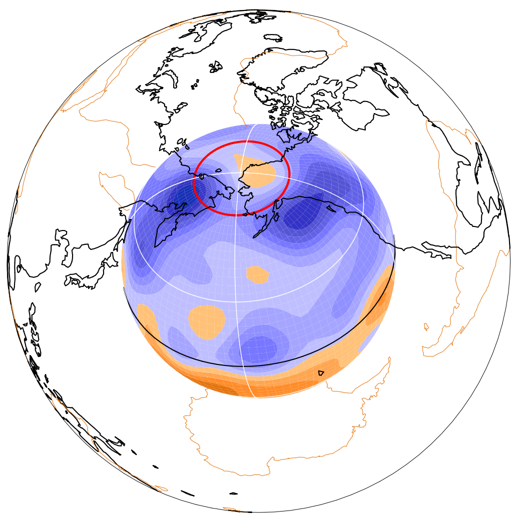
LEOPACK



shc_sphere_plot

Spherical harmonic coefficient Sphere Plot

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1 shc_sphere_plot

Source code is in

LEOPACK_DIR/GPROGRAMS/shc_sphere_plot.f

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

shc_sphere_plot plots a function of latitude and longitude, described by spherical harmonic coefficients, on a spherical surface in a satellite projection. The function, $f(\theta, \phi)$, must be defined by the expansion

$$f(\theta, \phi) = \sum_{l=1}^{LH} \sum_{m=0}^{l} \left(f_l^{mc} \cos m\phi + f_l^{ms} \sin m\phi \right) P_l^m(\cos\theta) \tag{1}$$

where the associated Legendre function, $P_l^m(\cos\theta)$, satisfies Schmidt quasi-normalisation such that

$$\int_0^{\pi} [P_l^m(\cos\theta)]^2 \sin\theta d\theta = \frac{2(2-\delta_{m0})}{2l+1}. \tag{2}$$

The coefficients must be stored in a file of the following format:

- First line must be blank
- Second line contains a single integer, the maximum spherical harmonic degree, l, used: LH.
- After this, there follow LH*(LH+2) numbers in the format (5d16.7). They are stored in the order such that g_l^{mc} is stored as element number IND = INDSHC(L, M, 1) and g_l^{ms} is stored as element number IND = INDSHC(L, M, 2). (indshc.f is an integer function in the $LEOPACK_DIR/SUBS directory.) Conversely, the coefficient stored in element number IND has l and m given by a call to the subroutine LMFIND using

  ```
  CALL LMFIND( IND, L, M, ICS )
  ```

  If ICS = 1, the coefficient is g_l^{mc}. If ICS = 2, the coefficient is g_l^{ms}.

The files are written by the subroutine SHSFWT and read by the subroutine SHSFRD.

A typical input file for shc_sphere_plot is

```
* input file for shc_sphere_plot
 80.0   20.0  -50.0                     : alpha beta gamma
example_OUTPUT                          : Filename stem
coefs.shc                               : SHC coefficient file
 120.0   0.0  1.0   1.00                : huepos, hueneg, csat, scal
 -1   1   6.0    0                      : nlev idev papwidth  ias
 80  120                                : NTHE NPHI
```

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 `shc_sphere_plot` with the above input file will create either the file `example_OUTPUT.ps` or `example_OUTPUT.gif`: depending upon the value of the integer flag `idev`.
- `SHC coefficient file`. Name of file of the above format, describing the spherical function.
- `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` → landscape gif file.
  `idev = 2` → portrait gif file.
  `idev = 5` → landscape colour postscript file.
  `idev = 6` → portrait colour postscript file.
- `papwidth`. Width of the output in inches. (Since we are always plotting full spheres, we set the height equal to the width!)

- `ias`. Axisymmetric only flag.
  `ias = 0` → full 3D solution is used.
  `ias = 1` → only the axisymmetric part is used.

- `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 ...)

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
      PARAMETER ( NRADMX = 1, NTHMAX = 250, NPHMAX = 250,
     1            NLEVM = 20, LHMAX = 160,
     2            NHMAX = LHMAX*(LHMAX+2) )
```

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

- `NRADMX`. Irrelevant to this code. Simply required for subroutine compatibility.

- `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.

1.2 Sample runs of shc_sphere_plot

The directory

`$LEOPACK_DIR/SAMPLERUNS/SHC_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 shc_sphere_plot
 80.0   20.0  -50.0                      : alpha beta gamma
example_aOUTPUT                          : Filename stem
y22.shc                                  : SHC coefficient file
 120.0   0.0  1.0   1.00                 : huepos, hueneg, csat, scal
 -1   1   6.0    0                       : nlev idev papwidth  ias
 80  120                                 : NTHE NPHI
```

Figure (1) shows a gif file produced by the above input file. The coefficient file `y22.shc` has every number zero apart from the seventh which, according to the rules of the series outlined above, corresponds to the coefficient f_2^{2c}. We have imposed the special RGB colour scheme by use of `nlev = -1`.

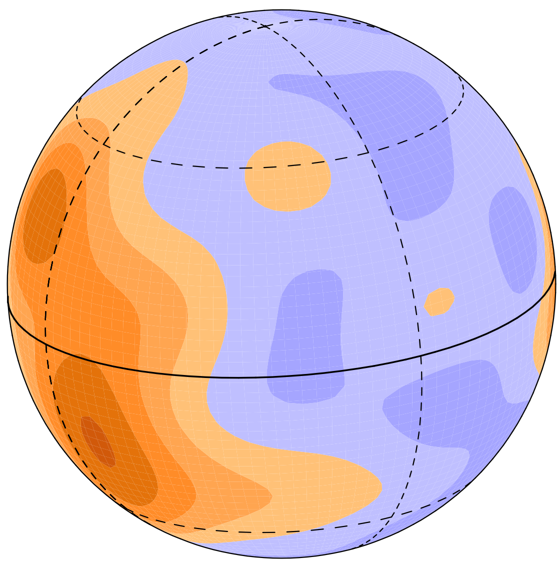

Figure 1: Output from shc_sphere_plot with example_a.input (Section 1.2.1).

1.2.2 Example b

```
* input file for shc_sphere_plot
 20.0   45.0  -135.0                       : alpha beta gamma
example_bOUTPUT                           : Filename stem
../../EXAMPLES/SHEARWAVE/output_coeffs    : SHC coefficient file
 305.0  50.0  1.0   1.00                  : huepos, hueneg, csat, scal
 15   6   6.0    0                        : nlev idev papwidth  ias
 80  120                                  : NTHE NPHI
```

Figure (2) shows a postscript file produced by the above input file. The example chosen here is the coefficients describing seismic shear-wave velocity at the bottom of the mantle, courtesy of Guy Masters.

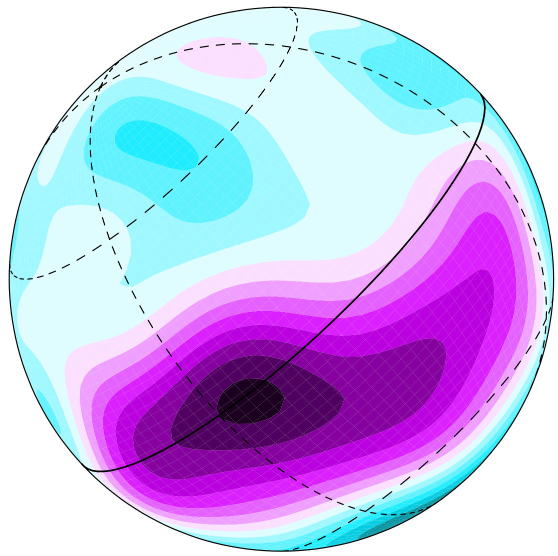

Figure 2: Output from shc_sphere_plot with example_b.input (Section 1.2.2).

1.2.3 Example c

```
* input file for shc_sphere_plot
 80.0   20.0  -135.0                      : alpha beta gamma
example_cOUTPUT                           : Filename stem
../../EXAMPLES/JUPITER/jupiter_shc        : SHC coefficient file
 305.0  50.0  0.0   1.00                  : huepos, hueneg, csat, scal
 15   6   6.0    0                        : nlev idev papwidth  ias
 160  120                                 : NTHE NPHI
```

Figure (3) shows a postscript file produced by the above input file. The example chosen here is zonal wind speed on the surface of Jupiter as derived from Voyager 2 data by Limaye ([Lim86]). Dark bands are fast eastward flow and light bands are fast westward flow.

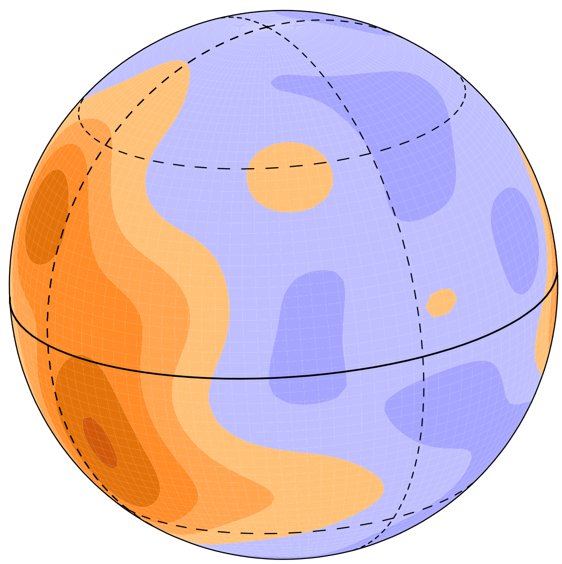

Figure 3: Output from shc_sphere_plot with example_c.input (Section 1.2.3).

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.

[Lim86] S. S. Limaye. Jupiter: New estimates of the mean zonal flow at the cloud level. *Icarus*, 65:335–352, 1986.