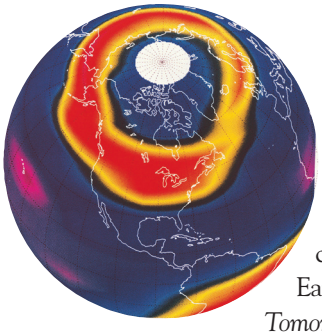


Inside global warming

Over the last 15 years, much attention has been given to global warming, and whether the increase in the Earth's temperature in recent decades threatens the survival of life on Earth. Release of the films *The Day After Tomorrow* (2004), where North America is rapidly plunged into a new ice age, and *An Inconvenient Truth* (2006), where Al Gore focuses on the future impacts of global warming, has raised much public and media attention on the subject. As such, it's important that science teachers understand the basics behind the scientific phenomenon, the controversy surrounding the topic, and how to discuss and explore global warming with their students.

What is global warming and what causes it?

Global warming is the observed overall statistical increase in the average temperature of the Earth's atmosphere and oceans over recent years. According to the U.S. National Academy of Sciences, the Earth's surface temperature has risen by about one degree Fahrenheit in the last century, with accelerated warming in the last two decades. While there are a number of causes for global warming, strong scientific evidence proposes that over the last 50 years the largest contributor to global warming has been human activities that have released certain heat-trapping gases into the atmosphere, increasing global mean temperature because of the greenhouse effect.

The *greenhouse effect* refers to the radiative effect by which the atmosphere warms a planet, i.e., the trapping of the Sun's rays within atmospheric gases and how that trapping of the rays—and their heat—moderates global temperature (Figure 1). Without the greenhouse effect, our planet would not be able to sustain life—it would be too cold. The increased retention of solar radiation as a result of increased amounts of greenhouse gases in the atmosphere—called greenhouse warming—is proposed by scientists to be responsible for 50% of the global warming in the past 50 years.

The naturally occurring gases in our atmosphere that trap solar radiation—and therefore contribute to greenhouse warming—include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and ozone (O_3). While all of these gases are naturally occurring (water vapor and CO_2 are primary gases emitted in volcanic eruptions, for example), significant levels of these gases are also produced via human activity. CO_2 is a product of combustion (burning of solid waste, wood, and fossil fuels such as oil, gas, and coal). CH_4 is emitted during the production and transport of fossil fuels and the decomposition of organic wastes. NO_2 is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

In addition, other non-naturally occurring gases that greatly contribute to the atmosphere's ability to trap solar radiation include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), all of which are generated via industrial processes.

Each individual greenhouse gas differs in its ability to absorb heat in the atmosphere. Of the non-naturally occurring gases, HFCs and PFCs are the most heat-absorbent. Of the naturally occurring gases, methane traps over 21 times more heat per molecule than carbon dioxide and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Therefore, it is important when discussing emissions of gases into the atmosphere to remember that not all greenhouse gases are equal in contributing to greenhouse warming; both the quantity and heat-trapping potential of each gas must be considered.

How is the Earth's temperature different now than it has been in the past?

Reliable data on global temperature is available from approximately 1880 forward. As stated earlier, it is estimated that the Earth's global mean temperature has risen approximately 1°F in the last 100 years (see Figure 2). In addition, the 10 warmest years in the last century all occurred within the last 15 years.

One degree Fahrenheit may not seem to be a significant change to the vast majority of the public; however, examining the effects of a 1°F increase in mean global temperature shows how delicate and vulnerable the Earth is to such an increase. The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased dramatically during the last 50 years. Globally, sea level has risen 4–8 inches over the past century. Worldwide precipitation over land has increased by about 1%. The frequency of extreme rainfall events has increased throughout much of the United States. Recent warming has degraded large sections of permafrost, with pockets of soil collapsing as the ice within melts. The results include buckled highways, sinkholes, destabilized houses, drunken forests (trees that lean at wild angles), and even sinking cit-

Roxanne Greitz Miller (rgmiller@chapman.edu) *is assistant professor of secondary and science education at Chapman University in Orange, California, and a former middle school and senior high school science teacher in the public schools of Florida.*

ies—such as the city of Kipnuk, Alaska (see Figure 3). Global warming's effects are not limited to North America; Europe, Asia, and Antarctica have all experienced changes.

Is global warming connected to the hole in the ozone layer?

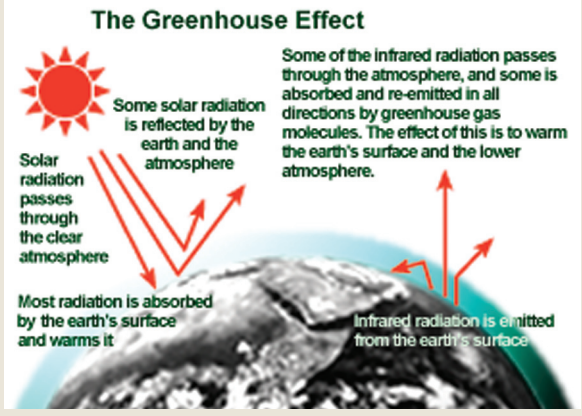
Global warming and ozone depletion are two separate but related threats to our climate. Global warming and the greenhouse effect refer to the warming of the lower part of the atmosphere (the troposphere). The ozone hole (or ozone depletion) refers to the loss of ozone in the upper part of the atmosphere known as the stratosphere (see Figure 4). Stratospheric ozone blocks incoming ultraviolet radiation from the Sun, some of which is harmful to plants, animals, and humans. Greenhouse ozone is released into the lower atmosphere, thereby contributing to greenhouse warming, but it does not plug the ozone hole in the upper atmosphere. However, global warming and ozone depletion are related in a number of ways, including:

- CFCs trap heat and destroy the ozone layer. Currently, these gases are responsible for less than 10% of total atmospheric warming, far less than the contribution from the main greenhouse gas, carbon dioxide.
- The ozone layer traps heat, so if it gets destroyed, the upper atmosphere actually cools, thereby offsetting part of the warming effect of other heat-trapping gases. But that's not entirely good news—the cooling of the upper layers of the atmosphere can produce changes in the climate that affect weather patterns in the higher latitudes.
- Trapping heat in the lower part of the atmosphere allows less heat to escape into space and leads to cooling of the upper part of the atmosphere. The colder it gets, the greater the destruction of the protective ozone layer (see "Frequently asked questions about global warming" in Resources).
- Reducing ozone-depleting gases is necessary to prevent further destruction of the ozone layer, but eliminating these gases alone will not solve the global warming problem.

How is Earth likely to be affected in the next 100 years?

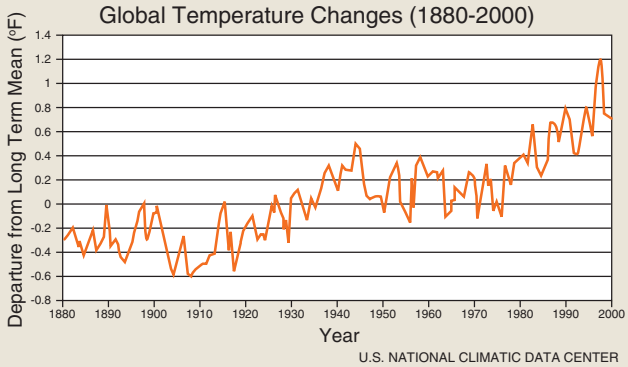
Based on scientific modeling from the IPCC (Intergovernmental Panel on Climate Change), the Earth's average surface temperature in the next 50 years could rise by 0.6 to 2.5 degrees Celsius (1 to 4.5 degrees Fahrenheit); this estimated change represents a 200% to 900% increase in the rate of change experienced on Earth in the last 100 years. By the year 2100, global mean temperature could rise 1.4 to 4.8 degrees Celsius (2.5 to 10.4 degrees Fahrenheit) relative to 1990.

FIGURE 1 **The greenhouse effect**



EPA

FIGURE 2 **Global temperature changes, 1880–2000**



U.S. NATIONAL CLIMATIC DATA CENTER

FIGURE 3 **Kipnuk, Alaska, a coastal Inuit village, is home to 500 people**

The village is sinking because it sits atop thawing permafrost.

LOWER KUSKOKURM NEA

Predicted warming is greater over higher latitudes than lower ones (meaning polar and near-polar regions will experience greater warming; a significant implication for thawing of permafrost and glaciers), and more warming is predicted to occur over land than over sea. Rainfall rates and the incidence of heavy precipitation are expected to increase; higher evaporation rates would accelerate the drying of soils after precipitation events. The result will be lower relative humidities and higher daytime temperatures, especially during the warm season, and will likely effect semi-arid regions such as the U.S. Great Plains significantly.

According to a recent National Center for Atmospheric Research (NCAR) model, global warming may thaw the top 10 or more feet of perennially frozen soil—permafrost—in the Northern Hemisphere, altering ecosystems across Canada, Alaska, and Russia. NCAR's simulations show that more than half of the area covered by this topmost layer of permafrost could thaw by 2050, and as much as 90% by 2100 (Figure 5). Scientists expect the thawing to send considerable amounts of water into the oceans, and to release large amounts of carbon into the atmosphere. Runoff to the Arctic has increased about 7% since the 1930s; if high-emissions continue as represented in the NCAR simulation, runoff would grow by another 28% by the year 2100. That increase includes contributions from enhanced rainfall and snowfall (see "Most of Arctic's near-surface permafrost may thaw by 2100" in Resources), as well as the water from ice melting within soil.

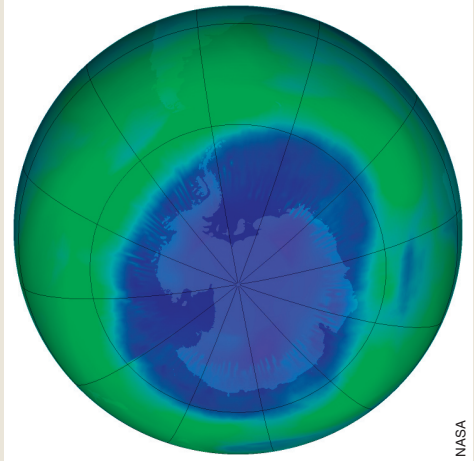
However, thawing permafrost has another major implication for global warming other than the release of water into the world's oceans. A new study highlights concern about emissions of greenhouse gases from thawing soils. Permafrost may hold 30% or more of all the carbon stored in soils worldwide. As the permafrost thaws, it could lead to large-scale emissions of methane and/or carbon dioxide beyond those produced by fossil fuels. Therefore, the thawing of permafrost can contribute more greenhouse gases to the atmosphere, and therefore increase global warming in addition to being a consequence of it.

What is the ultimate predicted outcome of global warming?

If global warming proceeds as predicted, barring any changes to reduce the effects, the following consequences are anticipated:

- food shortages;
- water shortages, as meltwater sources are decreased and evaporation rates are increased;
- rise in sea levels and coastal flooding;
- increased storm activity and precipitation levels, with accompanying storm damage to inland and coastal regions,
- increased droughts;
- increased rates of species extinction;
- movement of disease-vector species into currently unaffected areas—think about mosquitoes that are usually contained in warm water areas spreading further north and to higher altitudes; it is already being seen in many regions.

FIGURE 4 **Ozone layer hole**



Are humans to blame for recent climate change?

Global warming (and the greenhouse effect) has natural causations, as well as anthropogenic (human-made) ones. For example, increased solar radiation contributes to global warming (more radiation equals more heat trapped by the atmosphere), and gases emitted from volcanoes and other natural processes of the Earth contribute to trapping more radiation within the atmosphere via the greenhouse effect. Global warming is accepted as fact by most of the scientific community, including the U.S. National Academy of Sciences; however, *greenhouse warming* is not as widely accepted. Many scientists contend that global warming is more the result of natural climate change than the result of human actions contributing greenhouse gases to the atmosphere; and that when viewed historically over centuries, the recent increase in global mean temperature is not something that we should be concerned about. Further, because of carbon dioxide's positive influences on plant productivity (remember, plants take in carbon dioxide and release oxygen in photosynthesis), they propose that the relative prosperity and levels of plant productivity—and food abundance—are a benefit of higher carbon dioxide levels in the atmosphere in recent years, and that decreasing carbon dioxide output into the atmosphere, which is recommended by many scientists and governments as a remedy to global warming, will actually have negative effects for life on Earth.

However, climatologists who have analyzed global temperature for different historical epochs counter this position. They have found that temperature fluctuations prior to the Industrial Revolution were driven primarily by natural

solar and volcanic forcings (causes). In the early 20th century, natural and anthropogenic forcings seem to contribute equally; but from midcentury onwards, greenhouse gas emissions appear to be the primary cause of warming—thus, they state that the case for blame rests overwhelmingly with humans.

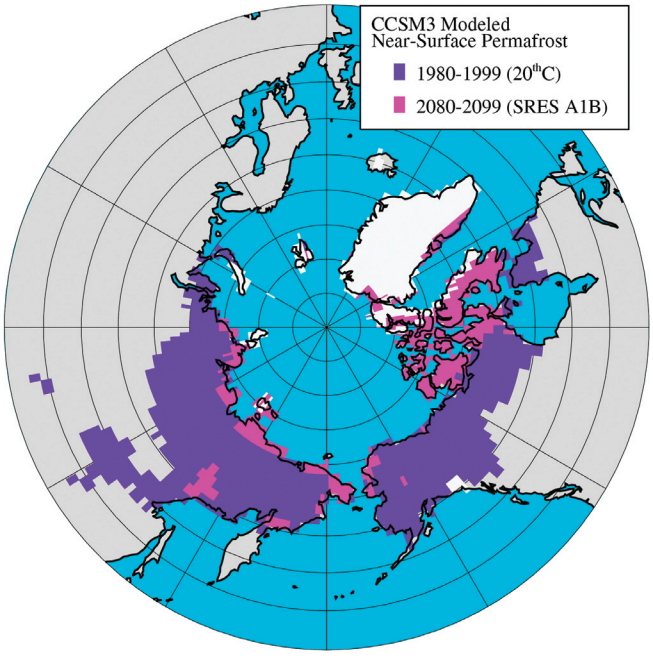
What can people do to reduce global warming?

To reduce global warming, people have to reduce the amounts of greenhouse gases going into the atmosphere. Here are some relatively simple ways that this can be done:

- Reduce, reuse, recycle—Because combustion and other industrial processes release carbon dioxide and other greenhouse gases into the atmosphere, employing the 3 Rs helps to reduce the amount of waste generated (and therefore needing to be disposed), and reduces industrial processing needed to make new products.
- Reduce the amount of energy used in your home—Insulating your home, caulking windows, using weather stripping around doors, raising/lowering your thermostat to conserve energy, reducing your consumption of hot water in clothes washing and dishwashing, and buying energy-efficient appliances and products (such as fluorescent light bulbs) all reduce the amount of energy used in your home, and therefore lower the amount of energy needed to be produced by power plants that release steam (water vapor) or fossil-fuel emissions into the atmosphere.
- Encourage and support efforts to end deforestation—Deforestation (cutting down forests to provide clear land for farming or building) has a profound effect on the global carbon cycle. From 1850 to 1990, deforestation worldwide (including the United States) released 122 billion metric tons of carbon into the atmosphere, with the current rate being approximately 1.6 billion metric tons per year. In comparison, fossil-fuel burning releases about 6 billion metric tons per year. Clearly, deforestation makes a significant contribution to the increasing CO_2 in the atmosphere. Tropical deforestation also affects the local climate of an area by reducing the evaporative cooling that takes place; as trees and plants are cleared away, more of the Sun's energy is able to warm the Earth's surface and, consequently, the air above, leading to a rise in temperatures.
- Reduce your dependence on fossil-fuel burning transportation—Rather than using a fossil-fuel-based automobile for all your transportation needs, bicycle or walk short distances, carpool or use mass transit, or consider switching to a cleaner fuel (such as compressed natural gas or biofuel) or electric vehicle. See my article, "Inside Alternatively Powered Vehicles: The Problems and the Possibilities," in *Science Scope*'s January 2006 issue for a full discussion of the options.

FIGURE 5 **Permafrost projection map**

Purple shows the extent of permafrost from 1980 to 1999; pink indicates the permafrost projected to be remaining in 2080–2099.



Classroom activities and resources

Global warming is a natural interdisciplinary science topic that can be explored at the middle grades and beyond. Because it combines meteorology, astronomy, biology, chemistry, and physics, there are a number of science courses in which global warming can be used as a topic of study, and a variety of curriculum standards can be covered during units on global warming. The following are some resources that you may find useful in your own classrooms:

In *Science Scope*'s January 2001 issue, Pamela Galus discusses her simulation of how carbon dioxide increases temperature in a closed system in her article "The Greenhouse Effect or Earth's Natural Cycle?" It is a simple but fantastic experimental simulation that provides students a concrete experience with observing temperature increase from CO_2 emissions.

At the EPA Global Warming website (*http://*

yosemite.epa.gov/oar/globalwarming.nsf/content/index.html) and its companion site for kids *(www.epa.gov/globalwarming/kids/index.html)*, you'll find information on global warming, climate change, and the greenhouse effect. The sites provide news articles (the most timely social, scientific, and logistic information available on the global warming issue), online tools, and relevant links. Educators can access lesson ideas, flash animation simulations of climate changes, and much more. The Kids Site also has links to different games, activities, and quizzes students (or teachers) can use to assess their understanding of the content.

Tom Brown and Michael Dias's article, "Demonstrations to Save the World," in *Science Scope*'s April 2003 issue, which provides an activity called Biosphere Bubbles, allows students to explore the properties of carbon dioxide bubbles, contrast them with regular air bubbles, and make some predictions about their own contribution of carbon dioxide to the atmosphere and its effects.

The Global Warming Unit available on the Michigan State University website *(http://commtechlab.msu.edu/sites/letsnet/noframes/subjects/science/b5u1.html)* provides complete lessons on global warming, and guides students through writing a research paper on global warming and presenting their research to their school.

The Day After Tomorrow DVD contains a special feature on the science behind climate change, and this portion of the DVD could be used with students to prompt discussion. Please note that the actual film itself is widely regarded as being scientifically inaccurate; excerpts from the film could be shown as examples of how climate change trends are misinterpreted.

The World Wildlife Fund Climate Change Campaign *(www.panda.org/about_wwf/what_we_do/climate_change)* is committed to persuading western industrialized nations to reverse the trend of rising greenhouse gas emissions. Their website addresses climate change issues (cause, impacts, solutions) and provides a series of related articles and coverage of world climate news.

Canada's Global Climate Change website *(http://climatechange.gc.ca/english)* was developed to inform people about climate change and how it affects our environment. It houses many resources for both teachers and students regarding climate change and its impact and solutions, which include school projects, maps, related links to government sites, as well as a directory of organizations that support teachers.

The Climate Change Calculator *(www.americanforests.org/resources/ccc)* is an interactive software tool designed to raise people's awareness of the greenhouse gases they produce through their daily activities and lifestyle choices. It is a fun, informative, and interactive tool with supporting resources and data on the website.

Common Questions About Climate Change *(www.gcrio.org/ipcc/qa/index.htm)* provides answers to some of the most commonly asked questions about climate change, including whether the Earth has warmed, which human activities are contributing to climate change, what further climatic changes are expected to occur, and what effects these changes may have on humans and the environment.

Parting thoughts

Regardless of the approach that you take with your students, whether it be an experiment, research, debate, or simply a discussion, global warming is something that they are likely to be interested in and concerned about. While their heightened interest is an inducement to learning, particular care should be taken with students in discussions about global warming, due to its possible emotional implications—as a middle school teacher you surely know that a young adolescent with a little bit of knowledge and a heightened emotional state can be a potentially dangerous thing. It is precisely for this reason that we must try to equip these students with a greater understanding of the science behind global warming, and with definite ways in which they can take action to help mitigate its effects in the future.

Acknowledgment

The author wishes to thank Angie Sanchez, who contributed to the research in preparation of the article.

Resources

In addition to the resources previously mentioned, the following were used in preparation for this article. All information published was current as of press date; however, due to the daily release of information, please check all websites for the latest updates.

A paleo perspective on global warming—*www.ncdc.noaa.gov/paleo/globalwarming/what.html*.

Are you a global warming skeptic? Part IV—*http://blog.sciam.com/index.php?title=are_you_a_global_warming_skeptic_part_iv&more=1&c=1&tb=1&pb=1*.

Frequently asked questions about global warming—*www.ucsusa.org/global_warming/science/global-warming-faq.html*.

Global Citizens For Change. Climate Change Links and Resources—*www.citizens4change.org/global/environment/climate_change_link.htm*.

Most of Arctic's near-surface permafrost may thaw by 2100—*www.ucar.edu/news/releases/2005/permafrost.shtml*.

Permafrost meltdown across the Arctic—*www.ens-newswire.com/ens/dec2005/2005-12-20-03.asp*.