACK\_T96\_MGNP

Description: Evaluate location relative to magnetopause.

Calling Sequence: `geopack_t96_mgnp, xn_pd, vel, x_gsm, y_gsm, z_gsm,`  
`x_mgnp, y_mgnp, z_mgnp, dist, id`

Inputs/Outputs: `xn_pd`: Solar wind proton density or ram pressure for `vel`<0 or `vel`>0, respectively.

`vel`: Solar wind velocity.

`x, y, z`: GSM input coordinates.

`x_mgnp, y_mgnp, z_mgnp`: GSM position of magnetopause location having the same tau coordinate as `x, y, z`.

`dist`: Distance to magnetopause in units of  $R_E$ .

`id`: Flag indicating `x, y, z` location inside (+1) or outside (-1) the magnetopause.

Keywords: None.

## **Rules of the Road:**

History has shown that the understanding of the obligations with respect to the use “free software” differs widely within the research community. Therefore, I suggest the following rules, which should be obeyed when using this software:

1. If this software greatly facilitates the research presented in a publication or presentation, please show your support and acknowledge the use of the IDL GEOPACK DLM.
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## **Acknowledgements:**

I thank Kolya Tsyganenko for creating the GEOPACK library and the external magnetic field models, which have always been extremely useful to my research. I thank Vassilis Angelopoulos and the THEMIS team for support to port the software to various Unix operating systems. The inclusion of TS07 and TA15 magnetic field models was supported by NASA grant NNX15AF53G.

## **Version History:**

v1.0: Initial release.

v1.1: GEOPACK\_RECALC now separate routine. Therefore, date was removed as input to most routines.

v1.2: T01S model implemented.

v1.3: Fixed bug in order of parameters to GEOPACK\_SPHCAR with /TO\_SPHERE set.

v1.4: First public version. TILT keyword added to GEOPACK\_RECALC.

v1.5: Fixed bug in interpretation of arguments to GEOPACK\_RECALC due to TILT keyword. Windows DLLs have been combined and files have been renamed to idl\_geopack.\*.

v1.6: New license algorithm.

v1.7: Minor fixes.

v2.0: Implemented Geopack 2005 library.

v2.1: License algorithm removed.

v2.2: T04S model implemented.

v2.3: Removed obsolete FORTRAN exports in DLL.

v2.4: FORTRAN code recompiled with IVF 9.0.

v2.5: Minor fixes.

v2.6: Added routine GEOPACK\_HELP and HELP keyword to all routines.

v2.7: Vectorized GEOPACK\_TRACE.

v3.0: Project switched to Visual Studio 2005 and Intel Visual FORTRAN 9.1 beta.

- v3.1: Fixed compile warnings.
- v3.2: Input coordinates in routines `GEOPACK_IGRF_GEO`, `GEOPACK_SPHCAR`, and `GEOPACK_BSPCAR` are no longer converted to radians if keyword `DEGREE` is set.
- v3.3: Fixed serious bugs with interface to T96 and T04S external field routines. Disabled code optimization. Created post v4.1.
- v4.0: Renaming `IDL32.DLL` to `IDL.DLL` in IDL 6.3 broke the old DLM code. To remain current, the project is switched to IDL 6.3 beta. Thus v3.3 is the final version for IDL versions  $\leq 6.2$  unless RSI finds a workaround for the problem.
- v4.1: Fixed serious bugs with interface to T96 and T04S external field routines. Disabled code optimization.
- v4.2: Updated help messages and documentation.
- v4.3: Recompiled with IVF 9.1 release version and linked against `idl.lib` from IDL 6.3 release version to ensure compatibility.
- v4.4: Geopack May 2006 updates and T01 & TS04 June 2006 updates incorporated. Warning issued when using storm-time T01 model since it is no longer maintained.
- v4.5: Changed processing of `HELP` keyword to show usage info without invoking `GEOPACK_RECALC` first.
- v4.6: Output array dimensions now identical with input array dimensions.
- v4.7: Added `NOBOUNDARY` keyword to `GEOPACK_TRACE` for overriding the boundary limits built into the original routine.
- v4.8: Added `DATE` keyword to `GEOPACK_RECALC`.
- v4.9: Increased the maximum number of trace steps in `GEOPACK_TRACE` from 1000 (Geopack default) to 10000.
- v5.0: Minor internal changes to definition of field line elements arrays in `GEOPACK_TRACE`.
- v5.1: Added `GEOPACK_GETW` for calculation of W parameters used in T04S model.
- v5.2: Combined `GEOPACK_T01N` and `GEOPACK_T01S` in `GEOPACK_T01`; the storm-time version of T01 is now invoked using the `STORM` keyword (remember, the `T01_S` is now obsolete). Added `QUIET` keyword to `GEOPACK_T01` and

GEOPACK\_TRACE to suppress “T01\_S obsolete” warning. Renamed GEOPACK\_T04S to GEOPACK\_TS04. Added GEOPACK\_GETG routine to calculate G parameters used in T01 and T01\_S models.

v5.3: Minor fixes to eliminate compiler warnings under Linux.

v5.4: FLINE keyword in GEOPACK\_TRACE returns actual field line points only and is no longer zero-padded.

v5.5: Project switched to IVF 10.0.

v5.6: Fixed bug in leap year logic.

v5.7: Output values are returned as scalars if the input values are scalars.

v5.8: Removed references to YEAR keyword in routines GEOPACK\_DIP and GEOPACK\_TRACE from help text and documentation.

v5.9: Added keywords IOPGEN, IOPT, IOPB, and IOPR to routines GEOPACK\_TS04 and GEOPACK\_TRACE to improve control of TS04 model.

v6.0: Added range check for keywords IOPGEN, IOPT, IOPB, and IOPR.

v6.1: Minor changes to allow compilation on SunOS and Intel Mac OS X.

v6.2: Fixed bug in GEO to GSE coordinate transformation.

v6.3: Added trace routine with refined foot point location by Vassilis Angelopoulos. Access to routines is provided with keyword REFINE to GEOPACK\_TRACE. Tracing to ionosphere or equatorial plane is controlled with keywords IONOSPHERE and EQUATOR, respectively. Other minor fixes and improvements.

v6.4: Added EPOCH keyword to applicable routines to allow internal execution of RECALC during vectorized processing. Added GEOPACK\_EPOCH for converting between UTC and EPOCH time formats.

v6.5: Minor bug fixes in GEOPACK\_EPOCH.

v6.6: Bug fixes related to EPOCH keyword. Added foot point to field line array in GEOPACK\_TRACE.

v6.7: Bug fix for tracing to the equatorial plane with GEOPACK\_TRACE /REFINE.

- v6.8: Fixed bug in GEOPACK\_TRACE /REFINE that resulted in an endless loop if equatorial trace was started at the Earth's surface. Updated help information for external field routines. Added DOY keyword to GEOPACK\_EPOCH.
- v6.9: Fixed bug in GEOPACK\_EPOCH to clean up internal variables when using /BREAKDOWN\_EPOCH keyword.
- v7.0: Routines using the TILT keyword irreversibly modified the Geopack common block variables PS, SPS, and CPS, requiring GEOPACK\_RECALC to be recalled. This has been fixed so that the modifications are temporary and the variables are reset after the routine calls.
- v7.1: Increased precision of PI.
- v7.2: Updated DGRF/IGRF coefficients for 2005 and added DGRF/IGRF coefficients for 2010.
- v7.3: Fixed temporary variable clean-up problem in GEOPACK\_EPOCH.
- v7.4: Fixed segmentation fault in GEOPACK\_RECALC in some Linux OS.
- v7.5: Changed disclaimer to refer to "Rules of the Road" in this document.
- v7.6: Added GEOPACK\_T96\_MGNP routine.
- v7.7: Fixed rare variable cleanup warning in GEOPACK\_EPOCH routine.
- v7.8: Fixed rare variable cleanup warning in GEOPACK\_EPOCH routine; bug in v7.7.
- v7.9: Fixed rare variable cleanup warning in GEOPACK\_EPOCH routine; was still buggy in v7.8. Problem does not affect computed values but may cause memory leaks.
- v8.0: Increased the maximum allowed array elements from 10,000 to 100,000.
- v8.1: Fixed bug when reinitializing model using EPOCH keyword.
- v9.0: Major update to include Geopack 2008 version. In addition to providing parallel routines of previously existing routines, new routines exposed through the DLM interface are GEOPACK\_SHUETAL\_MGNP(\_08) and GEOPACK\_GEODGEO\_08.
- v9.1, v9.2: Fixed bug when reinitializing model using EPOCH keyword.
- v9.3: Fixed bug in refine trace routine. The bug was introduced in v9.0, earlier versions of the DLM were not affected.

- v9.4: Added IGRF 12 (2015) coefficients and extended extrapolation to 2020.
- v10.0: Added TS07, TA15B, and TA15N magnetic field models.
- v10.1: Added TS07 model to trace routines.
- v10.2: Limit default trace distance of TS07 model to  $X > -30$  RE.
- v10.3: Bug fixes in TS07 logic.
- v10.4: Added TA15 models to GEOPACK\_TRACE(\_08).
- v10.5: Fixed crash in GEOPACK\_TRACE(\_08) when tracing more than 10000 locations simultaneously.
- v10.6: Added IGRF-13 coefficients through 2020 and extrapolation through 2025.

## **References:**

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