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 purpose of this library is to provide easy access to the GEOPACK Fortran library by N. A. Tsyganenko and related routines. I do not claim any rights to those routines. My only intellectual assets are in the interface itself. The interface allows calling of the Geopack functions, which are commonly used in geospace research, from the IDL command line without any 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.

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_bspcar(_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 geopgraphic 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.
TO_GEO: Specify destination in geopgraphic 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.
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.
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 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.

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 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.

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 T04S 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_GETG
Description: Calculate G parameters for T01 model.

Calling Sequence: geopack_getw, vsw, by, bz, g
geopack_getw, nsw, vsw, bz, g, /STORM

Inputs: nsw: n-element array containing solar wind density [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 parameters for each time step.

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

17. GEOPACK_GETW
Description: Calculate W parameters for TS04 model.

Calling Sequence: geopack_getw, nsw, vsw, bz, w

Inputs: nsw: n-element array containing solar wind density [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: w: n-by-6 element array containing W parameters for each time step.

Keywords: None.

18. 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.

19. 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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The IDL Geopack DLM is BEERWARE. If use it, like it, adore it, or even worship it, buy me a beer. ☺

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I thank Kolya Tsyganenko for creating the Geopack libraries and the external magnetic field models, which are in wide-spread use across the geospace research community. I thank Vassilis Angelopoulos and the THEMIS team for support to port the software to various Unix operating systems.

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 <=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.

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