Student Guide to Activity 2: Sunspot Number Variations

Problem: What pattern(s) emerge when sunspot numbers are plotted over a period of time?

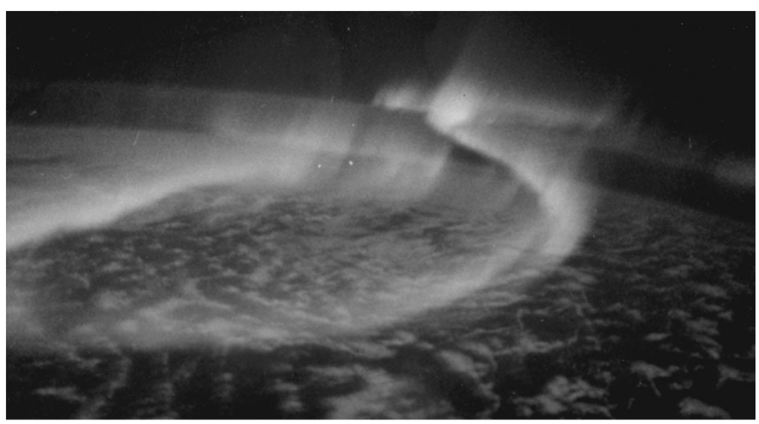
Introduction

A student's dream comes true! On a quiet, mild, mid-afternoon, the overhead lights flicker just a little. A few minutes later, the same lights dim faintly, then suddenly all is dark. A hoot of delight reverberates throughout the school as students' hopes for an unexpected vacation rise. What happened to cause this sudden surprise?

If you live in the north, perhaps it was due to a sudden snowfall or sleet storm. If you live in the south, maybe it was a power overload on a hot day. But, this is a mild, quiet afternoon. What could cause a dramatic power outage? Just a few short decades ago we would never have suspected that our ultimate energy source, the Sun, was the culprit! How could that be?

That reliable sphere of glowing gas that rises daily in the east and sets in the west sends us visible light that arrives on Earth after about 8 minutes of travel through space. Besides its dazzling brightness, the Sun's next most obvious features are the appearance of dark, cool areas called sunspots that can be seen when the Sun's image is projected onto a piece of white cardboard through a pin-hole (never look at the Sun directly!!). Sunspots are huge magnetic field bundles that are shaped somewhat like a horseshoe magnet. These magnetic fields result in cooler, darker regions on the surface of the Sun that we see as sunspots. Sunspots are sources of a tremendous amount of energy including solar flares, the most violent events in the solar system. In a matter of minutes, a large flare releases a million times more energy than the largest earthquake.

Sunspots and the resulting solar flares affect us, here on Earth. In fact, the more we learn about sunspots and solar flares, the greater their influence on Earth appears to be. Solar flares emit radiation that includes X-rays and ultraviolet rays, and charged particles called protons and electrons. This radiation surge may damage electrical power systems, interfere with telecommunications, disrupt high-tech ship navigation systems, harm an astronaut in space, or create the spectacular **aurora** (Northern and Southern lights).



Auroral curtains photographed by astronauts on NASA's STS-39 mission (courtesy of NASA)

Currently, scientists at NOAA's Space Environment Center in Boulder, Colorado, conduct research in space physics and develop new techniques for forecasting solar events like solar flares. The Space Environment Services Center is the national and world warning center for these disturbances, called **space weather**. Space weather affects both people and equipment not only in airline and space travel, but also in Earth-based jobs such as long-line telephone communication systems, pipeline operations, and electric power distribution.

Space Environment Forecast Center (courtesy of the Space Environment Center, NOAA)

Through years of study, we now know that the chances of a sudden surge in radiation on Earth caused by a solar flare is related to an increase in the number and complexity of sunspots. Therefore, researchers plot average sunspot numbers over a period of time so that we know when to expect the next series of disruptive, potentially dangerous solar flares. The sunspot number (also called the Wolf number after Rudolph Wolf, who devised the method) is not actually the number of sunspots on the Sun. It is calculated with a formula that does depend on the number of visible sunspots recorded at selected observatories around the world.

Another mysterious connection between sunspots and life on Earth has to do with climate. During a period from 1645 to 1715 known as the Maunder minimum, almost no sunspots were seen. During that same time, Earth's Northern Hemisphere experienced the "Little Ice Age" as average temperatures dipped and rivers froze. What is the connection? Scientists are not certain, but sunspots must be telling us something important about how the Sun works and produces energy.

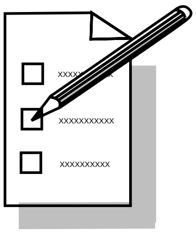
Europe experienced a Little Ice Age in the seventeenth century. This painting, *Skating/ Frozen River*, recorded by Hendrick Avercamp is of an unusual freezing of Dutch canals.

Thus, as our knowledge of the interaction between the Sun and Earth improves and our use of the space environment increases, space weather forecasting becomes more important. Although we may feel, see, or hear nothing unusual, our electrical power may fail, our telecommunications may falter, and satellites may no longer function. Some people may speak of mysterious, superstitious forces, but we know that none other than our closest star, the Sun, is the culprit. And in the long term, studying sunspots could help us solve the many mysteries of our nearest star — mysteries that could mean life or death for planet Earth.

ACTIVITY 2 STUDENT WORKSHEET

Procedure:

1. Working in groups of three, read the text for this activity.



2. When all of you are done reading the text, obtain three sheets of graph paper (one for each of you), colored pencils and a ruler from your teacher. Each of you will now complete a graph.

NOTE: Be sure to agree beforehand on what scale you will use (for example, each vertical line might represent 1 year), because you will be taping these together once all graphs have been completed.

- Use your ruler to Draw a horizontal line (x-axis) along the bottom and label it "Time in Years." One student will number his or her graph from the year 1700 to the year 1799. Another will label the second graph from 1800 to 1899. The third student will number the third graph from 1900 to 2020.

- Draw a vertical line (y-axis) along the left hand side of the paper and label it "Sunspot Numbers." Counting by tens, number from 0-200 sunspots. (Do not skip lines.) ***Again, be sure that all three of you use the same scale.***

3. Plot the number of sunspots for each year using Charts #1 and #2. Connect the data points with a continuous solid line. Observe the resulting pattern in your graph and record your ideas in the space provided.

4. When each of you completes the graph, tape together the three graphs (put the tape on the back of the paper) so that the graph represents a time line from 1700 to 2020.

NOTE: Tape your graph together so that the time line is continuous, i.e. with no breaks. One or more of you may need to cut off the part of the edge(s) of your graph in order to accomplish this.

Discuss the pattern with your group and record your ideas in the space provided, along with a sketch of your group's graph.   Be prepared to share your ideas with the class.

Sketch

NOTE: Sunspot cycles have been numbered beginning with the minimum that occurred about 1755. A cycle includes an increase and the following decrease in sunspot numbers. Cycle number 22 peaked in 1990. The next two sunspot cycles are numbered 23 and 24.

5. Beginning with the sunspot maximum about year 1761, number each sunspot maximum directly above the line graph.

6. Using a dashed line -------, draw your prediction for the next two sunspot cycles on the graph (i.e. cycles 23 and 24).

7. In the space provided, compare what you now know about sunspots and their variation to what you knew when you started this activity.

8. What pattern(s) emerge when sunspot numbers are plotted over a period of time?

Answer the following questions and explain your answers:

1. What is the average time between the high points (periods of maximum sunspot activity)?

2. Predict the years for the next two sunspot maxima (sunspot cycle numbers 23 and 24). Show your work.

3. Predict the years for the next two sunspot minima.

4. Predict how many sunspots there will be in the year that you graduate from high school.

5. What additional patterns do you see when you observe data over a long period of time compared to observing data for the shorter period of time? (For example, compare the individual graph that you made for the 100 year time period to the larger graph.)

6. Why is it important to collect and to study data over a long period of time before drawing conclusions? Give an example other than sunspot data.

Explore More:

7. Explain (tell why you came up with) your prediction for the years of sunspot maxima (cycle numbers 23 and 24).

8. Predict how large sunspot cycle numbers 23 and 24 will be. Explain your prediction.

9. Predict the "shape" (on the graph) of the next sunspot cycle (23). Explain your prediction.

Sunspot Chart #1: 1700 - 1850

Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number	
1700	5		1738	111	M	1775	7	m	1813	12.2	
1701	11		1739	101		1776	19.8		1814	13.9	
1702	16		1740	73		1777	92.5		1815	35.4	
1703	23		1741	40		1778	154.4	M	1816	45.8	M
1704	36		1742	20		1779	125.9		1817	41.1	
1705	58	M	1743	16		1780	84.8		1818	30.1	
1706	29		1744	5	m	1781	68.1		1819	23.9	
1707	20		1745	11		1782	38.5		1820	15.6	
1708	10		1746	22		1783	22.8		1821	6.6	
1709	8		1747	40		1784	10.2	m	1822	4	
1710	3		1748	60		1785	24.1		1823	1.8	m
1711	0		1749	80.9		1786	82.9		1824	8.5	
1712	0	m	1750	83.4	M	1787	132	M	1825	16.6	
1713	2		1751	47.7		1788	130.9		1826	36.3	
1714	11		1752	47.8		1789	118.1		1827	49.6	
1715	27		1753	30.7		1790	89.9		1828	64.2	
1716	47		1754	12.2		1791	66.6		1829	67	
1717	63	M	1755	9.6	m	1792	60		1830	70.9	M
1718	60		1756	10.2		1793	46.9		1831	47.8	
1719	39		1757	32.4		1794	41		1832	27.5	
1720	28		1758	47.6		1795	21.3		1833	8.5	m
1721	26		1759	54		1796	16		1834	13.2	
1722	22		1760	62.9		1797	6.4		1835	56.9	
1723	11	m	1761	85.9	M	1798	4.1	m	1836	121.5	
1724	21		1762	61.2		1799	6.8		1837	138.3	M
1725	40		1763	45.1		1800	14.5		1838	103.2	
1726	78		1764	36.4		1801	34		1839	85.7	
1727	122	M	1765	20.9		1802	45		1840	64.6	
1728	103		1766	11.4	m	1803	43.1		1841	36.7	
1729	73		1767	37.8		1804	47.5	M	1842	24.2	
1730	47		1768	69.8		1805	42.2		1843	10.7	m
1731	35		1769	106.1	M	1806	28.1		1844	15	
1732	11		1770	100.8		1807	10.1		1845	40.1	
1733	5	m	1771	81.6		1808	8.1		1846	61.5	
1734	16		1772	66.5		1809	2.5		1847	98.5	
1735	34		1773	34.8		1810	0	m	1848	124.7	M
1736	70		1774	30.6		1811	1.4		1849	96.3	
1737	81					1812	5		1850	66.6	

Sunspot Chart #2: 1851 - 1995

Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number	
1851	64.5		1888	6.8		1924	16.7		1960	112.3	
1852	54.1		1889	6.3	m	1925	44.3		1961	53.9	
1853	39		1890	7.1		1926	63.9		1962	37.6	
1854	20.6		1891	35.6		1927	69		1963	27.9	
1855	6.7		1892	73		1928	77.8	M	1964	10.2	m
1856	4.3	m	1893	85.1	M	1929	64.9		1965	15.1	
1857	22.7		1894	78		1930	35.7		1966	47	
1858	54.8		1895	64		1931	21.2		1967	93.8	
1859	93.8		1896	41.8		1932	11.1		1968	105.9	M
1860	95.8	M	1897	26.2		1933	5.7	m	1969	105.5	
1861	77.2		1898	26.7		1934	8.7		1970	104.5	
1862	59.1		1899	12.1		1935	36.1		1971	66.6	
1863	44		1900	9.5		1936	79.7		1972	68.9	
1864	47		1901	2.7	m	1937	114.4	M	1973	38	
1865	30.5		1902	5		1938	109.6		1974	34.5	
1866	16.3		1903	24.4		1939	88.8		1975	15.5	
1867	7.3	m	1904	42		1940	67.8		1976	12.6	m
1868	37.6		1905	63.5	M	1941	47.5		1977	27.5	
1869	74		1906	53.8		1942	30.6		1978	92.5	
1870	139	M	1907	62		1943	16.3		1979	155.4	M
1871	111.2		1908	48.5		1944	9.6	m	1980	154.6	
1872	101.6		1909	43.9		1945	33.2		1981	140.4	
1873	66.2		1910	18.6		1946	92.6		1982	115.9	
1874	44.7		1911	5.7		1947	151.6	M	1983	66.6	
1875	17		1912	3.6		1948	136.3		1984	45.9	
1876	11.3		1913	1.4	m	1949	134.7		1985	17.9	
1877	12.4		1914	9.6		1950	83.9		1986	13.4	m
1878	3.4	m	1915	47.4		1951	69.4		1987	29.4	
1879	6		1916	57.1		1952	31.5		1988	100.2	
1880	32.3		1917	103.9	M	1953	13.9		1989	157.6	M
1881	54.3		1918	80.6		1954	4.4	m	1990	142.6	
1882	59.7		1919	63.6		1955	38		1991	145.7	
1883	63.7	M	1920	37.6		1956	141.7		1992	99.3	
1884	63.5		1921	26.1		1957	190.2	M	1993	54.6	
1885	52.2		1922	14.2		1958	184.8		1994	29	
1886	25.4		1923	5.8	m	1959	159		1995	19.5	
1887	13.1										

Each "M" marks a sunspot cycle maximum and each "m" is a minimum. Through 1944, yearly means were calculated as the average of the 12 monthly means; since 1945, yearly means have been calculated as the average of the daily means.