REDFIT 3.8e

Estimating red-noise spectra directly from unevenly spaced paleoclimatic time series

Manual (November 2010)

This program has been placed in the public domain. You should feel free to pass the program to your colleagues as long as you do not charge for it and you include each of the original files in unaltered form. The latest version of the program can be found at the following web site: `http://www.geo.uni-bremen.de/~mschulz/`

The program has been tested, though not rigorously, and is correct to the best of our knowledge. If you find any errors or have any suggestions, we would appreciate it if you would let us know:

Michael Schulz
MARUM, Univ. Bremen,
Leobener Str., D-28334 Bremen, FRG
mschulz@marum.de

Manfred Mudelsee
Climate Risk Analysis
Schneiderberg 26, D-30167 Hannover
mudelsee@mudelsee.com

Please cite the following reference if you use the program to analyze your data for publications:

Schulz, M. and Mudelsee, M. (2002) REDFIT: Estimating red-noise spectra directly from unevenly spaced paleoclimatic time series. Computers and Geosciences, **28**, 421-426.

DISCLAIMER OF WARRANTY

1. Installation/Contents of the ZIP Archive

Copy the ZIP-archive to an empty directory and make sure to keep the directory structure when unzipping the archive. At the command line this can be done with the following command:

```
unzip redfit38.zip -d
```

You should end up with the following directory structure:

`.\bin`	Executable files
`.\src`	Fortran 90 source code
`.\doc`	Documentation
`.\example`	Example 1 from Schulz & Mudelsee

2. Running REDFIT

REDFIT was successfully tested under Win9x, NT, 2000, XP and Win7. To use the program open a DOS-Box (Start → run → cmd.exe) and change to the `.\bin` directory. All program options and parameters are set in a configuration file that is passed to REDFIT via the command line. An example configuration file (redfit38.cfg) can be found in `.\bin`. To run the example, change to the example directory and enter the following command line and press the return key:

```
..\bin\redfit38 redfit38.cfg
```

Note the space between the program name and the name of the configuration file.

2.1 Configuration File Format

The configuration file is in ASCII format and can be edited with any text editor. We recommend that you copy the original `redfit38.cfg` file to a working file in order to have a backup. The configuration file contains a Fortran 90 namelist, e.g.:

```
    &cfg
          fnin = 'c:/data/foo.dat',
         fnout = 'c:/data/foo.red',
          nsim = 1000,
        mctest = T,
          ofac = 4.0,
         hifac = 1.0,
           n50 = 3,
        rhopre = -99.0,
          iwin = 2
       /
```

(If you are unfamiliar with namelists, please note the following:

- a string &cfg in the first line and a single slash in the last line
- each data line, except the last, ends with a comma
- filenames must be enclosed in ´...´ or ″...″
- directories are marked by a normal slash and NOT by the usual DOS backslash
- namelist entries can be in lower or upper case
- comment lines are marked by a leading "!")
- logical values can be entered as T, .true., F or .false.
- use point (not a comma) in decimal numbers

The parameters in the namelist have the following meaning:

fnin   Input filename with time series data

fnout   Results are written to this file (ASCII format)

nsim   Number of Monte-Carlo simulations (1000–2000 should be o.k. in most cases)

mctest   Toggle calculation of false-alarm levels based on Monte-Carlo simulation,
         if set to T : perform Monte-Carlo test,
         if set to F : skip Monte-Carlo test (default).

ofac   Oversampling factor for Lomb-Scargle Fourier transform (typical values: 2.0– 4.0)

hifac   Max. frequency to analyze is set to hifac * $<f_{Nyq}>$ (default = 1.0)

n50   Number of WOSA segments (with 50 % overlap)

rhopre   Prescibed value for ρ; unused if < 0 (default = -99.0)

iwin   Window-type identifier used to suppress sidelobes in spectral analysis:
            (0: Rectangular
            1: Welch
            2: Hanning
            3: Triangular
            4: Blackman-Harris).

Parameters `ofac`, `hifac`, `n50` and window type are identical to the SPECTRUM program (see Schulz and Stattegger, 1997 for further details). Except `mctest`, `hifac` and `rhopre` all parameters must be specified.

2.2 Input Data Format

Time series data are read from space- or tab-delimited ASCII files of the following format:

```
# comment lines
    # .
    # .
    t(1)   x(1)
    t(2)   x(2)
     .       .
     .       .
    t(N)   x(N)
```

where $t(1) < t(2) < ... < t(N)$ are GEOLOGICAL AGES and not physical times! In decimal numbers, decimal digits MUST be separated by a point (not a comma even if your Windows environment supports this, e.g. 1.23 NOT 1,23). The maximum number of data points N is only limited by the available amount of memory. The files must not contain more than two data columns. Make sure that the file contains NO BLANK LINES at the end of the file and within the data section. Comment lines are indicated by a leading # and are only allowed at the beginning of the file. The number of comment lines is unlimited.

REDFIT checks if the ages are in increasing order. If the program encounters decreasing ages, that is, $t(i+1) < t(i)$, it will stop. Identical age entries and the corresponding data values are automatically averaged. The averaged time series is written to the file `TimeSeries.avg`.

3. Output

- Estimated parameters and spectra (including false-alarm levels) are written to `FNOUT`.
- Error and warning messages are written to `REDFIT.LOG`.
- Automatically averaged time series, generated from input files with duplicate age entries, are saved to `TimeSeries.avg`.

The output file is in ASCII format and can be processed by the GNUPLOT graphic package or can be imported into most spreadsheets. The file is subdivided into several sections and should be largely self explanatory:

<u>Input:</u>   Lists the main settings from the configuration file.

<u>Initial values:</u>

`idum`   Seed value for random-number generator (generated internally).

`Data variance` Estimated variance of the data based on the area under the spectrum.

`Avg. dt`   Average sampling interval of the input data (Δt).

<u>Results:</u>

`Avg. tau`   Estimated values of τ. (Mudelsee, 2002. Note that τ is estimated separately for each WOSA segment and subsequently averaged.)

`Avg. autocorr. coeff., rho` $\rho \equiv \exp(-\Delta t / \tau)$

`Degrees of freedom`   Used for calculating χ^2 percentiles to scale red-noise estimate (see below) to false-alarm levels.

`6-dB Bandwidth`   Resolution bandwidth (in frequency units).

`Critical false-alarm level (Thomson, 1990)`
  `==> corresponding scaling factor for red noise`
        False alarm level = $(1-1/n) \times 100$ %, where n is the number of data points in each WOSA segment. Multiply the red-noise estimate (see below) with the scaling factor to plot the false-alarm level.

<u>Equality of theoretical and data spectrum: Runs test</u>
`5-% acceptance region:    rcritlo`
`                          rcrithi`

`r_test`
        Check appropriateness of the AR1 model to describe $x(t_i)$ by testing the equality of $G_{rr}(f_j)$ and $\hat{G}_{xx}(f_j)$ using a nonparametric runs test. If `r_test` falls outside the interval [`rcritlo`, `rcrithi`] the null hypothesis that the spectrum is consistent with an AR1 model is rejected. In such cases: (*i*) Check for the presence of harmonic components (can be subtracted using SPECTRUM; Schulz and Stattegger, 1997). (*ii*) If the misfit occurs at the high frequency end of the estimated spectrum (visual

inspection!) reduce `hifac` to exclude this frequency range from the calculation. (*iii*) Prescribe ρ based on your intuition (`rhopre`). Note that the test is only performed with the setting `n50 = 1`, `iwin = 0` and `hifac = 1`

`Elapsed time [s]:`   To check if your neighbors PC is faster than yours.

`Data Columns:` Meaning of data columns should be largely self explanatory.
– Frequency units = 1/age units
– MC (= Monte-Carlo) false-alarm levels are only calculated if `mctest = T`
– Spectral amplitudes are scaled such that the area under the spectrum is an estimator for the data variance (provided that `hifac= 1.0`).
– Usually one plots col. 3, 4 and some out of 7–13 vs. col. 1.

4. Notes and Troubleshooting
• A linear trend is subtracted from each WOSA segment prior to taking the Fourier transform.
• If your computer runs out of memory, try the following
  – increase `n50`
  – set `mctest = F`
  – reduce `nsim` (e.g. 500)
  – set `ofac = 1.0`

5. Recompiling REDFIT
A Fortran 90 compiler is required to compile REDFIT. The program was successfully compiled with Lahey's LF90 (V. 4.0e) and LF95 (V. 5.6e). The only nonstandard Fortran statements are related to the command line retrieval in the module `mutil.f90` and a `carriagecontrol = "FORTRAN"` specifier in some open statements. The program makes extensive use of the following subroutines from Press et al. (1992, 1996; these routines are not included due to copyright limitations):

```
avevar.f90
erfcc.f90
gammln.f90
gammp.f90
gasdev.f    (we prefer the F77 function instead of the F90 subroutine)
gcf.f90
gser.f90
ran.f90
sort.f90
```

Make sure to modify the include statements at the end of `redfit38.f90` according to your local setting. In addition to these routines, the following modules from Press et al. (1996) are required: `nr.f90`, `nrtype.f90` and `nrutil.f90`.

References

Mudelsee, M., 2002. TAUEST: a computer program for estimating persistence in unevenly spaced weather/climate time series. Computers & Geosciences, **28**, 69-72.

Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P., 1992. Numerical Recipes in FORTRAN, 2nd ed. Cambridge University Press, Cambridge. 963 pp.

Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P., 1996. Numerical Recipes in Fortran 90. Cambridge University Press, Cambridge. 571 pp.

Schulz, M. and Stattegger, K., 1997. SPECTRUM: Spectral analysis of unevenly spaced paleoclimatic time series. Computers & Geosciences, **23**, 929-945.

Thomson, D.J., 1990. Time series analysis of Holocene climate data. Philosophical Transactions of the Royal Society of London, Series A 330, 601-616.