


Ice Core Investigations

Exploring climate change in ice core samples



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What can glaciers tell us about volcanoes and atmospheric conditions? How does this information relate to our understanding of climate change? Ice Core Investigations is an original and innovative activity that explores these types of questions. It brings together popular science issues such as research, climate change, ice core drilling, and air pollution to create a meaningful science learning experience for students.

Teaching science and climate change

Typically, we may teach our students about climate by having them memorize the types and locations of different climates, and their influences on Earth's ecosystems. However, science teachers can easily modify this and other traditional approaches to be an interesting inquiry-based activity that allows students to examine a simulated record of climate change. Through the study of ice core samples, Ice Core Investigations leads students to a greater understanding of the natural systems involved in climate change, the history of Earth's climate, and the human influences on climate today. Students investigate the relationship between airborne particles in a glacial ice core, the thickness of layers within the core sample, and pH values. In the analysis of these ice cores, students make predictions and draw conclusions similar to scientists' findings, increasing their familiarity and experience with current climate change research.

While we usually see the study of climate and ecosystems in Earth and physical science classes at the 8th- and 9th-grade levels, the content of the Ice Core Investigations lesson is interdisciplinary and applicable to several areas of science at the 10th- and 11-grade levels as well. The approach used in this lab could easily be used in a chemistry class to illustrate concepts of acids, bases, and suspensions or in a biology class to make connections between water quality and conditions for life.

Glaciers hold many clues about climate and atmospheric conditions throughout Earth's history. Within glaciers, there are sequential layers of ice deposition that contain characteristics of the atmosphere at the time they formed. Within an ice core, it is possible to infer differences in temperature, precipitation, atmospheric composition, volcanic activity, and wind patterns using a typical coring strategy (Palais et al. 1988; Zielinski et al. 1994; Fiedel, Southon, and Brown 1995; Riebeek 2005).

Scientists drill into ice sheets or glaciers and then label and analyze the ice core for data, which can include oxygen isotopes, layer thickness, the gases in air bubbles, methane levels, chemical composition of dust, and dates of ash layers. From these measurements we can infer atmospheric conditions and global climate at the time the sample formed. In the Ice Core Investigations activity, students analyze ice core samples (created by the teacher) and focus on three variables: the thickness of the ice, the presence of airborne particles, and the pH value of each section of the sample.

Connecting to the "big picture"

Throughout Earth's history, there have been extended periods of volcanic activity, which have greatly affected Earth's climate. Volcanoes emit ash and gases that affect atmospheric conditions, which, in turn, affect climate. In most cases, greatly increased volcanic emissions cause colder global temperatures and acidic precipitation. These geological events are recorded in the layers of ice found in glaciers and correlate directly with climate conditions inferred from tree-ring growth data from the same time period.

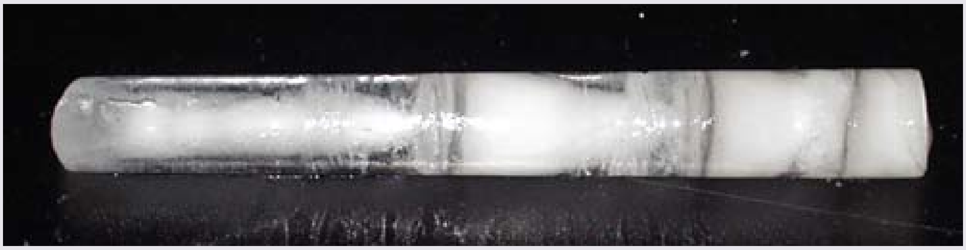
Classroom perspectives.

This activity was field tested by preservice teachers as part of a secondary science teaching methods class offered at Montana State University–Bozeman. Preservice teachers reported that they liked this activity because it is quantitative, involves good hands-on experimentation, has an element of discovery, and adds an inquiry-based aspect to their teaching and learning.

FIGURE 1

Sample ice core.

This photo shows the variations in layer size and abundance of particulates found in ice core samples.



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We are well aware of the critical role that air pollution, especially carbon-dioxide emissions, plays in global climate change. From bacterial microbes to plants and animals including humans, air pollution affects all Earth systems, and industrial pollution can clearly be seen within the ice core record. However, most educational resource materials for students do not provide them with the scientific information needed to connect the ideas of volcanic emissions, atmospheric particulates, air pollution, and acidic precipitation, and therefore do not help them tie these ideas together to create the "big picture" of global climate change.

Through teacher creativity, the Ice Core Investigations activity can offer students the opportunity to ask questions about the issue of global climate change and create their own experimental studies. Students can also use their findings, along with principles, theories, and empirical data about "marine sediment cores, soil and rocks on the Earth's surface, and unique water and rock formations in caves" to better understand Earth's climate history; like scientists, students "must bring together all of these scattered threads into a single, seamless story" (Riebeek 2005, p. 7). Ultimately, participating in this activity encourages students to think critically about the science behind the concept of climate change.

Materials

For this activity, teachers will need to prepare one ice core sample for each pair or triad of students. The materials needed for a class of 30 students, with groups of 3, include:

- coffee filters

FIGURE 2

Example data table.

Layer	Thickness (cm)	Volume (mL)	Mass (g)	pH	Presence of particles	Mass of particles (g)	Prediction	Results
A								
B								
C								
D								

- 1 × 1 m^2 pieces of newspaper
- matches
- 1,000 mL of water
- a freezer
- 10 (10 mL) graduated cylinders
- 1 sheet of cardboard (to support graduated cylinders from falling over in the freezer)
- vinegar
- pH test kit (ranging from 4.0–7.0 or 1.0–14.0)

For the classroom investigation, students can choose from a bucket of tools to analyze their ice core. We like to include the following:

- 1 mortar and pestle
- 1 box of colored pencils
- 3 rulers
- 5 petri dishes
- 1 pH indicator
- 25 cm strips of pH paper (in sealed container)
- 5 coffee filters
- 5 pipettes or eyedroppers
- 3 watch glasses
- 3 magnifying glasses
- 1 dissecting kit, butter knife, or pair of scissors
- several dissecting microscopes for the class (optional)

Teacher preparation

In preparing the ice core samples, it is important that teachers make the various layers of ice different from each other by alternating what we will call "volcanic year" layers with "average year" layers. The difference in these layers results from historical evidence that volcanic eruptions coincide with cooler seasons (Oppenheimer 2003) and that a rapid increase in hydrovolcanic eruptions may be linked to an increase in snow and ice cover (Palais et al. 1988). Note that the pH of tap water may vary greatly, with values ranging from 6.0–7.4, so it is important that teachers also test their tap water first and adjust the pH levels for each layer accordingly.

Two batches of water representing volcanic and average years should be prepared before creating the ice layers. The 1,000 mL of water is separated into two containers: one container holds 750 mL of volcanic year water, the other holds 250 mL of average year water. The volcanic year layers will be thicker than the average year layers and can vary in size.

Teachers should select containers for making ice cores that can stand upright inside of the freezer; a 100 mL graduated cylinder works well. Over a period of one week, layers of water are added to the cylinder, and each layer of water is allowed to freeze before the next is added. (If time is an issue, this process can be condensed into one day, as each layer takes approximately two hours to freeze.) When developing this activity for the first time, it is a good idea to create the first layer as an average year; the second, third, and fourth layers as volcanic years; and the final layer as an average year. Keeping the volcanic and average year layers at consistent volumes (25 mL and 12 mL, respectively) is the most basic approach to this activity.

The two batches of water should be prepared according to the following specifications.

Volcanic year (tap water + newspaper ash + vinegar)

A study conducted by Oppenheimer indicates that "rhyolitic-composition glass shards have been filtered out of the acid horizon from Greenland and South Pole cores" (2003, p. 418). Rhyolite is an igneous, volcanic rock, so its presence in the ice provides evidence for volcanic activity. These rhyolitic glass shards can be simulated by burning paper and mixing the ashes in with water. An approximate pH value of 4.0 is acceptable for the volcanic year water. Due to the differences in tap water pH, however, teachers may need to adjust pH by adding vinegar. For instance, our tap water has a pH value of 6.4, so we cut a 1 × 1 m^2 piece of newspaper into thin strips, burn them, place the ash in a container, and add the 750 mL of tap water, along with about 8 mL of regular household vinegar. This changes the pH level to 4.0. Additionally, we remove large pieces of ash from the water using a coffee filter. We have found that if these large ash particles are not removed, they will sink to the bottom of the layer, making it appear as two separate layers instead of one, which can be confusing for students. A finer filter can be used during the lab to show that fine ash is present. The melted ice layer from a volcanic year will also vary in color, being slightly grayer than that of an average year.

Average year (tap water + vinegar)

Again, for this batch of water, the pH of tap water may need to be lowered slightly (as average precipitation has a slightly acidic value of 5.6) by adding vinegar. Our tap water, having a pH value of 6.4, needs about 3 mL of vinegar per liter of water to lower the pH to 5.6.

Prior knowledge

To discover students' prior knowledge and prepare them for the investigation, teachers can conduct a general class discussion about air pollution and climate change. Students can be asked how they would go about finding evidence of air pollution, perhaps from a volcano. They can also draw a picture of emissions—of ash particles leaving the volcano, moving into the atmosphere, and being incorporated into the snow or rain—and then explain the process. Open-ended questions that are appropriate for eliciting relevant student knowledge include:

- What does air pollution look like? Is it ever invisible?
- How does air pollution get into the snow?
- What comes out of a volcano?
- What happens after the volcano erupts?
- What effect would particles that escape from a volcano have on the amount of sunlight reaching Earth?

Classroom investigation

This lesson should be taught with an inquiry approach. As Collins and O'Brien state, "Inquiry teaching is a form of instruction in which teachers provide students with information, experiences, or problems that serve as the focus for the students' research activities. The students generate hypotheses or tentative solutions, gather relevant data, and evaluate the data to arrive at a conclusion" (2003, p. 180). In this vein, we have attempted to keep our instructions less structured for the activity to accommodate the varying nature of students, teachers, and methods of teaching inquiry.

FIGURE 3

Extension: Historical climate statistics.

This activity focuses on the analysis and discussion of the historical temperature records from central England from 1659 A.D.–2000 A.D. Figure 4 (p. 58) shows the average winter temperature during this time. The objective is to demonstrate the concept of climate change at a specific place over time. From the historical and geologic records, we know that global temperature change reflects both dramatic episodes and gradual changes. We also know that events such as volcanic eruptions can have an effect on local and global temperature. Discuss with students their interpretation of their ice core data, and how it relates to this activity.

Students investigate the physical and chemical characteristics of each layer in their ice core sample, as shown in Figure 1 (p. 55). Layers can be seen clearly if a light is directed at their ice core from various angles. Students should measure, draw, and label the thickness of the different layers of ice and graph the data over imaginary time. Students then take samples from sections of the core and test for particulates and pH. Finally, students can use their group and class data to draw conclusions.

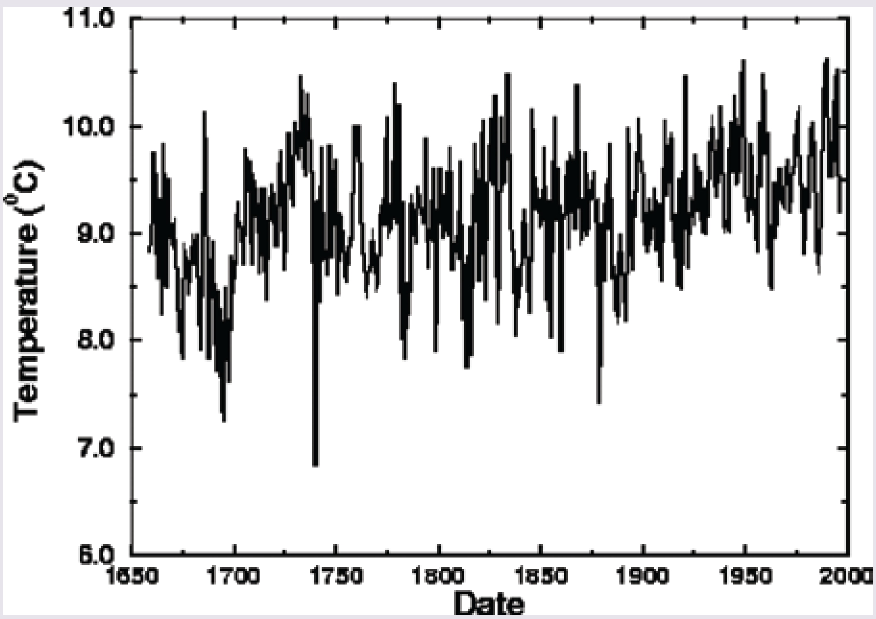
For this inquiry-based activity, students can perform their investigations in the following steps. (**Safety note:** All students should wear goggles, and correct use of laboratory tools should be reviewed with students before beginning the activity. It is important to cover the proper uses for any cutting instruments that may be used to score the ice cores, such as scissors, scalpels, or butter knives. The ice cores can be quite slippery, so using a towel to stabilize the ice core is suggested. In addition, instructions about proper use of the hot plate and microscopes should always be included.)

1. Each group receives a teacher-prepared ice core sample. Groups of three seem to work best for distribution of labor and provide enough individual and diverse input for discussion of predictions and results.
2. Students predict whether or not there will be evidence of air pollution in their ice core. They might be able to see pieces of ash in the ice or slight differences in color between layers. A magnifying glass can be used during this step.
3. Students identify layers of ice as "volcanic years" or "average years." Students may use different criteria to make this identification. Having students explain their criteria to the teacher and the class during discussion is an important part of this inquiry lesson. Students should then measure and diagram the layers. Each layer can be easily seen by shining a flashlight on the ice core and looking for changes in light penetration and reflection.

4. Students typically choose to separate the layers by cutting or breaking the ice. Sometimes scoring the ice with a scalpel (from the dissecting kit), butter knife, or scissors and then tapping it on a table is useful. Teacher supervision is important during this process.
5. Students can measure the mass of each layer. This should be done with an accurate scale, and must be done in a container to collect the melting ice water. After a discussion of the need for accuracy, students record their results.
6. Students can measure the volume of each layer using a graduated cylinder after the ice has melted (a hot plate can be used to speed up this process). The importance of precision and accuracy should again be discussed with students.
7. For an extension of the study, students might choose to pour the water through a filter and mass the particles from each layer of ice using an electronic balance precise to 0.01 g. (Traditional triple-beam balances may not be precise enough to determine the change in mass for this step.) A dissecting microscope, along with the probe (from the dissecting kit) can be used to identify specific particulates.
8. Students determine from the group and class data whether or not air pollution is present in their samples based on the sedimentation found in each of their melted layers, and by measuring the pH level. Figure 2 (p. 56) provides an example data table that can be used for this step.

FIGURE 4

Central England temperature (1659–2000).



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Discussion

After students complete the investigation portion of the activity, the following prompts can be used for class discussion:

1. Students reconsider their initial predictions about air pollution and compare them with the observations made in the final step of the procedure.
2. Using a large visual display, all groups report their results. Teachers construct a class data table and have students
   - compare their predictions to their results;
   - compare their group's data to the overall class data;
   - look for trends in the data (e.g., high and low pH versus presence of air pollution); and
   - determine if pH helps to predict the presence or absence of air pollution in an ice core.
3. Students should determine that the pH of the water is more acidic in the layers with large amounts of particles, and that the ice is thicker when the particles are present. Teachers discuss with them the connection between ice layer thickness, acidity, and abundance of particles. (**Note:** The U.S. Geological Survey's [USGS] Cascades Volcano Observatory in Vancouver, Washington has compiled many sources that expand upon the link between volcanic activity, cooler temperatures, and acid precipitation [see "On the web" at the end of this article].)
4. Teachers discuss with students what their results might indicate about global temperature and climate change. How could ice thickness serve as a proxy for temperature? How could this idea be expanded to include industrial pollution?
5. A follow-up discussion includes methods that scientists use in predicting the presence of air pollution and determining its effect on temperature and climate. As there is bound to be some anomalous data, teachers should discuss with the class sources of error and how the process of science includes aspects of non-confirming data.

Assessment and outcomes

Student outcomes for the Ice Core Investigations activity include: understanding the concepts of air pollution and climate as they apply to authentic investigations; learning skills associated with data collection, analysis, and drawing conclusions; and gaining an appreciation for science processes, the importance of evidence, and the tentative nature of scientific conclusions. We assess this activity for content, skills, and dispositions among our students. (See Figures 3 and 4 [pp. 57 and 58] for an extension of the Ice Core Investigations activity.)

Addressing the Standards

The National Science Education Standards (NRC 1996) addressed in the Ice Core Investigations activity are related to several areas of science. Selected standards include:

- Unifying Concepts and Processes: evidence, models, and explanation (p. 111)
- Science as Inquiry: abilities necessary to do scientific inquiry (p. 173)
- Science and Technology: understandings about science and technology (p. 190)
- Science in Personal and Social Perspectives: environmental quality (p. 193)
- History of Nature and Science: nature of scientific knowledge (p. 200)

In this activity, students participate in a scientific investigation of climate change, air pollution, and ice thickness that has relevance in the modern world. The activity is based on modern technologies used by scientists to locate valuable scientific and environmental resources.

Scientific inquiry is an important aspect of the Standards and is emphasized at all grade levels. In this activity, students gain the following fundamental understandings about scientific inquiry (NRC 2000, p. 20):

- Scientific explanations must adhere to certain criteria: a proposed explanation must be logically consistent; open to questions and possible modification; based on historical and current scientific knowledge; and abide by the rules of evidence (p. 20).
- Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists (p. 20).

Conclusion

In the past several years, the general public has become increasingly concerned with climate change. This activity not only provides the opportunity for students to participate in an inquiry lesson that builds their critical-thinking skills, but also capitalizes on a topical science issue. Ice Core Investigations encourages students to become informed and knowledgeable about science and current events. It will also allow students to think through the data, make conclusions on their own, and discuss results with their peers. ■

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On the web

The Habitable Planet: A Systems Approach to Environmental Science: *www.learner.org*

USGS Volcanoes and Weather: *http://vulcan.wr.usgs.gov/Glossary/VolcWeather/description_volcanoes_and_weather.html*

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