

12.009/18.352 Problem Set 8

Due Thursday, May 7, 2015

Problem 1: 20 pts — (a,b)=(10,10)

Problem 2: 30 pts — (a,b,c)=(10,15,5)

Problem 3: 50 pts — (a,b,c,d,e)=(10,10,10,10,10)

1. *Very Dusty*: Along with oxygen isotopes and a plethora of other gases trapped in air bubbles, ice cores also store an often overlooked tracer, dust. The following 800,000 year record of dust

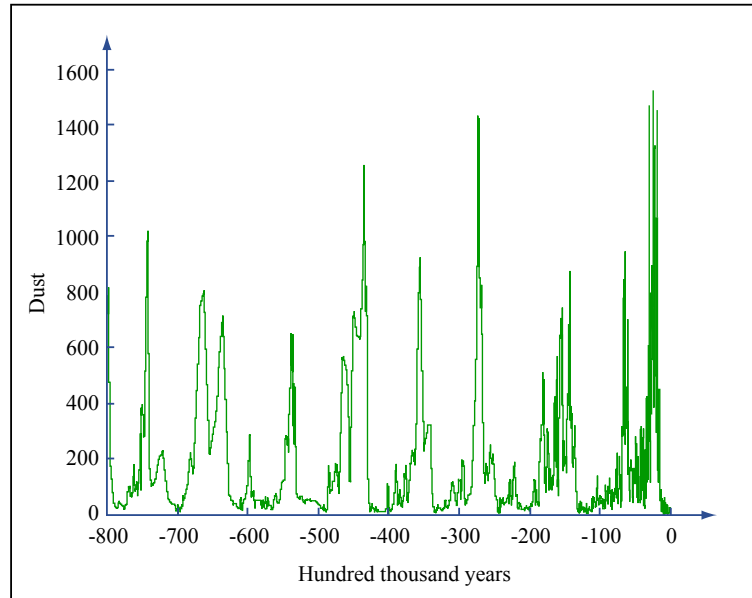
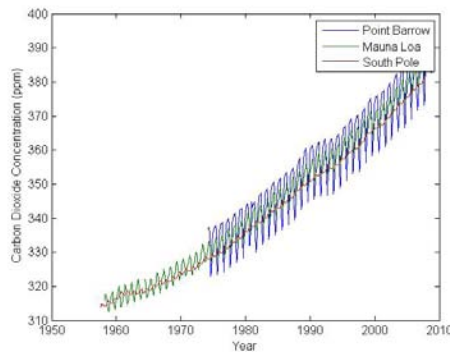


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was taken in Antarctica from the longest continuous ice record available. This data can be found in `dusty.mat`.

- (a) The data in `dusty.mat` is the original, unevenly spaced data directly from the core. In order to use normal Fourier Transform methods we must interpolate the data so that it is evenly spaced. Use MATLAB function `interp1` to get an evenly spaced data set and make a plot of the data. How does the dust data set compare to the data set for $\delta^{18}\text{O}$ from the last problem set (`vostok.mat`)? What might cause these differences?
 - (b) Make a plot of the power spectrum for this data and label the dominant peak with its frequency. How does the power spectrum of dust compare to the power spectrum of $\delta^{18}\text{O}$ from the last problem set?
2. *Our Noisy Reality*: In both the case of the oxygen isotopes and the dust we ignored the influence of random processes in determining the power spectrum. Here, we ask if the peaks we see in the power spectrum are due to random chance. For this part, we will use the $\delta^{18}\text{O}$ data set only (`vostok.mat`) and compare the spectrum to that of a null-model, uncorrelated random events.
 - (a) Write a code in MATLAB which will generate a random time series having the same mean and variance as the $\delta^{18}\text{O}$ data. Make a plot of one of these random time series on top of a plot of the $\delta^{18}\text{O}$ time series. How do they compare?

- (b) We are interested in understanding which peaks in the power spectrum of $\delta^{18}\text{O}$ are significantly different than what we could expect to be generated from a random, uncorrelated time series. Write a MATLAB script which generates many random time series and their power spectra. On your plot of the power-spectrum for $\delta^{18}\text{O}$ plot a boundary curve for which 95% of the random spectra did not pass. We will refer to this as a ‘noise floor’. What does it mean for a peak to be greater than this?
- (c) Which frequencies in the power spectrum are both consistent with orbital forcing and above the ‘noise floor’ for the random null model?
3. *Modern Climate Change:* In a previous problem set, we looked at modern climate time series and thought about what caused the oscillations and phase shifts between the climate records in Point Barrow, Mauna Loa, and the South Pole.



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For the analysis in this problem use the time-series for carbon dioxide at the Mauna Loa station. See problem set 3 for information on accessing the data.

- (a) Make a plot of the power spectrum for the entire record and label the peak. Where is the spectral peak and what is its physical interpretation?
- (b) Looking at the power spectrum more closely, what do you think the power spectrum of the noise is in this system?
- (c) Repeat the above pair of calculations using the first 5, 10, 15, 20, 25 and 30 years of the record. How does the height of the ‘noise floor’ and spectral peak scale with the length of the time series?
- (d) Show that this is consistent with the calculations done in class. Assuming Gaussian white noise, what is the probability that the dominant peak in the record appeared there by random chance?
- (e) Use the `fft` and `ifft` commands in MATLAB, along with some coding of your own, to remove the dominant periodic signal from the data. What part of the signal remains? How might these ideas be very useful for analyzing more complicated data sets? Verify that the imaginary part of the inverse fourier transform is within numerical noise. Include a plot of both the real and imaginary parts of the inverse transform in your answer.

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