

# The Variable Sun

## Background Information

It is not surprising that much attention has been focused on our star—the sun. We bask in the warmth and light produced by complex fusion reactions that begin in the sun's core, releasing high-energy, short-wavelength gamma rays. Thousands of years later, this energy works its way to the surface of the sun and is emitted as visible light and energy of other wavelengths. This energy travels to Earth in approximately 8 min. Though less than a billionth of the sun's energy output is received by the Earth, it is sufficient to power the Earth processes that make Earth a livable planet.

Other products of the fusion of hydrogen, which results in the production of helium, are great tongues of fiery gases, or solar flares, which reach more than a million kilometers from the sun's surface. From the corona, or outermost layer of the sun's atmosphere, come highly charged particles that stream toward the Earth in a disruptive solar wind. This wind is responsible for the auroras (northern and southern lights), radio transmission interference, and, sometimes, power failures.

The innermost and easiest layer to observe, the sun's photosphere glows brightly at 6000 to 10,000 kelvins (K). As early as Galileo's time (1610), dark spots were observed in the photosphere in their march across the visible disk of the sun. This sunspot motion was later interpreted in more detail to reveal that it was a result of the sun's rotation. Different rates of rotation for different parts of the sun caused the spots to move. It is also this differential rate of solar rotation that tangles the sun's magnetic field lines, allowing them to rise to the sun's surface where they produce relatively cool blemishes, or sunspots.

Is there order in the solar disorder? A good way to check on this is to put sunspot data into a model, in this case, a graph. Once this is done it will be easier to compare solar variability to other variations on Earth, which may be related to long- and short-term changes on the sun.

## Problem

How can variations in solar activity be analyzed?

## Materials

none

## Procedure

Using the sunspot data provided in Figure 1, plot the number of sunspots for the years 1850 through Present. Use the graph grid provided. Plot the years on the long axis, and the number of sunspots on the short axis.

*Graphing Sunspot Cycles Worksheet*

Name: \_\_\_\_\_

1. Set up a graph on your graph paper with years on the x-axis and number of sunspots on the y-axis. Number the graph so that it takes up as much room on the paper as possible.
2. Plot the sunspot number against time.

Sunspot number table, courtesy of the National Geophysical Data Center in Boulder (USA).

| Sunspot<br>Year Number | Sunspot<br>Year Number | Sunspot<br>Year Number | Sunspot<br>Year Number | Sunspot<br>Year Number |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| 1700 5                 |                        |                        |                        |                        |
| 1701 11                | 1761 85.9              | 1821 6.6               | 1881 54.3              | 1941 47.5              |
| 1702 16                | 1762 61.2              | 1822 4.0               | 1882 59.7              | 1942 30.6              |
| 1703 23                | 1763 45.1              | 1823 1.8               | 1883 63.7              | 1943 16.3              |
| 1704 36                | 1764 36.4              | 1824 8.5               | 1884 63.5              | 1944 9.6               |
| 1705 58                | 1765 20.9              | 1825 16.6              | 1885 52.2              | 1945 33.2              |
| 1706 29                | 1766 11.4              | 1826 36.3              | 1886 25.4              | 1946 92.6              |
| 1707 20                | 1767 37.8              | 1827 49.6              | 1887 13.1              | 1947 151.6             |
| 1708 10                | 1768 69.8              | 1828 64.2              | 1888 6.8               | 1948 136.3             |
| 1709 8                 | 1769 106.1             | 1829 67.0              | 1889 6.3               | 1949 134.7             |
| 1710 3                 | 1770 100.8             | 1830 70.9              | 1890 7.1               | 1950 83.9              |
| 1711 0                 | 1771 81.6              | 1831 47.8              | 1891 35.6              | 1951 69.4              |
| 1712 0                 | 1772 66.5              | 1832 27.5              | 1892 73.0              | 1952 31.5              |
| 1713 2                 | 1773 34.8              | 1833 8.5               | 1893 85.1              | 1953 13.9              |
| 1714 11                | 1774 30.6              | 1834 13.2              | 1894 78.0              | 1954 4.4               |
| 1715 27                | 1775 7.0               | 1835 56.9              | 1895 64.0              | 1955 38.0              |
| 1716 47                | 1776 19.8              | 1836 121.5             | 1896 41.8              | 1956 141.7             |
| 1717 63                | 1777 92.5              | 1837 138.3             | 1897 26.2              | 1957 190.2             |
| 1718 60                | 1778 154.4             | 1838 103.2             | 1898 26.7              | 1958 184.8             |
| 1719 39                | 1779 125.9             | 1839 85.7              | 1899 12.1              | 1959 159.0             |
| 1720 28                | 1780 84.8              | 1840 64.6              | 1900 9.5               | 1960 112.3             |
| 1721 26                | 1781 68.1              | 1841 36.7              | 1901 2.7               | 1961 53.9              |
| 1722 22                | 1782 38.5              | 1842 24.2              | 1902 5.0               | 1962 37.6              |
| 1723 11                | 1783 22.8              | 1843 10.7              | 1903 24.4              | 1963 27.9              |
| 1724 21                | 1784 10.2              | 1844 15.0              | 1904 42.0              | 1964 10.2              |
| 1725 40                | 1785 24.1              | 1845 40.1              | 1905 63.5              | 1965 15.1              |
| 1726 78                | 1786 82.9              | 1846 61.5              | 1906 53.8              | 1966 47.0              |
| 1727 122               | 1787 132.0             | 1847 98.5              | 1907 62.0              | 1967 93.8              |
| 1728 103               | 1788 130.9             | 1848 124.7             | 1908 48.5              | 1968 105.9             |
| 1729 73                | 1789 118.1             | 1849 96.3              | 1909 43.9              | 1969 105.5             |
| 1730 47                | 1790 89.9              | 1850 66.6              | 1910 18.6              | 1970 104.5             |
| 1731 35                | 1791 66.6              | 1851 64.5              | 1911 5.7               | 1971 66.6              |
| 1732 11                | 1792 60.0              | 1852 54.1              | 1912 3.6               | 1972 68.9              |
| 1733 5                 | 1793 46.9              | 1853 39.0              | 1913 1.4               | 1973 38.0              |
| 1734 16                | 1794 41.0              | 1854 20.6              | 1914 9.6               | 1974 34.5              |
| 1735 34                | 1795 21.3              | 1855 6.7               | 1915 47.4              | 1975 15.5              |
| 1736 70                | 1796 16.0              | 1856 4.3               | 1916 57.1              | 1976 12.6              |
| 1737 81                | 1797 6.4               | 1857 22.7              | 1917 103.9             | 1977 27.5              |
| 1738 111               | 1798 4.1               | 1858 54.8              | 1918 80.6              | 1978 92.5              |
| 1739 101               | 1799 6.8               | 1859 93.8              | 1919 63.6              | 1979 155.4             |
| 1740 73                | 1800 14.5              | 1860 95.8              | 1920 37.6              | 1980 154.6             |
| 1741 40                | 1801 34.0              | 1861 77.2              | 1921 26.1              | 1981 140.4             |
| 1742 20                | 1802 45.0              | 1862 59.1              | 1922 14.2              | 1982 115.9             |
| 1743 16                | 1803 43.1              | 1863 44.0              | 1923 5.8               | 1983 66.6              |
| 1744 5                 | 1804 47.5              | 1864 47.0              | 1924 16.7              | 1984 45.9              |
| 1745 11                | 1805 42.2              | 1865 30.5              | 1925 44.3              | 1985 17.9              |

|      |      |      |      |      |       |      |       |      |       |
|------|------|------|------|------|-------|------|-------|------|-------|
| 1746 | 22   | 1806 | 28.1 | 1866 | 16.3  | 1926 | 63.9  | 1986 | 13.4  |
| 1747 | 40   | 1807 | 10.1 | 1867 | 7.3   | 1927 | 69.0  | 1987 | 29.4  |
| 1748 | 60   | 1808 | 8.1  | 1868 | 37.6  | 1928 | 77.8  | 1988 | 100.2 |
| 1749 | 80.9 | 1809 | 2.5  | 1869 | 74.0  | 1929 | 64.9  | 1989 | 157.6 |
| 1750 | 83.4 | 1810 | 0.0  | 1870 | 139.0 | 1930 | 35.7  | 1990 | 142.2 |
| 1751 | 47.7 | 1811 | 1.4  | 1871 | 111.2 | 1931 | 21.2  | 1991 | 145.8 |
| 1752 | 47.8 | 1812 | 5.0  | 1872 | 101.6 | 1932 | 11.1  | 1992 | 94.5  |
| 1753 | 30.7 | 1813 | 12.2 | 1873 | 66.2  | 1933 | 5.7   | 1993 | 54.7  |
| 1754 | 12.2 | 1814 | 13.9 | 1874 | 44.7  | 1934 | 8.7   | 1994 | 29.9  |
| 1755 | 9.6  | 1815 | 35.4 | 1875 | 17.0  | 1935 | 36.1  | 1995 | 17.9  |
| 1756 | 10.2 | 1816 | 45.8 | 1876 | 11.3  | 1936 | 79.7  | 1996 | 8.6   |
| 1757 | 32.4 | 1817 | 41.1 | 1877 | 12.4  | 1937 | 114.4 | 1997 | 21.5  |
| 1758 | 47.6 | 1818 | 30.1 | 1878 | 3.4   | 1938 | 109.6 | 1998 | 64.3  |
| 1759 | 54.0 | 1819 | 23.9 | 1879 | 6.0   | 1939 | 88.8  | 1999 | 93.3  |
| 1760 | 62.9 | 1820 | 15.6 | 1880 | 32.3  | 1940 | 67.8  | 2000 | 119.0 |
|      |      |      |      |      |       |      |       | 2001 | 110.9 |
|      |      |      |      |      |       |      |       | 2002 | 104.0 |
|      |      |      |      |      |       |      |       | 2003 | 63.7  |
|      |      |      |      |      |       |      |       | 2004 | 40.4  |
|      |      |      |      |      |       |      |       | 2005 | 29.8  |
|      |      |      |      |      |       |      |       | 2006 | 15.2  |
|      |      |      |      |      |       |      |       | 2007 | 7.5   |
|      |      |      |      |      |       |      |       | 2008 | 2.9   |
|      |      |      |      |      |       |      |       | 2009 | 3.1   |

## Question for the Students

1. Connect the points you've plotted with a smooth curve. You'll notice that there are very clear peaks (maximums) and valleys (minimums). Which years are the maximums and which years are minimums? Label these years on your graph with a capital M and lower case m, respectively.
2. Is there is a regular pattern? To answer this question, take note of what scientists call the solar cycle, i.e., how many years are there between a solar maximum, a solar minimum and the next solar maximum? For example, in 1705 there is a maximum, in 1711-1712 there is a minimum, in 1717 a maximum. So the first solar cycle you plotted lasted 12 years (subtract 1705 from 1717). Take note of the other solar cycles by making a table of maximums, minimums and the years between 2 maximums.
  - a) If you had to guess at the average solar cycle length, what would it be from 1700-present?
  - b) Now find the average solar cycle length with a calculator. Show your work:
3. If you had to make a prediction for the years 2011 and 2017, would the years be maximums or minimums?
4. How many sunspots were there during the year you were born? Predict whether it will be closer to a maximum or a minimum when you graduate from high school and for when you turn 21 years old.

