

## **ASSIGNMENT 6. SPECTRAL ANALYSIS -- SMOOTHED PERIODOGRAM METHOD**

1. Run geosa6.m, selecting one series from either V1 or V2 for analysis. (Series from V3 would generally be unsuitable for this exercise because they are dominated by trend). Run the script on either the full series length or some sub-period, but use the same period for both runs described below.
2. Run the program in exploratory mode, varying the smoothing to observe the effect on the spectral detail. Decide on two levels of smoothing for your final analysis – a wide smoothing and a narrow smoothing. The bandwidth (plotted bar on the figure) for wide smoothing should be about 1/5 the width of the frequency axis. The bandwidth for narrow smoothing should be less than 1/10 the width of the frequency axis. The final decision on those bandwidths is yours. Select reasonable tapering and padding values; the defaults are usually fine. Use either a white noise or AR(1) null continuum. Specify 95% confidence interval. You should have 8 figure windows, each time you run the script, but will need to use windows #1, #7 and #8.
3. Re-run the script twice, using your selected wide-smoothing and narrow-smoothing choices. Save Figure Windows #1 and #7 from either run, and Figure Window #8 from each run. You will turn in 4 Figures.
4. (Caption to Fig. 1 [Fig Window 1]) Time series plot. Describe the appearance of the time series plot with respect to any quasi-periodic appearance (e.g., any waves that make you expect high variance in a particular frequency band). Use MATLAB's figure annotation tools as needed to illustrate these waves. If no waves apparent, illustrate this also in terms of selected fluctuations. .
5. (Caption to Fig. 2 [Fig Window 7]) Raw periodogram with superposed spectrum. What does a high value of the raw periodogram at a particular frequency mean? What determines the frequency spacing of the raw periodogram, and what is the frequency spacing for your periodogram? What visual effect on the spectrum did you observe from varying the spans of the Daniell filters used to smooth the periodogram?

6. (Caption to Fig. 3 [Fig Window 8 from wide-smoothing run]) Spectrum with 95% confidence interval. Describe the general shape of the spectrum. Did you decide to use a white noise or an AR(1) null continuum, and explain why. Does the sample spectrum differ significantly from the null continuum at any particular frequency range?
7. (Caption to Fig. 4 [Fig Window 8 from narrow-smoothing run]) Spectrum with 95% confidence interval. Describe changes in the spectral appearance from the version smoothed with the wide filter. How has the width of the confidence interval changed in going to a narrower smoothing filter?

Running goesa6.m

1. >geosa6
2. Message box introducing geosa6.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 either V1 or V2 as the source structure for your time series
5. Menu: click on the time series to be analyzed. You can only select one series, and when you do, an asterisks appears in its box. If you click again on another series, that series becomes your selection. When satisfied with you choice, click "Accept Selection"
6. Input dialog: select either the default (full length) or enter any sub-period for analysis; click OK
7. Click OK to acknowledge the message box with information on your selection
8. Choose from among four options for choice of null continuum
9. Question dialog: choose "No" for question on hypothesis test mode
10. Input dialog: enter the decimal fraction of series to taper. The default is to taper 10%, which means 5% at either end. The default is fine; click OK
11. Input dialog: enter the padded length of series. The default is the next power of two higher than the length of series. For example, if the series has 439 years, the default padded length is 512. You can accept the default, or enter a higher power of two (for example, 1024 years). The higher padded length would give the periodogram estimates at a finer frequency spacing. Click OK.

Figure windows 1-7 are now generated, with Figure 7 as the current figure window. Figure 7 is a plot of the raw, or unsmoothed, periodogram. The opening screen message described these windows. A menu also appears...

12. Menu: choose to smooth the periodogram (or revise smoothing), or to accept the spectrum. The spectrum is the smoothed periodogram. The first time through you should not choose to accept the spectrum because you have not yet estimated the spectrum. Choose to smooth the periodogram

Figure window 7 is now changed to show the spectrum as well as the periodogram. The spectrum has been produced by smoothing the periodogram with default spans of a Daniell filter. Information on the spans is at the top of the figure.

The previous menu has also reappeared, allowing you to revise the spectrum or accept it. Choose to revise ...

13. Input dialog: enter different spans of Daniell filters to get different smoothing. You may change the number of spans and the length of individual spans. For example, a single span of length 7 is “[7]”, while three spans with lengths 5, 7 and 11 is “[5 7 11]”. Use only odd numbers of weights in the spans. Try out a few variations. This is a repeated menu, so you can always change back. You see the smoothness of the spectrum changed in Figure window 7. You also see the menu to revise or accept the spectrum.
14. When satisfied, choose “Accept Spectrum.”
15. Optional Menu—appears only if smoothed periodogram version of null continuum: choose to 1) make or revise the null continuum or to 2) accept the null continuum. The first time through, you must make the null continuum.

The sequence of steps here is analogous to steps 12-14 above. You keep revising the null continuum until you think it adequately follows the very smooth underlying shape of the spectrum. Note that the null continuum hypothetically is a smooth underlying line against which the peaks in the spectrum will be tested for significance. Accordingly, the null continuum should not track spectral peaks. An example of a null continuum is “white noise”, which is represented by a horizontal line in the spectral plot. When you are happy with the appearance of the null continuum, choose “Accept”.

16. Menu: Either 1) make or revise final spectral plot, or choose 2) “Satisfied” to quit the program. The first time through you must make the final spectral plot. Choose that option...
17. Menu: Choose what confidence band (95%, 99% or none) to be plotted on the final spectrum. You can try various options, but settle on 95% for the assignment as your last choice.

Figure window #8, the final spectrum with confidence band appears. If using hypothesis test mode a vertical line at the hypothesis frequency is also produced. Also reappearing is the menu to revise the final spectrum or “satisfied.” Press “Satisfied.”

18. This file will go into your current working directory, where you can view it with a text editor.
19. The closing message refers to a structure Results that remains in the workspace. Results.what describes the fields in Results. Results.model contains selected data and statistics from the analysis, including settings for the analysis. For example, Results.f and Results.s are the frequencies and spectral estimates. Typing Results.what at the command prompt defines the fields in Results.
20. You will keep figure windows #1 and #7 for turning in with the assignment. Copy those as instructed in the assignment into word document text boxes
21. Repeat steps 1-19 two more times, saving figure window #8 each time. The first time through save the version of spectrum made using the broad smoothing window. The second time through save the version made using the narrow smoothing window.

## **PROGRAMMING NOTES**

The user-written function **pdgm5.m** does most of the work in script **geosa6.m**. Function **pdgm5.m** is quite easy to apply to any time series if the series and a corresponding year vector have been brought into the MATLAB workspace. See the comment section in **pdgm5.m** for instructions on running **pdgm5.m** on its own (outside of **geosa6.m**).

Matlab functions called :

**fft** - Fast Fourier transform

**chi2inv** -- inverse of the chi-square cumulative distribution function (cdf)

User-written Matlab functions called:

**danbw2** -- bandwidth and degrees of Daniell filter for smoothing periodogram into spectrum

**danwgtn** - filter weights for a modified-Daniell filter, single or multi-span

**whit1** - fits AR model to time series

**arspectrum** - computes theoretical autoregressive spectrum