Earth/Environmental Science Grades 9-12

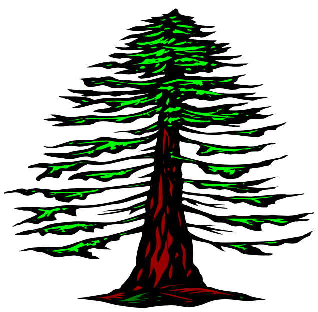
COMPETENCY GOAL 5: The learner will build an understanding of the dynamics and composition of the atmosphere and its local and global processes influencing climate and air quality.

Objectives

5.01 Analyze air masses and the life cycle of weather systems:
- Planetary wind belts.
- Air masses.
- Frontal systems.
- Cyclonic systems.

5.02 Evaluate meteorological observing, analysis, and prediction:
- Worldwide observing systems.
- Meteorological data depiction.

5.03 Analyze global atmospheric changes including changes in **CO_2**, **CH_4**, and stratosheric **O_3** and the consequences of these changes:
- Climate change.
- Changes in weather patterns.
- Increasing ultraviolet radiation.
- Sea level changes.

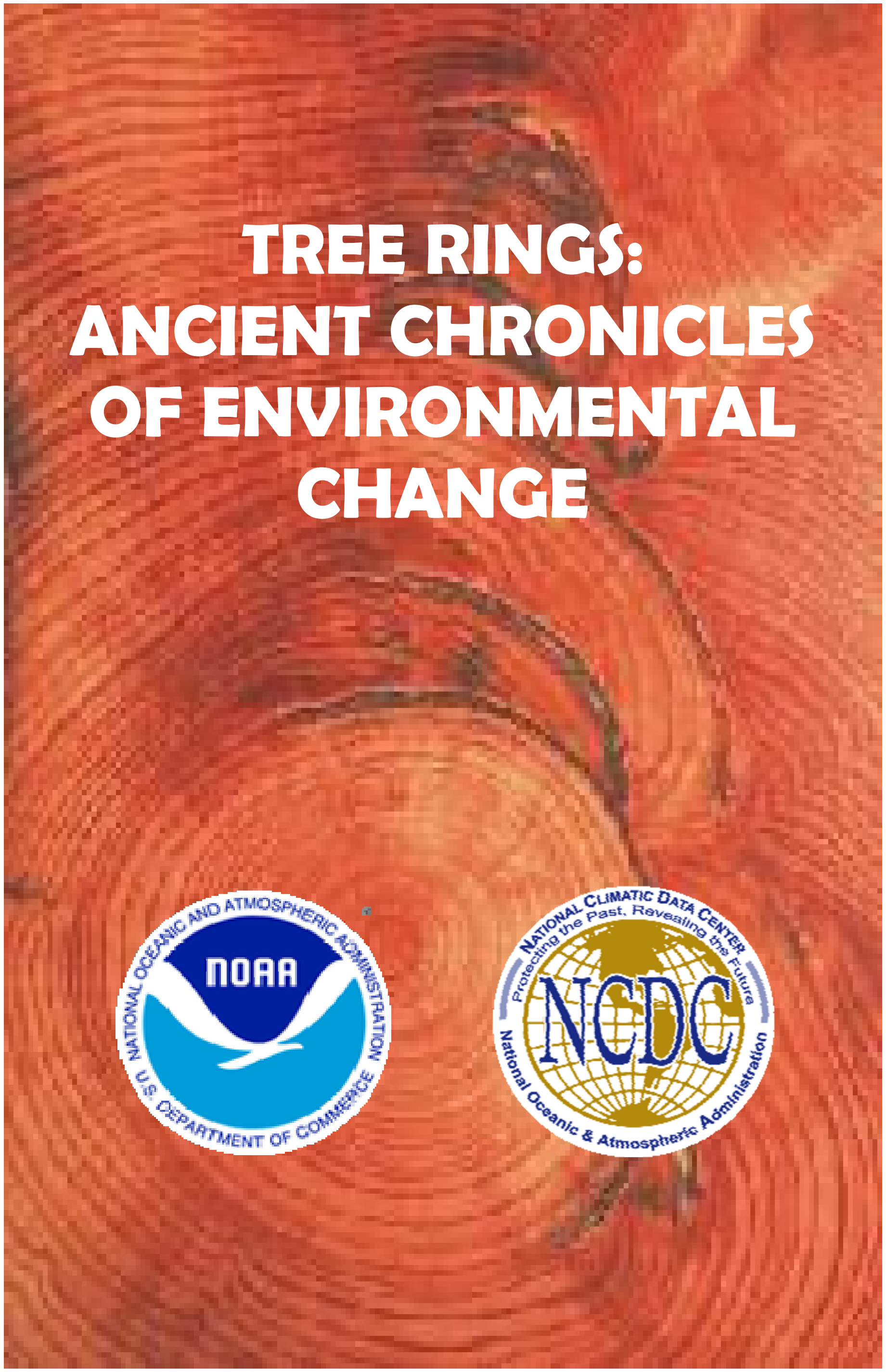


NOAA serves the nation by providing information on past changes in climate and the environment, and by providing estimates of future change. Tree rings are one of the few sources of information on the large changes (temperature, drought, and the hydrologic cycle) that have occurred over hundreds and thousands of years. The information obtained from these natural recorders of earth history play a valuable role in helping societies understand and live with our changing environment.

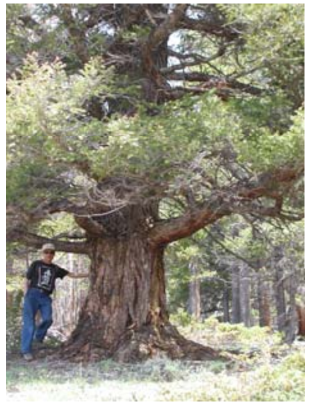
For more visit http://www.ncdc.noaa.gov/paleo/

NOAA Paleoclimatology Program

TREE RINGS: ANCIENT CHRONICLES OF ENVIRONMENTAL CHANGE



Introduction



Dendrochronology is the science that deals with the dating and study of annual growth rings in trees. Trees at mid– to high-latitudes generally grow one ring per year, and the width of the ring reflects variations in environmental conditions that influence tree growth during that year. For example, trees in arid areas are sensitive to drought and will grow narrow rings in dry years and wide rings in wet years, while trees growing at high latitudes or high elevations are limited in growth by summer temperatures and will grow narrow rings in cold summers and wide rings in warm years. The photo to the upper left shows an example of a ponderosa pine tree growing on an semi-arid site in western Colorado, and below it, a ponderosa pine cross section with variations in ring widths due to variations in precipitation.

Tree rings provide information important for understanding climate. Because trees can grow to be hundreds to thousands of years old, variations in their growth rings can contain records of past climate that extend far beyond the roughly 100 years length of our **instrumental records** from rain gages and thermometers. These long proxy climate records allow us to evaluate current and recent climate events, such as droughts, in the context of a longer period than the instrumental records allow. These records can help answer questions such as:

How often do we get a drought as severe as the one in 2002 or the 1930s Dust Bowl, and have there been more severe droughts in the past?

Is the warming trend in the 20th century part of natural climate variability or is it unusual in the context of the past thousand years?

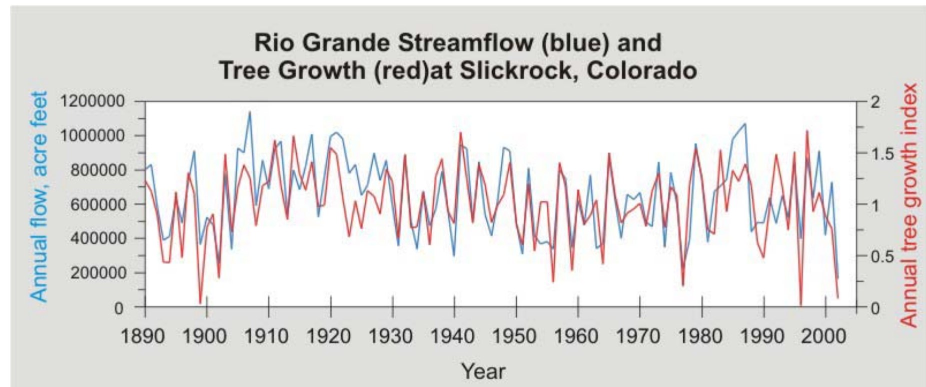
NOAA Photo Library, Dust Bowl

So, how do we get information from tree rings and what do they say about past climate? The sections that follow describe:

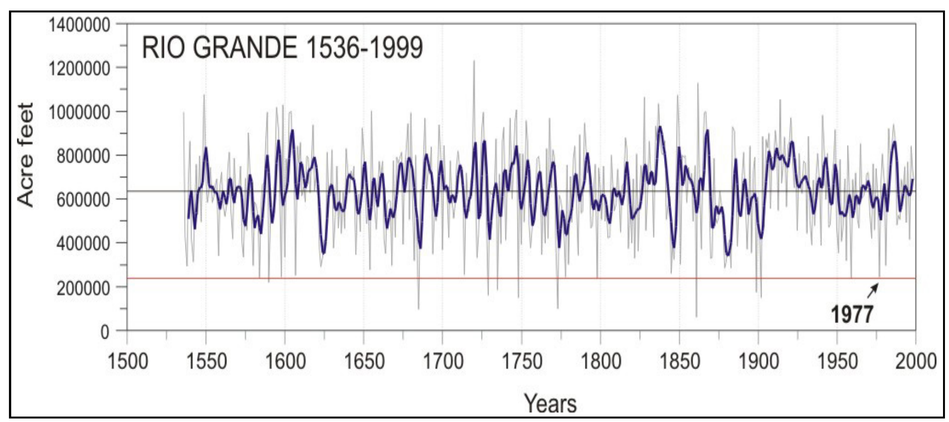
- How tree rings are formed
- Tree ring sampling and preparation
- Reconstructions of past climate from tree rings

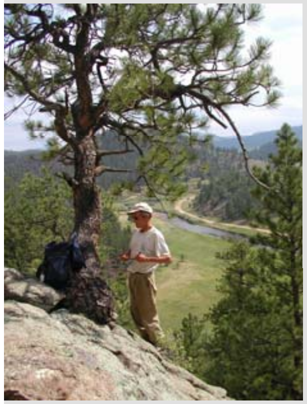
Calibrating Tree Rings with Climate

Tree-ring chronologies can be calibrated with a climate-related record, such as annual streamflow, to create a reconstructions of climate back in time. This extends the climate record to the length of the tree-ring data, typically 300 to 800 years. To start, the tree-ring data are compared visually and statistically with the climate data, here annual flow for the Rio Grande River in Southern Colorado (shown in the graph below). If there is a good match, the two time series, annual tree growth and streamflow, are calibrated over the years common to both series, generating a statistical model of the relationship. This statistical model is then applied to the tree-ring chronology to produce a reconstruction of past streamflow (below of the page). Often, more than one chronology may be used in the statistical model.



The full length reconstruction can then be used to assess the 20th century part of the record in a long term context. For the Rio Grande River, the lowest flow year in the last 50 years was 1977. In the graph below, the light line shows annual values, the dark line the 5-year smoothed values, and the red line marks 1977. The Rio Grande flow reconstruction, which extends back to 1539, shows that a number of years in past centuries had flows lower than 1977.

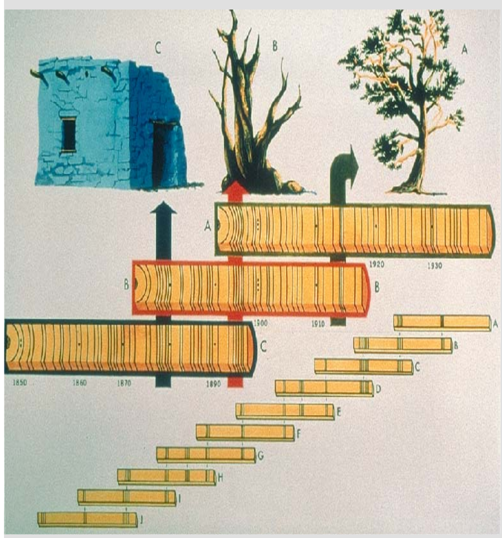




How Tree Rings are Sampled and Prepared for Analysis

Once a site with trees that are sensitive to climate is selected, about 20-30 trees are sampled using an **increment borer**. An increment borer is a hollow shaft of steel with a sharpened bit at one end and a handle at the other. The photo to the left show a core being taken from a tree. Below that , a core is being extracted from the borer. The hole left by the increment borer quickly fills with sap, which is the tree's way of healing the wound. Cores are taken back to the lab where they are mounted and sanded to a fine surface. An example is shown below. The bark is at the left end of the core.

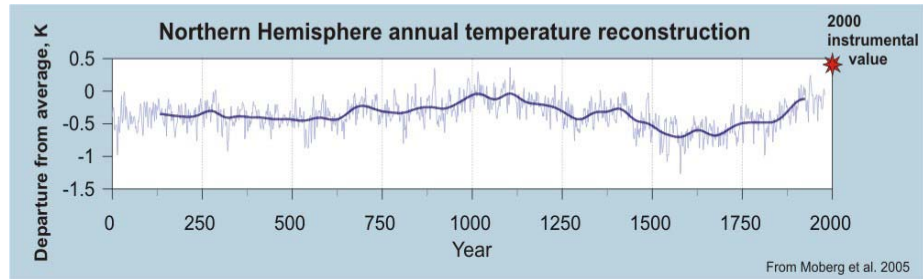
Next, tree rings are dated using a process called **cross dating** (illustrated in the diagram below, left). Cross dating matches the ring-width patterns from tree to tree. Because the same set of environmental conditions influences tree growth across a region, the same pattern of annual ring widths is found from tree to tree across that region. This matching is necessary, rather than just ring counting, because some trees may have missing or false rings in some years, and these must be accounted for so that all rings are assigned the correct calendar year date.



After dating all cores and rings are measured (below). Measurements are averaged to create a **tree-ring chronology**, which reflects the common ring width pattern for all trees at the site.

Reconstructions of Temperature

Tree rings can also be used to reconstruct temperature. A number of reconstructions of Northern Hemisphere temperature have been generated from tree rings, and a combination of other types of proxy data. All of the reconstructions have differences in data and methods used, so all are slightly different. However, almost all have the same message: 20th and 21st century temperatures are higher than at any period during the past 2000 years. The graph below is an example of one reconstruction that combined tree-ring and other types of data. The light line shows annual values, and the dark line shows the smoothed values. The instrumental temperature values for 2000 is marked by the red star.



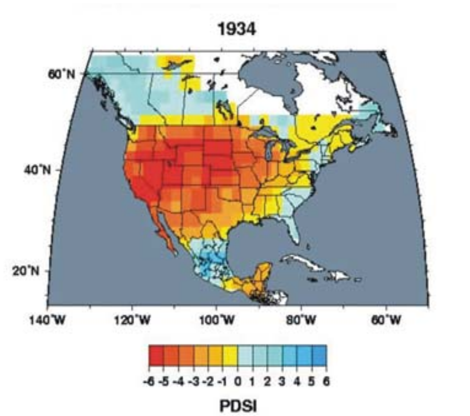
Summary

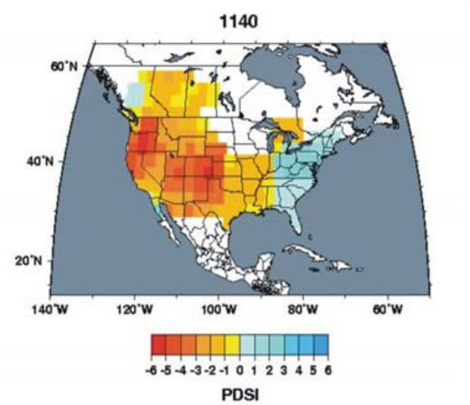
- Because many trees are sensitive to variations in climate, tree rings can record annual variations in climate that are precisely dated to the calendar year.
- Tree rings can be used to reconstruct past climate, before the time of records from rain gages and thermometers (instrumental records).
- The reconstructions of past climate generated from tree rings are important because they allow us to assess the climate of the 20th and 21st centuries in a long term context.
- Knowledge of the climate of the past, and its variability and range of extreme events, can provide an understanding of the range of natural climate variability over a longer period of time than just the past 100 years.

For more information about tree rings, go to http://www.ncdc.noaa.gov/pale/treering.html

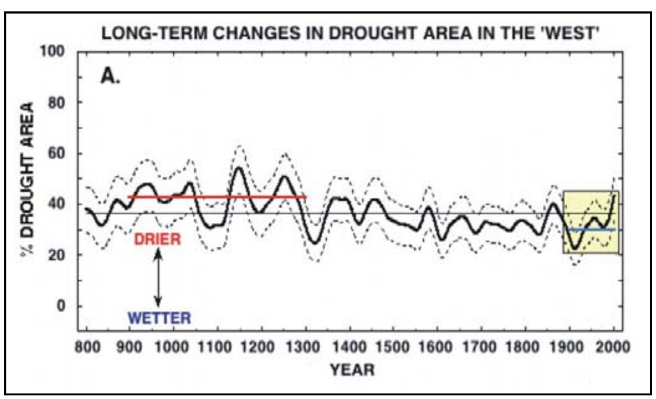
Drought Reconstructions From Tree Rings

Climate reconstructions from tree rings can show climate variations over both time and space. A network of 835 tree-ring chronologies has been used to generate reconstructions of summer drought for 286 evenly spaced grid points across North America back to A.D. 1000. When all the grid point values for a desktop publishing year are mapped, the extent of drought across the continent can be assessed. The maps for two drought years are shown to the right, 1934 and 1140. Drought is measured by the Palmer Drought Severity Index (PDSI). Red values are the driest, and blue are the wettest. Even in the context of past centuries, drought conditions in 1934 were remarkably severe and wide-





This gridded network of drought reconstructions can also be used to look at the spatial extent of drought over time. By calculating the number of grid points with PDSI values under a certain threshold, the area under drought each year can be determined. The graph below shows the percent of area under drought (here the threshold PDSI<-1 is used) from A.D.800 to 2002. Values have been smoothed, and the dotted lines show the uncertainly related to the reconstruction, and the 20th century is shown in the box. What is evident is that drought covered a larger area in the period of A.D.900 TO A.D.1350 than any time since.

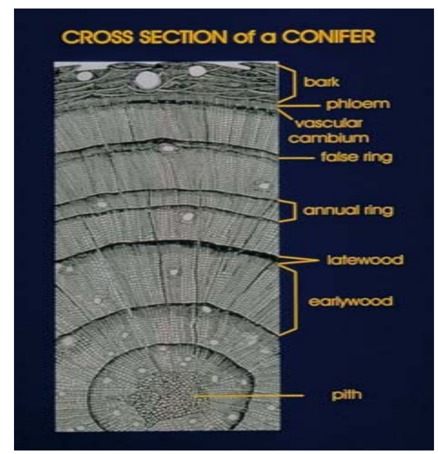


History of Dendrochronology

In the United States, A.E. Douglass is known as the Father of Dendrochronology. Douglass, an astronomer working in Arizona in the early 20th century, was interested in the relationship between sunspots and climate. His interest in extending climate records led him to examine regional patterns of tree growth in tree rings. Douglass recognized that common ring-width variations between trees were related to climate and pioneered the technique of crossdating for building long tree-ring chronologies. He is also well-known for his work in dating many of the archeological site in the southwestern U.S. By applying the process of crossdating, ring patterns in timbers were matched with ring patterns in living trees of known dates, thus establishing dates for many dwellings. An example is the Anasazi ruin, Keet Seel (above), dated to AD 1250.

How Tree Rings are Formed

The diagram to the right shows a cross section of a young pine tree. The pith is at the center of the tree, and the outside is marked by the bark. Just inside the bark is a layer called the vascular cambium, where the cells that form tree rings are produced. Each year, the vascular cambium produces two types of cells, **Phloem**, which transports nutrients, becomes bark, and xylem, which becomes a tree ring. The current year growth ring is the one right inside the bark.



During the early part of the growing season, the xylem cells produced are thinwalled and light in color. This is the **earlywood**. As the end of the growing season approaches, xylem cell walls are denser, making up the **latewood**. The gradation from the lighter earlywood to the darker latewood makes the annual ring visible. At the end of the growing season, cell growth ceases, and a marked ring boundary is discernable. In some areas, trees may produce what looks like two rings in a year. One of these rings is a **false ring**, and an example can be seen in the diagram. In addition, some trees may not produce an annual ring in a year when climate conditions are extremely severe, and that is called a **missing ring**.