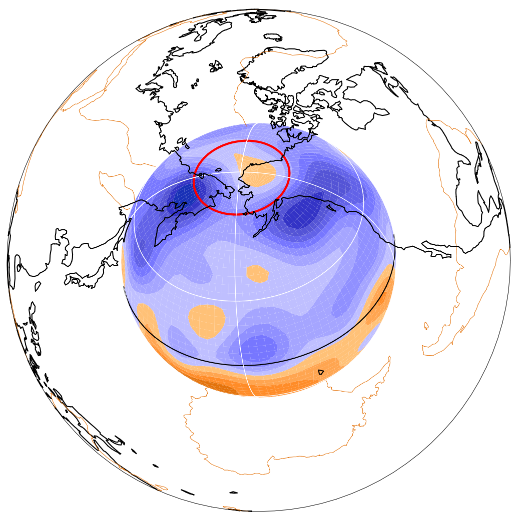
LEOPACK



cicsvpnsmap

Conducting **I**nner **C**ore **S**olution **V**ector: **P**erturbation and **N**ew **S**patial **M**esh **A**daption **P**rogram

Steven J. Gibbons, Oslo

Original document: November 21^{st}, 2001. Updated: October 30^{th}, 2022.

1 cicsvpnsmap

Conducting **I**nner **C**ore **S**olution **V**ector: **P**erturbation and **N**ew **S**patial **M**esh **A**daption **P**rogram

This program interpolates a solution for the conducting inner core dynamo problem onto a new spatial grid defined by the input file. This is essentially just a modification of the svpnsmap program which takes into account that the velocity and temperature functions (outer core only) are stored in one set of files, e.g. `root.intsv`, `root.vecsv` and `root.xarrv`, and the magnetic field (outer, and possibly inner, core) is stored in a different set of files, e.g. `root.intsm`, `root.vecsm` and `root.xarrm`. It also ensures that the output is a valid solution vector for the conducting inner core time-stepping codes (e.g. `cicubcdts2`, `cicibcdts2`).

The inputs file must have the following format.

```
* Input file for cicsvpnsmap
*
old_stem.intsv                        : Velocity Harmonics file
old_stem.vecsv                        : Velocity Vector file
old_stem.xarrv                        : Velocity Radial grid nodes
old_stem.intsm                        : Magnetic Harmonics file
old_stem.vecsm                        : Magnetic Vector file
old_stem.xarrm                        : Magnetic Radial grid nodes
new_stem                              : Filename stem
 40  2  20  3   4     4     0.00000   : NRVNW ISPV NRICNW ISPIC IFORMF NNDS DMAG
 36    36    36   36    36            : LH1   LH2   LH3   LH4   LH5
 1    2   2    20                     : ISV ISM MINC MMAX
```

Any line in the input file beginning with an asterisk, `*`, is ignored by the program and can thus be used to enter comments and notes.

The arguments are as follows

- `Velocity Harmonics file`: name of already existing indices file describing initial velocity and temperature functions.
- `Velocity Vector file`: name of already existing vector file describing initial velocity and temperature functions. Must contain the same number of radial functions as indicated in the `.intsv` file.
- `Velocity Radial grid nodes`: name of already existing radial spacings file describing initial velocity and temperature functions. Must contain the same number of radial grid nodes as indicated in the `.vecsv` file.
- `Magnetic Harmonics file`: name of already existing indices file describing initial magnetic field functions.

- `Magnetic Vector file`: name of already existing vector file describing initial magnetic field. Must contain the same number of radial functions as indicated in the `.intsm` file.

- `Magnetic Radial grid nodes`: name of already existing radial spacings file describing initial magnetic field. Must contain the same number of radial grid nodes as indicated in the `.vecsm` file.

- `Filename stem`: First characters in output files to be generated.

- `NRVNW`: Number of radial grid nodes requested for the new outer core radial functions.

- `ISPV`: Flag for the spacing of the new radial grid nodes. Can take the options

  1. Forces evenly spaced grid nodes from `ESNAAS`.
  2. Forces Chebyshev-zero spaced nodes from `ZCPAAS`

- `NRICNW`: Number of radial grid nodes requested for the new inner core radial functions.

- `ISPIC`: Flag for the spacing of the new radial grid nodes. Can take the options

  1. Forces evenly spaced grid nodes from `ESNAAS`.
  2. Forces Chebyshev-zero spaced nodes from `ZCPAAS`
  3. Forces Chebyshev-zero spaced nodes from `ZCPAA2`

- `IFORMF`. Flag which chooses the order in which elements in the solution vector are stored. `IFORMF` can take the values `3` or `4`.

- `NNDS`: Number of grid nodes used for interpolation of radial functions by `SVRINT`.

- `DMAG`: Scales the noise added to new radial functions.

- `LH1`: Highest spherical harmonic degree, l, requested for poloidal velocity

- `LH2`: Highest spherical harmonic degree, l, requested for toroidal velocity

- `LH3`: Highest spherical harmonic degree, l, requested for temperature

- `LH4`: Highest spherical harmonic degree, l, requested for poloidal magnetic field

- `LH5`: Highest spherical harmonic degree, l, requested for toroidal magnetic field
- `ISV`. Requested symmetry for the velocity.
  1. Velocity is equatorially symmetric.
  2. Velocity is equatorially anti-symmetric.
  3. Velocity contains both equatorially symmetric and equatorially anti-symmetric parts.
- `ISM`. Requested symmetry for the magnetic field.
  1. Magnetic field is equatorially symmetric.
  2. Magnetic field is equatorially anti-symmetric.
  3. Magnetic field contains both equatorially symmetric and equatorially anti-symmetric parts.
- `MINC`: The lowest non-zero wavenumber to be included. Note $m = 0$ is always included.
- `MMAX`: Maximum wavenumber.

1.1 Subprograms required for cicsvpnsmap

SUBS subroutines

```
hmfrd.f svfrd.f xarrrd.f hminda.f esnaas.f zcpaas.f
zcpaa2.f svrint.f hmfwt.f xarrwt.f svfwt.f fopen.f
fclose.f gfdcfd.f fnamer.f matop.f
```

SUBS integer function

```
indfun.f
```

BLAS integer function

```
idamax.f
```

BLAS subroutines

```
dgemv.f dgemm.f dtrsm.f dswap.f dger.f  dscal.f
dtrmm.f dtrmv.f
```

LAPACK subroutines

```
xerbla.f dgetrf.f dgetri.f dgetf2.f dlaswp.f dtrtri.f
dtrti2.f
```

LAPACK integer function

```
ilaenv.f
```

LAPACK logical function

```
lsame.f
```

1.2 Run-time limitations

Several parameters are set at the outset which limit the physical size of the problem.

```
 INTEGER NRVMAX, NRMMAX, NHVMAX, NHMMAX, IVVMAX, IVMMAX, LHMAX,
1        NDCS, NNDM
 PARAMETER ( NRVMAX = 300, NRMMAX = 300, NHVMAX = 6000,
1            NHMMAX = 6000, LHMAX = 200,
2            NDCS = LHMAX+4, IVVMAX = NRVMAX*NHVMAX,
3            IVMMAX = NRMMAX*NHMMAX, NNDM = 6 )
```

If the values are insufficient, then change them and recompile.

- `NRVMAX` is the maximum number of radial grid nodes allowed for the outer core.
- `NRMMAX` is the maximum number of radial grid nodes allowed for the full core (inner and outer regions).
- `NHVMAX` is the maximum number of radial functions allowed for "outer core only" functions (velocity, temperature).
- `NHMMAX` is the maximum number of radial functions allowed for magnetic field functions.
- `LHMAX` is the highest permitted spherical harmonic degree, l.
- `NNDM` is the maximum permitted value of `NNDS`.

1.3 Outputs from CICSVPNSMAP

If the filename stem "root" was specified in the input file, the files `root.intsv`, `root.vecsv` and `root.xarrv` will all be created for the velocity and temperature functions, along with `root.intsm`, `root.vecsm` and `root.xarrm` for the magnetic field.

1.4 Sample runs of cicsvpnsmap

The directory

```
$LEOPACK_DIR/SAMPLERUNS/CICSVPNSMAP
```

contains example input files and model output. Do not under any circumstances edit these files, as these examples should serve as a control for the correct working of the code. After compiling the program, copy the `.input` files to another directory, run the code and confirm that the output agrees with that in the directory.

1.4.1 Example a

The directory

```
$LEOPACK_DIR/SAMPLERUNS/CICSVPNSMAP
```

contains the files

```
cicRa75000.intsm   cicRa75000.vecsm   cicRa75000.xarrm
cicRa75000.intsv   cicRa75000.vecsv   cicRa75000.xarrv
```

which describe a dynamo with a fixed (i.e. not freely rotating) conducting inner core. It is very closely related to the Case 1 benchmark dynamo model from [CAC+01] and therefore has a four-fold azimuthal symmetry. A program such as `cicubcdts2` could be used to time-step this solution. We wish to apply a Y_2^2 spherical harmonic temperature heterogeneity to the outer surface of this model. This would not be possible with the current set of vectors as all of the spherical harmonic radial functions have wavenumbers which are multiples of 4. The file

```
example_a.input
```

expands the solution vectors such that all the necessary radial functions which are multiples of 2 are also added. The resulting files;

```
example_aOUTPUT.intsm   example_aOUTPUT.vecsm   example_aOUTPUT.xarrm
example_aOUTPUT.intsv   example_aOUTPUT.vecsv   example_aOUTPUT.xarrv
```

could indeed by time-stepped by a program such as `cicibcdts2` with a temperature function with a azimuthal wavenumber $m = 2$. (Note that `DMAG` can be set to zero since in this case we will add a temperature heterogeneity which will put values into the $m = 2$ radial functions. If we were preparing these initial vectors for a heterogeneous boundary calculation, `DMAG` would have to be non-zero, or otherwise the symmetry would never be broken.)

References

[CAC+01] U. R. Christensen, J. Aubert, P. Cardin, E. Dormy, S. Gibbons, G. A. Glatzmaier, E. Grote, Y. Honkura, C. Jones, M. Kono, M. Matsushima, A. Sakuraba, F. Takahashi, A. Tilgner, J. Wicht, and K. Zhang. A numerical dynamo benchmark. *Phys. Earth Planet. Inter.*, 128:25–34, 2001.