A window into a tree’s world

Featured scientists: Jessie K Pearl, University of Arizona and Neil Pederson, Harvard University. Written by Elicia Andrews.

Research Background:

According to National Aeronautics and Space Administration (NASA) and the National Oceanic Atmospheric Administration (NOAA), the years 2015-2018 were the warmest recorded on Earth in modern times! And it is only expected to get warmer. Temperatures in the Northeastern U.S. are projected to increase 3.6°F by 2035. Every year the weather is a bit different, and some years there are more extremes with very hot or cold temperatures. Climate gives us a long-term perspective and is the average weather, including temperature and precipitation, over at least 30 years.

Over thousands of years, tree species living in each part of the world have adapted to their local climate. Trees play an important role in climate change by helping cool the planet - through photosynthesis, they absorb carbon dioxide from the atmosphere and evaporate water into the air.

Scientists are very interested in learning how trees respond to rapidly warming temperatures. Luckily, trees offer us a window into their lives through their growth rings. Growth rings are found within the trunk, beneath the bark. Each year of growth has two parts that can be seen: a light ring of large cells with thin walls, which grows in the spring; and a dark layer of smaller cells with thick walls that forms later in the summer and fall. Ring thickness is used to study how much the tree has grown over the years. Dendrochronology is the use of these rings to study trees and their environments.

Different tree species have different ranges of temperatures and rainfall in which they grow best. When there are big changes in the environment, tree growth slows down or speeds up in response. Scientists can use these clues in tree’s rings to decipher what climate was like in the past. There is slight variation in how each individual tree responds to temperature and rainfall. Because

Jessie taking a tree core in the winter.
of this, scientists need to measure growth rings of multiple individuals to observe year-to-year changes in past climate.

**Teacher Note:** It is important to note that a tree’s rings store more information besides climate factors. A tree’s ring patterns reflect the age of the tree, climate (temperature, rainfall), tree to tree competition, genetic differences, human disturbance and disease, and more. Because multiple variables influence ring patterns, dendrochronologists must be selective when choosing the trees for their climate research. They also need to collect many samples from multiple individuals to get a good representation and minimize noise.

Atlantic white cedar was chosen for this study based on past research. Research indicated that Northern tree populations would be more likely to respond to temperature change. Atlantic white cedar primarily grow in wet environments, which creates a cooler condition for growth. This is represented by thinner rings. The scientists predicted that increasing temperatures due to climate change would create wider rings in Atlantic white cedar growth.

Jessie and Neil are two scientists who use tree rings for climate research. Jessie entered the field of science because she was passionate about climate change. As a research assistant, Neil saw that warming temperatures in Mongolia accelerated growth in very old Siberian pine trees. When he later studied to become a scientist, he wanted to know if trees in the eastern U.S. responded to changes in climate in the same way as the old pine trees in Mongolia. As a result, there were two purposes for Jessie’s and Neil’s work. They wanted to determine if there was a species that could be used to figure out what the climate looked like in the past, and understand how it has changed over time.

Jessie and Neil decided to focus on one particular species of tree – the Atlantic white cedar. Atlantic white cedar grow in swamps and wetlands along the Atlantic and Gulf coasts from southern Maine to northern Florida. Atlantic white cedar trees are useful in dendrochronology studies because they can live for up to 500 years and are naturally resistant to decay, so their well-preserved rings provide a long historical record. Past studies of this species led them to predict that in years when the temperature is warmer, Atlantic white cedar rings will be wider. If this pattern holds, the thickness of Atlantic white cedar rings can be used to look backwards into the past climate of the area.
To test this prediction, Jessie and Neil needed to look at tree rings from many Atlantic white cedar trees. Jessie used an increment borer, a specialized tool that drills into the center of the tree. This drill removes a wood core with a diameter about equal to that of a straw. She sampled 112 different trees from 8 sites, and counted the rings to find the age of each tree. She then crossdated the wood core samples. Crossdating is the process of comparing the ring patterns from many trees in the same area to see if they tell the same story. Jessie used a microscope linked to a computer to measure the thickness of both the early and late growth to the nearest micrometer (1 micrometer = 0.001 millimeter) for all rings in all 112 trees. From those data she then calculated the average growth of Atlantic white cedar for each year to create an Atlantic white cedar growth index for the Northeastern U.S. She combined her tree ring data with temperature data from the past 100 years.

Let’s look at a section of a tree core to see how Jessie collected her data.

Tree core extracted, July 2018

↑ Year tree core taken (2018)   Center of the tree ↑

Observe the tree core. Notice there are two ring colors. The dark rings are made during slower growth and the light ring is made during faster growth. Each pair of light and dark rings represent one year. Count the dark rings to estimate the age of the tree.

Which years are the thinnest? Which are the thickest?


What do you think could have caused the differences in tree ring sizes?

Depending on the tree species, the large widths of the tree rings could represent ideal growing conditions and limited competition. The thin years could represent climatic change or ecological disturbance.

Teacher Note: Students can count the rings to determine the age of the tree

- There are approximately 28 years of growth represented in the cross section of the cross section of the tree core. Remind students that a year’s worth of growth includes both the light and the dark rings together. This tree began growing during 1990-1991 time frame.
- The center of the tree is the beginning of the tree’s growth and each year a ring gets added away from the center. This means the first year of growth starts on the right.
**Scientific Question:** How does the Atlantic white cedar respond to changing temperature?

**Scientific Data:**

Use the data below to answer the scientific question:

<table>
<thead>
<tr>
<th>Year</th>
<th>Atlantic White Cedar Growth Index</th>
<th>Jan-April Temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>-0.24</td>
<td>44.29</td>
</tr>
<tr>
<td>1915</td>
<td>0.02</td>
<td>44.02</td>
</tr>
<tr>
<td>1920</td>
<td>-0.62</td>
<td>43.35</td>
</tr>
<tr>
<td>1925</td>
<td>-0.81</td>
<td>43.85</td>
</tr>
<tr>
<td>1930</td>
<td>-0.95</td>
<td>43.79</td>
</tr>
<tr>
<td>1935</td>
<td>0.30</td>
<td>44.80</td>
</tr>
<tr>
<td>1940</td>
<td>-0.64</td>
<td>44.71</td>
</tr>
<tr>
<td>1945</td>
<td>-0.62</td>
<td>45.07</td>
</tr>
<tr>
<td>1950</td>
<td>-0.69</td>
<td>44.98</td>
</tr>
<tr>
<td>1955</td>
<td>0.82</td>
<td>46.16</td>
</tr>
<tr>
<td>1960</td>
<td>-0.19</td>
<td>44.66</td>
</tr>
<tr>
<td>1965</td>
<td>-1.02</td>
<td>43.73</td>
</tr>
<tr>
<td>1970</td>
<td>-1.43</td>
<td>44.21</td>
</tr>
<tr>
<td>1975</td>
<td>-0.42</td>
<td>44.60</td>
</tr>
<tr>
<td>1980</td>
<td>0.54</td>
<td>45.01</td>
</tr>
<tr>
<td>1985</td>
<td>1.10</td>
<td>45.12</td>
</tr>
<tr>
<td>1990</td>
<td>1.18</td>
<td>45.32</td>
</tr>
<tr>
<td>1995</td>
<td>0.10</td>
<td>45.03</td>
</tr>
<tr>
<td>2000</td>
<td>0.86</td>
<td>45.89</td>
</tr>
<tr>
<td>2005</td>
<td>1.09</td>
<td>45.22</td>
</tr>
<tr>
<td>2010</td>
<td>1.41</td>
<td>46.42</td>
</tr>
</tbody>
</table>

| Average | -0.01 | 44.77 |

*The growth index is calculated by comparing growth across a large number of individual trees to get one best estimate of tree growth. There are no units. Jessie and Neil used temperature data from January to April because previous research has shown that the temperature in these months has the strongest effect on Atlantic White Cedar growth.*
What data will you graph to answer the question?

Independent variable(s): Jan-April temperature (F)

Dependent variable(s): Atlantic white cedar growth index

Check for Understanding: After students have had some time to look at the data table, have a class discuss surrounding the question, “What type of graph should you make?” There are many different kinds of graphs, and each is appropriate for different types of data. What type of graph would be most appropriate to make with these data?

- Bar graphs: suitable for when you have categorical independent and continuous dependent variable. It is used to make comparisons among groups. A bar graph is not suitable as the dependent variable (time) is continuous.
- Pie graphs: suitable for showing data that are part of a whole. Makes it easier to see relative differences between quantities in each group. A pie graph is not suitable as this data does not represent a part-whole relationship.
- Histograms: while similar in appearance to a bar graph, differ in that they show the distribution of continuous data. A histogram could be an appropriate visualization for either temperature change over time. Here, the student could select an appropriate interval of time, for example, five or ten years, and use bar heights to represent the average temperatures over each period.
- Line graphs: suitable for when you have continuous independent and dependent variables, like changes over time, and are used to identify trends. A line graph would be useful for identifying trends of temperature change or growth over time. A line graph would not be useful for exploring the relationship between growth and temperature.
- Scatterplots: used to determine relationships between variables, and can be used to examine positive vs. negative, and linear vs. nonlinear correlation. Students can approximate a line of best fit than represent the rate of growth vs. temperature by calculating its slope. This is the best method for mathematically representing the relationship between growth and temperature, as a student can represent it as the slope of the fit line.

NOTE: In this Teacher Guide we have given you an example of the data graphed as a two-series line graph showing temperature and cedar growth, both over time. This graph type also appears in Student Type A activities. Level B students will be given axes that suggest plotting temperature vs. the growth index, and in Level C students will be able to create any graph they feel is most appropriate to visualize the data.

Draw your graph(s) below: Identify any changes, trends, or differences you see in your graph(s). Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

- There is variation in temperature from year to year. There is also variation in growth of white cedar from year to year.
- 2010 had the greatest average temperature of 46.42°F and the greatest white cedar growth index of 1.41.
- There has been a warming trend since 1965.

Teacher Note: Students may choose to add trend lines to their scatter plots, or connect the points to make line graphs. Both types of visualizations are appropriate for these data, and students can discuss why they chose the type of graph that they did.

In scatter plots, scientists add trend lines to look for positive or negative relationships. To do this the scientist looks for patterns in the data by plotting the two variables against each other. If the data points trend upward the correlation is positive, if they trend down the correlation is negative, and if the graph is horizontal or shows no clear direction there is no correlation. For a more precise correlation one can generate a best fit line. The best fit line is the line that comes closest to fitting all the points. An r-squared value is a statistical measure that uses each point’s vertical distance from the fit line to determine how strongly the dependent variable correlates to the independent value.
Interpret the data:

Make a claim that answers the scientific question.

The data show that even though there is variability year to year, over time the temperatures in the Northeast are increasing. Atlantic white cedar are also showing positive trends in their growth over time and grow best in years where the temperature is higher.

What evidence was used to write your claim? Reference specific parts of the table or graph(s).

The average temperature is 44.7°F. In 1910 the temperature was below average at 44.29°F. 100 years later, in 2010, the temperature was warmer than average at 46.42°F. Although there is variation, overall there is a positive trend in both temperature and tree growth over time.

The average white cedar growth index was -0.01 for the time span. 1910 was a cooler year (44.29 F) that had a low growth index of -0.24. 2010 was a warmer year (46.42) that had a high growth index of 1.41. Like temperature, there is a positive trend in white cedar growth over time.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how tree rings width is related to growth.

Teacher Note: This activity can be used to stimulate a classroom discussion on the issue of correlation versus causation. With this design, Jessie and Neil found that years that were warmer had higher growth for the cedar. This is supported by the positive correlation between the independent variable (Jan-April temperature [F]) and the dependent variable (Atlantic white cedar growth index). However, correlations do not imply causation.

Though the study looks at temperature, it does not rule out that other factors are affecting the growth of the Atlantic white cedar. What do we need to test for causation? We would need to eliminate the possibility that there is some other correlated variable actually responsible for the pattern. To do this, we need to design an experiment that isolates and manipulates only one variable at a time, holding all others constant. For this study that would be difficult as it is not possible to manipulate the climate on such a large scale. Have a class discussion about how you might be able to test for causation in this system.

For climate reconstruction, a dendrochronologist will choose trees in their sample plots to reduce other ecological variables. As stated previously it does not mean that the species growth is based on one individual factor alone. In addition, not all species will respond in the same way; this study shows the importance of studying the response of multiple species.
There is a positive correlation between the three variables. Over time, there is a positive trend for both temperature and white cedar growth. In years when temperatures are high, Atlantic white cedar also tend to have wider rings. Wider rings mean the trees grew more in a particular year. Although these data do not pinpoint the exact cause of the increased growth, it could be that Atlantic white cedar are benefiting from temperature increase.

**Meta Moment:** As a way to conclude this activity, discuss with students the value of long-term data. Harvard Forest is considered a Long-term Ecological Research site (LTER) located within an ecotone separating northern and southern range tree species. This makes the site particularly useful for climate studies. Funded by the National Science Foundation, they serve the community by making 40 years of ecological studies available to the public. The scientists at Harvard are studying a variety of issues ranging from climate, natural disturbances, environmental change and human impacts.

What is the value of long-term data collection for climate scientists? Is it really necessary to collect data for so long? Could we learn this same information by collecting data for a shorter time span? As an exercise, have students look at the data only 20 years at a time by covering up first the left side of the graph, and then the right side. Would students make the same claim with only 20 years of data, compared to 100?

As a class, you may also want to discuss that there are some limitations in the timeframe of the temperature data. The graph only represents a fraction of time found on the history of earth. It is important to talk about time in reference to the age of earth and not humans. Because the earth is known to be approximately 4.56 billion years old, different scales were developed to reference time: long-term-hundreds of millions, medium term-1 million, short term 100,000 years old and modern period-hundreds of years old.

**Your next steps as a scientist:** Science is an ongoing process. What new question(s) should be investigated to build on Jessie and Neil’s research? How do your questions build on the research that has already been done?

After determining the strong correlation, Jessie used the Atlantic White Cedar cores to reconstruct past temperature data for Eastern United States. She completed that task by comparing actual surface temperature to her reconstructed chronology. The results proved to be statistically significant. To date, Jessie’s study is considered the most recent temperature chronology for the Northeast United States. This is significant because past deforestation in the Northeast, combined with our lack of other paleoclimate markers such as coral or ice cores, have limited our ability to collect paleoclimate data.

Scientists are currently studying how species of trees are responding to changing climate variables in the Northeastern
United States. Students might wonder, if Atlantic White Cedars are growing better due to climate change, does it mean they will take over and be the dominant tree species, or are all species responding the same way? One may also wonder, is there a temperature threshold beyond which the Atlantic white cedar will not grow well? Is it possible for it to get too hot? Neil is currently looking at northern and southern range species and their growth response to climate variables. So far the data indicates that tree species are most sensitive to drought, but winter climatic changes including temperature may be affecting the future projections of tree growth distribution.

Suggestions for Inquiry

- Set up a field plot on your campus to identify and monitor the diameter of different trees growing. If you have access to an increment borer, sandpaper and dissection scope you can have students date and complete a lab activity by crossdating trees.
- Hands on lesson using wood cookies “What can tree rings tell us about climate?” by Chicago Botanic Garden
- Join, set up and participate in School Yard Ecology LTER Program by Harvard Forest. Real data and Real scientists
  - Our Changing Forests: How do forests grow and change over time?
  - Buds, leaves and Global Warming
  Link: https://harvardforest.fas.harvard.edu/schoolyard-lter-program
- Students can also explore how are other forms of paleoclimatology used to generate and predict future changes in the environment. Assign a field of study and create mini presentations and a jigsaw activity
- Explore available data related to your region. Determine if there are trends and correlations within the data.
- Create an assignment relating to climate data- Become involved in a local data jam and/or have students create an infographic relating to the lesson.

Resources for Teachers

If you are unfamiliar with the study of dendrochronology, please reference presentation created for intermediate students. The presentation highlights and clarifies different aspects of climate and dendrochronology that is not necessarily featured in the introduction of the Data Nugget. It also includes lesson suggestions and ideas that you can incorporate into your classroom. Additionally, the presentation can be edited to suit your personal needs.