Graphing Sunspot Numbers

Turn-in: Answers to all questions including the original question and all related graphs. The file at
http://serc.carleton.edu/files/introgeo/teachingwdata/examples/SunspotAssignmentWord.doc
Is a word document of this assignment that could be used to copy the original questions and then paste them into your answer sheet.

Learning objectives.
- Learn about the past sunspot record.
- Graph monthly mean Greenwich sunspot numbers from 1749 to 2004.
- Read the graph and answer questions related to the graphical data.
- Learn how to download and install the ***Spectra*** software program
- Perform a Fourier analysis on the monthly mean sunspot record using the Spectra Program.
- Learn about Fourier frequency analysis
- Use the relation between frequency and period of a component of the signal.

Introduction:
Go to the link **http://science.nasa.gov/ssl/pad/solar/sunspots.htm** **and answer the folowing questions.**

i. **When were the first European measurements of sunspots taken and by whom?**

ii. **What is the Maunder Minimum and when did it occur?**

iii. **Looking at the butterfly diagram**
In what region (between what solar latitudes) do sunspot generally occur?

As a sunspot cycle progresses do sunspot tend to move toward or away from the solar equator?

Part 1. Graphing sunspot numbers.

The file located at
http://serc.carleton.edu/files/introgeo/teachingwdata/examples/GreenwichSSNvstime.txt
contains monthly mean Greenwich sunspot numbers from January 1749 through July 2004.

Import the data contained within the file GreenwhichSunspotData.txt into Excel.
The easiest way to do this is to go to the link above, use select all from the edit menu and then copy from the edit menu, go to an empty Excel worksheet and use Edit paste command to paste into the upper left hand corner. All single column of data will appear with both time and sunspot number in that column. Use the Text to columns command from the data menu of Excel to separate these data into two columns. When using text to

columns the whole column must be selected. After pasting it should be but if for some reason it becomes deselected just click on the A at the top of column A to select that whole column before using the text to column command. Another way to go would be to save the above file to your hard drive and then open it into Excel.

Create an X-Y scatter graph of sunspot numbers on the y-axis and time (in years) on the x-axis. Make the graph look good, include units and labels for each axis, and a title for you graph. Print out the graph to turn in with the rest of you assignment,

1. Describe the pattern you see in the graph.

2. What is the smallest monthly mean sunspot number for the 255-year record?

3.   What is the largest monthly mean sunspot number for the 255-year record? When does this occur?

4.   Are we presently in a period of high or low solar activity (sunspot number)? The link http://science.nasa.gov/ssl/pad/solar/sunspots.htm has updated data to help you better answer this question.

5. Do you think that the total number of sunspots this year (all months added up) will be more or less than last year? (Explain your reasoning.)

6. Estimate the dominant period of the sunspot signal.   Explain and show your calculations below.

7.   During the next 15 years about when do you expect the solar activity to be high and when do you expect it to be low? Express each answer as a 2-year time interval like 1950 to 1951.   You may have more than one answer for each high and low activity. Explain you reasoning.

Part 2. Fourier Analysis to determine the frequency (period) of the dominant signal contained within the data.

Set-up:
The file located at
http://serc.carleton.edu/files/introgeo/teachingwdata/examples/GreenwichSSN.dat is a single column of monthly mean sunspot numbers from January 1749 through July 2004. Download this file and save it as to your hard drive in a directory that you will remember.

Download and install Spectra. This is fairly easy. Go to the URL
http://www.nuhertz.com/spectra/ and select **Download Spectra 1.8** **(2092 KBytes).** The file is about 2.0 Megs so if you have a slow modem you may want to talk to you instructor.
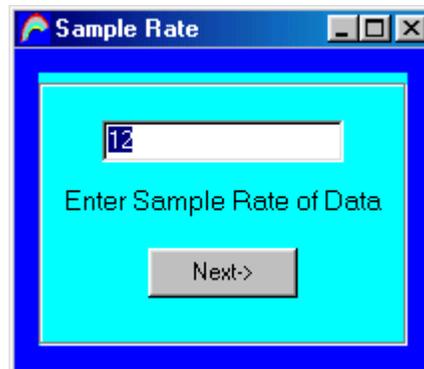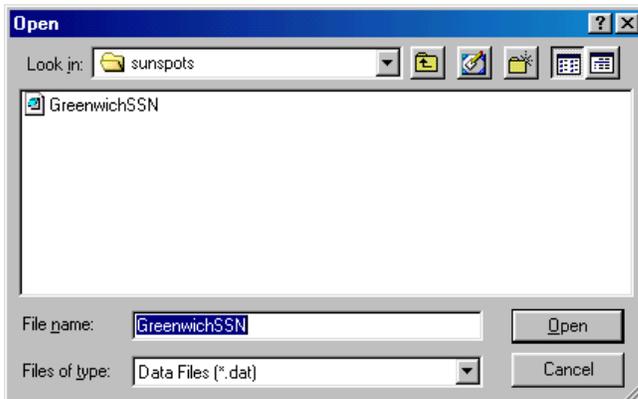
After installation:

Double click on the Spectra Icon `Spectra.lnk` to open it and the screen below appears. Click "Get Time Data" .


Find, select, and then open the file GreenwichSSN.dat. Set the sample rate to 12 per year and click Next.

The Spectra program is free and very simple. Hence it does not have many options. It automatically assumes that time units are in seconds and frequency in Hz (Cycles per second or 1/s). For our data, time is in years (12 samples per year) and frequency is in units of cycles per year (1/yr). Later, when looking at the frequency graph, the period of the sunspot signal (measured in years) is just $^1/_{\text{frequency}}$. Spectra does not have an option to label the axes correctly. Remember time axes have units of **years** and frequency axes **cycles per year**.

After a few seconds three windows will appear (data in text form, time plot, and frequency plot) as shown below.
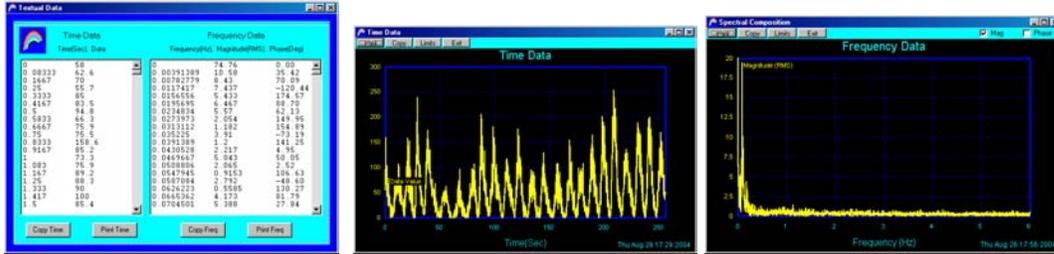
You can copy and paste either graph into a word document or other file for your report. In the text data window you can copy text data and paste it into an Excel spreadsheet. From the time data you can do this with the original data file so there is not much advantage. However, for the frequency data this is a big advantage since once in Excel you can easily alter your graph's appearance.

Uncheck the phase box on the frequency graph so that the magnitude is the only line showing. We will not discuss the phase in our analysis here. The frequency graph shows the magnitude (or amount) of each frequency that is contained within the data. The idea is that we assume that the signal is made up of a bunch of pure periodic signals of set frequency (and period).

$$\text{Period} = \frac{1}{\text{frequency}}$$

Questions: Use the frequency graph and frequency data table to answer these questions. Remember the units are (1/yr) not Hz as shown on the graph and in the table. *For example a frequency of 0.05 (1/yr) corresponds to a signal with a period =1/0.05=20 years.*

Print-out the frequency graph and turn it in with the rest of the assignment.

Describe the frequency graph/data and note the dominate frequencies and corresponding periods contained within the data. What is the frequency and period of the strongest signal (ignore zero frequency since its period is infinite)? Discuss the frequency and period of the other major signals. *Note: the large magnitude for zero frequency is due to the fact that the data has a gradual upward trend. Ignore this in your discussion. It's easiest to ignore this signal if you decrease the vertical limit (limit button on graph window) to 20. Decreasing the vertical limit even further can reveal smaller signals the may be important. Reading the frequency data table can also be helpful.*