Teacher's Guide

Cosmic Rays And Sunspot Number

Introduction

Cosmic rays are very energetic particles, mostly protons and electrons, that enter the solar system from the depths of interstellar space. Although the Earth's magnetic field partially shields us from these particles, so too does the much more extended solar wind with its own magnetic field. When the sun is most active, the solar magnetic field is more intense, and so it provides additional sheilding from cosmic rays near the Earth. When the sun is less active, the wind is weaker and the shielding is less effective.

Objective

The student will analyze and compare two or more graphs to determine if there is a correlation between Sunspot Number and the variation of Cosmic Ray Flux.

Procedure

1. Divide the students into either pairs or groups of four. Read the introduction to the students.

2. Review with the students an example of how graphs may be similar and different. Be sure to include shape, distribution,highs, lows,scale, axis. and the time frame.

3. Provide students with a copy of the Student Activity # 1. Allow a sufficient amount of time for the students to complete the activities. Discuss their results and their conclusions.

4. Provide students with a copy of Student Activity #2 and provide them with appropriate time to complete the exercises.

Have the groups present their findings to the class. Some of the groups will argue that there is an almost perfect inverse relationship between the two graphs. Other groups may see the inverse pattern, but be unable to explain it in correct terminology. Finally, other students may take their explanations to a higher level by discussing the maxima and the minima and the actual fit of the data.

5. Provide students with a copy of Student Activity #3. Allow a sufficient amount of time to complete the activities. Discuss the results.

6. Provide students with the technology aspect using the TI - 83 graphing calculator and the magnification of the graphs.

Materials

Student Activity #1
Student Activity #2
Student Activity #3
Ruler
Transparencies (optional)
TI -83 Graphing Calculator (optional)

Have the groups present their findings to the class. Some of the groups will argue that there is an almost perfect inverse relationship between the two graphs. Other groups may see the inverse pattern, but be unable to explain it in correct terminology. Finally, other students may take their explanations to a higher level by discussing the maxima and the minima and the actual fit of the data.

Conclusions

Students will determine that the relationship between Sunspot Number and Cosmic Ray Flux is an inverse correlation. This may not be readily apparent to some students since the scales are so diverse. The activities introduce the students to the concept of magnifying a graph in order to better see the fit of the data. Students will also see that regardless of the location of the observatory, be it northern hemisphere or southern hemisphere, there is still an inverse correlation between the Sunspot Number and the Cosmic Ray Flux. Students will see that the data from the Huancayo, Peru observatory and the Climax, Colorado observatory are almost a perfect fit. Students can further investigate the relationship of Cosmic Ray Flux and Sunspot Number if they so choose. In order to do so, they may wish to check out more observatories and their data. For reference purposes:

Calgary, Canada	N51	W114	Altitude...1128
Climax, Colorado	N39	W106	Altitude...3400
Deep River, Canada	N46	W77	Altitude.....145
Moscow, Russia	N55	E37	Altitude.....200

Key Terminology:

Maxima: The locations on a curve where the y-axis values are largest.

Minima: The locations on a curve where the y-axis values are smallest.

Inverse Correlation: When one quantity increases, the other quantity decreases

Cosmic Ray Flux: The flow of particles through a region of space in a given amount of time.

Cosmic Rays: Particles, usually electrons or protons or even light atomic nuclei, which travel at high speed through interstellar space.

Flux: A term used to describe the flow of particles or radiation through space given in units of particles per second per square centimeter, or watts per square centimeter.

Name _____ Date_____

Student Activity # 1

The following table contains the data for the variation of Cosmic Ray Flux. From these averages, use the table to create an appropriate graph for Huancayo's observations of the measurement of Cosmic Ray Flux, and then answer the following questions. Please use a scale from 2 to -2 in increments of tenths.

Huancayo Observatory's Measurement Of Cosmic Ray Flux Over Time

Year	Cosmic Ray Flux	Year	Cosmic Ray Flux
1954	1.35	1976	1.10
1956	0.00	1978	.600
1958	-1.3	1980	-.20
1960	-1.2	1982	-.90
1962	.400	1984	-.40
1964	1.00	1986	1.25
1966	1.20	1988	.100
1968	.100	1990	-.70
1970	0.00	1992	-.10
1972	.600	1994	0.00
1974	.400		

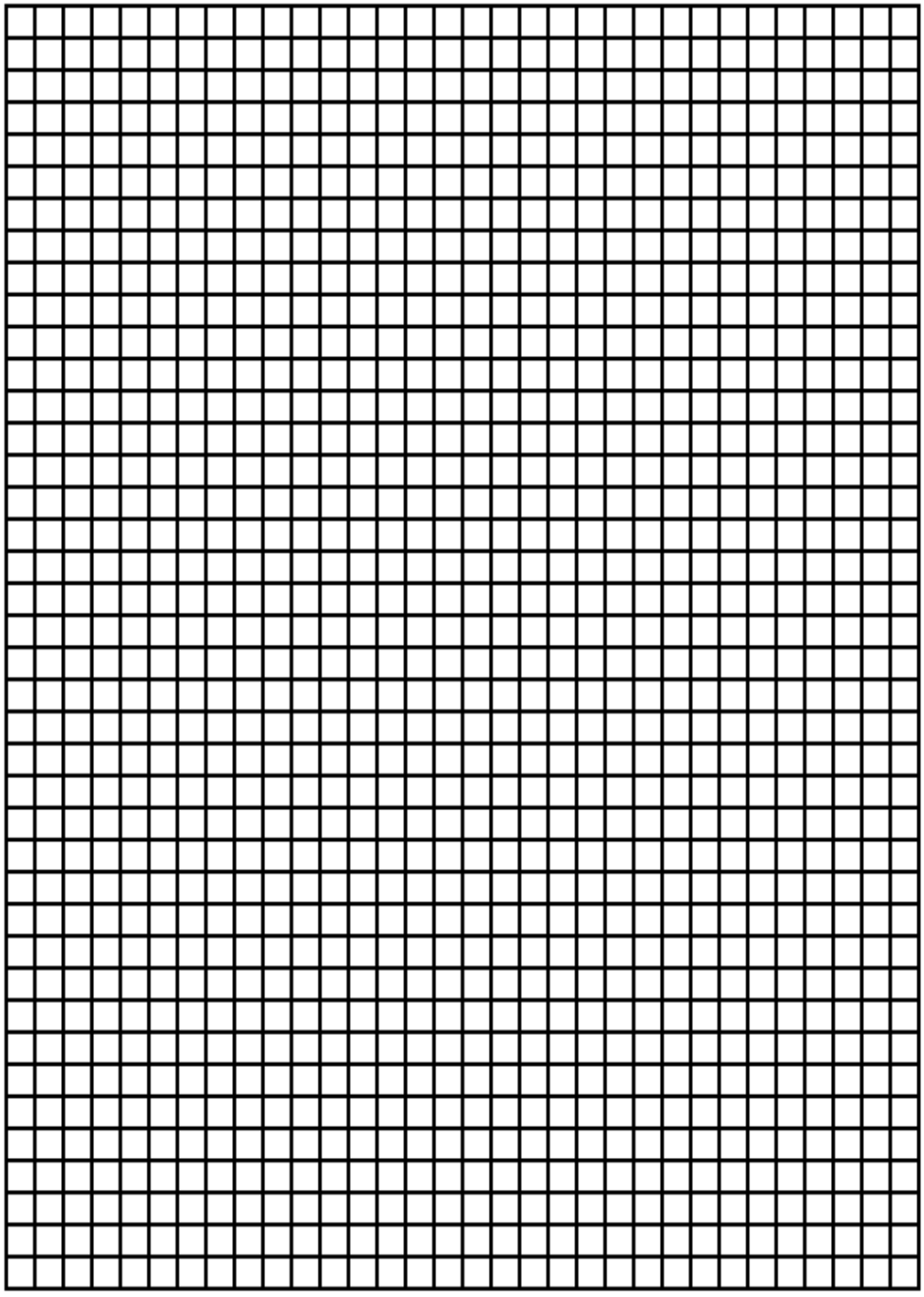
1. Describe any patterns that may be evident. Be sure to include the years that span maxima or minima.

2. Why do you think that a scale using tenths was selected

3. Would the shape and distribution of the graph change if we were to magnif the graph by a factor of ten

Name _____

Date_____



Name _____ Date_____

Student Activity #2

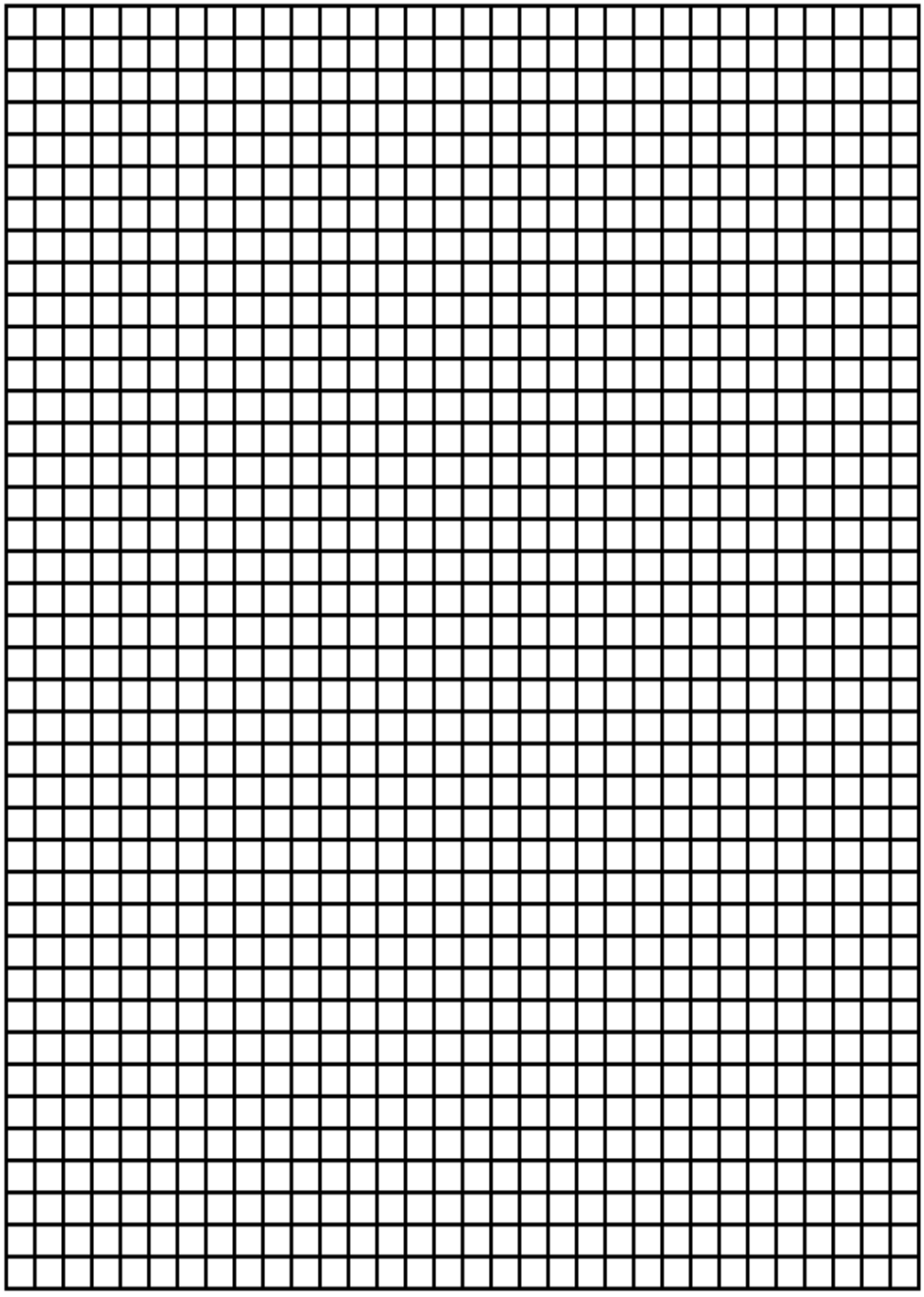
Construct the appropriate graph based on the following table and determine if there is a correlation with the graph of the variation of Cosmic Ray Flux from Huancayo. Communicate your analysis in the space beside the graph. Be sure to include supporting evidence.

Recorded Sunspot Number

YEAR	Sunspot Number	YEAR	Sunspot Number
1950	84	1973	38
1951	69	1974	34
1952	31	1975	16
1953	14	1976	13
1954	4	1977	27
1955	38	1978	92
1956	142	1979	155
1957	190	1980	154
1958	185	1981	140
1959	159	1982	116
1960	112	1983	67
1961	54	1984	46
1962	38	1985	18
1963	28	1986	14
1964	10	1987	32
1965	15	1988	98
1966	47	1989	154
1967	94	1990	146
1968	106	1991	144
1969	106	1992	94
1970	104	1993	56
1971	67	1994	30
1972	69		

Name _____

Date_____



Name _____ Date_____

Student Activity #3

The observatory in Huancayo, Peru is in the southern hemisphere.After completing the prior activities, it should seem evident that certain events in our universe affect one another. In order to investigate this connection further, more data will need to be analyzed.

Suppose we were to make a hypothesis that is based on the results from Huancayo. It is assumed that an observatory in the north may also experience some sort of a correlation. Based on the previous data analysis, state a hypothesis about an observatory in the northern hemisphere that would be observing the same events.

It just so happens that there is an observatory located in Climax, Colorado. Please construct the appropriate graph to display the given data. Please use a scale from 2 to -2 with increments of tenths.

Climax Observatory's Measurement Of Cosmic Ray Flux Over Time

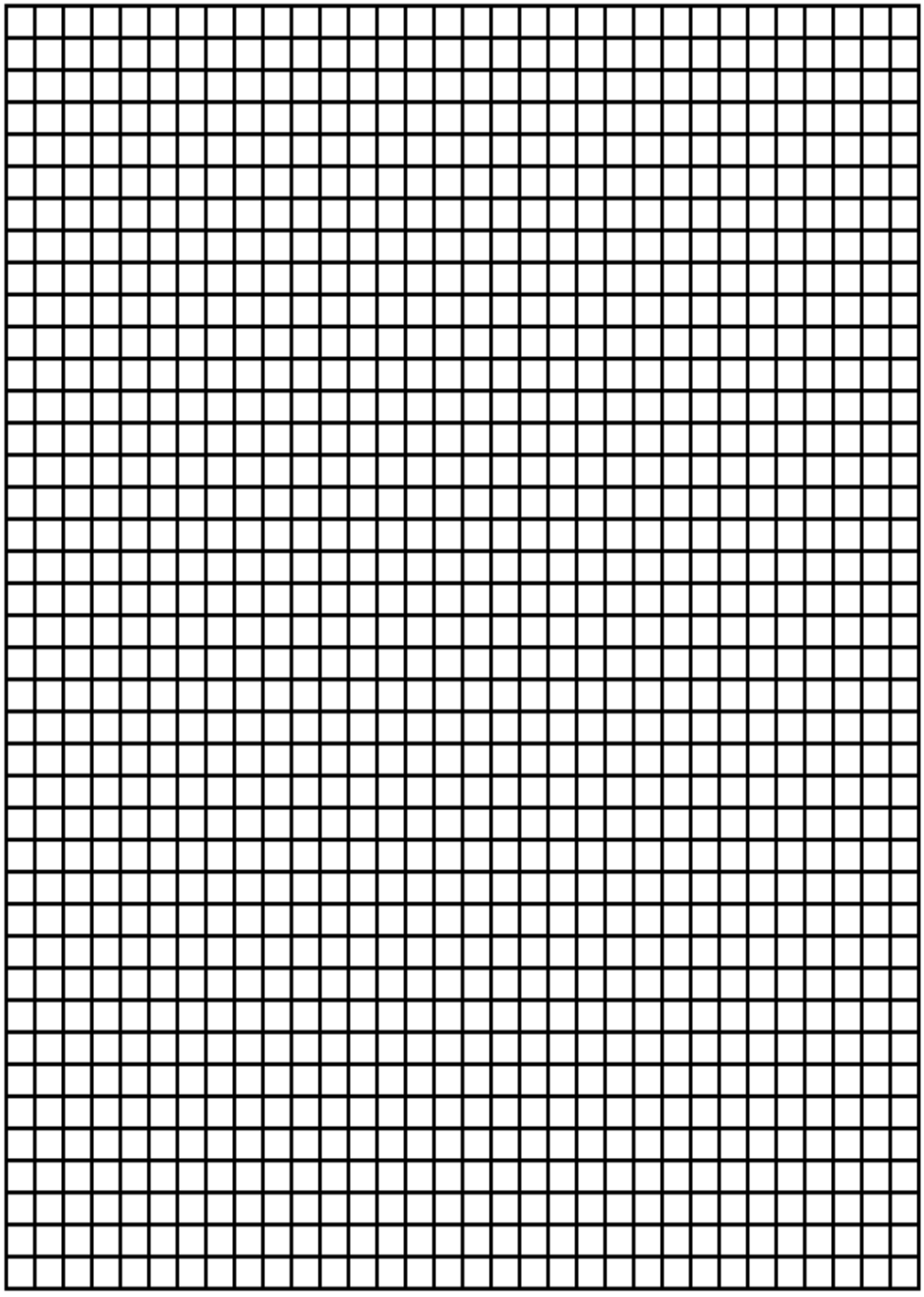
Year	Cosmic Ray Flux	YEAR	Cosmic Ray Flux
1954	1.30	1976	1.20
1956	0.70	1978	.800
1958	-1.7	1980	-.50
1960	-1.1	1982	-1.2
1962	.100	1984	-.40
1964	0.90	1986	1.20
1966	0.80	1988	.100
1968	-.40	1990	-1.8
1970	-.40	1992	-.70
1972	.900	1994	0.60
1974	.900		

Using the graphs for Huancayo and Climax, what conclusion can be drawn about the effects of the northern and southern hemisphere in regards to the variation of Cosmic Ray Flux. In addition, how does this conclusion relate with the Sunspot Number?

Suppose data from the observatories in Deep River and Calgary, Canada, as well as Moscow, Russia were given. What would be the expected correlation to both the variation of Cosmic Ray Flux as well as the Sunspot Number? Justify your reasoning.

Name _____

Date_____



Teacher Notes For The Graphing Calculator

Reminder: Be sure to reset the calculator using "Teacher Notes for the Graphing Calculator" included in the previous sunspot lesson. The commands for the graphing calculator are given in bold print beside the windows.

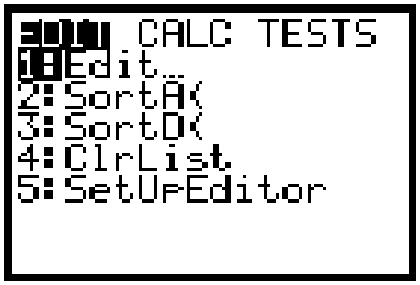
Students will enter the following estimated table of values taken from the measurement of Cosmic Ra Flux for Huancayo. The year will be entered into list 4, the Cosmic Ray Flux intensity will be entered in list 5, and the Sunspot Number for the corresponding years will be entered in list 6.

Directions For Activity #1 and Activity #2

Cosmic Ray Flux For Huancayo Versus The Sunspot Number

Year	Cosmic Ray Flux	Sunspot Number	YEAR	Cosmic Ray Flux	Sunspot Number
1954	1.35	4	1976	1.1	13
1956	0	142	1978	.6	92
1958	-1.3	185	1980	-.2	154
1960	-1.2	112	1982	-.9	116
1962	.4	38	1984	-.4	46
1964	1.0	10	1986	1.25	14
1966	1.2	47	1988	.1	98
1968	.1	106	1990	-.7	146
1970	0	104	1992	-.1	94
1972	.6	69	1994	0	30
1974	.4	34			

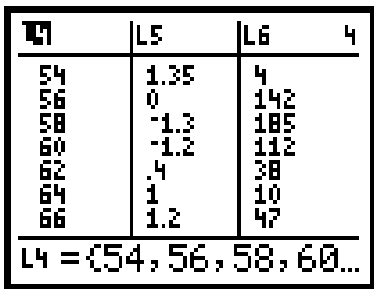
Entering the data into the list will consist of the following keystrokes:

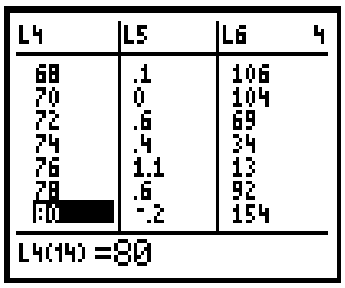


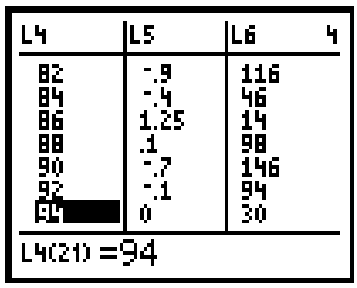
STAT **ENTER**

When entering data, enter the value and then **ENTER**, until the list is complete. Then arrow to the right, and enter the value for that list.

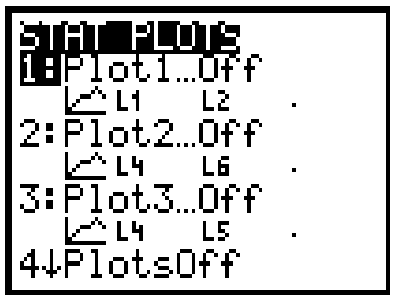
This will put you at the window to input the data for the year into your selected lists. **Note**: I selected to use lists 4, 5, and 6. When entering data, type the value and then push **ENTER**, until the list 4 is complete. Next arrow to the right, and enter the values for list 5 by typing the data value and pushing **ENTER**. Finally, arrow to the right, and enter the values for list 6 by typing the data value and pushing **ENTER**. Sample screen images shown below.





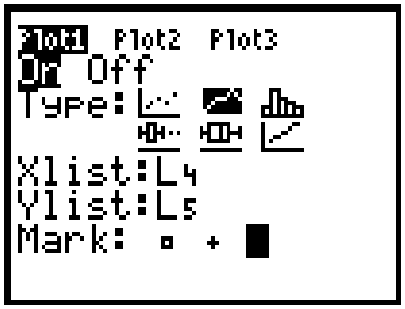


After the data has been entered into the lists, the stat plot needs to be turned on. To turn the plots on, use the following keystrokes:



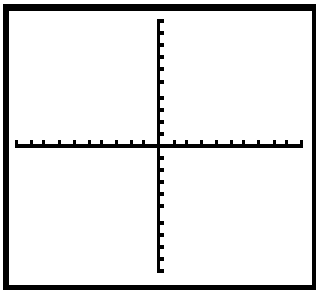
2ND Y = ENTER

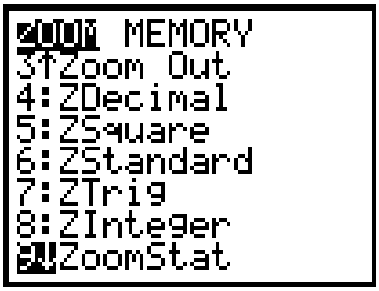
The next step is to turn on the appropriate graph and to use the correct data lists.
Since the data is in List 4, List 5, and List 6, those are the ones we shall select. To turn the plot on, make sure that the cursor is blinking over the **ON** and push **ENTER**. Next arrow down and over to select the second graph. Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 4,** arrow down to the Y list and push **2ND 5.** These steps have allowed for the data in lists four and five to be graphed. The appropriate windows would appear as follows:



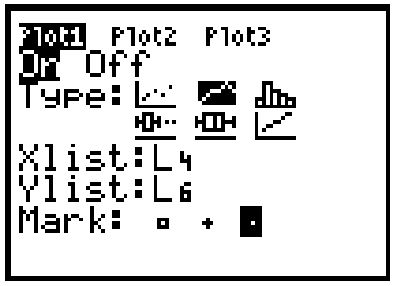
GRAPH

The next step is to graph the data. When the students push the graph key, they may or may not see a part of the graph. If the calculator was reset prior to beginning the lesson, the students would see the following blank display. It is necessary to adjust the viewing window using **ZOOM 9**. The window that the student should see is shown below.





To turn the second plot on, push **2ND Y =**. Next arrow down and select the second plot, **ENTER**. Make sure that the cursor is blinking over the **ON** and push **ENTER.** Next arrow down and over to select the second graph Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 4**, arrow down to the Y list and push **2ND 6**. These steps have allowed for the data in lists four and six to be graphed. Students may wish to see the graph at this point.

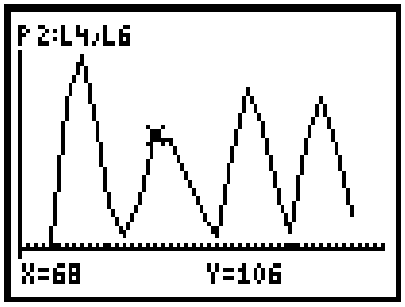


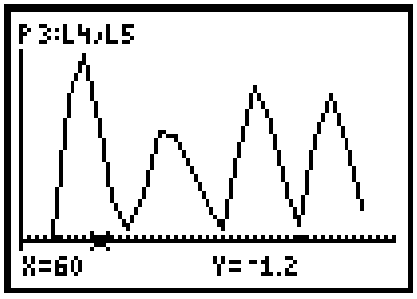
GRAPH

NOTE: The first time that the students did a zoom 9, they saw the data in list 4 and list 5, which is the Cosmic Ray Flux (ONE GRAPH!). When they push the graph button again they will see one graph, the Sunspot Number data in list 4 and list 6. It will not be until they use the **ZOOM 9** to fit the data that they will view both graphs. Even then, most students will believe that there is only one graph because the values in list 5 are so minimal. At this point, to help the students to understand that there are two graphs, it is necessary to move along the graphs and to look at the values displayed. In order to move along the values and to compare the two graphs, push **TRACE**.

The up and down arrow keys allow movement between the two graphs, and the right and left arrow key allow movement along a graph.

This is a good time to discuss the appropriate graph for this data and why it should be a line graph. Students are aware that a line graph is appropriate for time. However, be sure to include the fact that the data is continuous and needs to be displayed as such.



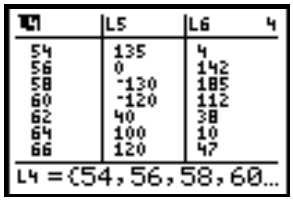


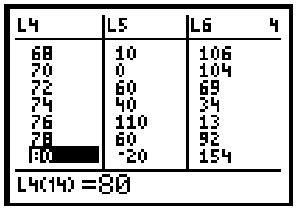
Students will have a very difficult time visualizing these two graphs, especially since the one for cosmic ray flux (L5) appears to not be there. If you look at the windows given above and note that the second window does display the values in the table, the students can start to understand that there really is a second graph. Explain to them that there are really two graphs displayed. This leads to a discussion about the scales and values needed to compare these two sets of data.

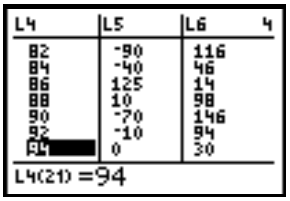
In the study of science, scientists need to sometimes magnify a certain set of data in order to visualize the correlation. In doing this exercise,and depending on your time available for exploration, a magnification of ten may be selected and applied to the values for Huancayo in list 5. The graph is still not readily apparent. This will lead the students to think that maybe they need to increase the magnification. Be aware that the magnification of 100 seems to be a nice visual representation. Have the students multiply the data for the Cosmic Ray Flux by 100, and then enter the data into list 5 . Follow the same procedures for entering and displaying the data.

Directions For Magnification

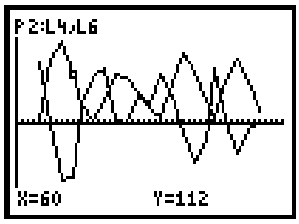
Have the students begin with a magnification of ten, and then view the data. After discussing that further magnification is necessary, magnify the data to 100 times the original. Display the results and discuss the conclusions.The windows for magnification of 100 times are:







The graph display then appears as the following:



TRACE

This allows the students to use the trace function, and to determine that there is an inverse relationship. That is, when the Sunspot Number is high, the Cosmic Ray Flux is low.

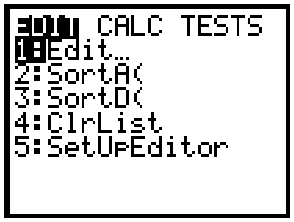
The same procedures can be followed for each of the remaining four stations. The results should be the same.

A variation may be to have the students decrease the scale on the Sunspot Number by a certain value.

Directions For Activity # 3

The data table for Huancayo and Climax will be needed. The year will be entered into list 1, Huancayo data in list 2, and Climax data in list 3.

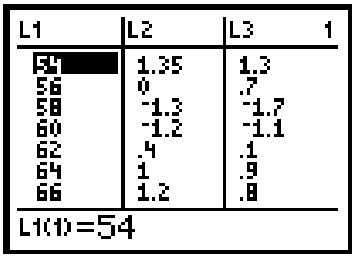
Entering the data into the list will consist of the following keystrokes:

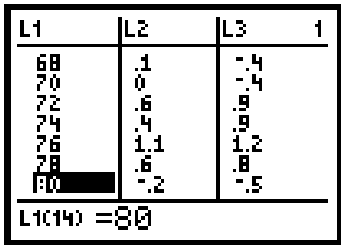


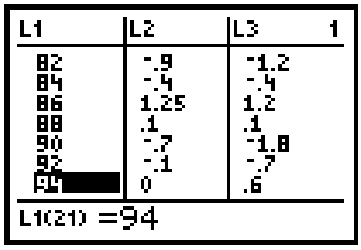
STAT ENTER

This will put you at the window to input the data for the year into your selected lists. When entering data, enter the value and then **ENTER,** until the list is complete. then arrow to the right, and enter the values for that list.

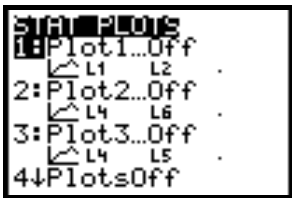
Sample screen images shown below.







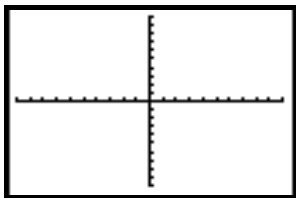
After the data has been entered into the lists, the stat plot needs to be turned on. To turn the plots on, use the following keystrokes:

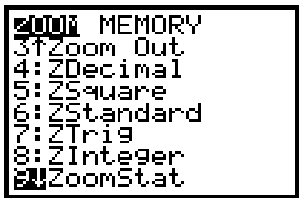


2ND Y = ENTER

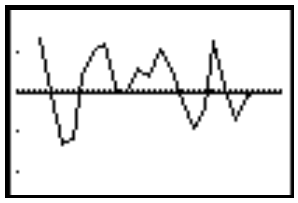
The next step is to turn on the appropriate graph and to use the correct data lists.
Since the data is in List 1, List 2, and List 3, those are the ones we shall select. To turn the plot on, make sure that the cursor is blinking over the **ON** and push **ENTER**. Next arrow down and over to select the second graph. Once the cursor is flashing over it , push ENTER. Arrow down to the X list and push **2ND 1,** arrow down to the Y list and push **2ND 2.** These steps have allowed for the data in lists one and two to be graphed. Students may wish to see the graph at this point. The window is displayed below.

The next step is to graph the data. When the students push the graph key, they may or may not see a part of the graph. If the calculator was reset prior to beginning the lesson, the students would see the following blank display. It is necessary to adjust the viewing window using **ZOOM 9**. The window that the student should see is shown below.

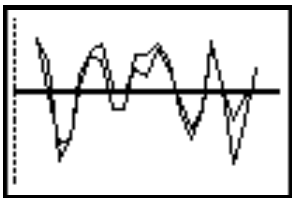




The students will be viewing the data for Huancayo only. The graph for Huancayo is as follows:



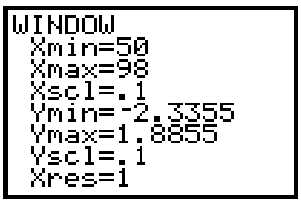
It is important that they realize that the second plot needs to be turned on to view Climax data.To turn the second plot on, push **2ND Y =.** Next arrow down and select the second plot, **ENTER**. Make sure that the cursor is blinking over the **ON** and push **ENTER.** Next arrow down and over to select the second graph Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 1**, arrow down to the Y list and push **2ND 3**. These steps have allowed for the data in lists one and three to be graphed. Students may wish to see the graph at this point. The graph is displayed below.



TRACE

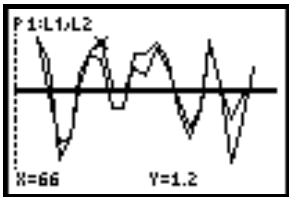
It is necessary to move along the graphs and to look at the values displayed.In order to move along the values and to compare the two graphs, push **TRACE**.The up and down arrow keys allow movement between the two graphs, and the right and left arrow keys allow movement along a graph.

Discuss with students the scale involved on the graphs. The calculator has used a scale, possibly of one. In order to more fully appreciate the graphs, the students will need to adjust their scale to tenths. Push the **WINDOW** key. Change the Xscl to .1 and the Yscl to.1. Return to the graph. A sample window is shown below.



GRAPH

Students can **TRACE** the graphs and see that they are almost exactly alike. The differences occur at the maxima and the minima, which are the inverse of the Sunspot Number's maxima and minima. The graph is displayed below.



This may be a good time to ask the students what they think will happen if the magnification is changed to .001, and then explore the effects on the graph by changing the window values. They should determine that it is the same graph with a different scale.

EXTENSION:

Have the students find or develop two sets of data that show a nice fit and correlation, a set of data that has an inverse correlation, and a set of data that appears to have no correlation. Next, have the students interpret that data and justify their results. Ask the students how they feel about manipulating data in this way to 'bring out detail'. Some students may not like to tamper with the data to be able to draw conclusions.

NOTE: This is a really nice activity and opportunity for students to explore and use real data on the internet.