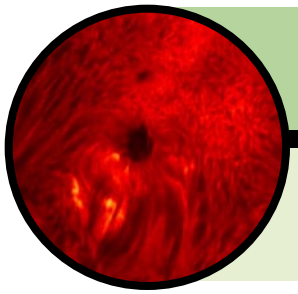

Sunspots and Climate

Unit: Little Ice Age
Lesson: 7

Materials & Preparation

Time:
- Preparation: 10 min
- Teaching: 60 min

Materials for the Teacher:
- Overhead projector
- Transparencies of the Sun (page 4)

Materials for Students:
- Pencil
- Ruler
- Student Page 1
- Student Page 2

National Science Standards
- Science as Inquiry: Content Standard A
- Earth and Space Science: Content Standard D

Colorado Science Standards
- Science: 1, 4.4, 6

Student Goals

Students will
- Understand that the Sun has features called sunspots.
- Understand that the number and location of sunspots changes over time.
- Learn through graphing data that the number of sunspots varies over time with a regular pattern.
- Learn through graph interpretation that when the temporal pattern of sunspots has been disrupted in the past, there has been climate change on Earth.

What Students Do in this Lesson

As an introduction, students identify sunspots on images of the Sun, discovering that the number, location, and size of spots is not always the same. During the first part of the activity, students make a graph that shows how the number of sunspots has changed over the past 30 years. Interpreting their graphs, students discover that there is a regular pattern to the number of sunspots (the 11-year sunspot cycle). During the second part of the activity, students interpret a graph of sunspot data from the coldest part of the Little Ice Age (Maunder Minimum). Students discover that the regular pattern of sunspots was disrupted in the past and this had an effect on the climate of our planet.

Key Concepts
- The Sun has features called sunspots that change in number and location over time.
- People have been keeping detailed records of the number of sunspots for hundreds of years.
- The number of sunspots waxes and wanes with a regular periodicity of 11 years; this is called the solar cycle.
- The solar cycle has been disrupted in the past, causing climate change on Earth (during the Little Ice Age, for example).

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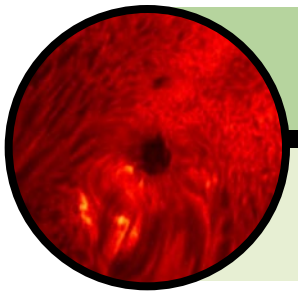


Graphing Sunspot Cycles

Advanced Preparation

- Copy overhead (page 4) onto transparency and familiarize yourself with the images.
- Copy Student Page 1 *(Graphing Sunspots)* and Student Page 2 *(Sunspots and Climate)* for each student.

Introducing the Lesson

- Tell students that they should never look directly at the Sun. (This can cause blindness.)
- Show students the transparency images of the Sun using the overhead projector. Describe how pictures like this are taken. (They are not photographs; the data is collected by a remote sensing instrument called MDI that is on the SOHO spacecraft and made into a representation or image that looks like a photograph.)
- Start with the upper left picture (A, courtesy of spaceweather.com). This shows a very large sunspot and quite a few smaller ones. To provide a sense of scale, there is a small dot to indicate the size of Earth as compared with the sunspots (point this out to students).
- Look at the other images on the transparency (B-D) and see if members of the class can find sunspots. All three of these images show the Sun on different days of July 2005. The date and time are in the lower left of each image. (All three images courtesy of NASA SOHO.)
- Discuss the following as a class:
    - Do the number of spots stay the same? Brainstorm ideas about why the number of visible sunspots might change over time. There are two reasons why this might be: 1) we are not always looking at the same side of the Sun, because the Sun rotates and Earth orbits, thus the number of spots we can see can vary with the time of day over a few days or weeks (example: compare images B-D); 2) the number of sunspots can change over weeks, months, years (example: compare image A with the others) .
    - Are all the spots the same? Notice that some spots are large and others are small.
    - Tell students that scientists have been observing the number of spots on the sun for hundreds of years. In this lesson they will investigate this data to see if there is a pattern to the number of spots.

Facilitating the Lesson: Part A

- Pass out *Student Page 1: Graphing Sunspot Data*.
- Describe to students that listed in the data table on the student page is the average number of sunspots for each year. Scientists take the size and number of sunspots into account in their observations as well as the side of the Sun they can view and the technology used to collect the sunspot data.
- Have students graph the points and answer the interpretation questions at the bottom of the student page.
- Discuss the answers to the interpretation questions, especially the pattern of the sunspot numbers. Describe that the pattern they are seeing is called the Solar Cycle. This cycle also correlates with other types of phenomena such as solar storms and other changes in space weather.

Facilitating the Lesson: Part B

- In this part of the lesson students examine a graph of sunspot data from 1630 to 1770. Ask students to predict the type of pattern they would expect to see in the number of sunspots, based on their knowledge of sunspots built during Part A of this lesson.
- Hand out Student Page 2: *Sunspots and Climate*
- Review Student Page directions with the class. Discuss how to interpret a graph.
- After students have had a chance to work individually on their answers to the questions on the Student Page,

Graphing Sunspot Cycles

discuss answers as a group. Students have hopefully recognized that the climate cooled when there were few sunspots. This period of time (1645-1715) was called the Maunder Minimum. It was the coldest period of the Little Ice Age. (See *Background* below.)

Extensions

Take a look at sunspots WITHOUT LOOKING AT THE SUN! To do this safely, you will need to project an image of the Sun through either a pair of binoculars, a telescope, or a device called a Sunspotter onto a piece of white paper or a white wall. For more information about how to safely look at sunspots with your class, see the websites listed in the *Additional Resources* section below. Additonally, consider taking a field trip to a local observatory, if possible.

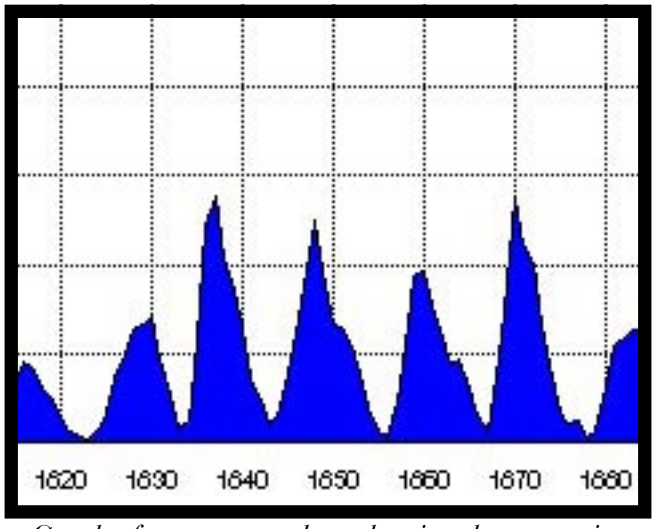
Science Background Information

When viewed through a telescope, sunspots have a dark central region surrounded by a somewhat lighter region. The dark area is slightly cooler than the surrounding area. This cool area is likely related to a strong magnetic field around the sunspot. Sunspots typically last anywhere from a few days to a few months.

People have been observing and keeping records of sunspots for hundreds of years. In 1612, Galileo proved there were spots on the Sun. He used a telescope to look at the Sun (not directly!). At the time, telescopes (and other optics) were very recent innovations and were allowing scientists such as Galileo to discover new aspects of our planet and space. Galileo's discovery was highly controversial at the time because the spots he found were viewed as imperfections. Many of his 17th century colleagues did not believe the Sun could be imperfect!

Over time, scientists have noticed a pattern in the number of sunspots. About every 11 years the number of sunspots reaches a high and then decreases again. This is known as the Solar Cycle. Other sorts of solar activity are related to this cycle as well, such as solar flares, which tend to occur on areas of the Sun near sunspots. The year 2011 will be a solar maximum, making 2006 and 2015 close to solar minimums.

When the Sun has fewer sunspots, it gives off less energy. This results in less energy making its way to Earth, and our planet cools. More than 300 years ago, when the climate was cooler for a time called the "Little Ice Age," people noticed there were no sunspots for several decades. This possible correlation between the number of sunspots and temperature is what students should find on the graph on Student Page 2.



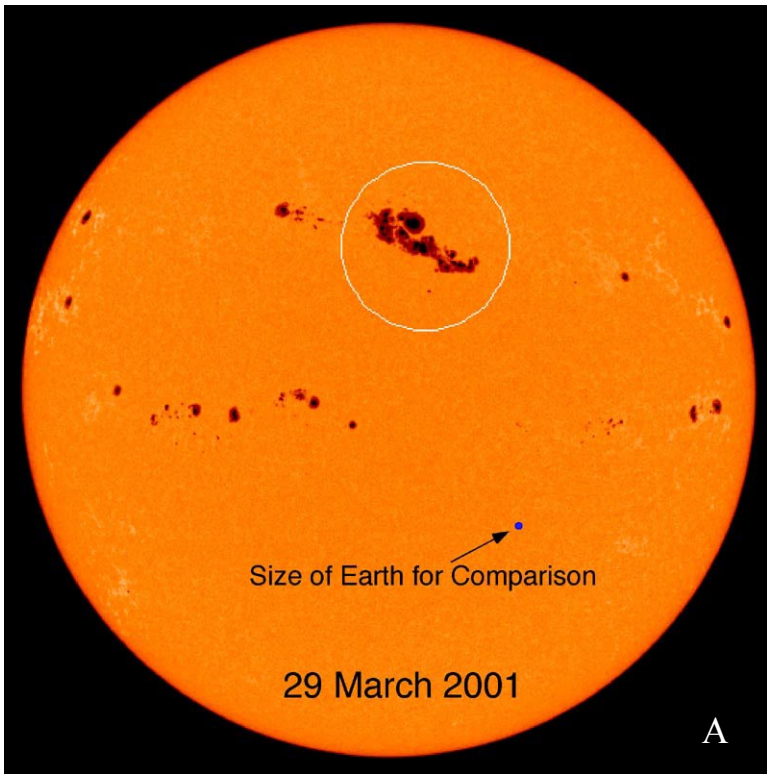
Graph of sunspot numbers showing the repreating pattern of the 11-year solar cycle.

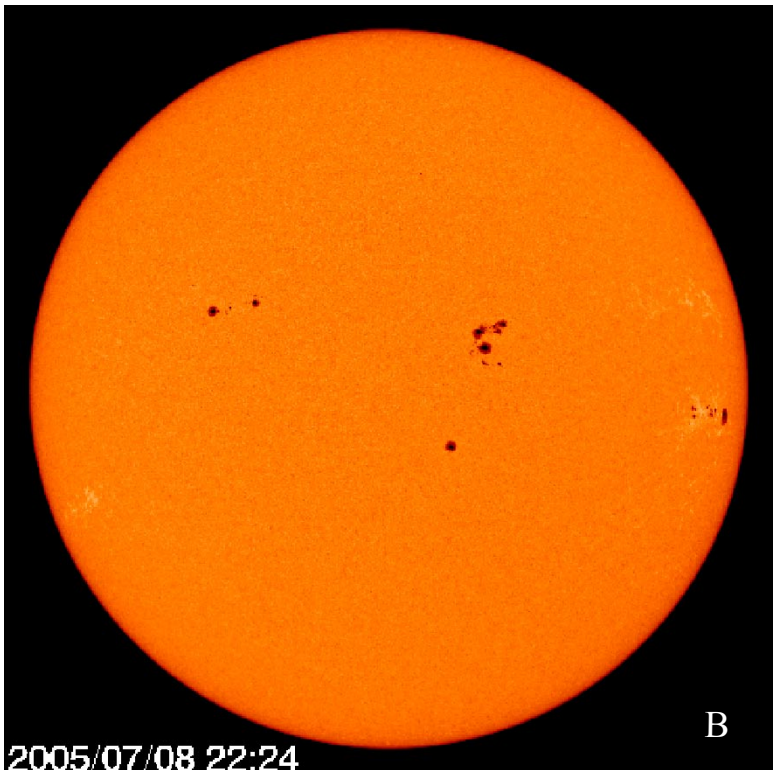
Additional Resources

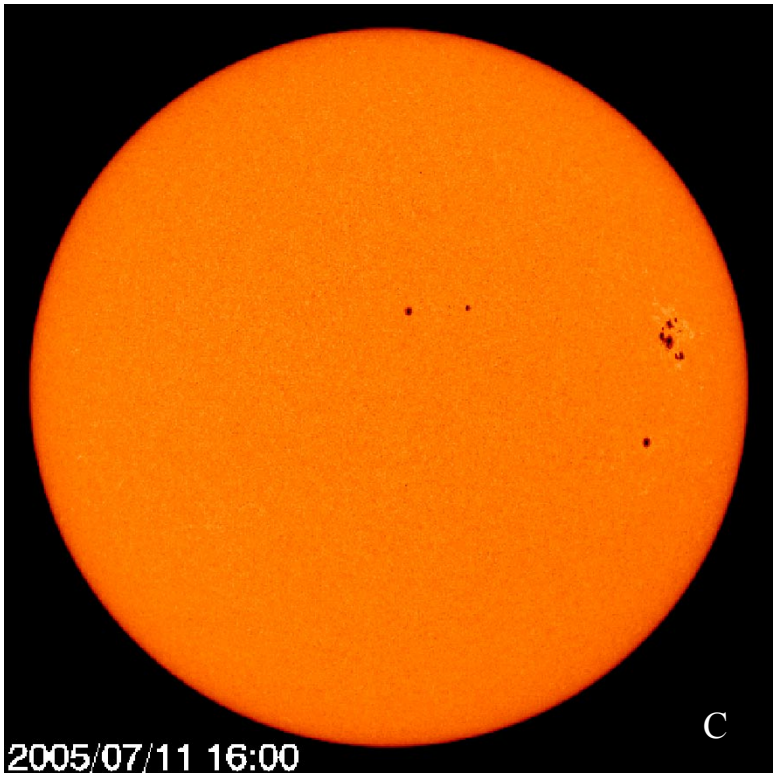
- Windows to the Universe http://www.windows.ucar.edu
- Resources for safely looking at sunspots:
  - Tips about Safe Sunwatching http://www.spaceweather.com/sunspots/doityourself.html
  - Information about Sunspotters http://scientificonline.com/product.asp_Q_pn_E_3112800

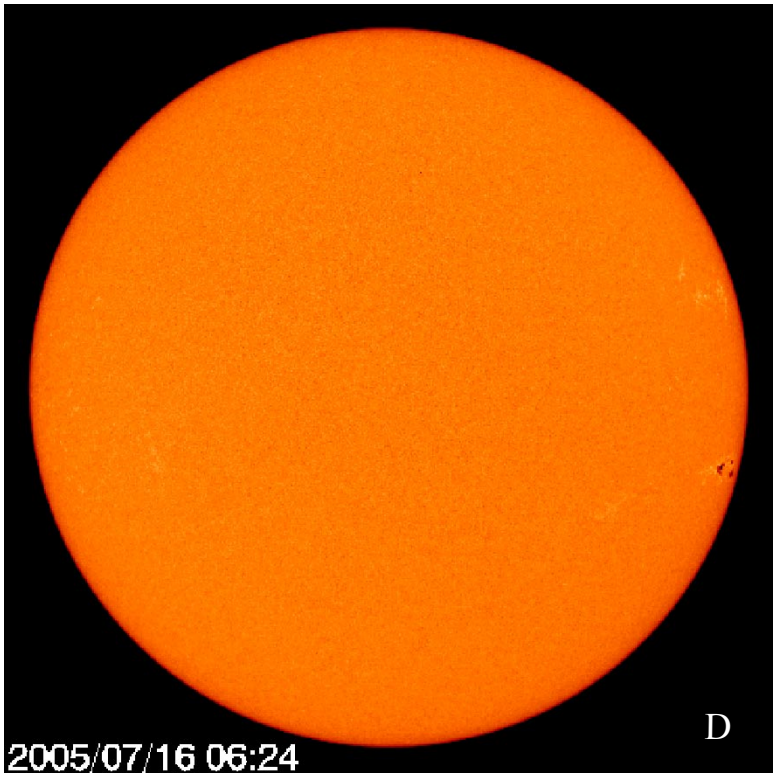
Graphing Sunspot Cycles

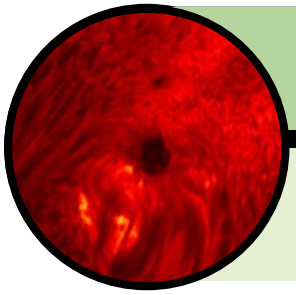
Instructor: Copy the following images of the Sun onto overhead transparency. See introduction for details about images.











Page 1: Graphing Sunspots

Name _____

Date _____ Class _____

Make a graph of the number of sunspots over time:

- The data below indicate the average number of sunspots for each year. Use the data to make a graph of average number of sunspots as they change over time.
- Plot sunspot number against time by making a dot on your graph wherever the year and appropriate sunspot number intersect.
- Connect the points you've plotted with a line.

1970	109
1971	74
1972	72
1973	39
1974	34
1975	15
1976	14
1977	30
1978	103
1979	156
1980	141
1981	141
1982	116
1983	72
1984	44
1985	17
1986	12
1987	28
1988	89
1989	148
1990	149
1991	146
1992	96
1993	54
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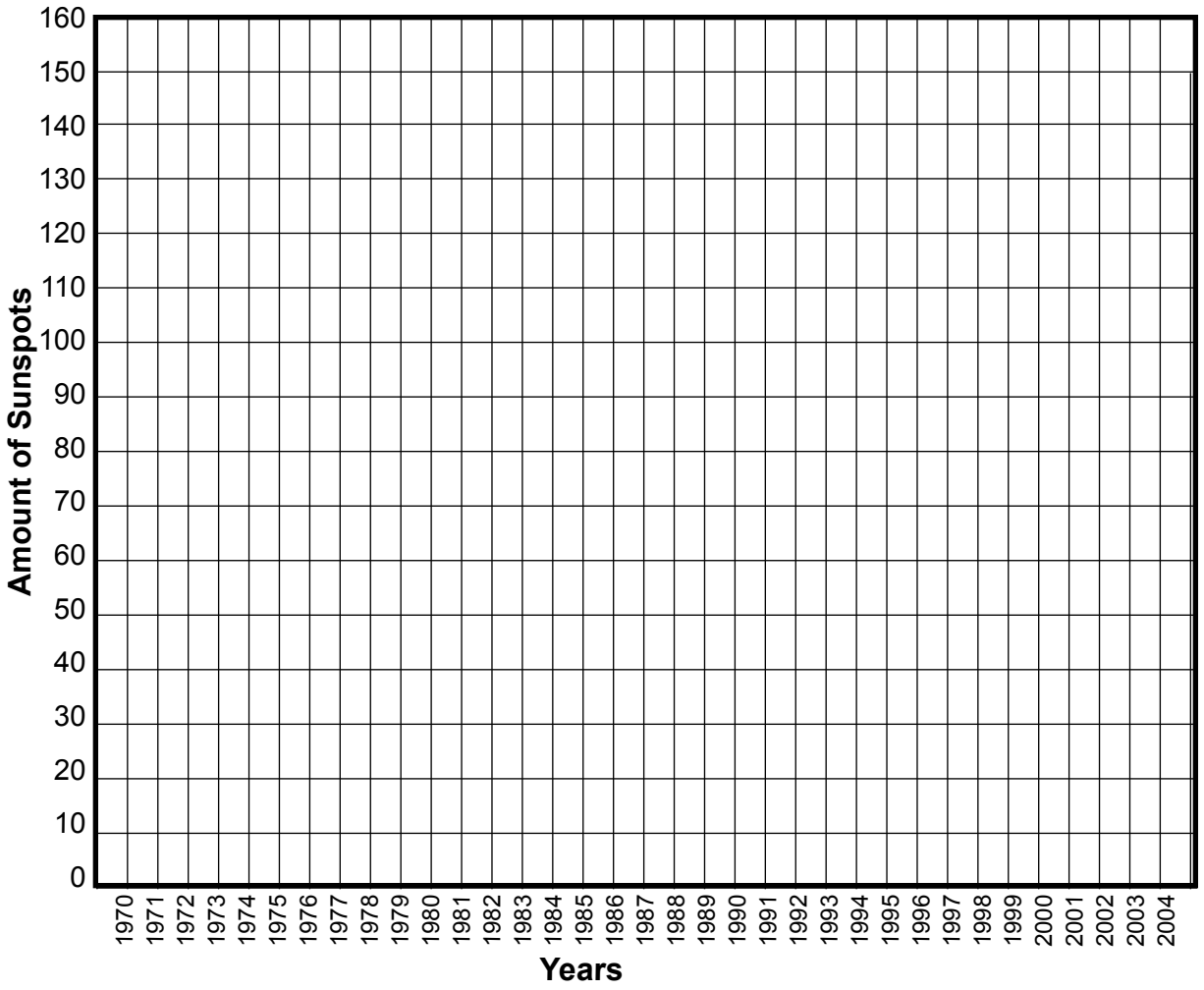
1996	9
1997	22
1998	65
1999	94
2000	120
2001	111
2002	104
2003	64
2004	41



Answer these questions!

1. How many years are there between each time of abundant sunspots and each time of fewest sunspots? (In other words, how often does the pattern repeat?)

   _____

2. Make predictions! Will there be many or few sunspots during:
   - the year you graduate from high school? _____
   - the year you were born? _____
   - the year you turn 21 years old? _____

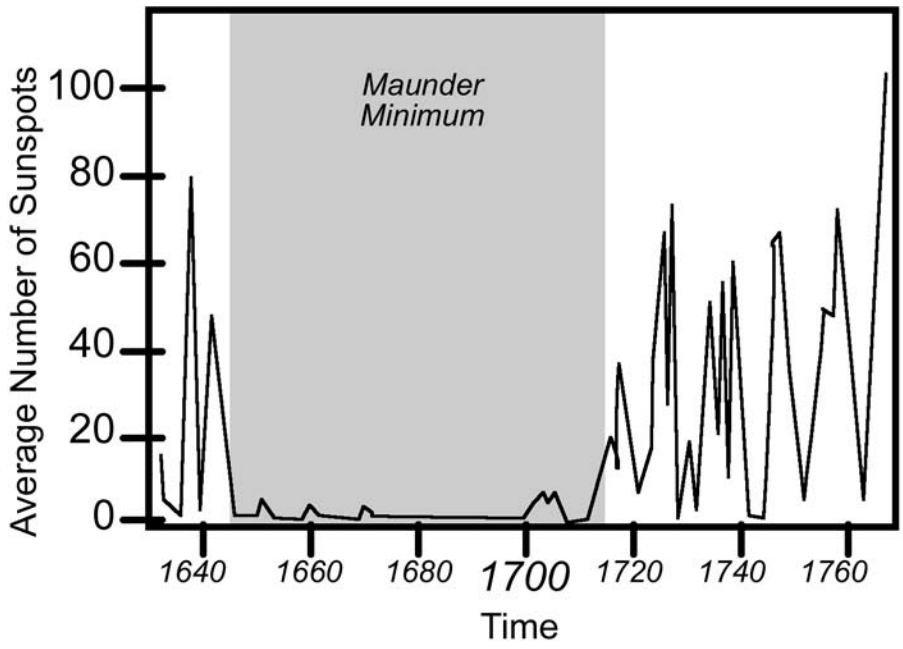
Page 2:
Sunspots and Climate

Name _____

Date _____ Class _____

Directions:

- Examine the graph and answer the questions below.
- To begin, identify the axes. What is the horizontal (x) axis? What is the vertical (y) axis? What does each axis represent?



Answer these questions!

1. How is this graph similar to the graph that you made of sunspot data from 1970-2004? _____

_____

2. How is this graph different than sunspot data 1970-2004?_____

_____

3. The area shaded grey indicates a time of cool climate called the *Maunder Minimum*. Knowing this clue, you will be able to mark the following **true** or **false**.

T F More sunspots mean more energy comes from the Sun.
T F Less sunspots means that Earth has a warmer climate.
T F Less sunspots means that Earth gets less energy from the Sun.
T F More sunspots means that Earth has a warmer climate.