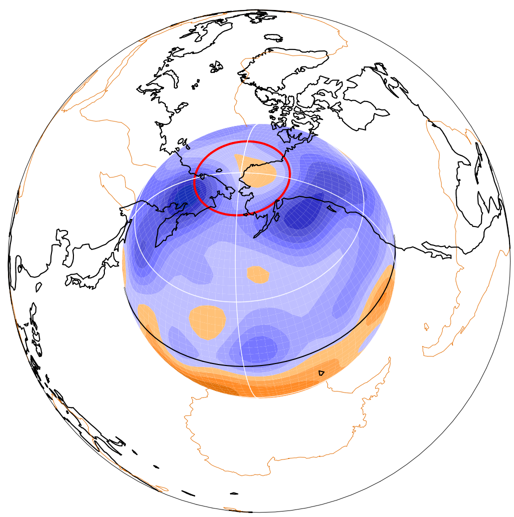
LEOPACK



full_sphere_plot

Full sphere plot

Steven J. Gibbons, Oslo

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1 full_sphere_plot

Source code is in

`LEOPACK_DIR/GPROGRAMS/full_sphere_plot.f`

although subprograms from `LEOPACK_DIR/GSUBS`, `LEOPACK_DIR/SUBS` and `LEOPACK_DIR/LINALG` are also required.

`full_sphere_plot` plots - from a solution in standard format (i.e. `.ints`, `.vecs` and `.xarr` files) - a component on a constant radius spherical surface with a satellite projection. A typical input file is

---

```
 80.0   20.0  -50.0                         : alpha beta gamma
example_aOUTPUT                             : Filename stem
../../EXAMPLES/FUNDAMENTALS/case1.ints      : integers
../../EXAMPLES/FUNDAMENTALS/case1.vecs      : vectorfile
../../EXAMPLES/FUNDAMENTALS/case1.xarr      : radialfile
 120.0   0.0  1.0   1.00                    : huepos, hueneg, csat, scal
 16   1   3   6.0     4                     : nlev idev nnds papwidth  icomp
 40   80   1.50                             : NTHE NPHI RADV2
```

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.

We are looking down upon the sphere using a satellite projection and have to perform some axis rotations in order to put the sphere in the desired position. We use Euler angles of rotation as described by [AW95]: see also the subroutine

`LEOPACK_DIR/SUBS/earcmc.f`

Some trial and experimentation is generally required to obtain the correct viewpoint - unless your sense of 3 dimensional relative frames of reference is somewhat better than mine!

The inputs in the above file are as follows

- `alpha`. Euler angle. See [AW95] or subprogram `earcmc.f`. In degrees.
- `beta`. Euler angle. See [AW95] or subprogram `earcmc.f`. In degrees.
- `gamma`. Euler angle. See [AW95] or subprogram `earcmc.f`. In degrees.
- `Filename stem`. First characters in output files to be generated by current run. Running `full_sphere_plot` with the above input file will create either the file `example_aOUTPUT.ps` or `example_aOUTPUT.gif`: depending upon the value of the integer flag `IDEV`.

- `name of .ints file`: name of already existing indices file describing solution.

- `name of .vecs file`: name of already existing vector file describing solution. Must contain the same number of radial functions as indicated in the `.ints` file.

- `name of .xarr file`: name of already existing radial spacings file describing solution. Must contain the same number of radial grid nodes as indicated in the `.vecs` file.

- `huepos`. Hue value for numbers greater than zero. Number between `0` and `360`. See Appendix (2) and Figure (4) for details.

- `hueneg`. Hue value for numbers less than zero. Number between `0` and `360`. See Appendix (2) and Figure (4) for details.

- `csat`. Saturation value. Number between `0.0` and `1.0` `csat = 1.0` implies full colour. `csat = 0.0` means monochrome and, in this case, the values `huepos` and `hueneg` become irrelevant and a grey-shade plot results with the most negative value as white and the most positive value as black. See Appendix (2) for details.

- `scal`. A very crude means of lightening a dark plot. Normal value is `scal = 1`, but reducing this (e.g. `scal = 0.7`) may give a better picture.

- `nlev`. The number of contour levels required. There is a special value `nlev = -1` which applies a 16 contour level Red/Green/Blue coefficient set provided by Andy Jackson.

- `idev`. Device number. Can take the following values:-
  `idev = 1` $\rightarrow$ landscape gif file.
  `idev = 2` $\rightarrow$ portrait gif file.
  `idev = 5` $\rightarrow$ landscape colour postscript file.
  `idev = 6` $\rightarrow$ portrait colour postscript file.

- `nnds`. Number of nodes for interpolating radial functions. `3` is a suggested value since no great accuracy is required here.

- `papwidth`. Width of the output in inches. (Since we are always plotting full spheres, we set the height equal to the width!)

- `icomp`. Field component to be displayed. Can take the following values:-
  `icomp = 1` $\rightarrow$ radial velocity, v_r.
  `icomp = 2` $\rightarrow$ theta velocity, v_θ.

`icomp = 3` $\rightarrow$ phi velocity, v_ϕ.
`icomp = 4` $\rightarrow$ radial magnetic field, B_r.
`icomp = 5` $\rightarrow$ theta magnetic field, B_θ.
`icomp = 6` $\rightarrow$ phi magnetic field, B_ϕ.
`icomp = 7` $\rightarrow$ temperature, T.
`icomp = 8` $\rightarrow$ heat-flux, $-(dT/dr)$.
`icomp = 9` $\rightarrow$ upwelling, $-(dv_r/dr)$.

- `NTHE`. Number of grid points in latitude.
- `NPHI`. Number of grid points in longitude. (Remember ofcourse that many of these longitude points will be hidden, so make sure that there are sufficient ...)
- `RADV2`. The radius at which the solution is to be viewed. This must lie between the first and last numbers in the `.xarr` file.

1.1 Run-time limitations

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

```
      INTEGER NRADMX, NTHMAX, NPHMAX, NLEVM, LHMAX, NHMAX,
     1        ISVMAX, NNDM
      PARAMETER ( NRADMX = 250, NTHMAX = 250, NPHMAX = 250,
     1            NLEVM = 20, LHMAX = 160, NHMAX = 3000,
     2            ISVMAX = NRADMX*NHMAX, NNDM = 6 )
```

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

- `NRADMX` is the maximum permitted number of radial grid nodes.
- `NTHMAX` is the maximum permitted number of grid nodes in latitude.
- `NPHMAX` is the maximum permitted number of grid nodes in longitude.
- `NLEVM` is the maximum permitted number of contour levels.
- `LHMAX` is the highest permitted spherical harmonic degree, l.
- `NHMAX` is the highest permitted number of spherical harmonic radial functions.
- `NNDM` is the highest permitted value of `nnds`.

1.2 Sample runs of full_sphere_plot

The directory

`$LEOPACK_DIR/SAMPLERUNS/FULL_SPHERE_PLOT`

contains example input files only. Do not under any circumstances edit these files. They refer to other (solution vector) files which are elsewhere in the distribution and provide a relative path to avoid unnecessary duplication of files. The outputs from the different files are displayed here rather than left in the directory.

1.2.1 Example a

```
* input file for full_sphere_plot
 80.0   20.0  -50.0                        : alpha beta gamma
example_aOUTPUT                            : Filename stem
../../EXAMPLES/FUNDAMENTALS/case1.ints     : integers
../../EXAMPLES/FUNDAMENTALS/case1.vecs     : vectorfile
../../EXAMPLES/FUNDAMENTALS/case1.xarr     : radialfile
 120.0   0.0  1.0   1.00               : huepos, hueneg, csat, scal
 16   1   3   6.0     4                : nlev idev nnds papwidth  icomp
 40   80   1.50                        : NTHE NPHI RADV2
```

Figure (1) shows a gif file produced by the above input file. It shows contours of B_r at the surface $r = 1.5$ (almost but not quite the outer boundary) for a solution to the Case 1 (insulating core) dynamo benchmark of [CAC$^+$01] (c.f. Figure 1 of that paper). The output is called `example_aOUTPUT.gif`.

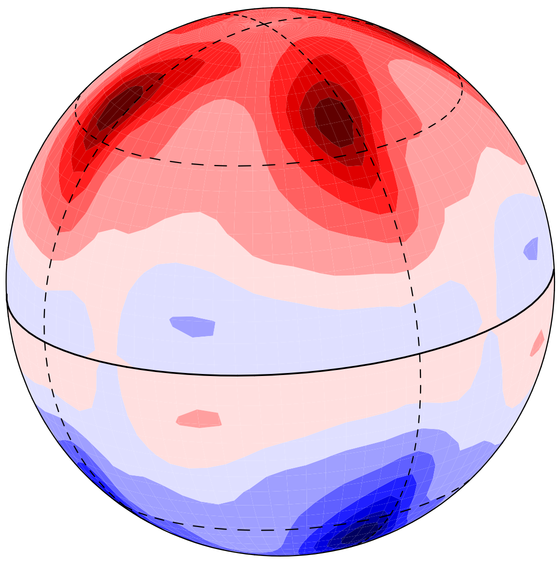

Figure 1: Output from full_sphere_plot with example_a.input (Section 1.2.1).

1.2.2 Example b

```
* input file for full_sphere_plot
 80.0   40.0  -80.0                         : alpha beta gamma
example_bOUTPUT                             : Filename stem
../../EXAMPLES/FUNDAMENTALS/case1.ints      : integers
../../EXAMPLES/FUNDAMENTALS/case1.vecs      : vectorfile
../../EXAMPLES/FUNDAMENTALS/case1.xarr      : radialfile
 120.0   0.0  1.0   1.00                : huepos, hueneg, csat, scal
 -1   6   3   4.0     4                 : nlev idev nnds papwidth  icomp
 40   80   1.50                         : NTHE NPHI RADV2
```

Figure (2) shows a postscript file produced by the above input file. It shows contours of B_r at the surface $r = 1.5$ (almost but not quite the outer boundary) for a solution to the Case 1 (insulating core) dynamo benchmark of [CAC$^+$01] (c.f. Figure 1 of that paper). The output is called `example_bOUTPUT.ps`. Other than the output device, we have chaned the Euler angles, used Andy Jackson's colour scheme (`nlev=-1`) and reduced the width.

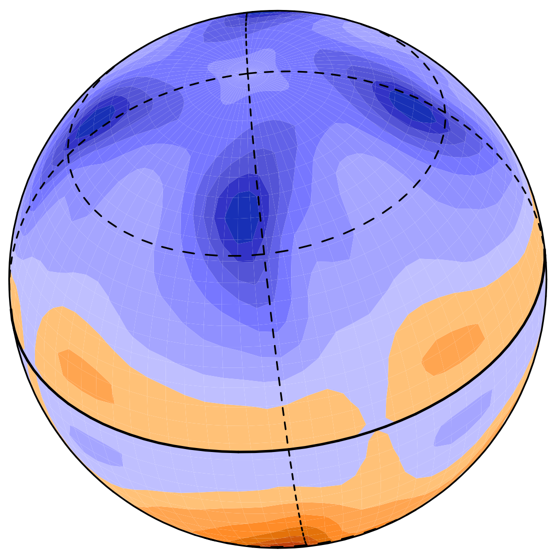

Figure 2: Output from full_sphere_plot with example_b.input (Section 1.2.2).

1.2.3 Example c

```
* input file for full_sphere_plot
 70.0   20.0  -45.0                         : alpha beta gamma
example_cOUTPUT                             : Filename stem
../../EXAMPLES/FUNDAMENTALS/case1.ints      : integers
../../EXAMPLES/FUNDAMENTALS/case1.vecs      : vectorfile
```

```
../../EXAMPLES/FUNDAMENTALS/case1.xarr   : radialfile
 155.0   275.0  0.8   1.00            : huepos, hueneg, csat, scal
 14   6   3   4.0     1              : nlev idev nnds papwidth  icomp
 60  140   1.213                     : NTHE NPHI RADV2
```

Figure (3) shows a postscript file produced by the above input file. It shows contours of v_r at the surface $r = 1.213$ ($r_i + 0.675$) for a solution to the Case 1 (insulating core) dynamo benchmark of [CAC+01] (c.f. Figure 1 of that paper). We have changed the Euler angles again, lowered the saturation somewhat (duller colours), chosen the most ghastly colour scheme available from Figure (4), increased the detail/resolution and imposed 14 contour levels. The output is called `example_cOUTPUT.ps`.

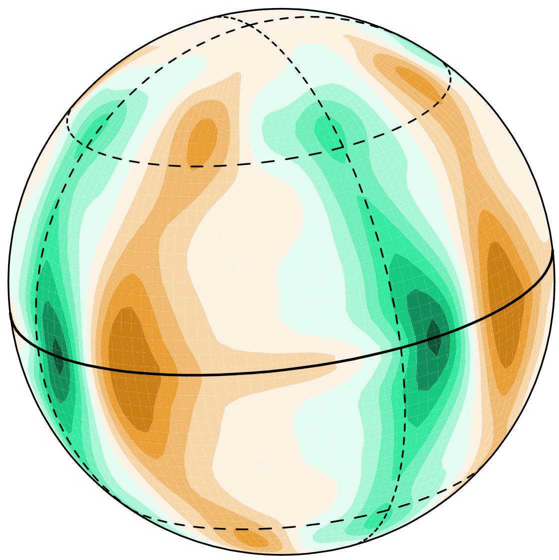

Figure 3: Output from full_sphere_plot with example_c.input (Section 1.2.3).

There are further representative examples in the section on the accompanying program `continent_full_sphere_plot`.

1.3 Note on full_sphere_plot

You will notice that each of the diagrams printed here has a think equatorial line, dotted lines for other lines of latitude and also lines of longitude. As I wanted the program to have as simple an input file as possible, I did not include a user option for getting rid of (or altering the properties of) these lines.

In order to change these lines, you need to edit the file `simple_sphere_plot.f`: which is ofcourse in the directory

`LEOPACK_DIR/GSUBS`

All the commands for plotting these lines come towards the end of this file: comment out and/or edit as desired (preferably leaving a copy of the original somewhere!).

2 The HLS colour scheme

When plotting using the PGPLOT software, a colour is specified by either one of the two calls

```
CALL PGSHLS( IND, CH, CL, CS )
```

or

```
CALL PGSCR( IND, CR, CG, CB )
```

The integer `IND` is the index of the colour being applied. `CR`, `CG` and `CB` are respectively the red, green and blue values in the ranges $[0, 1]$.

Figure 4: Colours as described by the integer HUE in the HLS (Hue, Light and Saturation) colour scheme.

The alternative HLS (Hue, Light and Saturation) system takes three real values

- `CH`. Hue. This is an angle between zero and 360 degrees which specifies the colour. Red is 120, Green is 240 and Blue is 0 (or 360). The full spectrum, in intervals of 5 degrees, is displayed in Figure (4).
- `CL`. Light. Ranges from 0.0 to 1.0 with black at lightness 0.0 and white at lightness 1.0.
- `CS`. Saturation. Ranges from 0.0 (grey) to 1.0 (pure colour). Hue is irrelevant when saturation is 0.0

I opted for the HLS system for the general graphics system - not because I thought the results were better - but because it is simply much easier to apply. I generally set one hue value for positive values and one for negative values and then vary the lightness as a function of the numbers being plotted.

Other users may find this colour scheme unappealing and so are welcome to devise a better way of assigning colours to contour levels! I did a job for Andy Jackson last year, for which he gave me a set of 16 red, green and blue (RGB) coefficients. This scheme is very nice and so I have implemented it in the majority of the codes as a special value of `NLEV` (the number of contour levels). Setting `NLEV = -1` should implement this colour scheme, resulting in 16 contour levels. I never got round to implementing any more general RGB scheme.

References

[AW95] G. B. Arfken and H. J. Weber. *Mathematical Methods for Physicists.* Academic Press, 1995.

[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.