



The Little Ice Age - Understanding Climate and Climate Change

Unit: Little Ice Age
Lesson: 9

Materials & Preparation

Time:

- Preparation: 10 min
- Teaching: 45 min

Materials for the Teacher:

- Overhead projector
- Overhead transparencies of student pages 1 - 4
- Overhead transparency marker

Materials for Students:

- Pencil
- 1 per student of student pages 1 - 3,
- OR one of student pages 1, 2, or 3 for each group of 3-4 students

National Science Standards

- Science as Inquiry: Content Standard A
- Earth and Space Science: Content Standard D
- History and Nature of Science: Content Standard G

Colorado State Science Standards

- Science: 1, 4, 6

Learning Goals

Students will:

- Read and interpret graphs about natural events.
- Communicate their understanding of scientific data to peers.
- Describe climate and changes in climate during the Little Ice Age.

What Students Do In This Activity

Students receive data about tree ring records, solar activity, and volcanic eruptions during the Little Ice Age (1350-1850). By comparing and contrasting time intervals when tree growth was at a minimum, solar activity was low, and major volcanic eruptions occurred, they draw conclusions about possible natural causes of climate change.

Key Concepts

- Sunspots numbers increase and decrease on an 11-year cycle but were virtually absent during the Little Ice Age.
- Particles in the atmosphere from volcanic eruptions can reduce the amount of sunlight reaching Earth and cool the planet. At times when volcanic eruptions were more common through history, they caused global climate to cool.
- The amount of tree growth changes from year to year in response to long term climate changes. Less growth correlates with shorter growing seasons. Thus, tree rings can serve as a proxy for temperature records.



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Advanced Preparation

- Prepare overhead transparencies of all four Student Pages
- Copy Student Pages 1-3 for students either (1) to have one of each for each student if they will be working individually, (2) to have enough for student groups to share pages, or (3) to have each group interpret a different Student Page.

Introducing the Lesson

- *Note: This lesson is a nice summary after students have gained experience with the interpretation of data about the Little Ice Age from other activities within the Paleoclimatology section of this Teacher Guide. For other activities, visit: www.eo.ucar.edu/educators/ClimateDiscovery/LIA.htm*
- Explain to students that they will compile and interpret clues about the causes and effects of the Little Ice Age. The clues that they will use are data about past natural phenomena.
- As a class, brainstorm a list of natural events that could cause the Earth's climate to cool and a list of effects that climate cooling might have on Earth.

Facilitating the Lesson

- Arrange the students into groups of three or four.
- Provide each group with Student Page 1, 2, or 3. (Or, provide all three pages to each group or each student.)
- Ask the students to study the graph and participate in discussions with each other as they answer questions about the graph(s) on their student page(s). Have a student from each group be a scribe and record group answers.
- Place a transparency of the table/timeline from Student Page 4 on the projector. Describe to students that they will collectively use the table to summarize the solar, volcano, and tree ring data.
- Invite student groups to report their conclusions to the class as they show an overhead transparency of their student page about solar activity, volcanic ash in the atmosphere, and tree growth.
- Ask one student from each group to use the erasable pen to mark the time periods on the Student Page 4 timeline that best represents periods of lowest tree growth and highest volcanic ash in the atmosphere.
- Ask the students if they can see any relationships between the tree ring, solar, and volcanic activity. Review class brainstorms from introduction in the context of their data interpretation (for example, less sunspots correlates with cooling).
- Ask students to hypothesize when the coolest part of the Little Ice Age was, according to their data interpretation.
- Summarize by reviewing the lesson's key concepts listed on Page 1 of this lesson.

Science Background Information

The Little Ice Age

The Little Ice Age (1350-1850) was a period of particularly harsh climate conditions around the Northern Hemisphere. A combination of decreased solar activity and numerous large volcanic eruptions cooled the Earth. Cooling caused glaciers to advance and stunted tree growth. Livestock died, harvests failed, and humans suffered from the increased frequency of famine and disease. The Little Ice Age illustrates changes to climate that occur when the Sun is less active and cooling of Earth is exacerbated by volcanic eruptions. Many other examples of climate change due to natural forces exist, including the "year without a summer" which followed the 1815 eruption of Tambora, Indonesia.

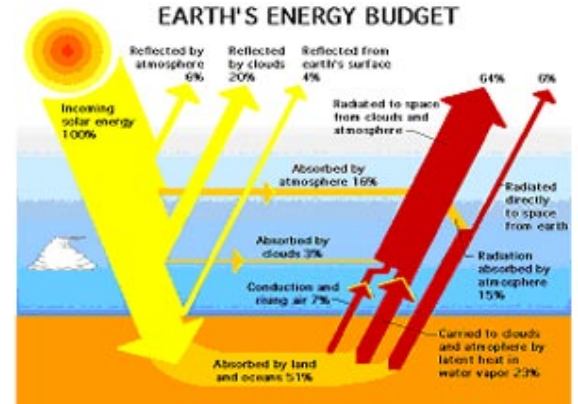


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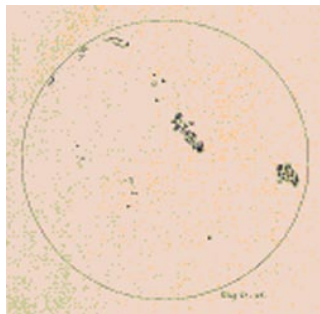
Solar and Volcanic Influences on Climate

Earth's climate is determined by the amount of energy it receives from the Sun, less the amount of energy that is reflected back into space. This is known as the "Earth's energy budget." The climate warms or cools depending upon the difference between energy absorbed and reflected.

Variations in the amount of solar radiation, due to variations in the number of sunspots, affect this balance. Volcanic eruptions produce clouds of dust, ash, and other tiny particles that encourage clouds to form, blocking incoming solar radiation and causing cooling. The combined effects of the solar cycle and volcanic eruptions naturally force changes in the climate. The Little Ice Age occurred at a time when the Sun's activity was at a minimum and volcanoes were very active. No sunspots were seen from 1645-1715, and volcanoes in South America and East Asia produced massive eruptions from 1600 through 1700.



(Source: NASA. Larger version suitable for classroom use available at <http://asd-www.larc.nasa.gov/erbe/components2.gif>)



Sunspots as recorded by Galileo on June 26, 1613

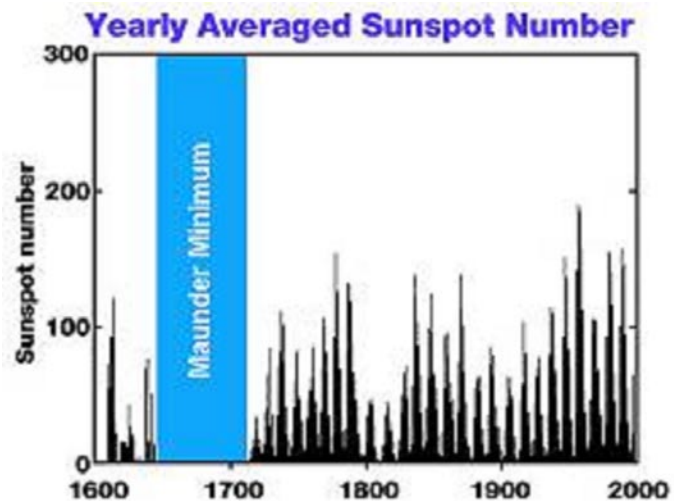
Cycles of Solar Activity

The energy output of the Sun, once thought to be constant, varies on an 11-year cycle in response to changes in the solar magnetic fields. Sunspots, areas of high magnetic activity, appear in greater or lesser numbers as the solar magnetic fields change. Cooler than their surroundings, sunspots occur along with heat producing events called faculae and flares. As a result, periods of intense sunspot activity correspond to increased energy from the Sun and warmer periods on Earth. The Earth cools when sunspot activity decreases.

The astronomer, Galileo Galilee observed and recorded sunspots in the early 1600's with the aid of one of the first

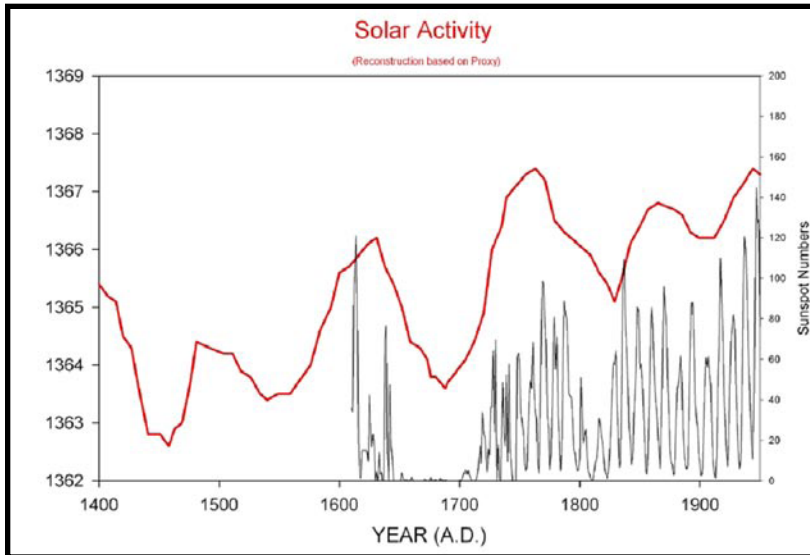
telescopes. Since then, astronomers have kept a near-complete record of sunspot activity. These records show that the numbers of sunspots increase and decrease approximately every 11 years.

In 1890, astronomer E.W. Maunder reviewed centuries of sunspot data and identified a period (1645-1715) during which few or no sunspots formed. The period, known as the *Maunder Minimum*, coincides with years of hardship and harsh winter conditions in Europe. Scientists have used other methods to look for increases and decreases in solar activity, including examining the concentration of Beryllium-10, an isotope produced in abundance when the





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Solar activity (red upper line) related to Sun spot numbers (black lower line) 1400 - 2000 (Source: Ammann)

reflects 31% of the energy received from the Sun. But the Earth's surface does not reflect energy uniformly. Clouds, ice, and snow reflect up to 90% of the light from the Sun, whereas oceans reflect only about 10%. The eruption of Mt. Pinatubo in June of 1991, forced approximately 25 tons of material into the atmosphere, increasing the atmospheric sulfuric acid content 100 times. Following the Pinatubo eruption, Earth cooled by 0.5 degrees Centigrade.

Polar ice layers preserve the record of ancient volcanic activity. Eventually, precipitation cleanses the atmosphere of the volcanic ash and gas. The layer of sulfuric acid in the atmosphere forms a layer of acid-rich ice at the poles. Scientists measure the levels of sulfuric acid in ice cores to reconstruct the history of volcanic activity.

Looking for Patterns in Data

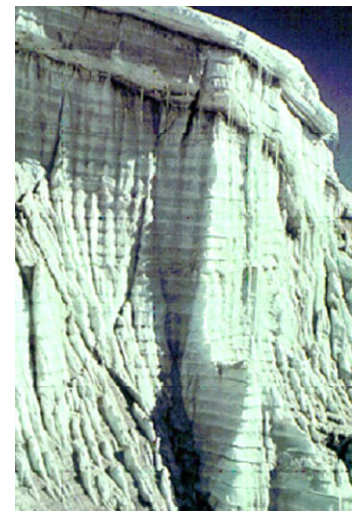
The British began the study of climate in the mid-1800s in an effort to predict the monsoon season and plan ocean travel to colonies in the Far East. One scientist, Charles Meldrum, found that monsoons increased as the number of sunspots increased. This study drew attention to the relationship between the Sun and Earth's climate. Scientists reasoned that the Sun's energy drove the climate and weather patterns on Earth and especially seasonal storms such as monsoons. A flurry of research activity produced numerous studies that related solar activity to observed events on Earth including wine production, rainfall, insect population, and more. Discrepancies in the research pointed out that the 11-year solar cycle explained only some of the changes in climate. Sometimes, when the activity of the Sun increased, the climate did not warm as predicted. At other times, cooling was extreme. Scientists began to look for other contributing factors to the Sun-climate change relationship. In 1960, Hubert Lamb proposed that volcanic activity accounted for the randomness of some

magnetic activity of the Sun decreases.

Volcanic Eruptions Cool Earth

Volcanic activity affects the Earth's energy budget. Major volcanic activity produces a layer of ash and gas that scatters incoming sunlight, therefore causing Earth to cool. Sulfur gas, shot into the atmosphere by an eruption, combines with water vapor in the atmosphere to form a layer of sulfuric acid. This layer of very fine molecules increases the reflectivity of the atmosphere and Earth's albedo.

Albedo describes the ability of a surface to reflect light. Albedo is measured on a scale from 0 to 1 where zero represents no reflectivity and 1 represents 100% reflectivity. On average, Earth





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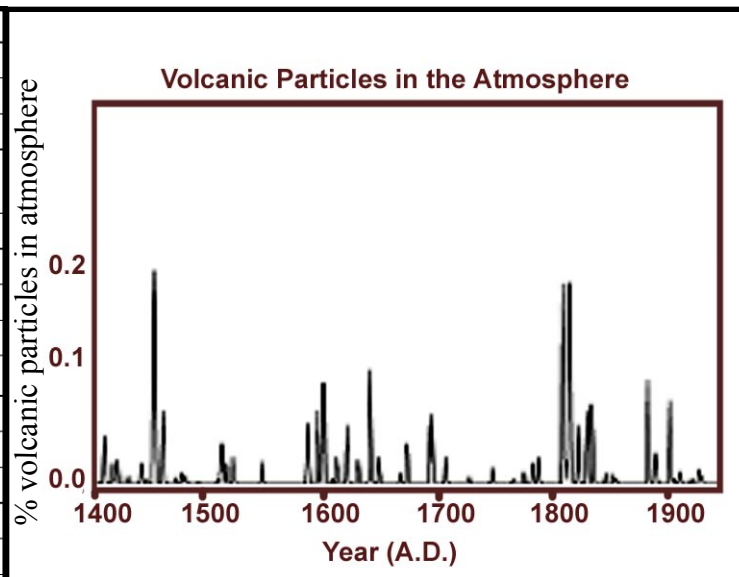
climate data. Since then, studies have shown that volcanic activity cools the climate and exacerbates cooling or inhibits warming trends associated with the 11-year solar cycle.

Nature responds to short and long term cycles of climate change. Trees respond to both punctuated volcanic events and long term solar activity, which causes variations in the growing season. Other natural phenomena respond to changes in the climate as well. For example, the bloom date for a flower plant such as the cherry tree, varies annually with weather and over many years in response to climate change.

Additional Resources

- Windows to the Universe, <http://www.windows.ucar.edu>
- Project LEARN, <http://www.ucar.edu/learn/>
- The Galileo Project, <http://galileo.rice.edu/index.html>
- Climate Change Sites
 - <http://www.ngdc.noaa.gov/paleo/education.html>
 - <http://www.exploratorium.edu/climate/>

Date	Volcano
1452	Kuuae, Vanuatu, SW Pacific
1480	St. Helens, Washington, US
1482	St. Helens, Washington, US
1580	Billy Mitchell, Bouganiville, SW Pacific
1600	Huaynaputina, Peru
1641	Parker, Philippines
1660	Long Island, New Guinea
1680	Tongkoko, Sulawesi
1815	Tambora, Lesser Sunda Island
1883	Krakatau, west of Java
1902	Santa Maria, Guatemala
1912	Novarauputa (Katmal), Alaska
1980	St. Helens, Washington, US
1991	Pinatubo, Philippines



Left: A partial list of major volcanic eruptions from 1400 to the present, source: Ammann
 Right: The amount of particulate matter generated by large volcanic eruptions between 1400 and the present. Source, Ammann



Name _____
 Date _____ Class _____

Solar Activity During the Little Ice Age

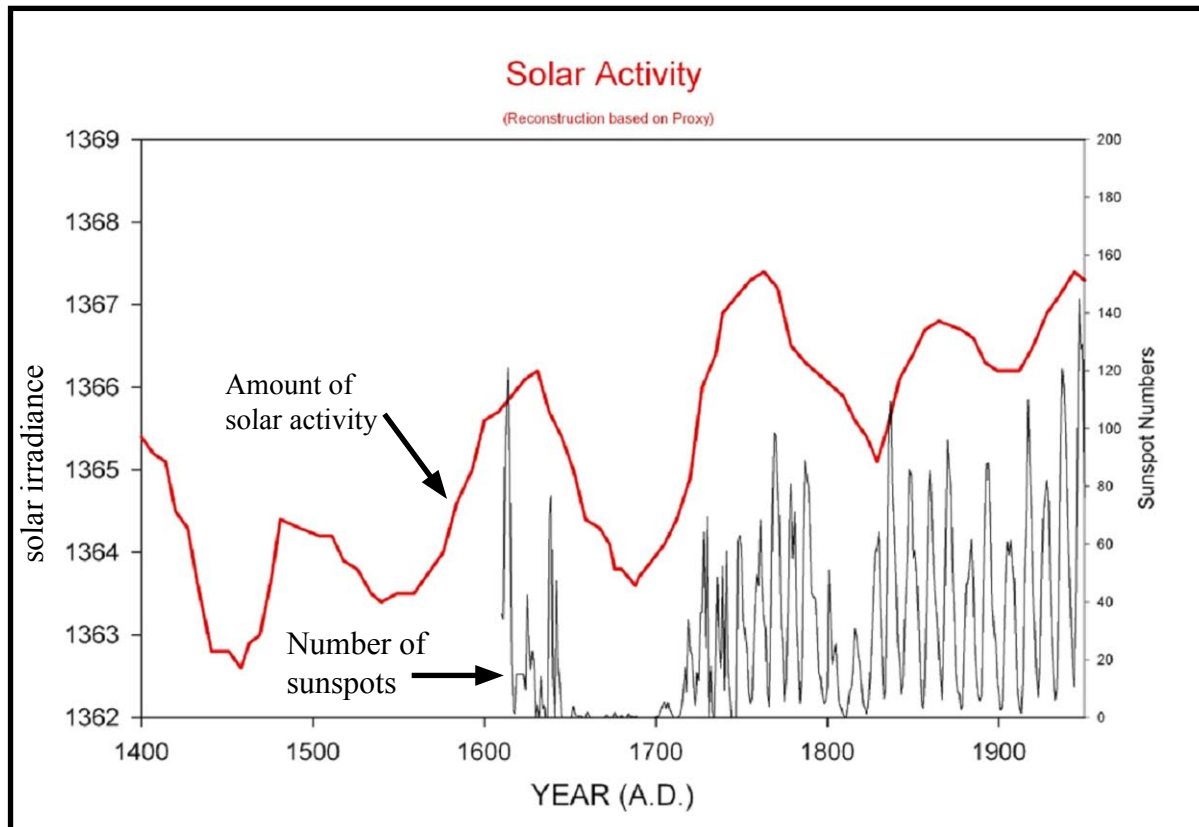
Directions:

In the graph below, the bottom jagged line indicates the number of sunspots counted during each of the solar cycles observed between 1400 and 1950 AD.

The upper line in the graph shows when solar activity increased and decreased during this time period, taking into account the sunspot cycles and other observations of the Sun.

Study the graph to answer the following questions:

- Do the highest numbers of observed sunspots coincide in any way with the line showing the highest levels of solar activity? If so, in about what years is this true?
- Do you think more solar activity would increase or decrease the amount of sunlight reaching the Earth's surface? Please explain.
- Write on the line below the years in which the sunspot cycle was entirely absent or the least number of sunspots were observed. Circle these locations on the graph.





Name _____

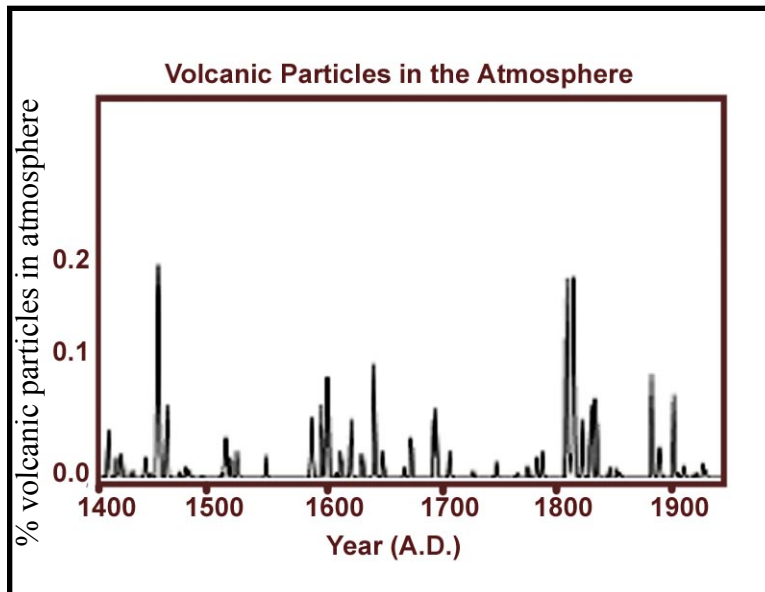
Date _____ Class _____

Volcanic Activity During the Little Ice Age

Directions:

Study the graph shown below of volcanic particles in the atmosphere as you answer the following questions.

- How do you think volcanic particles get into the atmosphere?
- What do you think volcanic particles are made of?
- Do you think volcanic particles in the atmosphere would increase or decrease the amount of sunlight reaching the Earth's surface? Please explain.
- Do you think that a major volcanic eruption might help bring about global warming, or global cooling? Explain your answer.
- Write on the line below the years in which there were especially high amounts of volcanic particles in the atmosphere. Circle these locations on the graph as well.





Name _____
Date _____ Class _____

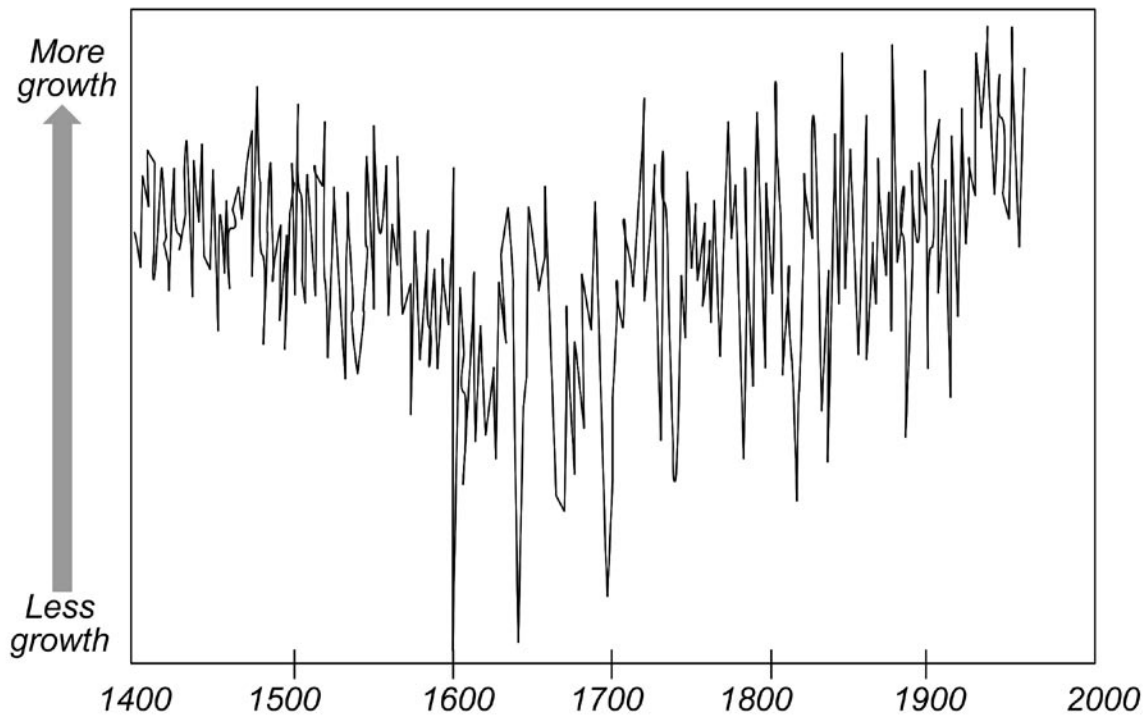
Tree Growth in Northern Europe

Directions:

The graph represents the average growth of many different trees, not just one tree. Study the graph below and answer the following questions:

- Does this graph indicate that the amount of tree growth tends to remain the same from year to year, or vary a lot over time?
- Does the pattern of tree growth indicate times when growth was slower? Circle places on the graph when tree growth was slower.
- What might slower growth mean about the climate?
- Write down the years on the line below when the amount of tree growth in Northern Europe was especially low.

Tree Growth in Northern Europe





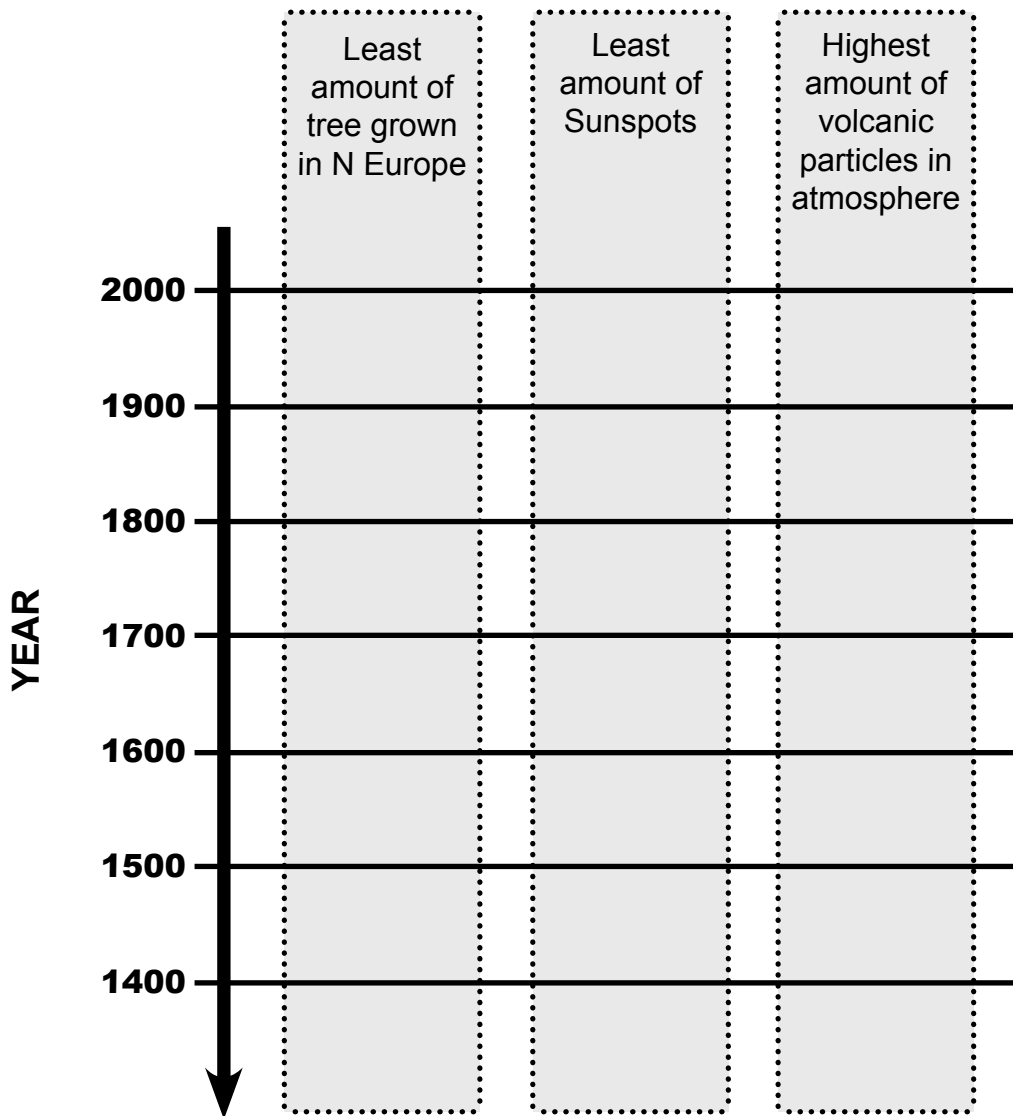
Name _____

Date _____ Class _____

Finding the Causes of Global Climate Change

Directions:

In the table below, place an X or draw a vertical line that covers a time period that best represents the information requested.



Question:

If low tree growth, few sunspots, and many volcanic particles mean cooler climate, when do you hypothesize that Earth's climate would be coolest based on the information in the table above?