ASSIGNMENT 8. FILTERING

Run geosa8.m, selecting one series from any of the three data sets, and using the entire series or any sub-period you wish for analysis. You will see the time series plot and spectrum in Figures 1 and 2. After viewing these plots, decide on a frequency range to retain, and go through the interactive filter design. Use any one of the three types of smoothing filters (binomial, Gaussian, windowing method). You will generate six figure windows, but turn only windows 1,2,3,4 and 6 in the assignment.

1. **(Caption to Figure 1 [Fig windows 1 & 2 in same text box]) Time plot and spectrum of series.** Summarize your filter-design strategy: 1) What frequency range do you intend to retain in the filtered series? 2) Mark that frequency range on the spectrum. 3) From the spectral plot, estimate roughly the percentage of variance of the original series likely to be retained in the filtered series, and say how you came up with the estimate. 4) Mark some feature on the time plot that you would expect to be retained in the filtered series following your design, and explain why it would be retained.

2. **(Caption to Figure 2 [Fig Window 3]) Time plots of original and filtered series.** Explain why the range of the filtered series is less than the range of the original series.

3. **(Caption to Figure 3 [Fig Window 4]) Amplitude of frequency response function of selected filter.** At wavelengths shorter than what threshold wavelength (approximately) would your choice of low-pass filter pass less than 1 percent of the variance (variations at wavelengths shorter than this would be essentially eliminated). Mark the wavelength on the figure, and explain your reasoning.

4. **(Caption to Figure 4 [Fig Window 6]) Spectra (not normalized) of original and filtered series.** Why do the areas under the two plotted spectra differ? Are the plotted spectra consistent with the filter being a "low-pass" filter. Explain.

Running goesa8.m

1. >geosa8
2. Message box: message introducing geosa8.m; click OK to remove message and move on
3. Respond to input dialog with the name of your data file; click OK
4. Menu: select any of V1, V3, or V3 as the source data set
5. Menu: click on the time series to be analyzed. You can only select one series, and when you do, an asterisk appears in its box. If you click again on another series, that series becomes your selection. When satisfied with your choice, click "Accept Selection"
6. Click OK to acknowledge the message box with information on your selection
7. Input dialog: accept the default (full length) period for analysis, or enter some sub-period and click OK

   Figures 1 and 2 and a menu appear. Fig 1 is the time series plot of the series, with a horizontal line at the long-term mean. Fig 2 is the spectrum and its 95% confidence interval. The spectrum is estimated by the Blackman-Tukey method, and a reasonable default is used for the size of the lag window as a fraction of the series length. You cannot change the lag window interactively in this assignment. You can, however, toggle the y-axis scaling between linear and log using the menu.

8. Menu: toggle the scaling of the y-axis back and forth between linear and log to see which best displays the spectrum, then choose "Accept Spectrum"
9. Menu: select the family of lowpass filter to use (Gaussian, binomial, or Hamming)
10. Menu: Choose to design or revise the filter (you have not designed it yet)
11. Input dialog:
    - If Gaussian filter or binomial filter, enter the desired period of the 50% filter response & click OK
    - If Hamming filter, enter the desired period and the number of filter weights and click OK. The number of weights should be odd, and must be greater than the desired period of the filter. Trial and error is necessary with the Hamming filter to get a combination that yields a filter with acceptable frequency response function
12. Menu: the previous menu reappears. This time choose to review the filter

    Figures 3, 4 and 5 appear. Fig 3 has superposed time series plots of the original and filtered series. Annotated are the variances of the two series, and the ratio of the variances. Fig 4 is a plot of the amplitude function of the frequency response of the filter. Annotated are the specifications (what you requested) and what you got in terms of frequency response. The number of filter weights is also annotated. Note that a frequency response of 0.5 means that a sine wave with the indicated wavelength would be reduced in amplitude by ½ in passing through the filter. Fig 5 is a plot of the filter weights. For all the filters possible here, the weights are symmetrical and sum to 1.0.

13. Menu: the previous menu is on screen again. You can choose to "Design or Revise" the filter, and if you do, again will be prompted for the input as in step 11 above. And if you revise, you must also follow that up with a review of the filter, as in step 12. Play with these settings to get a feel for the effect of different filters. Finally choose "Accept Filter"

    Figure 6 appears, and a menu. Figure 6 has superposed plots of the spectra of the original and filtered series. The plots show the frequencies at which variance is most affected by the

filter. The menu is another toggle menu for scaling of the y axis

14. Menu: As before, you may toggle the axis, check out the spectra. But before accepting the spectrum, return to the linear axis. This is because a question in the assignment that deals with areas under the spectra and their interpretation in terms of variance assumes a linear axis for the ordinate.

15. The closing message refers to a structure Results that remains in the workspace. Typing Results.what at the Matlab prompt will list the fields in Results. Among other things, Results holds the time series of original data, trend lines, and detrended data.

PROGRAMMING NOTES

Selected Matlab functions called :
spa – spectral analysis by Blackman-Tukey method
fir1 – compute finite irmpulse response filter

Selected user-written Matlab functions called:
filter1: given a time series and weights of filter, filters a series, keeping correct phase and including various adjustments for dealing with end-effects

fltplay2: interactive filter design ("filter play") that calls Matlab function **fir1** to get lowpass filter weights using Hamming window; design requires user input of desired frequency response of filter and number of filter weights

fltplay3: interactive filter design ("filter play") that optionally calls **wtsgaus** or **wtsbinom** for filter weights of binomial filter or Gaussian filter

freqres2: frequency response function for a symmetrical low-pass filter

wtsbinom: gives binomial filter weights; uses Matlab function **factorial**

wtsgaus: gives filter weights of Gaussian filter with desired frequency response; uses Matlab function **normpdf**

mafilt1: evenly weighted moving average; not used in geosa8, but a useful function