

# *It's a Small World:*



*Photo courtesy of Emily K. Heyerdahl.*

***How Oceans and the Climate  
Can Affect Wildland Fires  
Thousands of Miles Away***



## Meet the Scientists

**Dr. Thomas Kitzberger**, Biogeographer (bī ō jē ä grə fər): My favorite science experience is scouting large unexplored areas in search of evidence of past fires from old trees. It is like time traveling to find an old tree with many fire scars. It makes you think, "This tree was born way before Columbus arrived in America. This tree witnessed cultures from which humankind does not have written reports." Through careful study, trees tell stories about people and how they interacted with their environment. ►



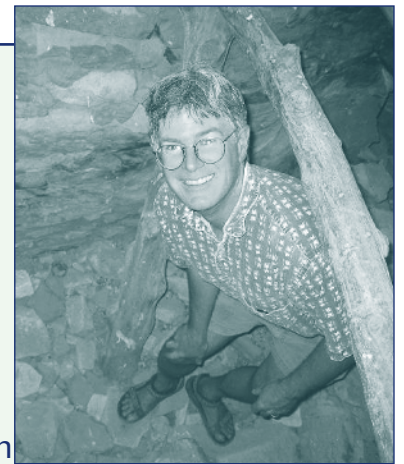
▲ **Dr. Emily Heyerdahl**, Dendrochronologist: My favorite science experience is solving ecological puzzles about past wildland fires using tree rings. Just as when I was a young woman, I like being outside all summer collecting data and **samples** from trees that were alive hundreds of years ago. During the winter and in the laboratory, I also take joy in dating wood samples with a microscope and in exploring data with a computer.



► **Dr. Peter Brown**, Dendrochronologist (den drō krə nă lə jist): My favorite science experience was certainly the earliest I can remember. I grew up on the Navajo Indian Reservation in northern Arizona. When I was in second grade, I rode a horse out to Keet Seel Ruin to visit a dendrochronologist named Jeff Dean. He was using tree rings to find the ages of the timbers used for construction of the village. Keet Seel is a very large and well-preserved cliff dwelling built by the Ancestral Pueblo people in the 13th century (1200s).

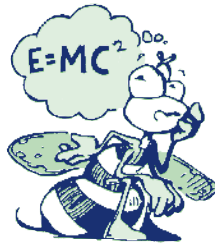
Using cross-dating, Dr. Dean documented the dates when people cut the trees used in their dwellings. Cross-dating is a method used to match tree-ring patterns in different trees. Cross-dating enables dendrochronologists to go back in time. This is what tree ring scientists do all the time, not only to study **archaeology**, but also to look at past rainfall and many other things that influence tree growth.

**Dr. Thomas Veblen**, Physical Geographer: My favorite science experience is learning what tree rings can tell us about the history of insect outbreaks on trees. ▼

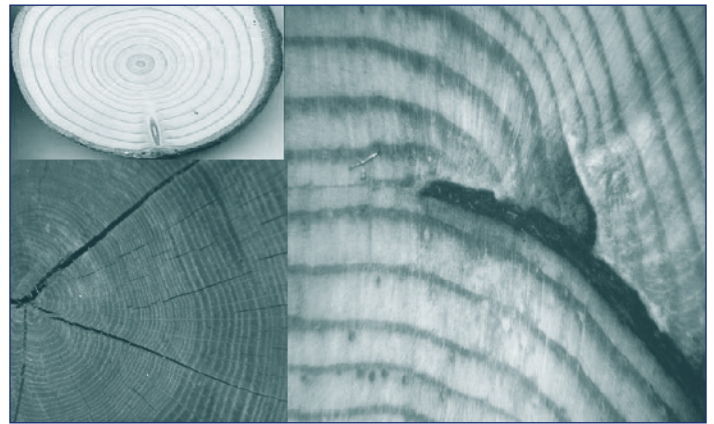


## Thinking About Science

Sometimes it is hard to study the past. This is especially true if the past you want to study was hundreds or thousands of years ago. It is made more difficult if the past you want to study has no written records. Some scientists, such as archeologists (**är kē ä lə jists**) and paleontologists (**pā lē än tā lə jists**), use items from the past as clues. Archeologists usually use human-made items, and paleontologists usually use natural clues. A dendrochronologist is a scientist who uses the natural clues found in tree rings (**figure 1**).



**Figure 1.** Dendrochronologists are able to date Native American historic and cultural sites using wood samples. Photo courtesy of Peter Brown.



**Figure 2.** Tree rings provide clues about a tree's history. On the right, a fire scar was created when a surface fire burned near the tree. Photos courtesy of Emily K. Heyerdahl and the Forest Service.

## Thinking About the Environment

You may have heard the expression, “It’s a small world.” It seems hard to believe, but many ecosystems on Earth are connected, even if they are located far apart. For example, glaciers in Arctic regions hold large amounts of fresh water when they are frozen and release that water when the temperature rises. This can cause changes in ocean temperatures and currents far from Earth’s Arctic regions. Another example is the Gulf Stream, which is a current of seawater moving up the eastern North American coast and finally eastward to northern Europe. Although Norway is located close to the Arctic

region, the Gulf Stream keeps that country’s west coast free of ice all year.

The oceans, in particular, affect many climatic (**klī ma tik**) and weather events on land. You are probably aware of the formation of hurricanes and cyclones, which form over ocean waters and sometimes reach coastal areas. Scientists have discovered that oceans can even affect the occurrence of wildland fire.

The scientists in this study were interested in exploring the connection between ocean patterns, climate, and the timing of wildland fires in the Western United States.

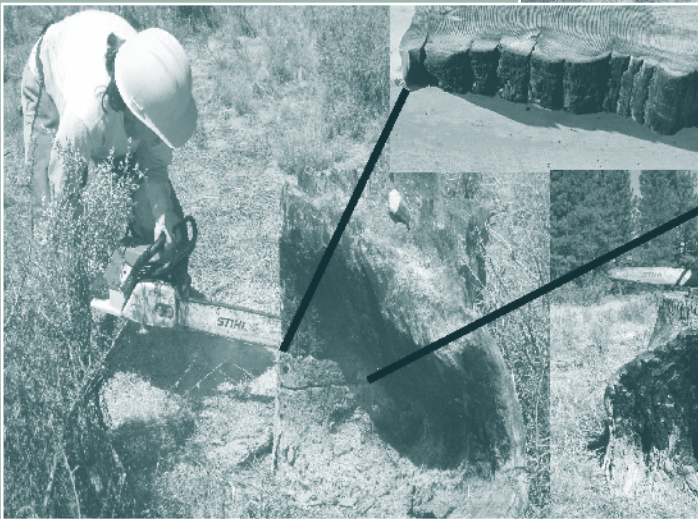




## What is dendrochronology?

Dendrochronology is the study of “tree time” and is also called tree-ring dating. Dendrochronology is a science based on the fact that every year a tree grows it adds a new layer of wood to its trunk; this process forms tree rings. Over a period of time, these rings form a series of light and dark circles that are visible on cross-sections of cut trees. A cross-section of a tree is when you cut a tree down and expose the middle of the tree (**figure 3**).

Often trees are sampled using a hand drill, called an increment (*in krə mənt*) borer (**figure 4**). Neither of these techniques kills the trees.



**Figure 3.** Dendrochronologists use chain saws to take samples from trees that are already dead, like these old stumps. Photo courtesy of James P. Riser, II, and Emily K. Heyerdahl.

**Figure 4.** Dendrochronologists do not have to kill trees to get information from tree rings. An increment borer allows scientists to pull a small sample of the tree’s rings. The hole created by the borer is then sealed to protect the tree. The sample is a long, thin cylinder of wood. Photo courtesy of Edward Cook and the National Oceanic and Atmospheric Administration (NOAA) Paleoclimatology Program, U.S. Department of Commerce.

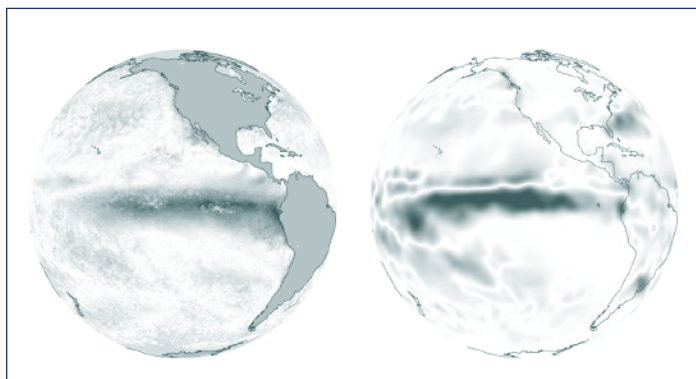
## Introduction

Scientists have identified a number of **periodic** changes in **sea surface temperatures** that affect climate over land. The scientists in this study were interested in three periodic changes, called **oscillations**, in sea surface temperatures that vary over different time scales (**figure 5**).

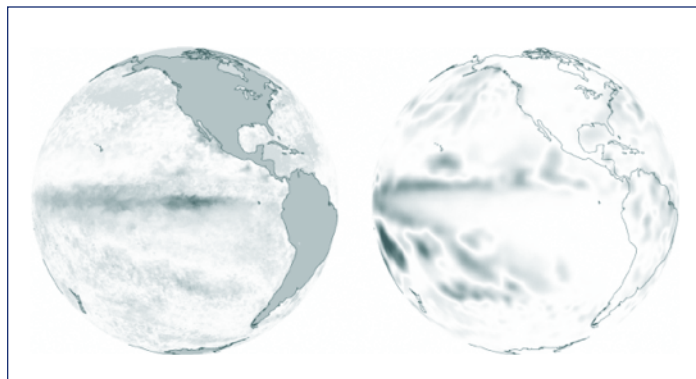
The most rapid periodic sea surface temperature change is called the El Niño–Southern Oscillation, or ENSO (**figures 6a and 6b**). ENSO changes every 2 to 7 years in the tropical Pacific Ocean. The change involves a warming or cooling of the water at the ocean’s surface. The warm phase of ENSO is called El Niño, and the cool phase is called La Niña.

Oscillation	Where?	How long?	Sea Surface Temperature?
ENSO	Tropical Pacific Ocean	2 to 7 years	Warm and Cool
PDO	North Pacific Ocean	20 years	Warm and Cool
AMO	Atlantic Ocean	60 years	Warm and Cool

**Figure 5.** A comparison of El Niño–Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and Atlantic Multidecadal Oscillation (AMO).



**Figure 6a.** These two globes show the relationship between ocean temperature and rainfall during the 1997 El Niño. On the left, the darkest streaks shows warmer ocean sea surface temperatures. The warm water easily evaporates and storms are more likely to form. On the right, the darkest areas indicate heavy rainfall. You can see that heavy rain fell in the Pacific Ocean, along the coast of Northwestern South America and in the Southeastern United States. From the National Aeronautics and Space Administration (NASA) Earth Observatory, <http://earthobservatory.nasa.gov>.



**Figure 6b.** These two globes show the relationship between ocean temperature and rainfall during the 1988 La Niña. On the left, the darkest streaks show that sea surface temperatures were cool in the east Pacific off of the coast of South America. Since cool air is dense, it does not rise and storms are not likely to form. On the right, the darkest areas show places where drought (very low rainfall) occurred in Northwest South America and the Southeastern United States. The Southeastern United States is the area in the United States most affected by ENSO. From NASA Earth Observatory, <http://earthobservatory.nasa.gov>.



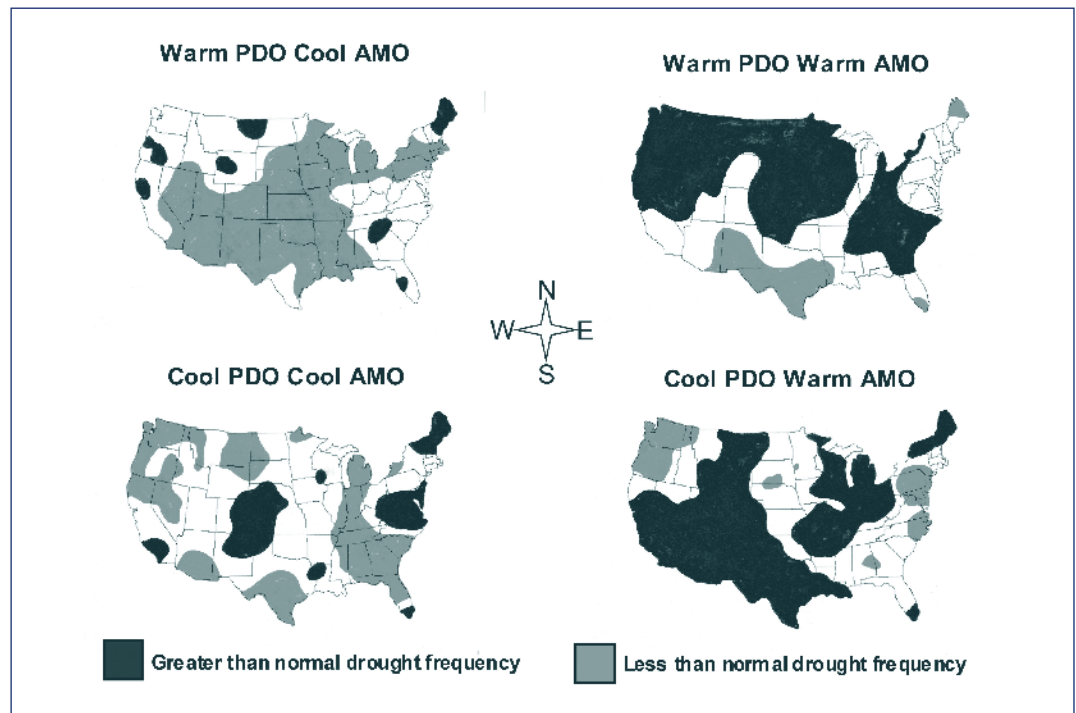
A second sea surface temperature change is the Pacific Decadal (de kə dəl) Oscillation, or PDO. PDO changes like ENSO, but only about every 20 years, and it occurs in the North Pacific Ocean. The sea surface temperature pattern that changes the most slowly is the Atlantic Multidecadal (mul tī de kə dəl) Oscillation, or AMO. It occurs in the Atlantic Ocean and changes about every 60 years (**figure 7**).

These periodic changes in sea surface temperature affect climate on land. For example, during years when AMO is in its warm phase, the entire Western United States is generally warm and dry (**figure 8**). These warm, dry conditions mean wildfires are more likely.

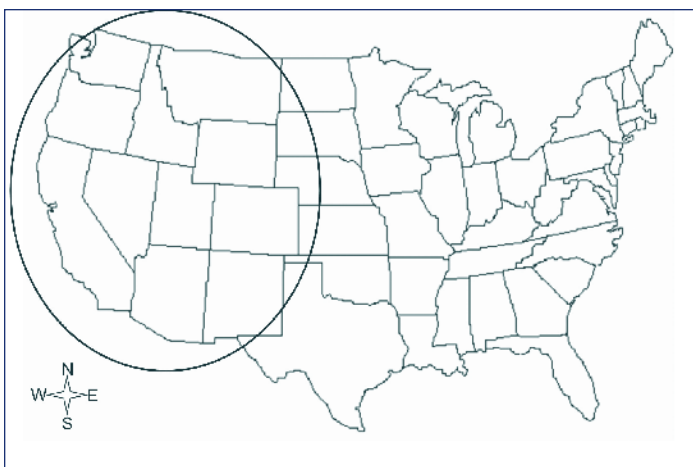
ENSO and PDO affect climate in different parts of the Western United States in different ways. For example, during years when ENSO is in its warm phase, the Southwestern United States is generally cool

and rainy whereas the Northwest is generally warm and dry. During these years, there is less chance of wildfires in the Southwest than in the Northwest.

The scientists in this study were interested in the relationship between the phases of ENSO, PDO, and AMO and when wildfires occurred in the Western United States over a 400-year time span.



**Figure 7.** PDO and AMO patterns affect **drought** conditions in the United States. Image adapted from the U.S. Geological Survey (USGS).



**Figure 8.** The Western United States.

## Reflection Section

- What is the question the scientists were trying to answer?
- Do you think there were written records about fire or sea surface temperature patterns such as ENSO, PDO, and AMO hundreds of years ago? Why or why not?

## Methods

The scientists studied the period of time between 1550 and 1924. They needed three kinds of information for the Western United States for each year of this 374-year period. First, they needed to know what the climate was like and how it differed across the area. For example, was it dry to the north but wet to the south or was it dry everywhere? Second, they needed to know the phase of each of the three oscillations. Finally, they needed to know when and where wildfires burned.

To get information about climate and sea surface temperatures, the scientists used information already collected by other scientists. From the ring widths of trees living during these 374 years, other scientists had identified which years were rainy and which were dry. Because sea surface temperature also affects climate, still other scientists had used ring widths from trees to identify sea surface temperature patterns. In other words, they identified which phases of ENSO, PDO, and AMO occurred each year.

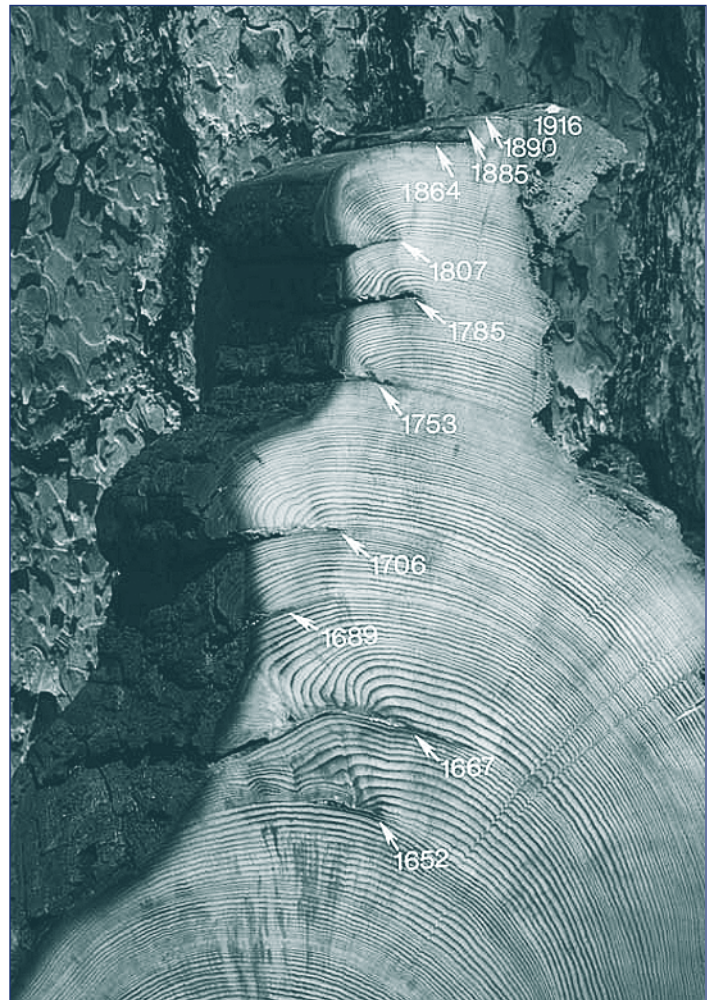
### Number Crunches

🍁 About how many warm phases of the AMO did the scientists study? About how many cool phases did they study? How many would they have been able to study if they only used written records from 1900 to today?

To get information about when and where wildfires occurred, the scientists once again used data that had already been collected. They did not need to collect new data because a **database** is available that contains a history of wildfires recorded by tree rings. The database is like a fire history museum. Scientists from around the world give their tree-ring data to

this database so anyone can use their data to study wildfires in the past. The scientists used information from the database that was collected from more than 4,700 trees whose rings had recorded 33,039 fire scars in the Western United States (**figure 9**).

Once they had collected the three kinds of information, the scientists identified the climate and phase of each oscillation during years when many fires occurred all across the Western United States and when many fires occurred only in certain areas. They used a computer to help them with their analysis because there was so much information.



**Figure 9.** Scientists examined tree-ring fire scars from samples already collected. Photo courtesy of Peter Brown.



# Wondering about wildfires



**Y**ou might be surprised to learn that fire is a natural part of the environment. Fire scars in tree rings show that in the past, fires burned in some forests every 10 to 20 years for many hundreds of years. Certain ecosystems depend on wildland fires to be healthy and **sustainable**. Wildland fires help plants grow by replacing **nutrients** into the ecosystem from the fire's ash. There are many different types of fires. Some wildfires burn at low temperatures and burn slowly (**figure 10**). By trying to eliminate wildfires in the past, we have actually encouraged more fires to burn in forests that mostly had surface fires in the past. Now, **forest managers** sometimes start small, controlled fires that burn the fuel that is close to the ground. These fires are called prescribed fires. For more information on wildfires, check out the *Natural Inquirer's* two Wildland Fire Editions!



**Figure 10.** Many trees can survive lots of fires. Fire scars are created when a surface fire burns near a tree. Photo courtesy of Michael G. Harrington.

## Reflection Section



-  Why do scientists share their data with other scientists? What is one advantage of sharing data?
-  Think about how the scientists gathered information about the past using tree rings. What are two other natural resources that contain information about the climate of the past?



## Findings

The scientists found that it really is a small world! They found that the location of wildfires was related to the phase of the oscillations during the 374-year period they studied. When ENSO and PDO were both in their warm phases, many wildfires burned in the Southwest where it was dry, but few burned in the Northwest where it was wet.



The opposite was also true. When ENSO and PDO were both in their cool phase, few wildfires burned in the Southwest but many burned in the Northwest. AMO had a different effect on wildfires. When AMO was in its warm phase, wildfires sometimes burned all across the Western United States because it was dry everywhere.

Scientists can only predict the weather a few days in the future. This is not enough to help

us know if or where wildfires are likely to burn during the next summer wildfire season. Sea surface temperature patterns, however, change periodically in ways that scientists can predict months or even years ahead. Because these oscillations affect climate, scientists can use them to predict whether and where wildfires are likely to burn in upcoming wildfire seasons.

### Reflection Section



-  In your own words, explain how trees that lived many years ago have helped scientists to understand what may happen in the future.
-  How might global climate change affect sea surface temperatures?



## Discussion

The scientists noted that the AMO pattern is now entering a warm phase. This will likely affect the occurrence of more wildfires in the Western United States. Global climate change, with rising temperatures, may cause even more warming in the Atlantic Ocean. This may increase the effect of the AMO even more.

With climate change, temperatures are likely to increase. These warming patterns may also increase the chance of wildfires in the Western United States. Larger and more frequent wildfires may occur as a result. If the patterns uncovered by the scientists continue and average temperatures continue to rise, people living in the Western United States should prepare for the possibility of more frequent wildfires in the future.

### Reflection Section



-  Now you understand that sea surface temperature patterns and wildfires appear to be connected. What are other natural processes that might be connected to each other?
-  Do you think the Western United States might have more frequent wildfires in the future? Why or why not?

## Fire Safety Tips from the Firewise Communities Program

**D**o you live in or near a forest? If so, ask the adults in your household if they have protected the house from a forest fire. Here are some fire safety tips you can do to protect your homes from fire:

1. Establish a space around your house that does not have any combustible materials. This space should be at least 30 feet or 9 meters across. The larger the space, up to 130 feet or 40 meters, the better protected your house will be. Fire is less likely to jump across 40 meters and ignite new materials.
2. Reduce the amount of vegetation close to your home.
3. Remove or thin overcrowded or weak trees near your home.
4. Cut your grass and other plants regularly.
5. Move woodpiles and building materials away from your home.
6. Keep your roof and yard clean. Clean your gutters regularly. Remove dead limbs and branches from your yard, and from the base of your chimney and deck.
7. Make sure your address is easy to read from the road, and that your driveway is large enough for emergency vehicles.
8. If you have a wood shake roof, replace it with a material that is more fire resistant.
9. Recycle your yard waste.
10. Listen to your local radio and TV stations for fire reports and instructions.

For more information check out <http://www.smokeybear.com> or <http://www.firewise.org>

## Glossary

**archeology** (är kē ä lə jē): The scientific study of historic or prehistoric peoples and their cultures by analysis of their artifacts, inscriptions, monuments, and other such remains.

**climate** (klī mət): The average condition of the weather over large areas, over a long time, or both.

**database** (dā tə bās): A comprehensive collection of related data organized for convenient access, generally in a computer.

**dendrochronologist** (den drō krə nă lə jist): A scientist who studies tree-rings.

**drought** (draüt): A period of dry weather with little or no rain.

**forest manager** (fö r əst mə ni jər): Skilled individual who takes care of natural resources.

**oscillation** (ä sə lă shən): A fluctuation between maximum and minimum values.

**periodic** (pir ē ä dik): Happening at intervals over time.

**sample** (sam pəl): Part or piece that shows what the whole group or thing is like.

**sea surface temperature** (sē sər fəs tem pə(r) chur): The temperature of the surface layer of sea or oceanic water.

**weather** (we thər): The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc.

**wildland fire** (wī(-ə)l(d) land fi(-ə)r): Fires that burn in forests, on prairies, or over other large natural areas.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide





## Time Needed:

1 class period

## Materials:

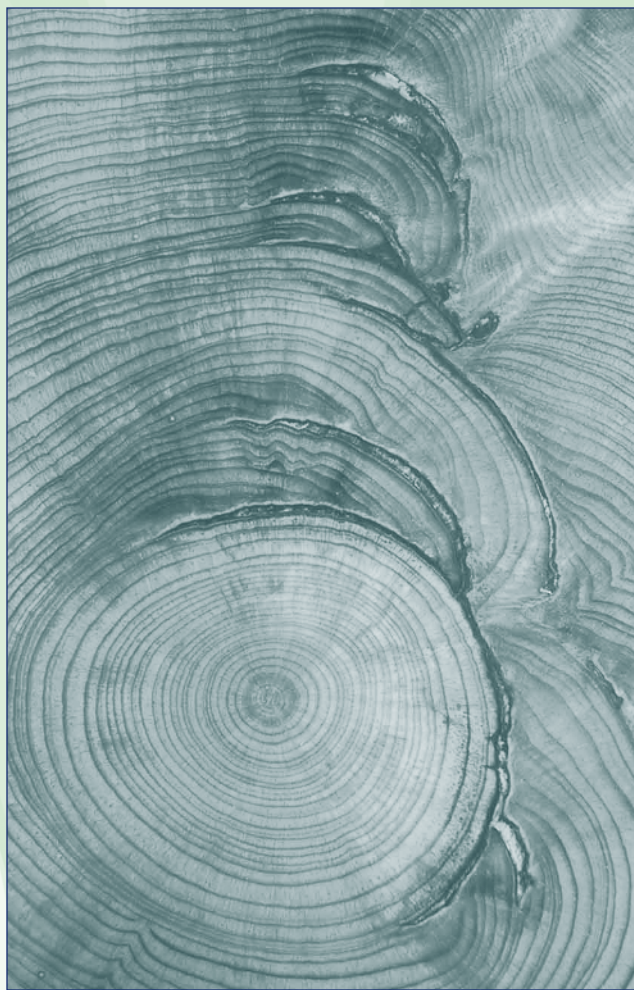
- White unlined paper.
- An assortment of crayons.  
Every student will need access to black, light brown, dark brown, and tan crayons.

The question you will answer in this FACTivity is: How do yearly weather conditions affect the way a tree's growth rings look? The objective of this FACTivity is to learn how to interpret tree rings. You will gain an understanding of what environmental factors can affect tree rings, and you will use your creativity and knowledge to create a cross-section of a tree, based on information given in the FACTivity.

Your teacher will provide the following background (or you may read it on your own):

In doing the research for this article, the scientists used tree rings that had been analyzed by dendrochronologists. Tree ring analysis requires observation and pattern recognition. Each year of its life, a tree creates a tree ring that has two parts: a light part and a dark part. The light part is called the early wood. It is created during the spring and early summer when there is usually more water available. The dark rings are called late wood. The late wood is created during the summer and sometimes in early autumn. The late-wood rings are thinner and darker than the early-wood rings because the tree does not grow as much during this time. One early-wood and one late-wood ring signify 1 year of growth for the tree.

Tree-ring width varies with growing conditions, for example the rings are wider if a lot of water is available, and they are thinner during times of low rainfall. Disease or an insect invasion can stress the tree resulting in less growth and thinner rings. Fire can leave a scar that will appear in the rings (**See figures 11-13**).

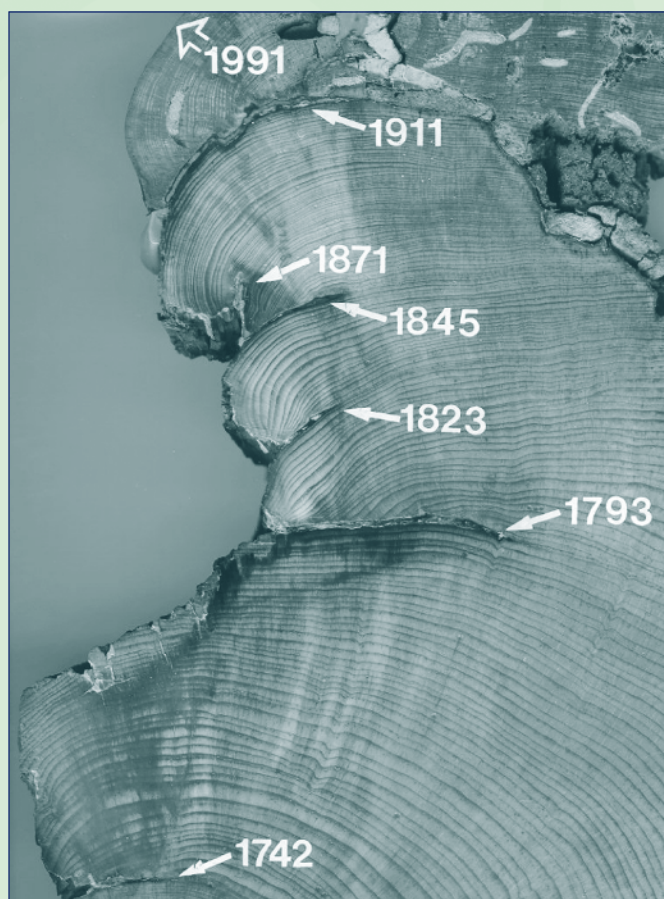


**Figure 11.** Tree cross-section showing fire scars. Photo courtesy of Peter M. Brown.



Scientists are able to study yearly weather conditions from observing tree rings. Scientists are also able to observe the tree rings and identify when insect invasions and damage from storms occurred.

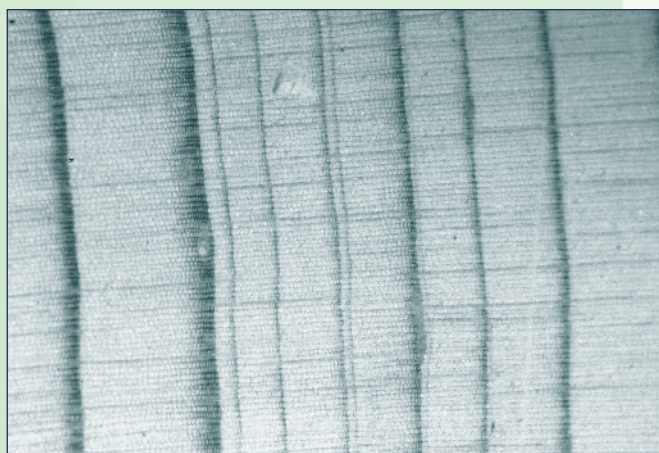
Brainstorm with other students about the different events a tree could experience during a year of growth. How might the event



**Figure 12.** Tree cross-section showing insect damage. Photo courtesy of Peter M. Brown.

affect the tree rings? For example, drought equals thinner tree rings, normal conditions will result in thicker tree rings, and insect damage could leave a scar and result in thinner tree rings.

Scenario: Scientists have the following information about the weather and other conditions that happened every year during the life of one tree. The scientists need your help to predict what the tree rings might look like during a 25-year period. Here is your opportunity to test the skills that many dendrochronologists use every day!



**Figure 13.** Tree cross-section showing years of plentiful rainfall and low rainfall. Photo courtesy of Peter M. Brown.



Refer to the chart below for the yearly conditions over the 25 years. Use a sheet of paper and crayons. Remember that one tree year includes two rings: an early-wood ring and a late-wood ring.

Based on the chart below, draw a cross-section of a tree. Remember that the tree rings for each year may look different,

depending on the weather or other conditions for that year.

Compare your completed tree cross-sections with other students. Should the cross-sections look similar? Why or why not? If they do not look similar, how are they different? Why are they different?

The 25-year period of information about weather, insect, and fire for one tree.

Year	Condition	Year	Condition	Year	Condition	Year	Condition	Year	Condition
1	Normal	6	Insect damage	11	Heavy Rain	16	Insect damage	21	Fire
2	Normal	7	Normal	12	Normal	17	Normal	22	Normal
3	Drought	8	Normal	13	Normal	18	Fire	23	Normal
4	Normal	9	Fire	14	Fire	19	Normal	24	Fire
5	Fire	10	Normal	15	Drought	20	Normal	25	Insect damage

Key to conditions:

Drought =  
little to no rain

Normal =  
adequate rain and  
no other major  
problems

Heavy rain =  
above average  
rain fall

Insect damage =  
invasion by insects  
with damage to  
tree

Fire =  
hot fire that did not  
kill tree

## Extension



Draw another tree cross-section. This time, consider what a tree might look like growing 50 years from now in a changing climate. Explain why you drew the tree cross-section the way you did. What yearly weather and other conditions will affect tree-ring growth in the future?

For additional information and another FACTivity about dendrochronology, see "Back To the Future" in this *Natural Inquirer* edition.

## What You Can Do:

# RECYCLE!

You can recycle paper and cardboard in your classroom and at home. Recycling helps keep the paper out of landfills and helps reduce the amount of carbon dioxide produced by burning the paper. You can also reduce the amount of paper you use by using both sides of the paper or by using paper as scrap paper once one side has been used.



**Teachers:** If you are a Project Learning Tree (PLT)-trained educator, you may use Activity #81, "Living with Fire" and Activity #86, "Our Changing World."

## National Science Education Standards

Standards addressed in this article include:

### Science As Inquiry:

Abilities Necessary To Do Scientific Inquiry,  
Understandings About Scientific Inquiry

### Life Science:

Populations and Ecosystems, Diversity and  
Adaptations of Organisms

### Science and Technology:

Understandings About Science and Technology

### Science in Personal and Social Perspectives:

Science and Technology in Society

### History and Nature of Science:

Science as a Human Endeavor,  
Nature of Science

## Additional Web Resources

### NOAA's El Niño Animations and Graphics

<http://www.elnino.noaa.gov/ani.html>

### Prentice Hall's Geoscience Animations for El Niño and La Niña

[http://esminfo.prenhall.com/science/geoanimations/animations/26\\_NinoNina.html](http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html)

### NASA's El Niño for Kids

<http://kids.earth.nasa.gov/archive/nino/intro.html>

### NOAA's Ocean Temperatures and Currents

<http://www.oar.noaa.gov/kl2/html/oceans2.html>

Adapted from Kitzberger, T.; Brown, P.M.; Heyerdahl, E.K.; Swetnam, T.W.; Veblen, T.T. 2007. Contingent Pacific-Atlantic Ocean influence on multicentury wildfire synchrony over western North America. *Proceedings of the National Academy of Sciences of the United States of America*. 104: 543–548. <http://www.pnas.org/cgi/doi/10.1073/pnas.0606078104>.