Background

Most of the visible light that reaches the Earth comes from the Sun’s photosphere, a layer of the Sun that is about 400 km deep with an average temperature around 5800 K. Dark spots on the solar disk have been observed for centuries. However, they became the object of scientific inquiry with the advent of the telescope in the 17th century. Logically dubbed “sunspots,” they are relatively cool (4600 K) sections of the photosphere, thereby appearing dark in contrast to the rest of the photosphere which is more than 1000K hotter.

Sunspots are transient features on the solar disk -- they can last from just hours to several months – and can change in size and shape during their lifetimes. Sunspots owe their existence to the complex nature of the Sun’s magnetic field. The complexity of the field arises, in large part, due to the fact that the Sun exhibits differential rotation. That is to say that, unlike the Earth which has a solid surface all parts of which rotate at the same rate, the Sun does not rotate uniformly -- some parts move faster than others.

Purpose

It is your task in this activity to learn more about sunspots. You will study whether the number of sunspots is relatively constant or if it changes over time. You will also figure out how sunspots are distributed on the solar disk. Finally, you determine the rate of rotation of the sun and discover how this rate of rotation varies as a function of latitude (distance north or south of the Sun’s equator).

Procedure:

Part I – Plotting the sunspot cycle

There is a historical dataset of monthly sunspots that goes back to 1749. It can be accessed at this webpage -- http://solarscience.msfc.nasa.gov/greenwch/spot_num.txt

Before going any further, notice what the data represents. The first two columns show the year and month and the third column (SSN) indicates the number of observed sunspots for that month. (Note: The fourth column is unimportant for the purposes of this activity.)

ANSWER QUESTION 1 on lab quiz

Once you have a feel for the overall trend, we’ll examine the data more closely. You’ll need to select all the data (CTRL – A) including the headers to the columns (YEAR MON SSN DEV). Once selected, copy this data to your clipboard (CTRL – C). You’ll now need to open up the application “Notepad.” This is done by hitting the Start button (Microsoft symbol at the lower left-hand corner of your screen), and clicking “All Programs.”
From here you may see “Notepad.” If not, you’ll need to open the folder “Accessories” in which you will find the “Notepad” program.

With Notepad open, paste your data by clicking CTRL-V. Once pasted, save this document by going to File – Save as – and then name the file “spot_num” and save it to the desktop, making sure that it is saved as a .txt file. (Note: if there is already a file named spot_num, go ahead and save over it)

Now you’ll need to open the graphing program Excel. You’ll find it by again going to the Start button, choosing All Programs, and finding Excel (it may be immediately visible or you may have to open a Microsoft Office folder). Once Excel has started, go to the “File” menu and click “Open.” Navigate to your desktop and make sure you are looking for all files, not just Excel files.
You should now see your “spot_num.txt” file – select it and hit “Open.” Since Excel is not used to dealing with these .txt files, you need to tell it how to format your incoming data. Make sure you choose data type as “Fixed width” and click the “My data has headers” option.

Hit “Next” and you should see your data divided into four columns. Double click the first divider to eliminate the line between your year value and your month value (they need to be imported together).
Click “Next” and you’ll now be asked to specify the format of your columns. With the first column selected (it should appear black), you’ll want to specify that it is a date with format YMD (year, month, day). Obviously, there are no days, but this won’t matter when the data is imported into Excel.

Now choose your third column (again, make sure that it appears black) and tell Excel not to import that column. For this exercise, we are only interested in the sun spot numbers (SSN) and the corresponding dates.
You can finally hit “Finish” and your data should import into an Excel spreadsheet.

You should now see a spreadsheet with two columns. Select all your data (CTRL-A) and click the “Insert” tab at the top of your screen. We want to take our data and turn it into a chart. Since versions of Excel can vary, the following instructions may or may not work precisely with your version of Excel. The bottom line is that you want to wind up with a chart (preferably a bar chart or a line chart) that shows the number of sunspots on the y-axis and time on the x-axis. In my version of Excel, this can be accomplished by choosing either the “Recommended chart” button or the buttons for bar or line charts.
Part II – Distribution of sunspots during the sunspot cycle

Hopefully in Part I, you saw that the sun does go through cycles of activity and inactivity. From your solar cycle chart, you should notice that the last complete cycle (from solar minimum to solar minimum) was from May 1996 to Jan 2008. It turns out that, not only does the number of sunspots vary during the solar cycle, but the locations of sunspots vary during the course of the cycle as well.

In this part of the activity, we will explore the locations of sunspots using the iSolSearch tool (https://www.lmsal.com/isolsearch).

Once you open the iSolSearch interface, you’ll need to clear need to clear all the event by clicking the “Clear” button and then hitting “Search”.

For our purposes, the only event we need to search for is “Sunspot.” We’ll be plotting sunspots from May 1 through May 4 for each year during our most recent complete solar cycle (from 1996 to 2008).
The first step is to click “Sunspot” as your event type as well as May 1, 1996 as your start date.

You’ll also need to set the end date as 5/4/96 as well as set the number of “Max hits” to 200.
When you hit “Search” the interface will look for sunspot reports during the search window of 5/1/96 to 5/4/96. If you have done everything correctly, you should find that there were no reports of sunspots during this time period.

**ANSWER QUESTION 3 on lab quiz**

Now move on to 1997 and do the same thing (change your start and end date and hit search again). Again, if done correctly you should only wind up with one sunspot report.

**ANSWER QUESTION 4 on lab quiz**
Answer Question 5 on lab quiz

Now click on the sunspot itself. When you do, a bunch of information about the sunspot will show up in the right-hand side of your screen. The important piece of information we’ll be looking for is the location of the sunspot, particularly the distance from the solar equator. Rather than latitude and longitude, the iSolSearch interface uses the HPC (Helio-projective Cartesian) coordinate system. The specifics are unimportant – what is important to us is that values north of the equator are positive and values south of the solar equator are negative. We’ll be using the second value on the location line (in this case, \(-379.63\)) in order to pinpoint the location of our sunspots from the solar equator.

Continue on now with data from 1998. This time there should be many more sunspot reports. Note that this is not the number of sunspots on the sun during this three-day period, but the number of reports. Note also that, although there may have been more than 200 reports during this time period, our search engine maxes out at 200 reports. Again, click on the most northern sunspot (you may find this easier to pick out by using the “Carrington Map” view) to get its location. Likewise, click on the most southern sunspot and record its location from the solar equator.

We can now compile some of our information in a data table. Note that you’ll get the fifth column by taking the value of your fourth column and subtracting it from the value of your third column. (Math tip: for many of these calculations you will be subtracting a negative value – remember that \(5 - (-3)\) is the same as \(5 + 3\).

<table>
<thead>
<tr>
<th>Year</th>
<th># of sunspot reports</th>
<th>Location of north-most sunspot</th>
<th>Location of south-most sunspot</th>
<th>Difference = column 3 – column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Scientists who have tracked the location and number of sunspots over long periods of time have discovered an interesting pattern.

ANSWER QUESTION 6 on lab quiz

ANSWER QUESTION 7 on lab quiz

ANSWER QUESTION 8 on lab quiz

ANSWER QUESTION 9 on lab quiz
ANSWER QUESTION 10 on lab quiz

Part III – Tracking sunspots using the iSWA interface

Once you have access to the internet, you’ll need to go to the iSWA website (http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp). Once at the interface, you’ll want to select the “ASSA detected sunspot groups on SDO HMI Continuum” data.

A new window will pop up showing the Sun and its current sunspot groups (Note: If there are no active sunspot groups, see your instructor in order to find a date and time of greater sunspot activity.) You’ll notice that in addition to the sunspots themselves, there are boxes and identifiers on your image. These are classifiers for sunspot groups, but are unimportant for our current activity.
You’ll also notice that there are gridlines on the image. These are lines of solar latitude and longitude and will be useful in tracking the motion of sunspots. While not numbered, the solar equator (0° latitude) should be pretty easy to pick out (it is the line that marks the “fattest” part of the solar disk). The lines of latitude then increase in 10 degree increments until reaching the poles (90° latitude). Likewise, the lines of longitude are spaced in 10 degree increments as well.

In order to create a movie, we will need to click on the movie icon in the lower right-hand corner of the interface.
This should produce a loop of images showing the motion of your sunspots across the solar disk. However, being only 10 frames long, this is too short a time frame to get a good feel for the speed of the sunspots. In order to increase the number of frames that are in the movie, select the dropdown next to the timestamp in the lower left-hand corner of the interface.
Increase the number of frames from 10 to 120 (each frame is an hour so we will now be making a movie of sunspot motion over 120 hours or 5 days).
Hit apply and the movie should render. (Note: Once the movie has rendered, you should slide the time controller from left to right. Watch the timestamp to ensure that you do indeed have a movie that lasts 5 days.)

Part IV – Measuring sunspot motion

Drag your slider to the left to get to the beginning of your movie. Choose a well-defined sunspot that is located relatively close to the sun’s equator. Slide all the way to the right to make sure that your sunspot remains visible on the disk during the entire time. If not, choose another sunspot to work with. The best sunspots to work with are ones that start to the left of center and finish to the right of center, but don’t get too close to either the left or right edge of the sun. You should note that your sunspots generally move parallel to lines of latitude so the latitude value for your spot is constant.

In order to determine the speed of your sunspot, make a note of the longitudinal starting point. You don’t need an actual value for your starting point, but you will need to keep track of how many lines of longitude your spot crosses during its 5 day journey.
(Starting and stopping points for a near-equator sunspot over the course of 5 days. This particular spot appears to move across 6.5 lines of longitude. Note that this is just an example – you will choose your own sunspot with its unique stopping and starting points.)

Remember that there are 10 degrees of longitude between neighboring lines of longitude. Therefore, to determine how far your spot has traveled, multiply your number of crossed lines by 10 to determine the number of degrees of motion.

**ANSWER QUESTION 11 on lab quiz**

**ANSWER QUESTION 12 on lab quiz**

**ANSWER QUESTION 13 on lab quiz**

**ANSWER QUESTION 14 on lab quiz**