Clarifying Tropical Cyclone Activity in Centuries Past

Over the last few years, hurricanes have affected millions of human lives and coastal communities throughout the United States. As I prepared for hurricane season this year, I was not alone in wondering how many hurricanes would hit the Southeast. News articles presented conflicting stories; some stated that hurricanes were increasing in frequency while others denied the claim.

In order to truly answer questions of hurricane frequency one must move past short-term human-documented meteorological records and find environmental proxies for determining historical hurricanes. Just recently, Miller et al. (2006) established such a proxy when they documented an oxygen isotope record from longleaf pine tree rings spanning 220 years. Because oxygen isotopes in precipitation from tropical cyclones and hurricanes are isotopically lighter than in surface water and other storm events, oxygen isotopes can be used to identify tropical cyclone events.

In this article, I describe an inquiry-based activity for high school students based on the research of Miller et al. (2006). This activity integrates chemistry, biology, and Earth/environmental sciences while engaging students in problem-solving exercises and group collaborations. By bringing current interdisciplinary research to high school classrooms, students gain an understanding of and enthusiasm for scientific research of societal significance.

Background

Oxygen isotope analysis is a tool that researchers use to detect tropical cyclones because tropical cyclones produce distinctly lighter isotopes in their precipitation than precipitation from other storm events. During tropical cyclones increased cloud height and/or cloud thickness increases the condensation of water vapor during these extended storm events (Lawrence and Gedzelman 1996). Since these water vapor molecules contain relatively less of the heavier oxygen isotope (^{18}O), the precipitation produced during tropical cyclones is isotopically lighter than typical storm precipitation (Lawrence and Gedzelman 1996). When trees with shallow roots take up this precipitation, they incorporate ^{18}O-depleted water molecules into their tree rings. Therefore, oxygen isotopes from tree rings provide clues to past tropical cyclone activity (Miller et al. 2006). This is similar to the analysis of oxygen isotopes in marine organisms (e.g., foraminifera) and carbonate deposits in cave stalactites, which also tell us about past climates.

Bringing research into the classroom

Because students are better able to understand new concepts when they reference familiar topics, the topics of isotopes, photosynthesis, evaporation, and basic plant physiology should be discussed before beginning this activity. The "Clarifying tropical cyclone activity" (Figure 1, p. 80) begins with an opening discussion that reviews relevant concepts previously covered. Once students are refreshed on these topics, they are divided into groups and questions pertaining to the lesson are posed by the teacher (see Figure 1, Part 1). These questions, when discussed in small groups, allow students to collaboratively inquire and research diverse scientific disciplines. Once students have had ample time to talk about these questions in their groups, a class discussion should synthesize and expand on these individual discussions.

Next, each group is provided with a variety of scientific clues and data to use in designing an experiment, which will test the null hypothesis that tropical cyclones have not increased in frequency over the last 200 years (Figure 1, Part 2). Students use the climate proxy of Miller et al. (2006) for this part of the activity. It is important to note that students are designing, not testing, their experiment. The goal is for students to synthesize the information provided, conduct necessary background research, and develop an experiment, simulating the research process of professional scientists. Additionally, this lesson explicitly engages students in the scientific process and covers multiple National Science Education Standards, including Content Standard A: Science as Inquiry (NRC 1996, p. 173) and Content Standard F: Science in Personal and Social Perspectives (NRC 1996, p. 193). Assessment activities include group presentations in the form of a poster and an accompanying oral presentation.

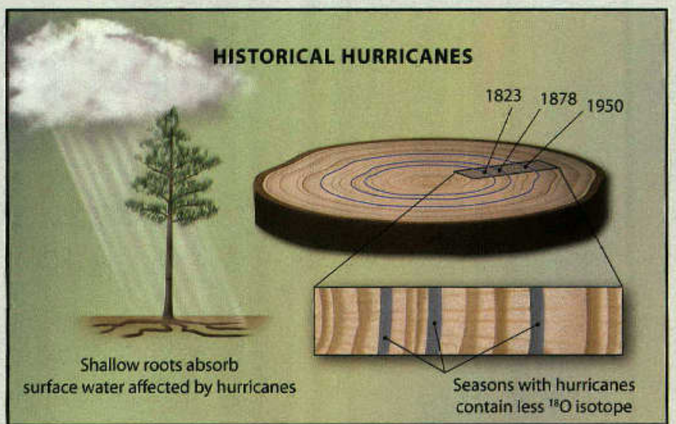
Once the assignment is complete, students should be able to understand and articulate the following:

- Oxygen isotope analysis can detect tropical cyclone events because the precipitation from tropical cyclones contains a distinctly lower ratio of heavier isotopes than precipitation from other storm events.

- This ^{18}O-depleted precipitation is taken up by trees with shallow roots, such as longleaf pine, and incorporated into their tree rings.
- These oxygen anomalies can be correlated with meteorological records over the past 100 years to determine if the method is reliable.
- If tropical cyclone activity is correlated with light oxygen isotope values, then an increase or decrease in the frequency of light oxygen isotope values in tree rings over time indicates an increase or decrease in tropical cyclone activity over time, respectively. This proxy has the potential for creating a record of tropical cyclone occurrence extending back many centuries (Miller et al. 2006).
- This proxy can be used to make chronologies of tropical cyclones with limiting factors including the age and potential preservation of the tree.
- The testing of multiple trees

FIGURE 1

Clarifying tropical cyclone activity.



ZINA DERETSKY, NATIONAL SCIENCE FOUNDATION

Part 1: Background research

Answer the following questions as a group:

- Are tropical cyclones and hurricanes the same thing? If not, how are they different?
- How do hurricanes and tropical cyclones form?
- How are trees affected by hurricanes and tropical cyclones?
- What do tree rings signify? Do all trees have rings? Why or why not?
- What are climate proxies?

Part 2: Design an experiment

Last night on the news you heard the statement, "Hurricanes are increasing in frequency." While hurricanes have captured our attention over the last few years, we do not know if they have increased in frequency over multiple centuries. Recent work by Miller et al. (2006) documented a new method that can be used to determine tropical cyclone frequency. Using the information provided below, design a way to test the validity of the news statement. Present your argument and experimental design to the class by constructing a poster that answers the following questions:

- What is the null hypothesis and how can you test this hypothesis using what you know about the climate proxy?
- What are the constraints of your method (i.e., what factors limit you from going back 5,000 years)?
- How do you know your method works? Is the proxy testable?
- Can your experiment properly test the news statement? If not, what hypothesis can your experiment test?

The following scientific information can assist in your research (you can add to this list with your own research):

- Oxygen isotopes in the precipitation from tropical cyclone events are isotopically lighter (they contain relatively less of the heavy ^{18}O isotope) than surface water and precipitation from noncyclone events.
- The shallow roots of trees absorb surface water that rains down during storms and cyclones.
- Tree rings are laid down during the growing season with dark bands indicating the end of the growing season.
- Isotopic depletions in tree rings can not discriminate between tropical cyclones and hurricanes (hint: refer to your answers in part one to remember the difference between tropical cyclones and hurricanes).

Reference: Miller et al. (2006).

in an area can make the study more robust.

- Tropical cyclones and hurricanes are slightly different, although hurricanes are a type of tropical cyclone. *Tropical cyclones* are storm systems with a low pressure center that produce significant rain and wind. *Hurricanes* are defined as intense tropical cyclones with wind speeds of greater than or equal to ~119 km/hr. Because oxygen isotopes can detect significant rain events but not wind intensity, depleted ^{18}O values can document tropical cyclone frequency but can not discriminate hurricanes from lower-intensity cyclones. Therefore, scientists can only determine how tropical cyclone (not hurricane) frequency has changed over time, using this method.

Lastly, students are presented with a general summary of the experimental design and results of the Miller et al. (2006) study, although the actual paper (available online) can be distributed to advanced students (e.g., AP Biology, Chemistry, or Environmental Science). Specifically, students learn that the researchers designed an experiment that sampled tree rings and correlated depleted ^{18}O values with documented tropical cyclone events. Because a strong correlation resulted, this method is reliable and can be used to track tropical cyclone activity over time.

In-class extensions include the use of a computer lab to conduct internet research for Part 1 and/or Part 2 of the activity. The content discussed can also be used as a stepping stone to discussions about experimental design, the development of future science fair projects, and lessons regarding how to properly read and comprehend a scientific paper.

In the past, scientific research often occurred in "ivory towers," reaching the public only when necessary. With growing public concern for scientific issues such as global warming, it is important that research not only reach the public but that students understand the implications of research and be able to correctly interpret the data presented.

Larisa R.G. DeSantis (lgrawe@ufl.edu) *is a paleoecology doctoral student in the department of zoology at the University of Florida /Florida Museum of Natural History in Gainesville, Florida.*

References

Lawrence, J.R., and S.D. Gedzelman. 1996. Low stable isotope ratios of tropical cyclone rains. *Geophysical Research Letters* 23:527–530.

Miller, D.L., C.I Mora, H.D. Grissino-Mayer, C.J. Jock, M.E. Uhle, and Z. Sharp. 2006. Tree-ring isotope records of tropical cyclone activity. *Proceedings of the National Academy of Sciences* 103(39): 14294–14297. *www.pnas.org/cgi/reprint/0606549103v1*

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

On the web

- National Weather Service, National Hurricane Center: Tropical Predication Center: *www.nhc.noaa.gov*
- Tree-Ring Data: World Data Center for Paleoclimatology: *www.ncdc.noaa.gov/paleo/treering.html*
- Tropical Cyclones: Hurricanes and Typhoons: *http://vathena.arc.nasa.gov/curric/weather/storms/tropcyclone.html*