**Goals**

In this activity you will:

- Compare data to understand the relationship of carbon dioxide to global temperature.
- Evaluate given data to draw a conclusion.
- Recognize a pattern of information graphed in order to predict future temperature.
- Understand some of the causes of global warming.

**Think about It**

“What really has happened to winter?” You may have heard this type of comment.

- **What causes “global warming”?**

What do you think? Write down your ideas to this question in your EarthComm notebook. Be prepared to discuss your responses with your small group and the class.
Investigate

Part A: Atmospheric Carbon Dioxide Concentrations over the Last Century

1. Graph the concentration of carbon dioxide in the atmosphere from 1900 to 2000. Put the year on the $x$ axis and the CO$_2$ levels (in parts per million) on the $y$ axis.

2. On the same graph, plot the global average temperature for the same period. Put another $y$ axis on the right-hand side of the graph and use it for global average temperature.

a) Is there a relationship between carbon dioxide concentration and global average temperature? If so, describe it.

b) What do you think is the reason for the relationship you see?

Part B: Atmospheric Carbon Dioxide Concentrations over the Last 160,000 Years

1. Look at the figure showing data from an ice core in Antarctica. The graph shows changes in concentrations of carbon dioxide and methane contained in trapped bubbles of atmosphere within the ice, and also temperature change over the same period.

### Data on 10-year Average Global Temperature and Atmospheric Carbon Dioxide Concentration

<table>
<thead>
<tr>
<th>time interval</th>
<th>average global temperature ($^\circ$F)</th>
<th>atmospheric carbon dioxide (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901–1910</td>
<td>56.69</td>
<td>297.9</td>
</tr>
<tr>
<td>1911–1920</td>
<td>56.81</td>
<td>301.6</td>
</tr>
<tr>
<td>1921–1930</td>
<td>57.03</td>
<td>305.19</td>
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<tr>
<td>1931–1940</td>
<td>57.25</td>
<td>309.42</td>
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<tr>
<td>1941–1950</td>
<td>57.24</td>
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<td>1951–1960</td>
<td>57.20</td>
<td>313.5</td>
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<tr>
<td>1961–1970</td>
<td>57.14</td>
<td>320.51</td>
</tr>
<tr>
<td>1971–1980</td>
<td>57.26</td>
<td>331.22</td>
</tr>
<tr>
<td>1981–1990</td>
<td>57.71</td>
<td>345.87</td>
</tr>
<tr>
<td>1991–2000*</td>
<td>57.87</td>
<td>358.85</td>
</tr>
</tbody>
</table>

*carbon dioxide data only through 1998.
Activity 5 How Do Carbon Dioxide Concentrations in the Atmosphere Affect Global Climate?

1. Work as a group to design an experiment to demonstrate the greenhouse warming in the atmosphere. The experiment should be simple in design, include a control element, and be performed in a short period of time (for example, a class period). The experiment will be presented to the community as a way to show the greenhouse effect.

   a) Record your design in your EarthComm notebook. Remember to include a hypothesis. Be sure to also include any safety concerns.

2. Decide on the materials you will use. The materials should be inexpensive and easy to get. The following is a possible list:
   - two identical 2-L plastic bottles with labels removed and tops cut off or two identical beakers
   - water
   - a clear plastic bag
   - a thermometer
   - ice cubes
   - a sunny windowsill or two similar lamps

   a) Record your list in your EarthComm notebook.

3. Decide on the measurements that you will make.

   a) Prepare a data table to record your observations.

4. With the approval of your teacher, conduct your experiment.

   ! Have the design of your experiment checked carefully by your teacher for any safety concerns.

Part C: The Greenhouse Effect

The phrase “greenhouse effect” is used to describe a situation in which the temperature of an environment (it could be any environment like a room, a car, a jar or the Earth) increases because incoming solar energy gets trapped because heat energy cannot easily escape. The incoming energy easily enters into the environment, but then, once it has been absorbed and is being re-radiated, it is harder for the energy to escape back out of the environment.
Climate Change

5. Use the results of your experiment to answer the following questions:
   a) How did this experiment demonstrate (or fail to demonstrate) the greenhouse effect?
   b) How can this experiment serve as an analogy for atmospheric greenhouse effects?
   c) Was there any difference observed between the greenhouse experiment and the control?
   d) If there was a difference (or differences) describe it (them) in both qualitative and quantitative terms.
   e) How did the data in each case change through time during the experiment?
   f) Did the experiment reach a point of equilibrium where continuing changes were no longer observed? (Note: To answer this question, it may take longer than the class period, or, alternatively, you could hypothesize an answer to this question based on the trends of the data that you were able to gather.)

Reflecting on the Activity and the Challenge

In this activity you designed an experiment to demonstrate the greenhouse effect. You also examined the concentration of atmospheric carbon dioxide to see if it is correlated with changes in global average temperature. You discovered that an increase in carbon dioxide seems to be correlated with an increase in global average temperature. You will need this information to begin writing your article on “What is Global Warming?”

Digging Deeper

CARBON DIOXIDE AND GLOBAL CLIMATE

Correlation Studies

The relationship between carbon dioxide and global climate was mentioned in previous activities. When there is more carbon dioxide in the atmosphere, global temperatures are higher. When there is less carbon dioxide in the atmosphere, temperatures are lower. A scientist would say that there is a correlation between carbon dioxide concentration and global temperature. You might think, “Oh, that’s because carbon dioxide concentration affects global temperature.” And you might be right—but you might be wrong.
Activity 5 How Do Carbon Dioxide Concentrations in the Atmosphere Affect Global Climate?

It is important to keep in mind always that a correlation does not, by itself, prove cause and effect. There are three possibilities: (1) carbon dioxide affects temperature; (2) temperature affects carbon dioxide; and (3) both are affected by a third factor, and are independent of one another! Any one of these three possibilities is consistent with the observations. It is the scientists’ job to try to figure out which is the right answer. There are good reasons to think that the first possibility is the right one. That is because carbon dioxide is a “greenhouse gas.”

What Are Greenhouse Gases?

The reason that the Earth is warm enough to support life is that the atmosphere contains gases that let sunlight pass through. Some of these gases absorb some of the energy that is radiated back to space from the Earth’s surface. These gases are called greenhouse gases, because the effect is in some ways like that of a greenhouse. Without greenhouse gases, the Earth would be a frozen wasteland. Global temperatures would be much lower. Water vapor is the most important contributor to the greenhouse effect. Other greenhouse gases include carbon dioxide, methane, and nitrogen oxides.

How do greenhouse gases work? Most solar radiation passes through the clear atmosphere without being absorbed and is absorbed by the Earth’s surface (unless it’s reflected back to space by clouds first). There is a law in physics that states that all objects radiate electromagnetic radiation. The wavelength of the radiation depends on the objects’ surface temperature. The hotter the temperature, the shorter the wavelength. The extremely hot surface of the Sun radiates much of its energy as visible light and other shorter-wavelength radiation. The much cooler surface of the Earth radiates energy too, but at much longer wavelengths. Heat energy is in the infrared range (infra- means “below,” and the color red is associated with the longest wavelength in the color spectrum). See Figure 1.
Greenhouse gases are those that absorb some of the outgoing infrared radiation. None of them absorb all of it, but in combination they absorb much of it. They then re-radiate some of the absorbed energy back to the Earth, as shown in Figure 2. That is what keeps the Earth warmer than if there were no greenhouse gases.

**Figure 2** Schematic diagram illustrating how the greenhouse effect works.

### The Carbon Cycle

Carbon dioxide is put into the atmosphere in two main ways: during volcanic eruptions, and by oxidation of organic matter. Oxidation of organic matter happens naturally in the biosphere. It occurs when plant and animal tissue decays. The organic matter is converted back to carbon dioxide and water. It also happens when animals breathe (and when plants respire too!). When you breathe, you take in oxygen, which you use to oxidize organic matter—your food. Then you breathe out carbon dioxide. Organic matter is also oxidized (more rapidly!) when it is burned. Carbon dioxide is released into the atmosphere whenever people burn wood or fossil fuels like gasoline, natural gas, or coal.

Plants consume carbon dioxide during photosynthesis. It is also consumed during the weathering of some rocks. Both land plants and algae in the ocean...
Activity 5 How Do Carbon Dioxide Concentrations in the Atmosphere Affect Global Climate?

use the carbon dioxide to make organic matter, which acts as a storehouse for carbon dioxide. Carbon dioxide is constantly on the move from place to place. It is constantly being transformed from one form to another. The only way that it is removed from the “active pool” of carbon dioxide at or near the Earth’s surface is to be buried deeply with sediments. Even then, it’s likely to reenter the Earth–surface system later in geologic time. This may be a result of the uplift of continents and weathering of certain carbon-rich rocks. This transfer of carbon from one reservoir to another is illustrated in the carbon cycle shown in Figure 3.

Carbon Dioxide and Climate

It appears that the more carbon dioxide there is in the environment, the warmer global temperatures are. Scientists have determined this from geologic data like the kind you worked with in the investigation. To what extent is this because carbon dioxide in the atmosphere acts as a greenhouse gas?
It is valuable to look at this question on two different time scales. On a scale of hundreds of thousands of years, carbon dioxide and global temperature track each other very closely. This correlation occurs through several glacial–interglacial cycles (Figure 4). It is not easy to develop a model in which carbon dioxide is the cause and global temperature is the effect. It’s much more likely that variations are due to Milankovitch cycles. They may well explain the variation in both global temperature and carbon dioxide. On a scale of centuries, however, the picture is different. It seems very likely that the increase in carbon dioxide has been the cause of at least part of the recent global warming.

Human emissions of greenhouse gases contribute significantly to the total amount of greenhouse gases in the atmosphere. For a long time humans have been adding a lot of carbon dioxide to the atmosphere by the burning of fossil fuels. This has especially increased in the past couple of centuries. Before the Industrial Revolution, carbon dioxide concentrations in the atmosphere were approximately 300 ppm (parts per million). As of 1995, carbon dioxide concentrations were almost 360 ppm. Scientists are concerned that the temperature of the Earth may be increasing because of this increasing concentration of carbon dioxide in the atmosphere.

Many nations have a commitment to reduce the total amount of greenhouse gases produced. It is their effort to reduce the risk of rapid global temperature increase. The trouble is that the size of the effect is still uncertain. Some people take the position that the increase in carbon dioxide should be reversed. They believe this is necessary even though the size of the contribution to global warming is not certain. It is their belief that the
consequences would be very difficult to handle. Other people take a different position. They consider that it would be unwise to disrupt the world’s present economy. They consider the future danger to be questionable. The big problem is that no one is certain that rapid global warming will take place. If it does, it may be too late to do anything about it!

Not all of the carbon dioxide released by burning of fossil fuels stays in the atmosphere. Carbon dioxide is also dissolved in ocean water. As carbon is put into the atmosphere, some of it is absorbed by the oceans. That lessens the impact of burning of fossil fuels on climate. Some people have even suggested that enormous quantities of carbon dioxide should be pumped into the oceans. That would tend, however, to just postpone the problem until later generations. Carbon dioxide is also stored by reforestation. Reforestation is the growth of forests on previously cleared farmland. Did you know that there is a lot more forested land in the eastern United States now than at the time of the Civil War? The Civil War took place almost 150 years ago. By some estimates, the United States is a sink, rather than a source, for carbon dioxide. Extensive reforestation is occurring east of the Mississippi, despite the continuing expansion of suburbs and shopping malls!

Geo Words

reforestation: the replanting of trees on land where existing forest was previously cut for other uses, such as agriculture or pasture.

Check Your Understanding

1. List four greenhouse gases. Which gas contributes most to the greenhouse effect?
2. Explain how greenhouse gases make it possible for humans to live on Earth.
3. What are two ways in which carbon dioxide is put into the Earth’s atmosphere?

Figure 5 Clear-cut forest area in Olympic National Forest, Washington.
Understanding and Applying What You Have Learned

1. Which of the following activities produce carbon dioxide? Which consume carbon dioxide? Explain how each can influence global climate.
   a) cutting down tropical rainforests
   b) driving a car
   c) growing shrubs and trees
   d) breathing
   e) weathering of rocks
   f) volcanic eruptions
   g) burning coal to generate electricity
   h) heating a house using an oil-burning furnace.

2. Describe the carbon cycle in your community. List the ways that carbon dioxide is produced and used up and the organisms responsible for cycling.

3. What are some difficulties involved with predicting concentrations of atmospheric carbon dioxide into the future?

4. Examine the graph your group prepared. You have gathered data through the year 2000. You have seen that this data has changed over time. Using additional graph paper, try to continue this pattern for the next 10 years.

5. The United States has a population of about 280 million people (according to the 2000 census) and uses about 70 billion gigajoules of energy a year. India has a population of about 835 million people (1990) and uses about 7 billion gigajoules of energy a year.
   a) Divide the United States’ total yearly energy use by its population to find out the yearly energy use per person.
   b) Calculate the yearly energy use per person for India.
   c) Give as many reasons as you can to explain the difference.
   d) Do you think you use more or less energy than the typical American? Explain.
   e) If you wanted to use less energy, what would you do?
   f) Why is how much energy you use important when considering how much carbon dioxide is in the air?

6. Determine one source of greenhouse gas emission in your community.
   a) What gas is being produced?
   b) How is it produced?
   c) Can you think of a way to determine the level of the gas that is being produced by your community?
   d) Propose a means for limiting emissions of this gas.
Activity 5 How Do Carbon Dioxide Concentrations in the Atmosphere Affect Global Climate?

Preparing for the Chapter Challenge

1. Using a newspaper style of writing, write several paragraphs in which you:
   • explain how humans have increased the concentration of carbon dioxide in the atmosphere
   • explain why scientists think that increased carbon dioxide levels might lead to global climate change.

2. Clip and read several newspaper articles containing quotations.

3. Interview a member of your community about global warming. Is this person concerned about global warming? What does he or she think people should do about it? Look over your notes from your interview. Pick out several quotations from the community member that might work well in a newspaper article.

Inquiring Further

1. Intergovernmental Panel on Climate Change (IPCC)
   The Intergovernmental Panel on Climate Change (IPCC) is a group of more than 100 scientists and economists from many countries that is investigating the possibility of global warming and proposing ways that the nations of the world should respond. Do some research on the IPCC and what they have reported.

2. Earth Summit
   Investigate the 1997 United Nations Earth Summit in New York. What did the world’s nations agree to at the Summit? Have the nations stuck to their promises?