In the 1800's it was popular to speculate that solar activity and sunspots were responsible for spells of unusually hot or cold weather. Trees are a good indicator of long-term climate change because they grow well when local conditions are favorable, and grow poorly when they are not. In 2005, a large tree in Kensington, Maryland was uprooted during a rain storm. In this activity, you will use tree ring data to test the hypothesis that sunspots affect climate, and hence the growth of trees.

Ring radius in millimeters

0	119	296
10	124	301
13	128	306
15	132	312
17	136	320
19	139	325
22	143	332
24	147	337
27	152	342
30	157	350
33	162	356
35	165	362
38	170	368
40	174	373
42	178	377
44	182	383
46	186	390
48	192	414
51	197	420
53	203	423
55	208	427
57	212	429
59	216	432
62	220	436
64	224	440
69	230	443
71	236	446
74	240	449
78	246	452
79	250	455
81	255	457
84	259	459
88	262	462
93	267	465
97	271	468
102	278	470
106	282	473
109	286	490
112	289	501
115	293	

The photo at the left shows the stump of an oak tree. The table is a list of the locations of the rings in millimeters from the center of the stump. Trees generate one ring each year as they grow. The thickness of the ring is usually an indicator of the vigorousness of the growing season during a specific year.

Question 1) How many years old was the tree at the time of death?

Question 2) About what year was the tree planted?

Question 3) What was the diameter of the tree in 2003?

Question 4) Would you have been able to encircle the tree with your arms so that your fingertips just touched on the far side of the trunk?

Visit http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html and look up the annual sunspot numbers for the tree growth years. Transfer these numbers to the entries in a column C in an Excel spreadsheet. Transfer the corresponding millimeter values in the table to the left to column D in the spreadsheet. In column B of the spreadsheet, begin the first entry with first row of the sunspot and tree ring data, and fill the subsequent rows with the year of the tree ring. The last row should be for the year 2005, and give the tree ring radius (column D) and sunspot number (column C).

Question 5) If the vigorousness of growth is indicated by the width of a tree ring, how can you extract from your spreadsheet the width of each tree ring for each year? As part of your answer, perform this calculation in Column E of the spreadsheet for each year.

Question 6) How would you set up a test to check the hypothesis that the growth of this tree has been influenced by the sunspot cycle? State the hypothesis you need to test, and describe the procedure you would use with the spreadsheet data to test the hypothesis. Then, create a plot that tests the hypothesis.

Question 7) How do you decide whether the data are correlated, not correlated, or anti-correlated? Describe the implication of each of these conditions on how you will test the hypothesis.

Question 8) What can you conclude from the sunspot and tree ring data about climate and solar activity for this one tree?

Question 9) What are some of the uncertainties and problems you experienced in setting up your test of this hypothesis using a single tree? How might you make your test more reliable and definitive?

Question 1) How many years old was the tree at the time of death?
Answer: There are 119 measurements so the tree was 118 years old.

Question 2) About what year was the tree planted? **Answer:** The 'Zeroth Year' was 1887.

Question 3) What was the diameter of the tree in 2003? **Answer:** The radius was 501 millimeters, so the diameter was slightly over 1 meter (3 feet).

Question 4) **Answer:** The circumference is about 3.14 x 1 meter or 3.14 meters (about 10 feet). It is unlikely that you could perform this feat!

Question 5) **Answer:** Subtract the current ring radius from the previous radius to get the ring thickness. Do this for all the rings in the list.

Question 6) **Answer:** You need to test the hypothesis "The thickness of the growth rings increases and decreases in step with the sunspot number for each year". Compare the sunspot numbers with the ring thickness on a plot.

Question 7) **Answer:** Describe the implication of each of these conditions on how you will test the hypothesis. Plot the ring thickness on the Y-axis and the sunspot number on the X-axis. Correlated means that as the sunspot number increases, the ring thickness increases. Anti-correlated means that as the sunspot number increases the ring thickness decreases. No correlation means that as the sunspot number increases, the ring thickness changes up and down in a random manner. If they are not correlated, then you have to conclude from this data that solar activity has no affect on tree growth. If anti-correlated ,this means that as the activity increases, tree growth tends to slow down. If correlated, this means that as the sun is more active, it causes trees to grow faster.

Question 8) What can you conclude from the sunspot and tree ring data about climate and solar activity for this one tree? **Answer:** Based on the study of one tree out of billions on Earth, the current data are insufficient to examine a global climate or solar phenomenon. There is too much variation due to local growing conditions to identify long-term trends. A better study would include thousands of trees across an entire country, or living under similar local growing conditions. This helps to control variables that are irrelevant to solar storms.

Question 9) **Answer:** Here are some possibilities: 1) It is hard to measure some tree rings to an accuracy less than 0.5 millimeters. 2) How constant are the ring thicknesses from different places on the same tree? 3) We don't know from this one set of data whether the same tree grows at different rates in different directions. 4) We don't know if this tree really is typical of all trees on Earth, or if it is an unusual tree whose growth was influenced by soil nutrients, geographic location or other local factors. 5) We don't know if this particular tree species (Oak) is by its nature, less sensitive to solar changes. It would be better to have a much larger sample of trees from many different geographic localities, species, and growing conditions. This helps 'average out' many local factors which should be random in their effects. The solar changes, which are not random, would then stand out better in the averaging process.

A copy of the EXCEL spreadsheet, and the relevant plots derived from this data are available at http://image.gsfc.nasa.gov/weekly/tree.xls.