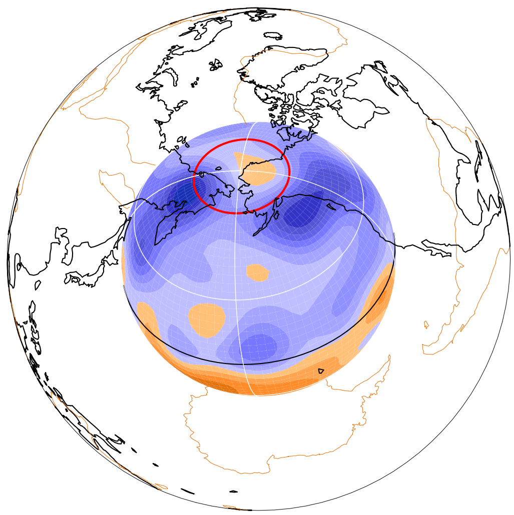
LEOPACK



cutout_sphere_plot

Cut-out sphere plot

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1 cutout_sphere_plot

Source code is in

`LEOPACK_DIR/GPROGRAMS/cutout_sphere_plot.f`

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

`cutout_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 "chunk" taken out. A typical input file is

```
 80.0   15.0  -50.0                             : alpha beta gamma
example_bOUTPUT                                 : Filename stem
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.ints        : integers
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.e001.vecs   : vectorfile
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.xarr        : radialfile
   0.0  90.0  1.0   1.00   1          : huepos, hueneg, csat, scal, iw
 16   6   3   8.0     6               : nlev idev nnds papwidth  icomp
 30   40   40    80   20   0.0  0.92 : NRAD NTHE NTHEP NPHI NPHIP PHIV1 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.

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_bOUTPUT.ps` or `example_bOUTPUT.gif`: depending upon the value of the integer flag `IDEV`.
- `integers`: name of already existing indices file describing solution.
- `vectorfile`: name of already existing vector file describing solution. Must contain the same number of radial functions as indicated in the `.ints` file.
- `radialfile`: 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.
- `iw`. Width of lines used. Integer, with `1` being the thinnest available.
- `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, $-(dv_r/dr)$.
- `NRAD`. Number of points in radius.

- NTHE. Number of grid points in latitude.
- NTHEP. Number of grid points in latitude which are going to be used for the cut-out. For example, if NTHEP is half the number NTHE then our cut-out will go down to the equator. If NTHE and NTHEP are equal, then the entire section between the longitudes specified will be omitted.
- NPHI. Number of grid points in longitude.
- NPHIP. Number of grid points in longitude which are used for the cut-out. Usually, we cut out a 90° segment and so set NPHIP to exactly half NPHI.
- PHIV1. Value of longitude to have at first side of cut-away. This angle is in radians (including the factor of π). Therefore, a 45° shift means PHIV1 = 0.392699. Note that this program can give really dreadful results, depending upon the angle viewed and the angle of the cutout. It does not intelligently judge what is visible and what is not visible - the user will need to make modifications if very general situations are to be viewed.
- RADV2. The radius of the outer sphere. This is a REAL radius (i.e. corresponds to the 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, NPMAX
      PARAMETER ( NRADMX = 250, NTHMAX = 250, NPHMAX = 250,
     1            NLEVM = 20, LHMAX = 160, NHMAX = 3000,
     2            ISVMAX = NRADMX*NHMAX, NNDM = 6,
     3            NPMAX = (LHMAX+1)*(LHMAX+2)/2 )
```

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

- NRMAX 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 cutout_sphere_plot

The directory

`$LEOPACK_DIR/SAMPLERUNS/CUTOUT_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 cutout_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   1         : huepos, hueneg, csat, scal, iw
 -1   1   3   6.0     4              : nlev idev nnds papwidth  icomp
 30   40   30    80   20    0.0  1.53 : NRAD NTHE NTHEP NPHI NPHIP PHIV1 RADV2
```

Another view of the Case 1 (insulating core) dynamo benchmark solution from [CAC+01] with B_r being plotted at (almost) the outer radius. The meridian sections which are exposed in the sliced are of exactly the same function; this is clear considering that the solution obeys a strict four-fold aziumthal symmetry and the cut away section has a 90° span. We show a constant θ surface at co-latitude $\theta = 3\pi/4$, given that `NTHEP` and `NTHE` are in this ratio. Andy Jackson's colour scheme is applied.

1.2.2 Example b

```
* input file for cutout_sphere_plot
*
 80.0   15.0  -50.0                      : alpha beta gamma
example_bOUTPUT                          : Filename stem
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.ints        : integers
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.e001.vecs   : vectorfile
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.xarr        : radialfile
   0.0  90.0  1.0   1.00   1         : huepos, hueneg, csat, scal, iw
 16   6   3   8.0     6              : nlev idev nnds papwidth  icomp
 30   40   40    80   20 0.392699 0.92 : NRAD NTHE NTHEP NPHI NPHIP PHIV1 RADV2
```

Here, `NTHEP = NTHE` and so no constant θ surface appears and a full segment is cut out. Here, we contour B_ϕ for the Kumar and Roberts standard dynamo solution. We again take a 90° slice, but have shifted by 22.5°. We take the spherical slice at a radius $r = 0.92$ to show a little of the function on the surface; at $r = 1$, the toroidal field goes to zero.

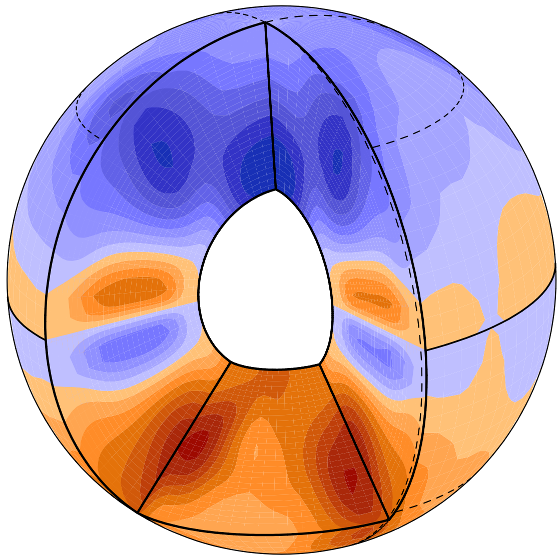

Figure 1: Output from cutout_sphere_plot with example_a.input (Section 1.2.1).

1.2.3 Example c

```
* input file for cutout_sphere_plot
*
  0.0    0.0    0.0                        : alpha beta gamma
example_cOUTPUT                            : Filename stem
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.ints        : integers
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.e001.vecs   : vectorfile
../../SAMPLERUNS/KRSSGEPS/example_aOUTPUT.run003.xarr        : radialfile
 165.0 290.0  1.0   1.00   1         : huepos, hueneg, csat, scal, iw
 16   6   3   8.0     6              : nlev idev nnds papwidth  icomp
 30   40   40    80   40   0.0  1.00 : NRAD NTHE NTHEP NPHI NPHIP PHIV1 RADV2
```

The same solution as in section (1.2.2) is plotted "head on" (look at Euler angles) and so we have a rather primitive way of getting a full meridian section.

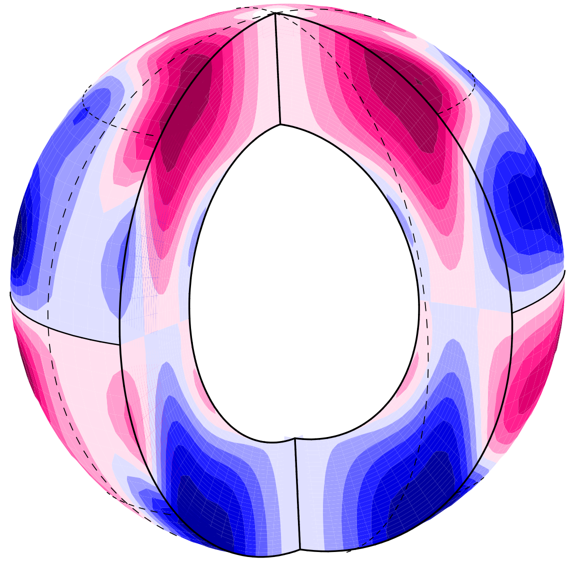

Figure 2: Output from cutout_sphere_plot with example_b.input (Section 1.2.2).

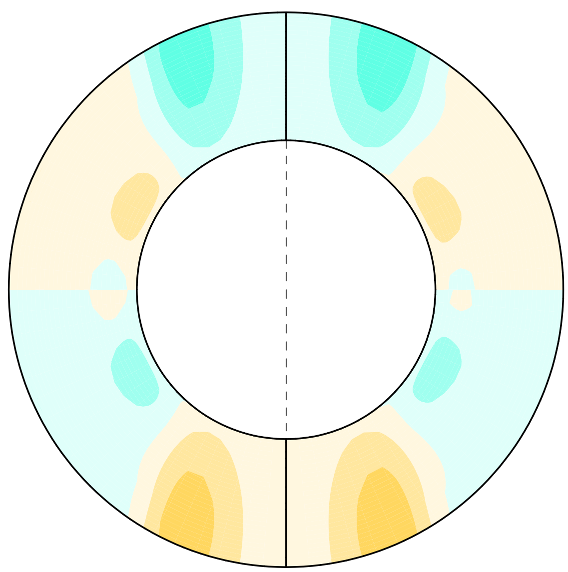

Figure 3: Output from cutout_sphere_plot with example_c.input (Section 1.2.3).

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.