Teaching Activity: Sunspots and Climate Change

Part I: Locating Sunspots: Our Sun is not a perfect, constant source of heat and light. As recently as the 17th century, Galileo got into trouble with the Church authorities for, among other things, pointing out that the surface of the Sun is sometimes marked by blemishes, known as sunspots. Observations since Galileo's time have revealed sunspots to be relatively cooler regions of gas on the surface of the Sun connected with disturbances in the solar magnetic field and if seen from the side, appear as deep depressions in the photosphere. The central, very dark portion of a sunspot is called the *umbra*, while the surrounding, less dark edge is referred to as the *penumbra*. This is surrounded by a very hot region called a *plage*. Sunspots usually come in pairs; the first one that moves across the disk of the Sun has the opposite electromagnetic charge (+/-) from the one that follows it, and generally drift from the high latitudes of the Sun toward the equator. Scientists believe that this is caused by the transport of heat within the photosphere, as well as the rotation of the Sun.

In the early years of a sunspot cycle, the sunspots tend to be smaller and to form at higher latitudes, both north and south of the Sun' s equator. As the cycle proceeds toward a maximum, spots are likely to form at latitudes of 10 to 15 degrees. As the cycle starts toward minimum, the spots get smaller and appear closer to the equator. There is an overlap at the end of one cycle and the beginning of the next as new sunspots form in the higher latitudes while spots from the present cycle are still present near the equator. This general drifting of sunspots from high latitudes toward the equator was discovered by Edward Maunder in 1904, when he plotted the latitudes of sunspots over many cycles. When sunspots are plotted according to their latitude and longitude, day after day, over a period of years, a specific "butterfly pattern" develops with a cycle of approximately 11 years.

Objective:

- To plot the location of sunspots by latitude/longitude on a grid of the Sun;
- To recognize the pattern in sunspot location that occurs as a result of heat transfer and the rotation of the Sun;

Materials: Paper/pencil, **Student Activity Sheet/ Sunspot Location Grid Sheet**, colored pencils;

Procedure:

1. Read and discuss the **Introduction** carefully with the class.
    - Review latitude and longitude.
    - Be sure students understand the concept of a "cycle".

2. Instruct students to refer to the spread sheet of sunspot locations.
    - They should locate each of the sunspots on the grid of the Sun's surface and place as dot where they belong.
    - When all of the sunspots have been located on the grid, students should connect the dot with a colored pencil and then color in the area inside the grid points.

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3. When students have completed working with the grid locations, they should complete the questions in the **Analysis and Comprehension** section.

Part II: Sunspot Cycles and Climate: In 1893, E. Walter Maunder, the superintendent of the Royal Greenwich Observatory solar division, while looking through some old records, discovered that the Sun had changed radically in recent times and that for a period of about 70 years, 1645-1715, sunspot activity had all but ceased. The total number of sunspots for this period was less than what is seen in an average year today and came to be known as the *Maunder Minimum.* Coincidentally, during this same time period, Europe experienced unusually cold weather for a prolonged period of time.

Maunder used the data from his sunspot research to develop a theory that there was a connection between the Earth and the Sun. He reasoned that if a normal eleven year cycle could be detected in changes in the magnetic field of the Earth or in the Earth's weather, then a prolonged change in the Sun's behavior should be reflected by major effects on Earth. In addition to representing a broad change in solar magnetic activity over an 11 year period, sunspot activity also evidence of variations in the number of particles shot out from the Sun across space (cosmic rays), as well as very small changes in the amount of heat radiated by the Sun. The "coincidence" that the Sun's cycle of activity seemed to have switched off exactly during the coldest decades of Earth's history, attracted attention from several other researchers before the 80 and 180-year climate rhythms were revealed by the Greenland and Antarctic ice cores in the 1970's. Since then, major studies of similar variations in Earth's climate have been carried out going back into the Bronze Age. Since no ancient astronomers were around to record observations of sunspot numbers over thousands of years, researchers have to depend on *proxy records* from other sources (Carbon-14 data in tree rings) to support their theories about a connection between sunspot activity and changes in Earth's climate.

Objectives:

- To compute the average number of sunspots recorded for each 12 month period at intervals of 5 years from 1750 to 1990;
- To create a line graph using data to illustrate that sunspots occur in cycles;
- To evaluate and draw conclusions about the behavior of sunspots based on the background information and the data provided;

Materials: **Student Activity Sheets**, calculator, colored pencils, ruler, paper/pencil;

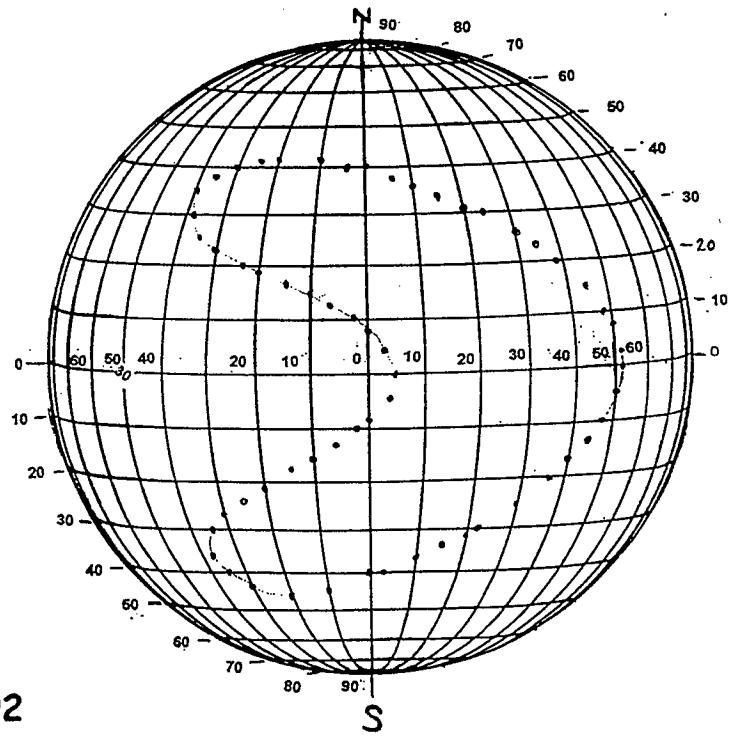
Procedure:

1. Carefully look over the spread sheet of **Monthly Mean Sunspot Numbers** with the class.
   - Point out that the data is presented for five year intervals over a period o 250 years.
   - Discuss any oddities that appear on the spread sheet.

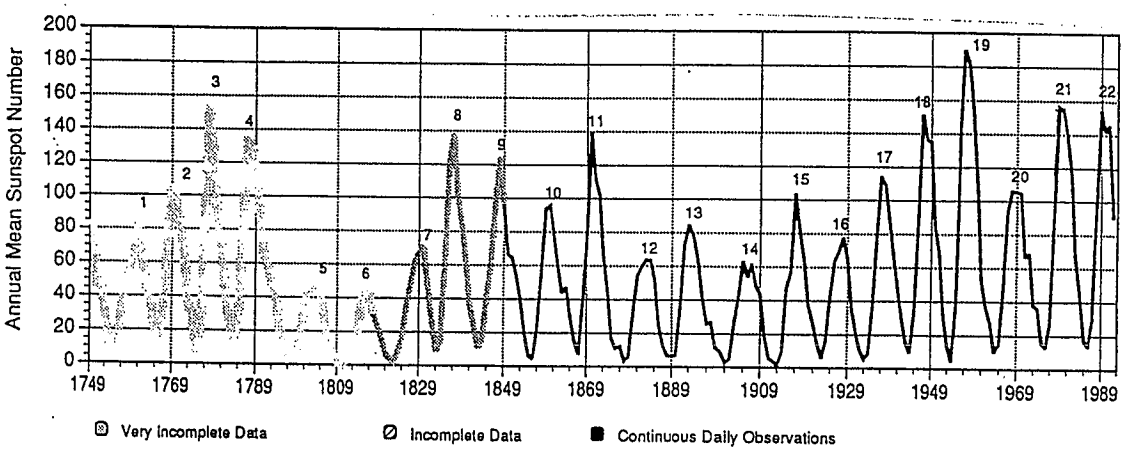
2. Tell students that they will be computing the average number of sunspots for each year on the spread sheet.
   - Go over how to compute an average.
   - As the complete the calculations, students should enter their data in the spaces provided on the spread sheet.

3. When students have completed all the calculations, they should graph their averages using a line graph format.
   - Students should label the X-axis : **Year** and the Y-axis: **Average Annual Sunspot Number**.
   - Students should place a dot in the correct location on the grid for each year reported and use a colored pencil to connect the dots.
   - When they have finished the graph, students should go ahead and answer the **Analysis/Conclusion** questions

Part I: Sunspot Location Grid



Part II: Sunspot Cycles 1749-1992



Student Activity Sheet: Sunspots and Climate Change

Part I: Locating Sunspots: Our Sun is not a perfect, constant source of heat and light. As recently as the 17th century, Galileo got into trouble with the Church authorities for, among other things, pointing out that the surface of the Sun is sometimes marked by blemishes, known as sunspots. Observations since Galileo's time have revealed sunspots to be relatively cooler regions of gas on the surface of the Sun connected with disturbances in the solar magnetic field and if seen from the side, appear as deep depressions in the photosphere. The central, very dark portion of a sunspot is called the *umbra*, while the surrounding, less dark edge is referred to as the *penumbra*. This is surrounded by a very hot region called a *plage*. Sunspots usually come in pairs; the first one that moves across the disk of the Sun has the opposite electromagnetic charge (+/-) from the one that follows it, and generally drift from the high latitudes of the Sun toward the equator. Scientists believe that this is caused by the transport of heat within the photosphere, as well as the rotation of the Sun.

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Objective:

- To plot the location of sunspots by latitude/longitude on a grid of the Sun;
- To recognize the pattern in sunspot location that occurs as a result of heat transfer and the rotation of the Sun;

Procedure:

1. Read and discuss the **Introduction** carefully with your teacher.
   - Be sure that you understand what latitude and longitude are and what a "cycle" is.

2. Refer to the spread sheet of sunspot locations.
   - Locate each of the sunspots on the grid of the Sun's surface and place as dot where they belong.
   - When all of the sunspots have been located on the grid, connect the dot with a colored pencil and then color in the area inside the grid points.

3. Complete the questions for **Part I** in the **Analysis and Comprehension** section.

Part II: Sunspot Cycles and Climate: In 1893, E. Walter Maunder, the superintendent of the Royal Greenwich Observatory solar division, while looking through some old records, discovered that the Sun had changed radically in recent times and that for a period of about 70 years, 1645-1715, sunspot activity had all but ceased. The total number of sunspots for this period was less than what is seen in an average year today and came to be known as the *Maunder Minimum.* Coincidentally, during this same time period, Europe experienced unusually cold weather for a prolonged period of time.

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- To create a line graph using data to illustrate that sunspots occur in cycles;
- To evaluate and draw conclusions about the behavior of sunspots based on the background information and the data provided;

Procedure:

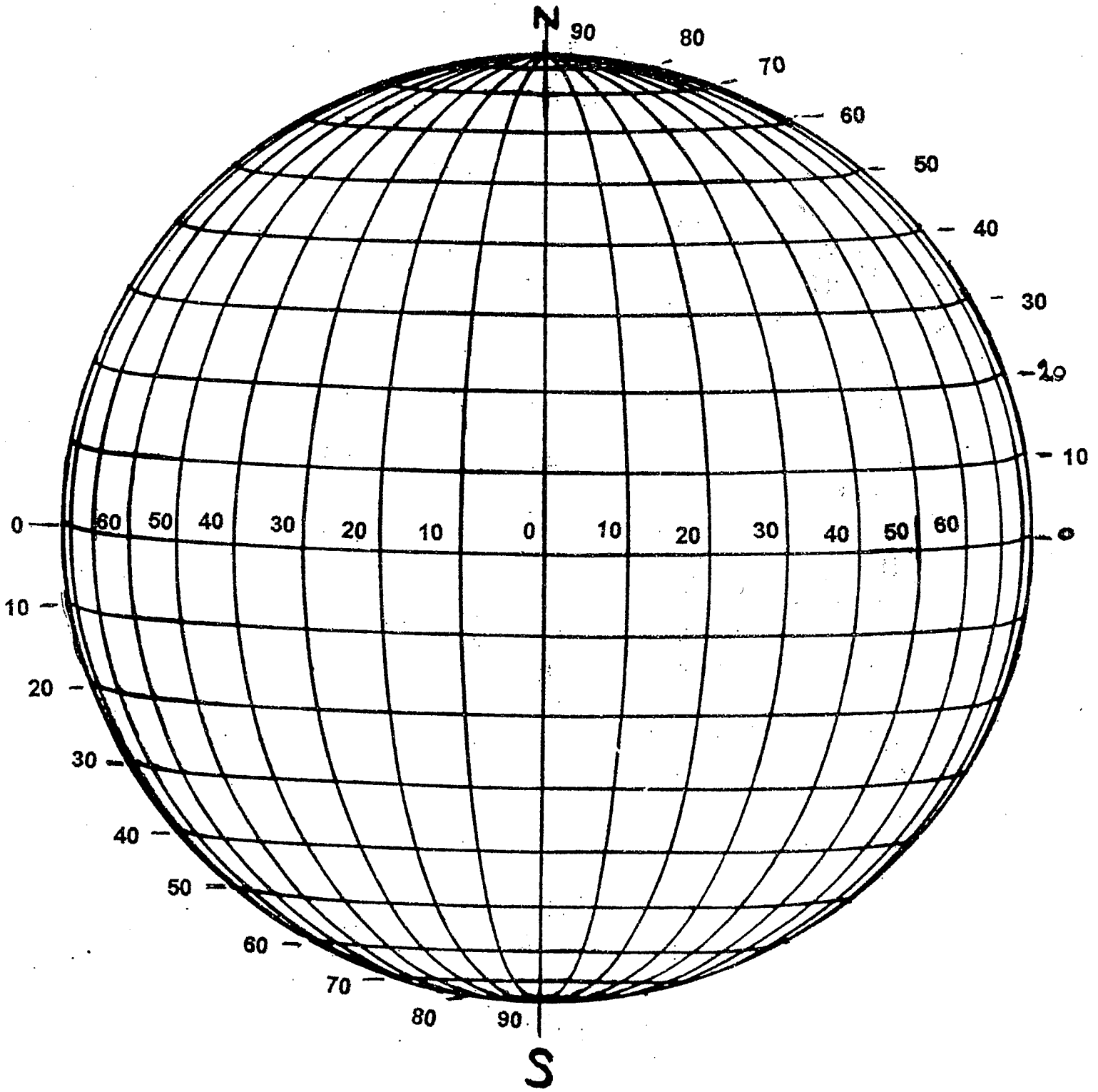
1. Carefully look over the spread sheet of **Monthly Mean Sunspot Numbers** with your teacher.
   - The data is presented for five year intervals over a period of about 250 years.
2. Compute the average number of sunspots for each year on the spread sheet.
   - Go over how to compute an average with your teacher.
   - As you complete the calculations enter your data in the spaces provided on the spread sheet.
3. When you have completed all the calculations, graph the averages on a line graph.
   - Label the X-axis : **Year** and the Y-axis: **Average Annual Sunspot Number.**
   - Place a dot in the correct location on the grid for each year reported and use a colored pencil to connect the dots.
   - Answer the **Part II Analysis/Conclusion** questions.

Sunspot Location Grid Data Sheet

#	Latitude	Longitude	#	Latitude	Longitude
1	0	E5	31	S40	W35
2	N8	0	32	S30	W35
3	N10	W3	33	S27	W30
4	N15	W10	34	S21	W20
5	N19	W20	35	S17	W10
6	N20	W23	36	S10	W2
7	N23	W30	37	S8	0
8	N30	W39	38	S5	E4
9	N35	W40	39	N5	E3
10	N40	W30	40	N12	W8
11	N41	W20	41	N18	W15
12	N41	W10	42	S32	E15
13	N40	0	43	S36	W37
14	N37	E10	44	S23	W25
15	N31	E20	45	S18	W15
16	N27	E30	46	N25	W35
17	N20	E39	47	N38	W36
18	N10	E49	48	N41	W24
19	N4	E51	49	N38	E7
20	S5	E50	50	N34	E15
21	S10	E47	51	N30	E24
22	S17	E40	52	N24	E35
23	S20	E36	53	N15	E45
24	S25	E30	54	S13	E42
25	S30	E21	55	S40	E3
26	S38	E10	56	S13	W8
27	S40	0	57	N40	W4
28	S45	W10	58	S31	E20
29	S46	W20	59	0	E52
30	S44	W30	60	N8	E50

Student Activity Sheet #1

SUNSPOT LOCATION GRID



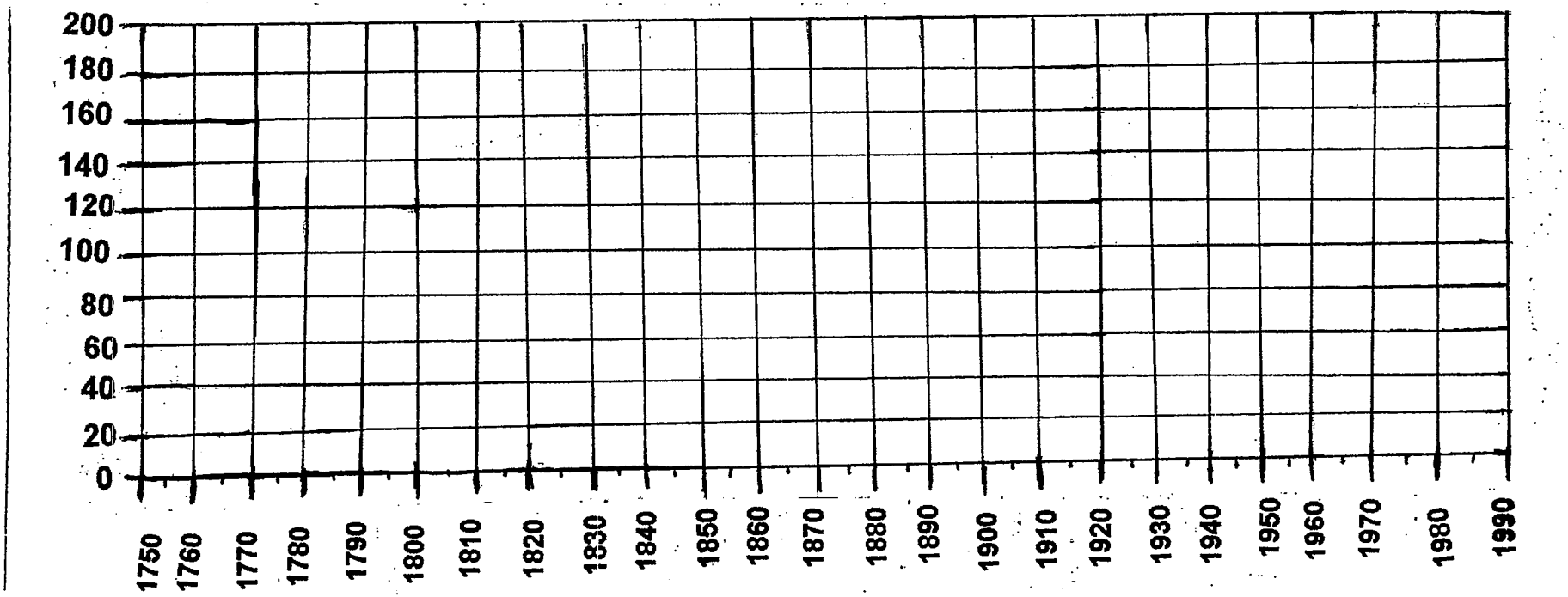
DATA TABLE: MONTHLY MEAN SUNSPOT NUMBERS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1750	73.3	75.9	89.2	88.3	90	100	85.4	103	91.2	65.7	63.3	75.4	
1755	10.2	11.2	6.8	6.5	0	0	8.6	3.2	17.8	23.7	6.8	20	
1760	67.3	59.5	74.7	58.3	72	48.3	66	75.6	61.3	50.6	59.7	61	
1765	24	26	25	22	20.2	20	27	29.7	16	14	14	13	
1770	104	142.5	80.1	51	70.1	83.3	109.8	126	104.4	104	132	102.3	
1775	4.4	0	11.6	11.2	3.9	12.3	1	7.9	3.2	5.6	15.1	7.9	
1780	70	98	98	95	107	88	86	86	93	77	60	58	
1785	6.5	8	9	15.7	20.7	26.3	36.3	20	32	47.2	40.2	27.3	
1790	103	127.5	96.3	94	93	91	69.3	87	77.3	84.3	82	74	
1795	21.4	39.9	12.6	18.6	31	17	12.9	25.7	13.5	19.5	25	18	
1800	6.9	9.3	13.9	0	5	23.7	21	19.5	11.5	12.3	10.5	40.1	
1805	61	44	51	37	39	40.5	37.6	42.7	44.4	29.4	41	38.3	
1810	0	0	0	0	0	0	0	0	0	0	0	0	
1815	19.2	32.2	26.2	31.6	9.8	55.9	35.5	47.2	31.5	33.5	37.2	65	
1820	19.2	26.6	4.5	19.4	29.3	10.8	20.6	25.9	5.2	8.9	7.9	9.1	
1825	5	15.5	22.4	3.8	15.5	15.4	30.9	25.7	15.7	15.6	11.7	22	
1830	52.2	72.1	84.6	106.3	66.3	65.1	43.9	50.7	62.1	84.4	81.2	82.1	
1835	7/5	24.5	19.7	61.5	43.6	33.2	59.8	59	100.8	95.2	100	77.5	
1840	81.2	87.7	67.8	65.6	69.2	48.5	60.7	57.8	74	55	54.3	53.7	
1845	25.7	43.6	43.4	57	47.8	31.1	30.6	32.3	29.6	40.7	39.4	59.7	
1850	78	89.4	82.6	44.1	61.6	70	39.1	61.6	86.2	71	54.8	61	
1855	12.3	11.4	17.4	4.4	9.1	5.3	0.4	3.1	0	9.6	4.2	3.1	
1860	82.4	88.3	98.9	71.4	107.1	108.6	116.7	100	92.2	90.1	97.9	95.6	
1865	48.7	39.3	39.5	29.4	34.5	33.6	26.8	37.8	21.6	17.1	24.7	12.8	
1870	77.3	114.9	157.6	160	176	135.6	132.4	154	136	146	148	130	
1875	14.6	21.5	33.8	29.1	11.5	23.9	12.5	14.6	2.4	12.7	17.7	9.9	
1880	24	27.2	19.3	19.5	23.5	34.1	21.9	48.1	66	43	30.7	29.6	
1885	42.8	71.8	49.8	55	73	83.7	66.5	50	39.6	38.7	30.9	21.7	
1890	5.3	0.6	5.1	1.6	4.8	1.3	11.6	8.5	17.2	11.2	9.6	7.8	
1895	63.3	67.2	61	76.9	67.5	71.5	47.8	68.9	57.7	67.9	47.2	70.7	
1900	9.4	13.6	8.6	16	15.2	12.2	8.3	4.3	83	12.9	4.5	0.3	

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1905	54.8	85.5	56.5	39.3	48	49	73	59	55	78.7	107	55.5	
1910	26.4	31.5	21.4	8.4	22.2	12.3	14.1	12	26.2	38.3	4.9	5.8	
1915	23	42.3	38.8	41.3	33	68.8	71.6	70	49.5	53.5	42.5	34.5	
1920	51.1	53.9	70.2	14.8	33.3	38.7	27.5	19	36.3	49.6	27.2	29.9	
1925	5.5	23.2	18	31.7	42.8	47.5	38.5	38	60.2	69.2	58.6	98.6	
1930	65.3	49.9	35	38.2	36.8	28.8	21.9	25	32.1	34.4	35.6	25.8	
1935	18.6	20.5	23.1	12.2	27.3	45.7	33.9	30	42.1	53.2	64.2	61.5	
1940	50.5	59.4	83.3	60.7	54.4	83.9	67.5	106	66.5	55	58.4	68.4	
1945	47.6	86.2	76.6	75.7	84.9	73.5	116	107	94.4	102	124	122	
1950	102	94.8	109.7	113	106	83.6	91	85	51.3	61.4	54.8	54.1	
1955	23.1	20.8	4.9	11.3	28.9	31.7	26.7	41	42.7	58.5	89.2	76.9	
1960	146	106	102.2	122	120	110	122	134	127	82.8	89.6	76.9	
1965	17.5	14.2	11.7	6.8	24.1	15.9	11.9	8.9	16.8	20.1	15.8	17	
1970	112	128	102.9	110	128	107	113	93	99.5	86.6	95.2	83.5	
1975	18.9	11.5	11.5	5.1	9	11.4	28.2	40	13.9	9.1	19.4	7.8	
1980	160	155	126	164	180	157	136	135	155	165	148	174	
1985	16.5	15.9	17.2	16.2	27.5	24.2	30.7	11	3.9	18.6	16.2	17.3	
1990	177	131	140.3	140	132	105	149	200	125	146	131	130	

Student Activity Sheet #3

Sunspot Cycles 1750-1990



Student Activity Sheet # 4

Analysis and Comprehension
Part I: Sunspot Location Grid

1. Who was the first scientist to point out the presence of sunspots?

_____

2. What have modern observations of the Sun shown sunspots to be? _____

_____

_____

3. What are the two main parts of a sunspot? _____

4. Do all sunspots have the same electromagnetic charge? Explain._____

_____

5. Describe the process of sunspot formation and movement across the surface of the Sun. _____

_____

_____

_____

_____

6. Who first recognized the drifting of sunspots across the surface of the sun?

_____

7. Why could it be said that sunspots are repetitious or that they occur in cycles?

_____

_____

_____

8. How are sunspots plotted? _____

_____

_____

9. From your grid, what comparison can you make about sunspot locations in the southern hemisphere and those in the northern hemisphere of the Sun?

_____

10. Would sunspot (40N, 0) be a new or an old sunspot? Why? _____

_____

_____

11. Would sunspot (0,5E) be a large or a small sunspot? Why? _____

_____

_____

12. How does the pattern that appears on your grid compare to the pattern described by Maunder? _____

_____

Part II: Sunspots and Climate Change

1. What did Walter Maunder discover about sunspot activity in 1893? _____

_____

_____

2. What made Maunder think that there might be connection between sunspots and Earth's climate?_____

_____

_____

3. Aside from indicating a change in the Sun's magnetic activity, what else do sunspots tell us? _____

_____

4. What has ice core research revealed about the Earth's climate? _____

_____

_____

5. Why are *proxy record*s important in climate research? _____

_____

_____

_____

6. From your graph, what can you say about the cycles of sunspots? _____

_____

_____

Student Activity Sheet #4

7. About how long are sunspot cycles? _____

8. List the years when sunspot numbers were the highest? _____

_____

_____

9. What should these years tells us about Earth's climate? _____

_____

_____

10. What would the years when sunspot numbers were low mean for the climate? _____

_____

_____

11. What other information would you need to support your answer in #10? _____

_____

_____