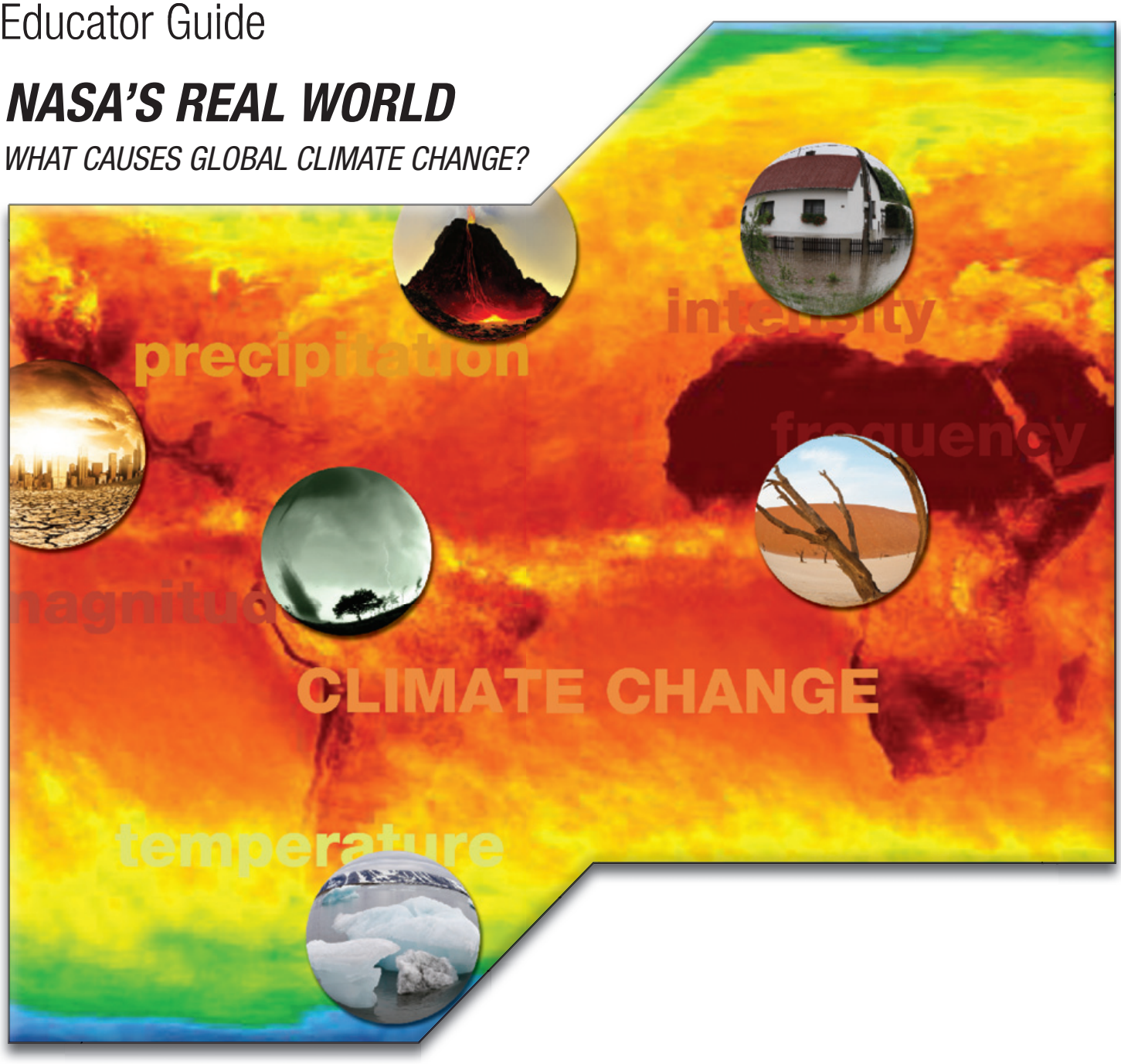
National Aeronautics and Space Administration

NASA eClips™
Educator Guide

NASA'S REAL WORLD

WHAT CAUSES GLOBAL CLIMATE CHANGE?



Educational Product	
Educators & Students	Grades 6-8

EG-2010-05-006-LaRC

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WHAT CAUSES GLOBAL CLIMATE CHANGE?

EDUCATOR GUIDE

National Standards:

National Science Education Standards (NSES)

Science as Inquiry

- Abilities necessary to do scientific inquiry

Earth and Space

- Structure of the Earth system

National Council of Teachers of Mathematics (NCTM)

Measurement

- Apply appropriate techniques, tools, and formulas to determine measurements
- Understand measurable attributes of objects and the units, systems, and processes of measurement

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
- Develop and evaluate inferences and predictions that are based on data

Essential Questions

- How might human activities affect climate change?
- What patterns and trends in climate change can be inferred by studying ice core samples?

Grade Level:
6-8

Subjects:
Earth and Space Science

Teacher Preparation Time:
50 minutes to prepare ice core samples (ten minutes per day spread over five days), 20 minutes to gather materials.

Lesson Duration:
Two 55 minute class meetings.

Time Management:
Preparing the ice core samples for the EXPLORE activity requires freezing separate layers in upright plastic graduated cylinders or other containers of similar diameter over the course of several days. Sections of the EXPLAIN, EXTEND, and EVALUATE may be assigned as out-side work to reduce class time.

Instructional Objectives

Students will

- demonstrate prior understanding and opinions about climate change through kinesthetic movement;
- make observations and gather data about simulated ice core samples;
- make inferences based upon data collected from simulated ice core samples;
- analyze historical climate data to identify trends, patterns and outliers.

EDUCATOR GUIDE

Lesson Overview:

Students begin this lesson by demonstrating their attitudes towards and prior understanding of global climate change. Then working in teams students observe, measure, and record data gathered from simulated ice core samples to model the work of climate scientists. Students graph and analyze real ice core data looking for patterns and trends. Students continue to look for trends when they analyze graphs and models developed by climate scientists. This lesson is developed using the 5E model of learning and utilizes NASA eClips™ video segments.

Icons flag five areas of interest or opportunities for teachers.

- **Technology Icon** highlights opportunities to use technology to enhance the lesson.
- **Modification Icon** denotes opportunities to differentiate the lesson.
- **Resources Icon** relates this lesson to other NASA educator resources that may supplement or extend the lesson.
- **Connections Icon** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **Check for Understanding Icon** suggests quick, formative assessment opportunities.

Materials List:

Explore

To prepare ice cores

- one package of food coloring – various colors
- one 1-L bottle of tonic water
- one bottle of white vinegar
- small amounts of various dusty, insoluble materials. Possible materials: ashes, cat litter, dirt, coffee grounds.
- one 100 ml plastic graduated cylinder for each group of students. Other cylinders approximately 2.5 cm in diameter, such as plastic storage tubes available at arts and crafts supply stores, may be substituted. If the diameter of the tube is too large, students will not be able to cut the ice core.
- freezer with enough space to store cylinders upright

Per group of three to four students

- prepared ice core
- device to measure pH. Universal pH paper works well for this activity.
- metric ruler
- balance
- five clear plastic cups (one cup for every layer of ice)

- tray or disposable plate
- plastic knife or other utensil to separate ice core layers
- permanent marker

5E Inquiry Lesson Development

ENGAGE (20 minutes)

The ENGAGE provides an informal pre-assessment of student attitudes and understanding of some factors affecting global climate change, setting the stage for discussions about facts, opinions, and inferences. A large, open area is required to complete the ENGAGE activity.

1. (**CHECK FOR UNDERSTANDING**) Students will need room to walk several steps forward or several steps backward; a hallway, cafeteria, playground or gym would be suitable for this activity. Ask students to stand shoulder to shoulder in a straight line.
2. Listed below are a collection of statements addressing global climate change. Read each statement to students and ask them if they agree or disagree with the statement. If students AGREE with the statement, ask them to walk one step forward. If they DISAGREE with the statement, ask them to walk one step backward. They must either agree or disagree; they may not remain in place.
   a. Human activity is the only cause of climate change.
   b. Increased global temperatures may result in the flooding of many cities.
   c. Greenhouse gases are always bad for the environment.
   d. The polar regions will always be frozen and icy.
   e. An increase in the carbon dioxide level of the atmosphere is heating the planet.
   f. If we were able to stop all carbon dioxide emissions, Earth's average temperature would decrease.
   g. Current global warming can be fully explained by natural cycles in the Earth system.
   h. A small temperature increase may have a great effect on life on Earth.
   i. Warming of average global temperatures on Earth can be stopped with human intervention.
3. Ask students to discuss their movements. Do they disagree with each other? Or agree with each other? Ask students for possible reasons for their responses.

EXPLORE (35 minutes)

Students gather and analyze data from simulated ice cores in the EXPLORE activity.

Pre-class preparation:

1. For each group of three or four students create an ice core sample that has three to five layers. To ensure the samples are frozen solid, allow samples to remain in the freezer overnight between adding layers.
2. The ice core samples will be frozen in 100 ml graduated cylinders or similar containers. The cylinders must remain upright until frozen solid.
   a. Gather the materials listed in the Materials section.
      SAFETY NOTE: The water will expand as it freezes. To minimize the risk of breaking the cylinder, do not use a glass graduated cylinder, do not seal the top of the cylinder, and use a cylinder which allows head space above the final layer of the ice core.
   b. Measure about 100 mL of tap water into a cup or beaker.
   c. Add a small amount of solid material, two drops of food coloring and stir vigorously until the solid particles are suspended.
   d. Pour between 10 and 20 mL of the mixture into each cylinder. The exact amount is not important. Try to add the same amount to each cylinder.
   e. Allow samples to freeze overnight.
   f. Repeat the steps above, increasing the amount of solid material and pH in each layer added on top of the others.
   g. To vary the pH for each layer, decrease the volume of tap water and increase the volume of tonic water. For the top layer or two, replace tonic water with increasing amounts of white vinegar. Below are some suggested amounts of liquids to mix. A household measuring cup is precise enough to use for liquid measurements.

Layers	Amount of Vinegar	Amount of Tonic Water	Amount of Tap Water
1	0 mL	0 mL	100 mL
2	0 mL	40 mL	60 mL
3	0 mL	75 mL	25 mL
4	40 mL	0 mL	60 mL
5	80 mL	0 mL	20 mL

h. Each ice core layer should have a unique color, composition, and thickness. The color variation will make it much easier for students to identify individual layers. The varying composition and thickness simulates different amounts of precipitation, levels of pollution and the amount of dissolved CO_2. It can also represent ash from volcanic eruptions. You may represent industrialization by adding a greater mass of solid materials to upper layers or early volcanic activity by adding a greater mass of solid materials to bottom layers.

i. Ice core samples not being used immediately can be stored in a cooler with an ice pack for several hours. The samples will remain frozen enough for classes meeting later in the day to work with.

Classroom Procedure

1. Ask students to read the background information in the Student Guide and answer questions 1 and 2 on page 5 of the Student Guide.
2. Distribute the materials for the EXPLORE activity to each group.
3. Have students follow the procedure on page 5 of the student guide to analyze their ice core. They will answer question #3 on page 5 of the Student Guide.
4. Next, students will follow steps 4 – 8 on pages 5 and 6 of the Student Guide and record their data in Data Table 1 which is also found on page 6.
5. (**CHECK FOR UNDERSTANDING**) Once all students have completed the activity, facilitate a discussion about the observations. Use these questions to guide the discussion:
   a. Which layer in the ice core represents the oldest layer? *(The bottom layer represents the oldest layer.)*
   b. Which layer in the ice core represents the youngest layer? *(The top layer represents the youngest layer.)*
   c. How is Earth's climate recorded within the layers of glacial ice? *(The air bubbles in the ice trap the ancient atmosphere. The analysis of the gases provides clues to ancient climates. The thickness of each layer represents the amount of precipitation and the particulates store information about volcanic activity as well as pollution)*
   d. (**MODIFICATION**) Have students create their own ice core sample based on what they have learned.
6. (**MODIFICATION**) Have students find the mass of the solid particles following the procedure they have written in question 9.

EXPLAIN (20 minutes)

Students will compare EXPLORE observations with data gathered by climate scientists to identify patterns and trends.

EDUCATOR GUIDE

1. (**TECHNOLOGY**) Show the NASA eClips™ video segment Launchpad: Global Warming – How Humans are Affecting Our Planet. This segment can be found on the NASA eClips™ page of the NASA web site:

   http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms="global%20warming"&category=0010

   The video may be streamed or downloaded from the nasa.gov web site and a captioned version is also available at the nasa.gov site. This video may be streamed from the NASA eClips YouTube™ channel:

   http://www.youtube.com/watch?v=rDYqlTsZfgw&feature=PlayList&p=D7BEC5371B22BDD9&index=42

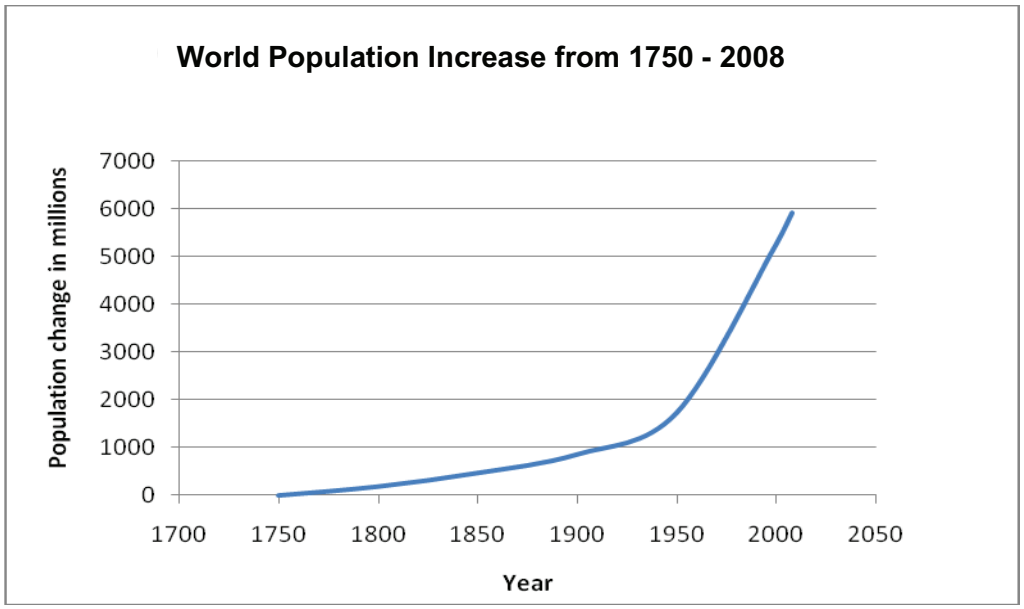
2. (**CHECK FOR UNDERSTANDING**) After watching the video segment, ask students to discuss some causes and effects of global climate change. *(One of the causes in average global temperature increase mentioned the burning of fossil fuels. One effect mentioned in the clip was a possible rise in sea level.)*
3. Ask students to complete questions 1 through 5 which begin on page 6 of the Student Guide.
4. (**TECHNOLOGY**) Using a spreadsheet program, ask students to generate the graph in question 4 on page 7. The Siple ice core data set is available in spreadsheet form in the Technology tools section of the Teacher's Toolbox at the NASA eClips™ site:

   http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/techtools.html

   A virtual Siple ice core is also available.
5. (**RESOURCES**) Students may learn more about factors affecting climate change by visiting NASA's Eyes on the Earth at:

   http://climate.nasa.gov/

6. (**CONNECTIONS**) Using the Estimated World Population Increase from 1750 – 2008 on page 7 of the Educator Guide, ask students to look for connections between world population data and the increase of carbon dioxide.
7. (**CONNECTIONS**) Have students look up events in history that correspond to the dates found in Table 2 on page 8 of the Student Guide to look for connections between historic events and the increase in carbon dioxide.



Year	World Population x 1,000,000	Population Difference from 1750 x 1,000,000
1750	791	0
1800	978	+187
1850	1,262	+471
1900	1,650	+859
1950	2,521	+1,730
1999	5,978	+5,187
2008	6,707	+5,916

Source: U.S. Census Bureau International Data Base

EXTEND (20 minutes)

In this activity students analyze data to look for patterns and trends and make inferences about global climate change.

1. Students complete the EXTEND activity on page 10 of the Student Guide.
2. (**TECHNOLOGY**) Watch and analyze this animation about carbon dioxide and climate change:

   http://www.nasa.gov/mov/314686main_KeelingCurveWeb-1280x720HD.mov
3. (**CHECK FOR UNDERSTANDING**) Based upon the graph and animation, students describe how changes in levels of carbon dioxide impact

the climate. *(The animation shows the seasonal variation of CO_2 in the atmosphere, as well as the extra CO_2 humans are adding to the atmosphere over time.)*

4. (**CONNECTIONS**) Read the Career Clip on page 11 of the Student Guide and answer questions 1 and 2. Reflect on how this classroom activity relates to the experiences of planetary scientist Peter Wasilewski featured in the clip.

EVALUATE (10 minutes)

1. Ask students to analyze the graphs and answer questions 1 and 2 on page 12 of the Student Guide.

Climate researchers often use mathematical models to understand how global changes such as increasing greenhouse gases or decreasing glacial ice might affect Earth. The Very Simple Climate Model is a simple model, focusing on the primary relationship between carbon dioxide emission, carbon dioxide concentration and average global temperature. There are many other factors influencing climate such as wind patterns, precipitation, and location of the carbon dioxide in the atmosphere, other greenhouse gases, ocean influence and the reflection of the sun's energy. The model predicts how Earth's climate is likely to change in the future.

2. Ask students to identify relationships between carbon dioxide production and average global climate temperature using the Very Simple Climate Model found at this link:
   http://www.windows.ucar.edu/tour/link=/earth/climate/cli_model.html
3. Repeat the ENGAGE pre-assessment activity to identify changes in students' attitudes and perspectives as a result of this study.

STUDENT GUIDE

What Causes Global Climate Change?

Essential Questions

- How might human activities affect climate change?
- What patterns and trends in climate change can be inferred by studying ice core samples?

Background

Earth's climate changes. Although there is debate over what causes this change, scientists agree that Earth's climate has changed and continues to change over time.

One way to learn about these changes is through the study of glacial ice cores. Ice cores create a layered historical record of the climate over time. Scientists drill deeper into older layers of ice; sometimes to a depth of over 3,500 meters (2.2 miles).

Figure 1. Ice Core Sampling.
Image credit: Reto Stöckii, NASA GSFC

By performing physical and chemical tests on ice cores, scientists can create a snapshot of the Earth at single points in time. Atmospheric gases, from hundreds to thousands of years ago, are trapped as small bubbles within the ice.

Measurements of gases, including **carbon dioxide**, paint a picture of the atmosphere at the time the gases were trapped.

What have scientists learned by studying the ice cores?
Scientists learn more about changes in Earth's climate by studying ice cores from Antarctica and Greenland. These ice cores suggest that Earth's climate was affected by changes in **solar radiation**, Earth's orbit, and **greenhouse gas** levels.

Snow layering and volcanic ash layers are both visible in ice cores. These materials create time markers and can be used to help determine the age of the ice.

The cores reveal that climate change happens rather suddenly, in tens of years not millions or even thousands of years. Ice cores also suggest that temperature and carbon dioxide are linked and that the current carbon dixoide level of the atmosphere is the highest it has been in at least 600,000 years. Ice coring also helps scientists understand Earth's linked systems.

Scientists also study changes in glacier ice sheets. In the past 650,000 years, Earth has had seven cycles of **glacial advance** and **glacial retreat**. The last **ice age** abruptly ended about seven thousand years ago, marking the beginning of the modern climate era as well as the beginning of our record of human civilization.

From 2003 to 2009, NASA's Ice Cloud and land Elevation Satellite (ICESat) used lasers to measure the thickness of ice near the Earth's poles. Over the past decade, Greenland's ice sheet has lost more ice than it has gained. Dr. Jay Zwally, project scientist on the ICESat mission, describes this loss as being in excess of 140 megagrams of ice every year. One way to understand how much ice this would be is to picture a large bulldozer carrying 140,000 kilograms of material. The loss of ice equals the amount of ice 1000 large bulldozers could dump in the ocean at once.

Operation ICE Bridge is in its second year of bridging the gap in laser observations of the ice sheets until the launch of the ICESat-II satellite. This satellite is scheduled to be launched in late 2015.

"NASA has a unique capability to look at these things from a bird's-eye

perspective, not only from space but also from multiple long-range, high performance aircraft," said John Sonntag a member of the IceBridge management team. "If not for IceBridge, the global science community and the public would miss out on a great deal of knowledge about Greenland and Antarctica."

How might human activities affect global climate change?
Most climate changes are the result of minor changes in Earth's orbit that affect the amount of solar radiation received by Earth.

However, in the last 100 years, the average global temperature has risen by about 0.83°C, or about 1.5°F. This rate is greater than any rate observed in the past 1,300 years.

What may be causing this increase? During this same time period, humans started to burn increasing amounts of **fossil fuels** to power new industries during the Industrial Revolution. Gases released from the burning of fuels, like carbon dioxide, play a key role in trapping the sun's energy through the greenhouse effect.

Earth observing satellites, such as NASA's Atmospheric Infrared Sounder (AIRS), attempt to understand and quantify the amounts of carbon dioxide and other greenhouse gases in Earth's atmosphere. They also try to identify the role these gases may play in influencing **global climate change**.

NASA continues to keep an eye on global climate change with its satellites and ground validation such as ice core studies.

Resources

Atmospheric Infrafed Sounder
http://airs.jpl.nasa.gov/

Greenland Ice Sheet on a Downward Slide
http://www.nasa.gov/vision/earth/lookingatearth/greenland_slide.html

ICESat Mission
http://icesat.gsfc.nasa.gov/

Jay Zwally on Earthsky audio recording
http://earthsky.org/water/jay-zwally-warns-loss-of-greenland-ice-is-canary-in-coal-mine

NASA IceBridge Mission
http://www.nasa.gov/icebridge

Vocabulary

carbon dioxide – Carbon dioxide is a colorless, odorless, non-poisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil fuel combustion.

climate – Climate is the long-term weather pattern of an area, including temperature, precipitation, and wind.

fossil fuel – Fossil fuel is a general term for crude oil, coal, natural gas, or heavy oils. These fuels are created by exposure to heat and pressure in the earth's crust over hundreds of millions of years.

glacial advance – Glacial advance is an increase in the thickness and area of a glacier. This term also describes the time period it takes for the increase in glacial thickness to occur.

glacial retreat – Glacial retreat occurs when backward melting at the front of a glacier takes place at a rate exceeding forward motion.

global climate change – Global climate change is the long-term fluctuations in temperature, precipitation, wind, and all other aspects of Earth's climate.

greenhouse gases- Greenhouse gases are gases that contribute to the warming of the Earth's atmosphere by reflecting solar radiation from Earth's surface. Carbon dioxide, ozone, and water vapor are examples of greenhouse gases.

ice age – An ice age is a cycle cold period marked by periods of glacial advance with episodes of glacial retreat.

ice core – Ice cores are cylinders of ice obtained by drilling into a glacier.

ice sheet - An ice sheet is the layer of ice covering a large land mass, notably Antarctica and Greenland. Ice sheets form from the compression of snow as new snow builds on top of it.

parts per million by volume (ppmv) – Parts per million by volume is the measure of the concentration of a gas within the atmosphere. In this case, it measures the concentration of carbon dioxide in the air.

pH – pH is a measure of the concentration of hydrogen ion (H^+) in a substance which determines if a solution is acidic or basic.

solar radiation – Solar radiation refers to energy that travels in rays or waves and originates from the sun.

EXPLORE

You are a member of an Antarctic expedition whose mission is to study ice cores and their relationship to global climate change. In this EXPLORE activity, you

and your team will observe and record data from a simulated ice core sample. You will use this data to make some inferences about conditions in which the ice core formed.

Answer these questions **BEFORE** analyzing the ice core sample:

1. The age of the ice core is measured from oldest layer (bottom) to youngest layer (top). Where would you expect to see the most dirt and particles in this sample? Why?

2. When carbon dioxide from the atmosphere combines with precipitation it may become carbonic acid. Carbonic acid lowers the pH and may be recorded in ice layers. When scientists find lower levels of pH in ice core samples, this may indicate an increase in carbon dioxide in the atmosphere. Where would you expect to find the lowest pH in this sample? Why?

Procedure:

1. Carefully remove the ice core from the container. To loosen the ice core, run warm water over the outside of the cylinder. Occasionally tilt the cylinder to the side to check if the ice core is loose.
2. Place the ice core on a tray.
3. Sketch the ice core sample in the space below. In your sketch, record the colors you observe from the oldest layer on the bottom of the youngest layer on the top. Record the thickness of each layer in centimeters.

4. Use the plastic knife to gently separate each layer. On the diagram, number the layers to match the age of the layer. The oldest layer is 1 and the

youngest layer is 5. Record the color of each layer in Data Table 1.

5. Number the plastic cups 1 through 5. Find the mass of each plastic cup and record it.
6. Place each ice core layer into the corresponding numbered cup. Find the mass of the cup and ice and record it. Using this information calculate the mass of each ice core layer and record the mass.
7. Melt each ice core sample by gently swirling the cup. Use a graduated cylinder to measure the volume of the melted ice and record it.
8. Determine the pH of each layer and record it.

Data Table 1. Ice Core Data

Layer Number	Color	Mass (g) of plastic cup	Mass (g) of plastic cup and ice layer	Mass (g) of ice layer	Volume (mL) of melted layer	pH
1						
2						
3						
4						
5						

9. Design your own procedure and data collection chart to measure and record the mass of the solid particles in each layer.

EXPLAIN

1. Based on what you have read, experienced, and seen in the NASA eClips™ Launchpad segment, what tools and evidence do scientists use to study climate change?

2. Explain how the work that you completed in the EXPLORE activity compares to the work scientists do when they study ice core samples.

3. Describe the change over time of the ice core layers. What might you infer about climate change based upon your observations and measurements?

4. The data in Table 2, which is found on page 8, was obtained from an ice core sample drilled at the Siple site in Antarctica. Use this data to create a line graph in Graph 1 on page 9.

5. Refer to the line graph to answer these questions.
   a. Describe the pattern or trend represented in the graph.

   b. What factors might have led to an increase in carbon dioxide?

Table 2. Historic Carbon Dioxide Data from Siple Station Ice Core

Year	CO2 Gas Concentration (parts per million by volume -- ppmv)
1744	**276.8**
1764	**276.7**
1791	**276.7**
1816	**279.7**
1839	**283.8**
1843	**287.4**
1847	**286.8**
1854	**288.3**
1869	**289.3**
1874	**289.5**
1878	**290.3**
1887	**292.3**
1899	**295.8**
1903	**294.8**
1905	**296.9**
1909	**299.2**
1915	**300.5**
1921	**301.6**
1927	**305.5**
1935	**306.6**
1943	**307.9**

Source: Carbon Dioxide Information Analysis Center (CDIAC) U.S. Department of Energy
http://cdiac.esd.ornl.gov/ftp/trends/co2/siple2.013

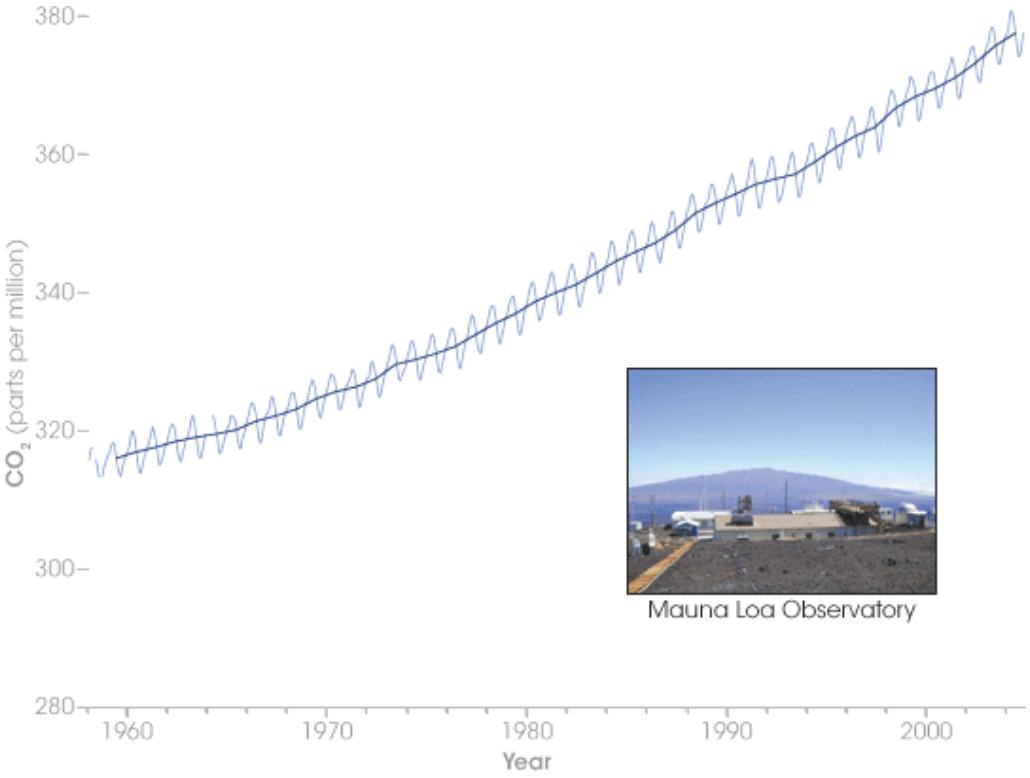
Graph 1. Carbon Dioxide Data from Siple Station Ice Core

EXTEND

In addition to studying ice core samples to determine levels of carbon dioxide, scientists can also determine carbon dioxide concentration directly by analyzing air samples from monitoring stations. One station, Mauna Loa on the island of Hawaii, has been recording direct measurements of atmospheric carbon dioxide since the mid 1950's. This is the longest and most consistent record of atmospheric carbon dioxide in the world. Here is a sample of this data.

Graph 2.

Atmospheric Carbon Dioxide Concentration, Mauna Loa Station, 1959 – 2004



1. Compare these data to the data you graphed from the Siple Station Ice Core. How is the data similar? How is the data different?

2. List two reasons why is it important for scientists to gather data in multiple ways.

STUDENT GUIDE

Throughout this lesson, you have been thinking and acting like scientists. Read this Career Clip to find out more about Dr. Peter Wasilewski, NASA Planetary Scientist at NASA Goddard Space Flight Center.

1. Describe how the investigations you have been conducting are similar to the work Dr. Wasilewski does every day.

2. What could you do today that would support you in preparation for a future career as a scientist?

EVALUATE

The top graph represents levels of atmospheric carbon dioxide measured in an ice core sample from the Vostok region of Antarctica. The bottom graph represents the approximate temperature in that same region. As you can see, the temperature change ranges from about 5°F warmer than the present to about 15°F colder than the present temperature.

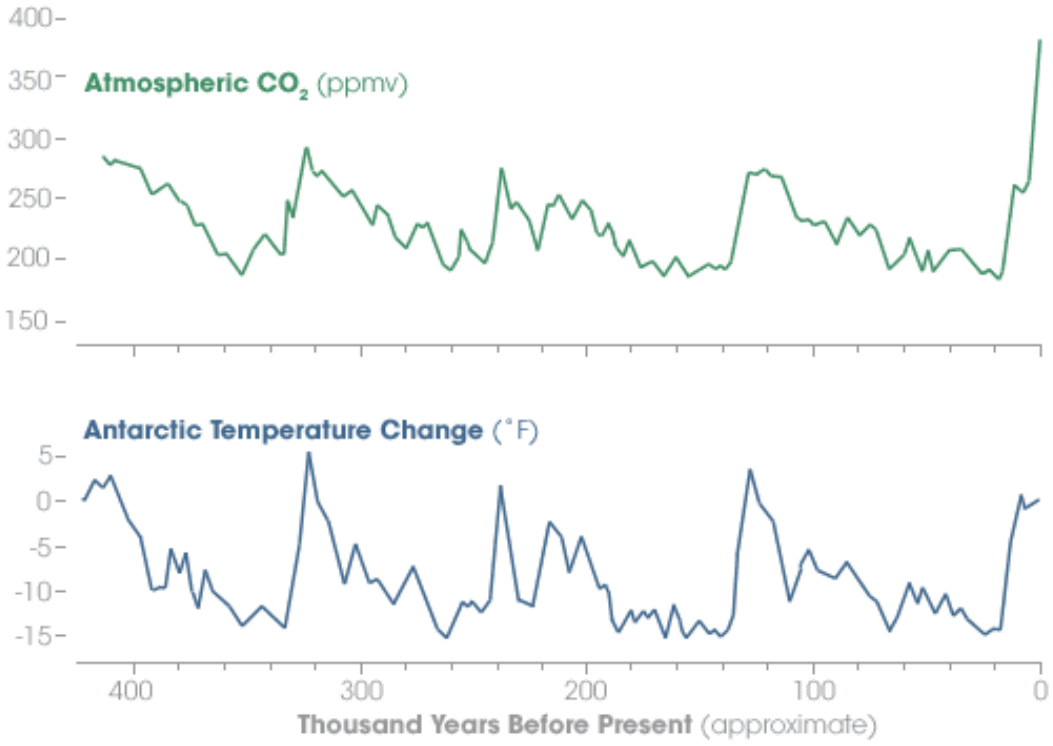


Figure 3. Graphs of Atmospheric Carbon Dioxide and Temperature Change.
Image credit: NASA Earth Observatory
http://earthobservatory.nasa.gov/Features/TimeShelf/Images/vostok_graph.gif

1. What patterns and trends can you identify between the top and bottom graph?

2. Describe how human activities may affect the changes observed in both graphs.

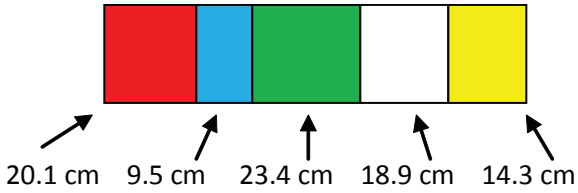
ANSWER KEY

EXPLORE

1. The age of the ice core is measured from oldest layer (bottom) to youngest layer (top). Where would you expect to see the most dirt and particles in this sample? Why?
   (Suggested responses may indicate that there would be more dirt and particles near the top of the ice core (most recent and youngest layer) due to an increase in industrialization and world population. Students would likely say that the youngest layers of ice had the greatest particulate concentrations.)
2. When carbon dioxide from the atmosphere combines with precipitation it may become carbonic acid. Carbonic acid lowers the pH and may be recorded in ice layers. When scientists find lower levels of pH in ice core samples, this may indicate an increase in carbon dioxide in the atmosphere. Where would you expect to find the lowest pH in this sample? Why?
   (Students may note that the lowest pH would be related to higher carbon dioxide concentrations. Students should suggest that there are higher carbon dioxide concentrations, resulting in lower pH in the younger layers.)

Ice core sketch

Sketches will vary but should include measurements, colors, and ways to indicate different ice layers.



Data Table 1. Ice Core Data (Answers will vary based upon ice cores.)

Layer Number	Color	Mass (g) of plastic cup	Mass (g) of plastic cup and ice layer	Mass (g) of ice layer	Volume (mL) of melted layer	pH
1	Red	7.8	26.4	18.6	18.0	6
2	Blue	7.6	16.6	9.0	8.8	6
3	Green	7.6	30.3	22.7	22.1	5
4	Clear	7.7	25.8	18.1	17.9	4
5	Yellow	7.8	21.6	13.8	13.4	4

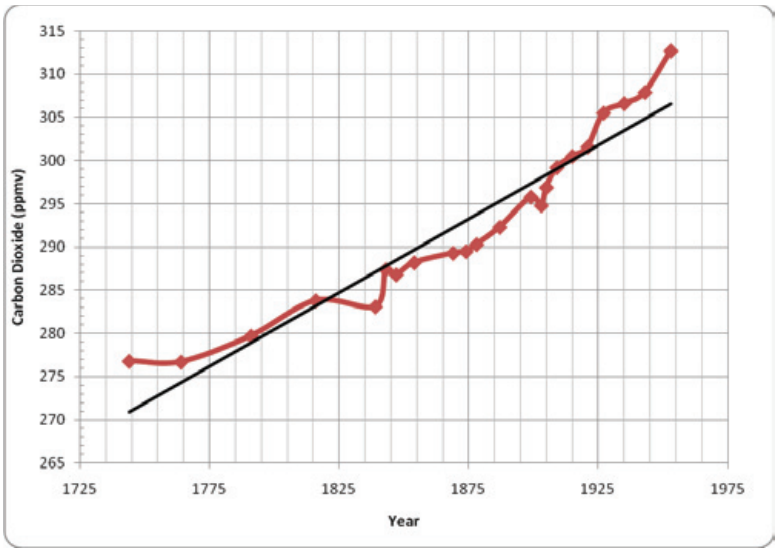
ANSWER KEY

9. Design your own procedure and data collection chart to measure and record the mass of the solid particles in each layer.
   (Answers will vary but students may choose to separate the solid particles from the melted ice using filter paper, paper towels, or coffee filters. Students should create step-by-step directions for this procedure.)

EXPLAIN

1. Based on what you have read, experienced, and seen in the NASA eClips™ Launchpad segment, what tools and evidence do scientists use to study climate change?
   (Suggested responses may include studying the physical properties like layer thickness and chemical properties like the composition of gases trapped by bubbles in the ice)
2. How did the work that you completed in the EXPLORE activity compare to the work scientists do when they study ice core samples?
   (Students should discuss the use of tools to help make quantitative observations. They should also discuss careful observations and recording observations NOT opinions.
3. How did the ice core layers change over time? What might you infer about climate change based upon your observations and measurements?
   (Students should notice an increase in solid particles and a decrease in pH as they observe older to younger ice core layers. Based upon these observations, students might infer an increase in particle pollutants and carbon dioxide in the atmosphere.)

4. **Graph 1**. Carbon Dioxide Data from Siple Station Ice Core



ANSWER KEY

5. Use the line graph to answer these questions.
   a. Describe the pattern or trend represented in the graph.
      (Students should note that there is a steady increase in the concentration of carbon dioxide in the atmosphere.)
   b. What factors might have led to an increase in carbon dioxide?
      (Students may discuss an increase in industrialization and world population. They may discuss carbon dioxide emissions from an increase in burning fossil fuels.)

EXTEND

1. How does this data compare to the data you graphed from the Siple Station Ice Core.
   (Students should note that both graphs indicate a steady increase in the amounts of carbon dioxide in the atmosphere.)
2. Why is it important for scientists to gather data in multiple ways?
   (Students should discuss the importance of gathering data in multiple ways to verify data.)

EVALUATE

1. What patterns and trends do you see between the top and bottom graph?
   (Students should observe that changes in carbon dioxide are mirrored by changes in temperature.)
2. How might human activities affect the changes observed in both graphs?
   (Answers will vary but students may discuss that an increase in population impacts the burning of fossil fuel. With an increase in burning fossil fuel, there is an increase in carbon dioxide emissions. And, with an increase in carbon dioxide in the atmosphere, the data supports that there is an increase in temperature.)

Career Clip

1. How is the work that you have been doing during this lesson similar to the work Dr. Wasilewski does every day?
   (Answers will vary but should center on the fact that studying ice cores is one way to find out about the long term history of a planet, something that planetary scientists would study.)
2. What can you do today that may help you prepare for a future career as a scientist?
   (Answer will vary. Students may mention taking more science classes and doing more labs or experimentation.)