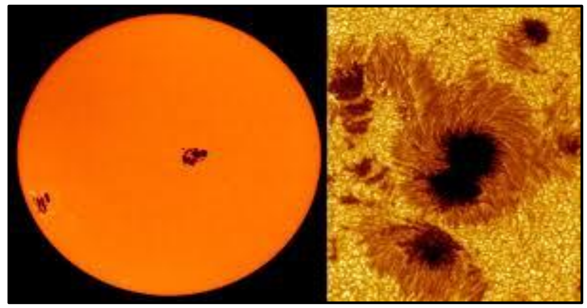
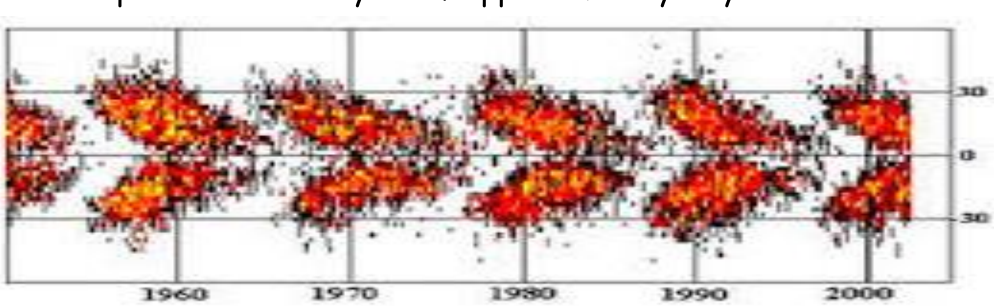
Student Sheet 1

MATH APPLICATION ACTIVITY: SUNSPOTS AND CLIMATE CHANGE

PART 1- LOCATING SUNSPOTS: Our Sun is not a perfect, constant source of heat and light. As early as the 17th Century, Italian astronomer, Galileo Galilei got into trouble with the Roman Catholic Church authorities for, among other things, pointing out that the surface of the Sun is sometimes marked with "blemishes," know today as ***sunspots***. Observations have shown sunspots to be relatively "cooler" areas of the Sun's surface or ***photosphere*** connected with disturbances in the ***solar magnetic field***. If seen from the side, they appear as deep depressions in the photosphere. Sunspots usually come in pairs; the first one that moves across the disc of the Sun has the opposite magnetic charge (+/-) from the one that follows it and generally drifts from the high latitudes of the Sun toward the equator. Scientists believe that this drifting 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 the higher latitudes, both north and south of the equator. As the cycle proceeds toward ***maximum***, spots form at latitudes of 10-15 degrees. As the cycle moves toward ***minimum***, the spots get smaller and appear closer to the equator. There is an overlap at the end of one cycle and the start of another, as new sunspots form in the in the higher latitudes, while spots from the present cycle are still visible near the equator. When sunspots are plotted according to their latitude and longitude, a very clear "butterfly pattern" develops within each cycle of approximately 11 years.

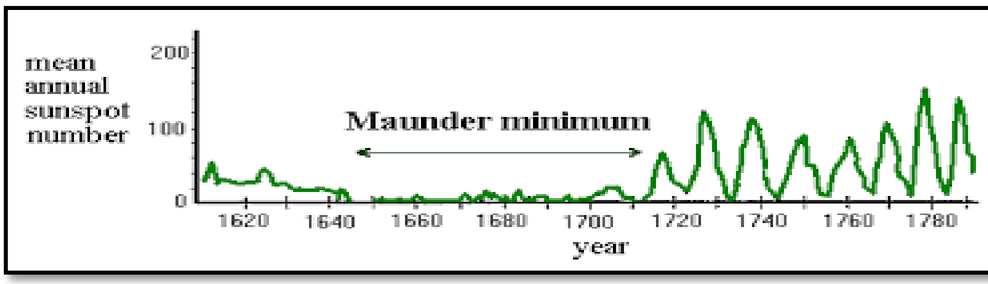


The "butterfly pattern" of sunspots

Student Sheet 2

PART 2: Sunspot Cycles and Climate

In 1893, E. Walter Maunder, the superintendent of the Royal Greenwich Observatory solar division in England, while looking through some old records, discovered data that showed 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 stopped. 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, the Northern Hemisphere experienced unusually cold weather for a prolonged period of time. In North America and Europe, rivers froze, glaciers grew, crops failed and people starved. The yearly averages of sunspot numbers are shown in the graph below. It is clear that there was very little sunspot activity from about 1650-1720, and that it coincides with the time known as ***The Little Ice Age.***



Graph of sunspot activity 1600-1800

Maunder used the data from these observations to develop a hypothesis about a connection between changes in the output of solar energy and changes in the Earth's climate. The "coincidence" that the Sun's cycle of activity seemed to have switched off exactly during the coldest decades of modern history attracted a lot of attention from other researchers who naturally wondered whether they might be able to connect climate changes with solar variations. However, the Sun appeared to be stable over the period of human civilization and attempts to discover variations in weather and connect them with the 11-year sunspot cycle, or other solar cycles extending to a few centuries long, gave results that were vague and got a well-deserved bad reputation

Student Sheet 3

From one century to another, evidence was accumulating that the Sun does change, at least superficially. From observation and research into historical climate data on the relationship between solar cycles and climate, scientists noticed a pattern in the number of sunspots. About every 11 years, the number of sunspots reaches a high and then decreases again and is known as the ***solar cycle***. During this eleven-year cycle of sunspots, the sunspot number increases -***solar maximum*** and decreases- ***solar minimum***. In addition, the solar magnetic field, ultraviolet radiation, and other features that may affect climate are found to rise and fall along with the sunspot number.

The next crucial question was whether a rise in the Sun's activity could explain the global warming seen in the 20th century? By the 1990s, there was an unconfirmed answer: minor solar variations could have been partly responsible for some past fluctuations... but future warming from the rise in greenhouse gases was far outweighing any solar effects.

Student Sheet 4

DATA TABLE 1: SUNSPOT LOCATIONS

#	LAT	LONG	#	LAT	LONG
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	N37	0	43	S36	W37
14	N31	E10	44	S23	W25
15	N27	E20	45	S18	W15
16	N20	E30	46	N25	W35
17	N10	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 Sheet 5

DATA TABLE 2: Sunspot Numbers: 1700 - 1850

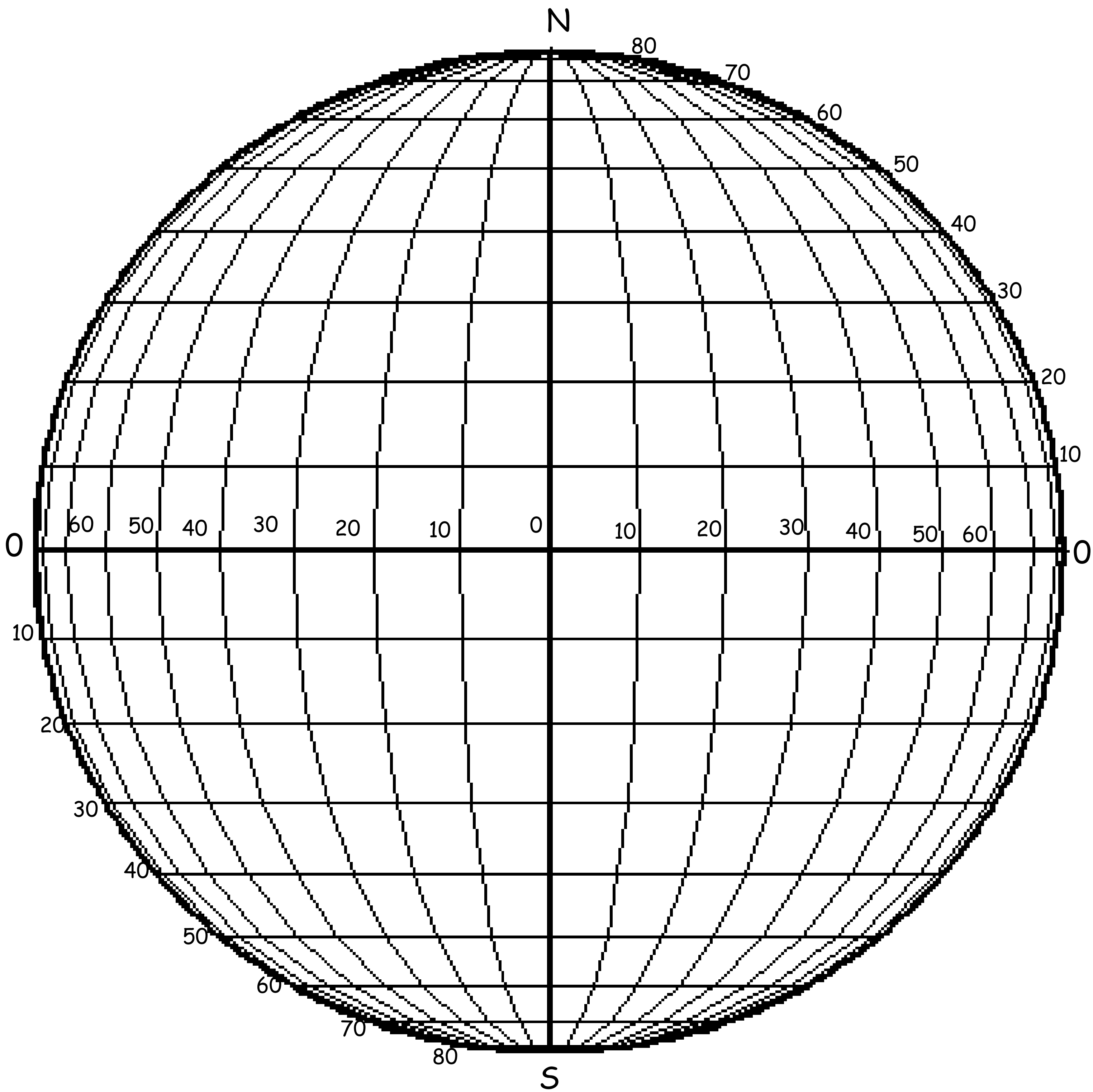
Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number	
1700	5		1738	111	M	1776	19.8		1814	13.9	
1701	11		1739	101		1777	92.5		1815	35.4	
1702	16		1740	73		1778	154.4	M	1816	45.8	M
1703	23		1741	40		1779	125.9		1817	41.1	
1704	36		1742	20		1780	84.8		1818	30.1	
1705	58	M	1743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

Student Sheet 6

DATA TABLE 3: Sunspot Chart #2: 1851 - 2015

Year	Sunspot Number		Year	Sunspot Number		Year	Sunspot Number	
1851	64.5		1907	62		1960	112.3	
1852	54.1		1908	48.5		1961	53.9	
1853	39		1909	43.9		1962	37.6	
1854	20.6		1910	18.6		1963	27.9	
1855	6.7		1911	5.7		1964	10.2	m
1856	4.3	m	1912	3.6		1965	15.1	
1857	22.7		1913	1.4	m	1966	47	
1858	54.8		1914	9.6		1967	93.8	
1859	93.8		1915	47.4		1968	105.9	M
1860	95.8	M	1916	57.1		1969	105.5	
1861	77.2		1917	103.9	M	1970	104.5	
1862	59.1		1918	80.6		1971	66.6	
1863	44		1919	63.6		1972	68.9	
1864	47		1920	37.6		1973	38	
1865	30.5		1921	26.1		1974	34.5	
1866	16.3		1922	14.2		1975	15.5	
1867	7.3	m	1923	5.8	m	1976	12.6	m
1868	37.6		1924	16.7		1977	27.5	
1869	74		1925	44.3		1978	92.5	
1870	139	M	1926	63.9		1979	155.4	M
1871	111.2		1927	69		1980	154.6	
1872	101.6		1928	77.8	M	1981	140.4	
1873	66.2		1929	64.9		1982	115.9	
1874	44.7		1930	35.7		1983	66.6	
1875	17		1931	21.2		1984	45.9	
1876	11.3		1932	11.1		1985	17.9	
1877	12.4		1933	5.7	m	1986	13.4	m
1878	3.4	m	1934	8.7		1987	29.4	
1879	6		1935	36.1		1988	100.2	
1880	32.3		1936	79.7		1989	157.6	M
1881	54.3		1937	114.4	M	1990	142.6	

1882	59.7		1938	109.6		1991	145.7	
1883	63.7	M	1939	88.8		1992	99.3	
1884	63.5		1940	67.8		1993	54.6	
1885	52.2		1941	47.5		1994	29	
1886	25.4		1942	30.6		1995	19.5	
1887	13.1		1943	16.3		1996	9	m
1888	6.8		1944	9.6	m	1997	21	
1889	6.3	m	1945	33.2		1998	64	
1890	7.1		1946	92.6		1999	93	
1891	35.6		1947	151.6	M	2000	119	M
1892	73		1948	136.3		2001	111	
1893	85.1		1949	134.7		2002	104	
1894	78		1950	83.9		2003	65	
1895	64		1951	69.4		2004	41	
1896	41.8		1952	31.5		2005	29	
1897	26.2		1953	13.9		2006	15	
1898	26.7		1954	4.4	m	2007	7.5	
1899	12.1		1955	38		2008	2.9	m
1900	9.5		1956	141.7		2009	3.1	
1901	2.7	m	1957	190.2	M	2010	16	
1902	5		1958	184.8		2011	56	
1903	24.4		1959	159		2012	58	
1904	42		1960	112.3		2013	72	
1905	63.5	M	1961	53.9		2014	81.9	M
1906	53.8		1962	37.6		2015	114	



SUNSPOT LOCATION GRID

Student Sheet 7

ANALYSIS:

PART 1: What are sunspots?

1. Who was the first scientist to actively describe sunspots?
2. What have modern observations shown sunspots to be?
3. What is their temperature like in comparison to the surrounding area?
4. What creates the "cooler" areas on the Sun's surface?
5. How does sunspot size compare to the size of the Earth?
6. Are all sunspots affected by magnetic fields? Explain.
7. Describe the process of sunspot formation and movement across the surface of the Sun.
8. Why can it be said that sunspots are repetitious or occur in cycles?
9. How are sunspots plotted?
10. From your completed grid, what can you say about sunspot locations in the Southern Hemisphere of the Sun and those in the Northern Hemisphere?
11. Would sunspot (40N, O) be and old or a new sunspot? Explain.
12. Would sunspot (0,5E) be a large or a small sunspot? Explain.

PART 2: Sunspots and Climate Change

13. What pattern emerges when sunspot numbers are plotted over a period of time?
14. What is the average time between the high points (periods of maximum sunspot activity?
15. Predict the years for the next to sunspot maxima.
16. Predict the years for the next two sunspot minima.
17. What additional patterns do you see when you observe the data over a longer period of time compared to observing the data for a shorter period of time?
18. Why is it important to study data over a long period of time before drawing conclusions?
19. What did Walter Maunder discover about sunspot activity in 1893?

Student Sheet 8

20. What made Maunder think that there might be a connection between sunspots and Earth's climate?
21. Aside from indicating a change in the Sun's magnetic activity, what else do sunspots tell us?
22. From your graph, what can you say about the cycles of sunspots?
23. How long are sunspot cycles?
24. List the years that the sunspot numbers were the highest.
25. What should these years tell you about Earth's climate?
26. What would you expect the climate conditions to be when the numbers are low?
27. What other information would you need to support your 2 previous answers?