Module 3, Investigation 3: Briefing
Are we warming Earth?

Background
Mark Twain once remarked that everybody talks about the weather but nobody does anything about it. If that was true in Twain's time, it may not be true today. Many scientists today think that rising temperatures on Earth are caused by specific human activities—that we *are* "doing something about the weather" but that we shouldn't be doing it. They have identified increasing global temperatures as a significant issue that requires the attention of the global community. They believe that major changes in our behavior are needed to stop human-caused **global warming**, also known as the theory of an **enhanced greenhouse effect**.

But some scientists disagree with this: they remind us that many climate changes have occurred in the past, and that attributing global warming to a human-enhanced greenhouse effect might be wrong. They argue that the assumptions and predictions of climate change are flawed and that we should not make significant changes in our behavior until more is understood. This investigation introduces you to the global warming debate and provides data to assist you in writing a persuasive editorial about it.

Objectives
In this investigation you will
- analyze variability of weather and climate,
- interpret global climate data,
- identify areas experiencing temperature and precipitation extremes,
- critically examine possible causes of global warming,
- describe human and physical consequences of global warming,
- consider possible changes humans need to make to reduce global warming, and
- synthesize information into a persuasive newspaper editorial.

Scenario
Imagine that you are a science writer for a major newspaper in the United States. You are writing an editorial, to be titled "Are We Warming Earth?," to try to persuade your readers that global warming should be taken seriously. You have decided to develop your editorial around the following four questions:

1. What facts point to global warming?
2. What are the possible causes of global warming?
3. How might global warming affect physical systems?
4. How might global warming affect human systems?

Work through this investigation so that you can write the best editorial you can about global warming.

Part 1: What facts point to global warming?
You can find many newspaper stories on this subject. The following are only two such examples.

Global Warming in '99
By Seth Borenstein
Knight Ridder Newspapers

WASHINGTON—Last year was the second hottest year ever recorded in the United States, despite a La Niña weather phenomenon that was supposed to cool off the Earth a tad. And that strengthens the scientific case for an ever-warming world, meteorologists say. . . .

Globally, the 1990s are the hottest decade ever recorded. The five hottest years were 1998, 1997, 1995, 1990, and 1999, in that order. Each year of the 1990s ranks among the 15 hottest years since 1880, when record keeping began.

Even though 1998 was the hottest year both globally and nationally, it is 1999 that really makes global warming hard to deny, meteorologists said. Even some of the few skeptics who have challenged the theory of global warming now say they are convinced.

"When you have a very warm year that occurs during a La Niña, that makes it more difficult to argue against the reality of global warming," said NASA senior climate scientist Roy W. Spencer, one of the more prominent skeptics. "We're now more willing to admit that global warming is occurring. The debate now is how much warming is going to be in the future."

Last year, the heat rose when it shouldn't have. When the water in the central Pacific Ocean warms, that's a weather event called El Niño that raises global temperatures. Scientists say El Niño was partly to blame for 1998's record heat. Some said 1998 was a freak year caused by a super-sized El Niño.

But El Niño's warm water turned cold in 1999, because of a strong La Niña, a separate weather phenomenon that is the cooling mirror image of El Niño. The arrival of La Niña is supposed to cool things down.

It didn't.

"This also tells you that there's a real warming here that's beyond what's going on in an El Niño," said Kevin Trenberth, head of climate analysis for the National Center for Atmospheric Research in Boulder [Colorado].

In 1999, water temperatures dropped to their lowest levels in five years, but global temperatures were still three-quarters of a degree above normal. The worldwide land temperatures alone were the second hottest ever, 1.36 degrees warmer than normal.

"It's becoming clearer each year that there is something unusual going on," said James Hansen, the godfather of global-warming alarms and head of NASA's Goddard Institute of Space Studies in New York.

The 1999 temperature statistics come on the heels of a National Research Council report that strengthened the scientific case for global warming. The report reconciled an apparent anomaly—why surface temperatures had been rising even though recent satellite data showed no warming in the lower atmosphere.

The report said there were reasons for the mismatched data, including volcanic eruptions in 1982 and 1991. It also said the rate of 20th-century warming has accelerated by 30 percent since 1995, when a majority of global climate scientists first agreed the phenomenon is indeed a problem. . . .

The average temperature in the United States last year was 55.98 degrees—second only to 1998's 56.36 degrees. Normal is about 54 degrees, based on 105 years of record keeping.

"America's 1999 heat was not from summer sizzle; it resulted more from a mild winter," said Michael Changery, head of the climate-monitoring branch at NOAA's National Climatic Data Center in Asheville, N.C., where the temperature figures were compiled. "January, February, March, December, and especially November were far warmer than normal," he said.

Nearly every Northern state recorded one of its 10 hottest years ever in 1999. Every state, save Alaska and California, was hotter than normal.

NASA's Hansen calculates numbers differently from NOAA's Changery. He factors in the heat-island effect for cities. [Temperatures taken in cities will usually be higher than temperatures taken in surrounding rural areas.] "Allowing for that measurement difference," he said, "1999 was only the 10th hottest year on record in the United States and the sixth hottest year globally."

"The difference between the two measures isn't much," said University of Washington meteorologist John M. Wallace. "What's important—and weird—is that it was hot when it shouldn't have been," he said (Borenstein 2000).

North Pole Visitors Find No Ice
By John Noble Wilford
The New York Times

The North Pole is melting.

The thick ice that has for ages covered the Arctic Ocean at the pole has turned to water, recent visitors there reported. . . . At least for the time being, an ice-free patch of ocean about a mile wide has opened at the very top of the world, something that has presumably never before been seen by human beings and is more evidence that global warming may be real and already affecting climate. . .

"It was totally unexpected," said James J. McCarthy, an oceanographer [and] . . . the co-leader of a group working for the U.N.-sponsored Intergovernmental Panel on Climate Change. . . .

McCarthy was a lecturer on a tourist cruise in the Arctic on a Russian icebreaker earlier this month. On a similar cruise six years ago, he recalled, the icebreaker plowed through an icecap 6 to 9 feet thick at the North Pole.

This time, ice was generally so thin that sunlight could penetrate and support concentrations of plankton growing under the ice. . . .

Recalling the reaction of passengers when they saw an iceless North Pole, McCarthy said: "There was a sense of alarm. Global warming was real, and we were seeing its effects for the first time that far north" (Wilford 2000).

Variability is a major characteristic of weather and climate. Weather varies (or changes) from hour to hour, day to day, month to month, and year to year. Climate, which is measured as long-term average weather, varies as well. Average values (such as the ones in Figure 1) can have extreme variations. As you look at temperature and precipitation data, remember that because of short-term variability, you will need to examine *trends* over periods of

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time to assess what is occurring to climate systems. This will become very important as you consider possible *causes* of increasing global temperatures. At the heart of the global warming debate is whether rising temperatures are the result of a human-enhanced greenhouse effect or just another natural trend.

Figure 1 gives annual global surface temperatures from 1880-1998 by showing the differences between annual global mean temperatures compared to the five-year mean.

Throughout this investigation, you should answer the questions on the Log at the end of this Briefing. Here are the first two questions:

1. Using Figure 1, describe the trend in average (mean) global surface temperatures since 1880.

2. Explain why average (mean) temperatures are used in Figure 1, as opposed to "highest" or "lowest" temperatures for that year.

You may be curious to know why global temperatures are not measured earlier than the 1800s. The first year that temperatures were recorded was 1886, so there is no measured data from prior years (Worldwatch Institute 1997). Critics of the theory of global warming will argue that the meteorological record is too short to assert that human activities are the cause of rising global temperatures.

Global temperatures in 1998 were the warmest in the past 119 years, since reliable instrument records began. The previous record was set in 1997. The global mean temperature in 1998 was 0.66°C above the long-term average value of 13.8°C. This was the 20th consecutive year with an annual global mean surface temperature that exceeded the long-term average.

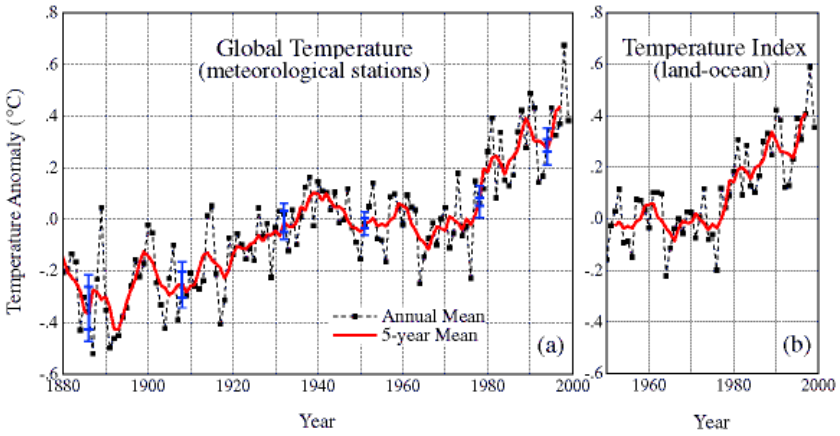
Scientists at the NASA Goddard Institute for Space Studies (2000) reported that global surface temperatures in 1999 fell from the record-setting high level of 1998. These scientists note, however, that 1999 was still a very warm year—the sixth warmest year on record.

Global warming patterns have been detected in the United States as well as the rest of the world. Figure 2 details average annual temperatures for the United States from 1895-1998. In these data, each mean annual temperature is subtracted from 13.8°C (56.9°F) to determine whether that year had increasing or decreasing temperatures (differences from the average are called **anomalies**). As you did with Figure 1, try to determine the trend in annual temperatures over time.

Answer Question 3 on the Log.

Figure 1: Annual global surface mean temperatures

Source: NASA Goddard Institute for Space Studies 2000, http://www.giss.nasa.gov/research/observe/surftemp/



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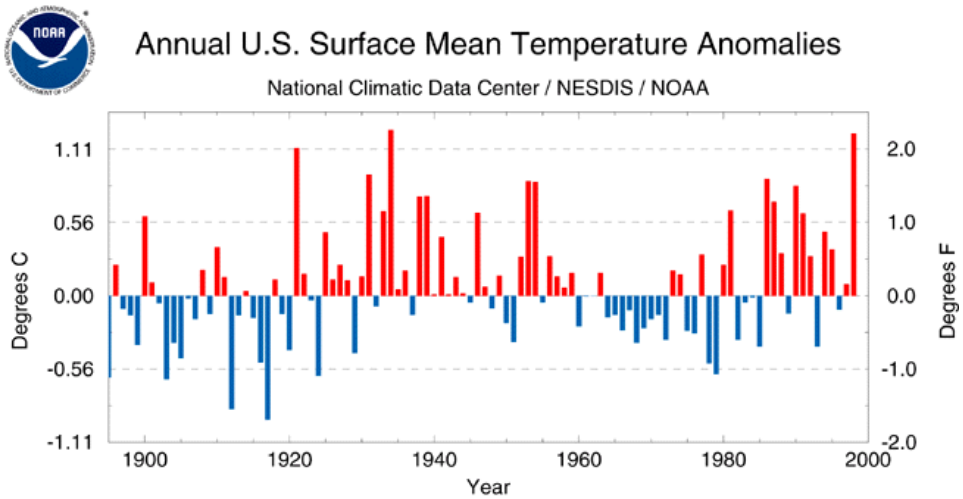

Figure 2: Average temperatures from 1895-1998 in the United States

Source: National Climatic Data Center 2000, http://www.ncdc.noaa.gov/ol/climate/research/1998/ann/us_annual.html

Part 2: What are the possible causes of global warming?

Temperature trends may very well indicate that we are experiencing a warming, but they do not tell us the cause of the warming. Without an agreed-upon scientific explanation for these trends, the cause of global warming is likely to continue to be debated.

Consider the argument that recent increases in global temperatures are part of a long-term recurring natural cycle. At many periods of Earth's history, global temperatures have been both warmer and cooler than they are today (recall our earlier discussion about variability). For example, the world has warmed by 3 to 5°C since the depths of the last ice age, 18,000 to 20,000 years ago (Stevens 1999). Some scientists—the skeptics about a human-enhanced global warming—say that current temperature change may be a return trend towards warmer temperatures. They argue that changing global temperatures are part of a natural, long-term trend.

On the other hand, it appears that most scientists support the idea of an enhanced greenhouse effect as a major contributor to increasing global temperatures. This view was reported as follows in 1995.

Panel finds humans cause warming
by Associated Press

NEW YORK—A U.N. scientific panel on climate change says it is now convinced that global temperatures have warmed over the last century because of human activity, *The New York Times* reported Sunday.

The statement, contained in a draft summary of a report by the Intergovernmental Panel on Climate Change, marks a shift in the views of top climatologists, who previously said that they could not tell whether global warming has been caused by the burning of fossil fuels or natural climatic variations.

The experts now say that a new generation of computer studies has given them confidence in data that suggests why the globe's surface temperature has risen 1 degree Fahrenheit since 1900, the *Times* reported.

The panel's summary says global warming "is unlikely to be entirely due to natural causes and that a pattern of climatic response to human activities is identifiable in the climatological record."

Scientific data now proves that the burning of wood, oil, and coal, which releases carbon dioxide into the air, is at least partly responsible for the so-called [enhanced] greenhouse effect, or warming of the Earth's atmosphere, said Dr. Tom M. L. Wigley, a climatologist at the National Center for Atmospheric Research in Boulder

[Colorado], one of the report's authors. . . .

The panel of international scientists advises world governments now negotiating reductions in the emissions of carbon dioxide and other greenhouse gases under a 1992 treaty on climate change.

At a U.N. Climate Conference in Berlin in April [1995], the panel said emissions of heat-trapping gases must be cut 60 percent if humanity is going to reverse the eventually catastrophic effects of global warming (Associated Press 1995).

Let's look at the so-called "greenhouse effect" (Figure 3). Like a greenhouse for growing flowers, Earth's temperature is determined by three factors: 1) sunlight received, 2) sunlight reflected, and 3) heat energy trapped and reradiated back to Earth by the atmosphere. If there were no atmosphere, incoming shortwave radiation (sunlight) and outgoing longwave radiation (heat energy) would be balanced. Earth would have an average surface temperature of -18°C. Since Earth has an atmosphere that includes gases such as carbon

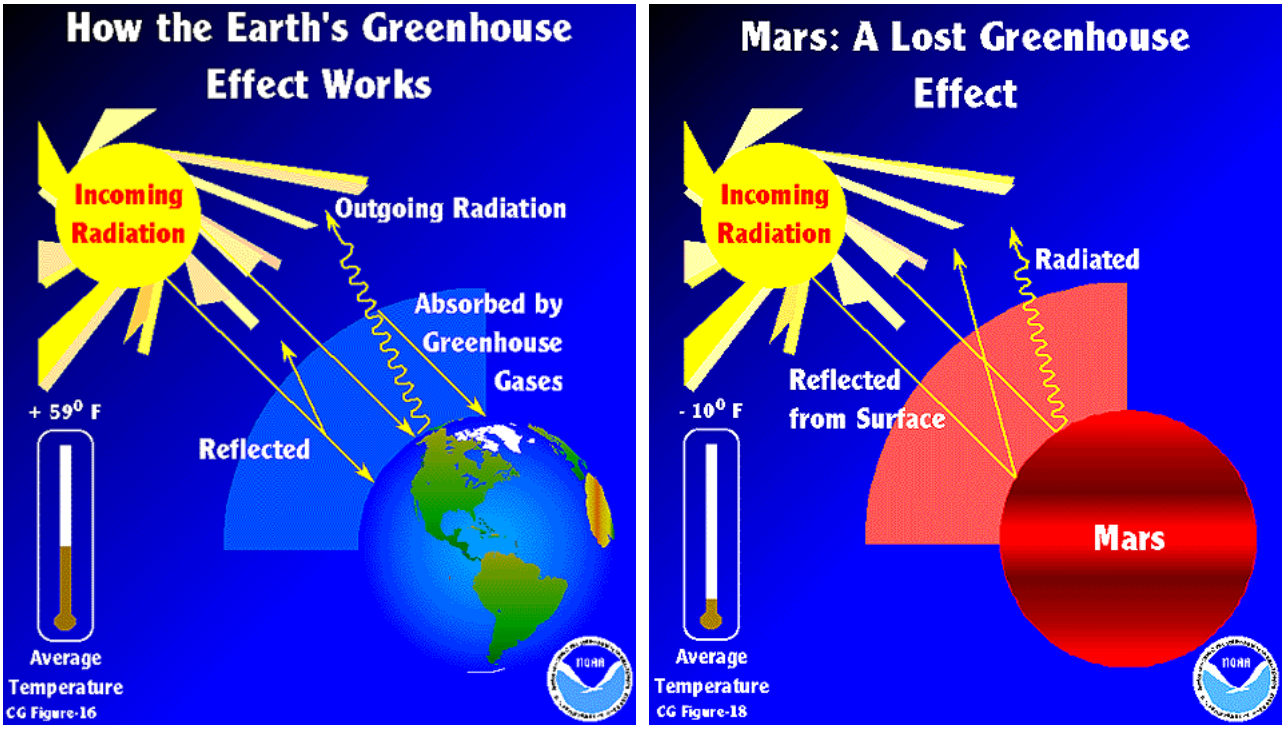

Figure 3: The greenhouse effect of the atmosphere on Earth's average temperature

Source: http://www.fsl.noaa.gov/~osborn/CG_Figure_16.gif.html> and <http://www.fsl.noaa.gov/~osborn/CG_Figure_18.gif.html

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Table 1: Increases of greenhouse gas amounts in Earth's atmosphere, 1850-2030 (parts per billion of atmosphere volume)

	1850 Estimated Average Concentration	1980 Measured Average Concentration	1990 Measured Average Concentration	2030 Probable Average Concentration
CO_2	260,000	338,500	353,000	450,000
CH_4	750	1,554	1,720	2,340
N_2O	280	296	310	375
CFCs	0	0.49	0.76	3.1

Sources: Smith and Tirpak 1988; World Resources Institute 1990; Brown and Postel 1987; Office for Interdisciplinary Studies 1991

dioxide (CO_2) and water vapor, outgoing heat energy is trapped, which results in a warmer climate. Because of this effect, Earth's average surface temperature is 15°C.

Carbon dioxide (CO_2) and water vapor are just two of the gases that contribute to the greenhouse effect. Two other important greenhouse gases are methane (CH_4) and chlorofluorocarbons (CFCs). Carbon dioxide and methane come from both natural sources and human activities. CFCs are synthetic gases that began being manufactured in the 1940s. They are used in refrigeration, foam packaging, and many other products. Water vapor mainly comes from the evaporation of the oceans.

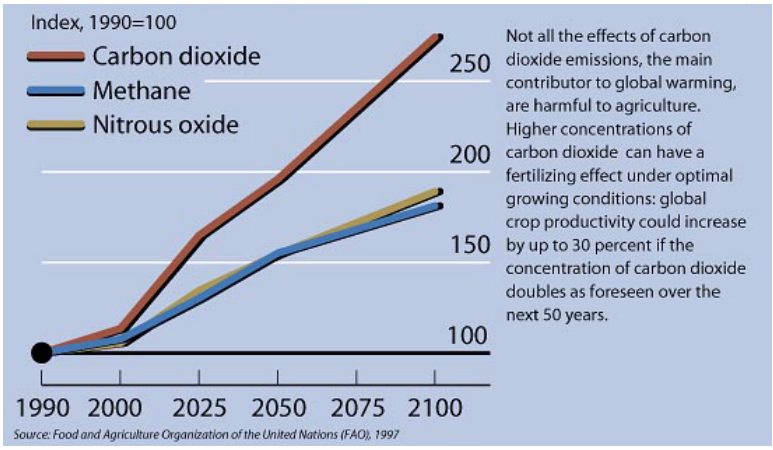

Figure 4: Projected emissions of greenhouse gases

Source: Food and Agricultural Organization of the United Nations 2000, http://www.fao.org/NEWS/FACTFILE/FF9714-E.HTM

Three gases—CO_2, CH_4, and CFCs—account for 86 percent of all human-produced greenhouse-gas emissions. Other greenhouse gases, including nitrous oxide (N_2O), represent the remaining total of about 14 percent of all human greenhouse-gas emissions (World Resources Institute 1990; Shea 1988). The amounts of all these gases have increased since the Industrial Revolution began in about 1850 (Table 1), and projections of the emissions of greenhouse gases have been made to 2100 (Figure 4).

Answer Questions 4 and 5 on the Log.

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Carbon dioxide, the major greenhouse gas, enters the atmosphere in a variety of ways (Figure 5), many of which result from *anthropogenic* (human) activities.

With the increasing concentration of greenhouse gases in the atmosphere, there is a tendency to link these increases with the changes in global temperature (Figure 6).

If the amount of carbon dioxide in the atmosphere continues to grow at its present rate, it will be twice as great as its pre-industrial concentration within the next century. Most scientists agree that this will increase the average surface temperature from 1.5° to 4.5°C (Schneider 1991). Earth's average surface temperature could go from its present 15°C to nearly 20°C by the year 2030.

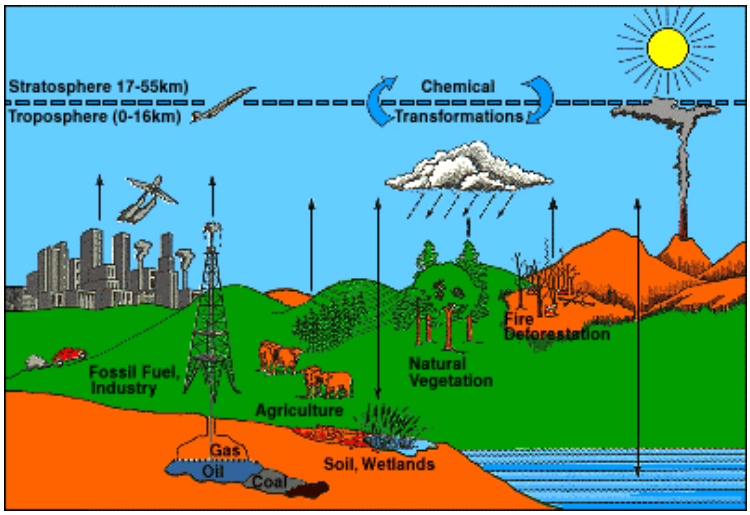

Figure 5: Illustration of biogeochemical cycles

Arrows denote major pathways of the biogeochemical cycling of trace gases.

Source: Fung 2000, http://www.giss.nasa.gov/research/intro/fung.01/

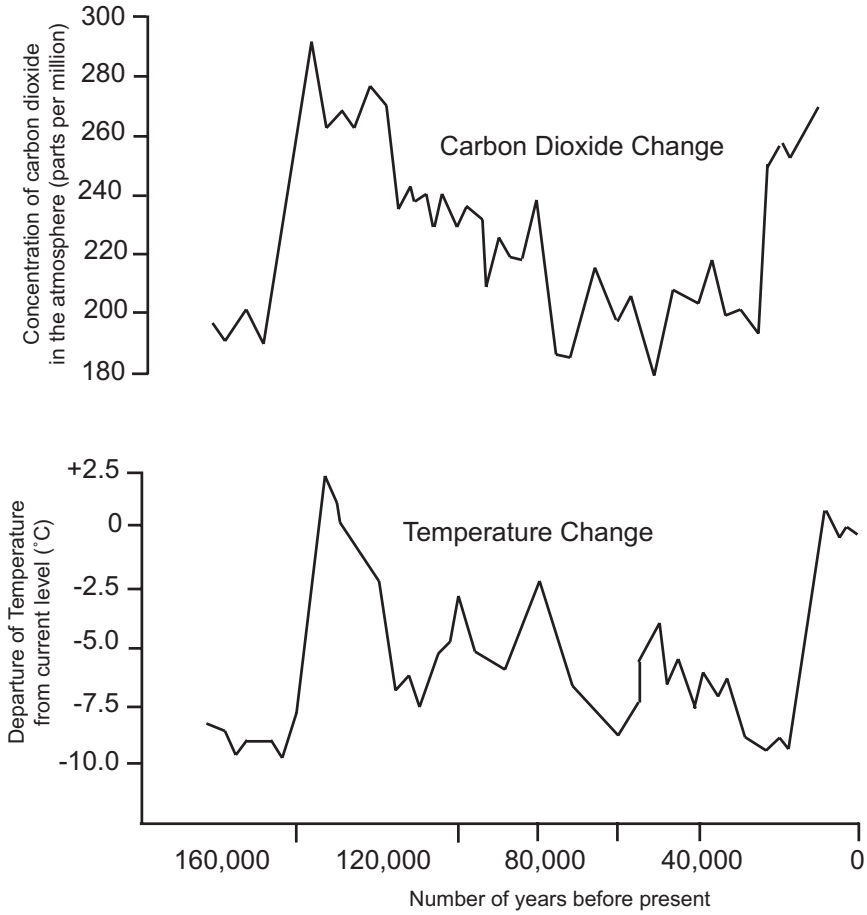

Figure 6: Long-term trends of global temperature and atmospheric carbon dioxide

Vertical scale on the bottom graph shows the temperature difference from the present average temperature (that is, the graph defines the present average temperature as zero).

Source: Barnola et al. 1987

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Energy (e.g., the burning of fossil fuels for heating and transportation), industrial processes (e.g., power used for manufacturing), deforestation (e.g., CO_2 released by burning forests), and agriculture (including methane released by livestock) are major sources of greenhouse gases as shown on Figure 7.

When you write your editorial at the end of this investigation, you will need to consider both sides of the global warming debate. Scientists on both sides of the issue agree that global temperatures are rising; however, they disagree on the cause. Remember, the greenhouse effect is a *fact*; if it did not exist, there would be no warmth on Earth for animal and plant production. On the other hand, the explanation that the human production of greenhouse gases is causing global warming is currently a scientific *theory*.

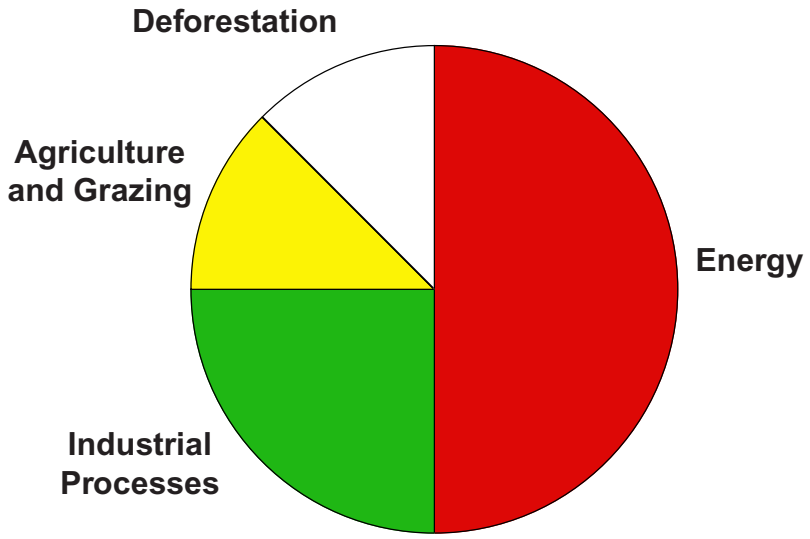

Figure 7: Sources of greenhouse-gas emissions by type of human activity

Source: World Resources Institute 1990

Part 3: How will global warming affect physical systems?

In writing your editorial, you should include the assumed positive and negative consequences of global warming on physical and human systems. Note that a number of effects are predictions, largely because we can't be certain what will occur.

<u>Answer Question 6 on the Log.</u>

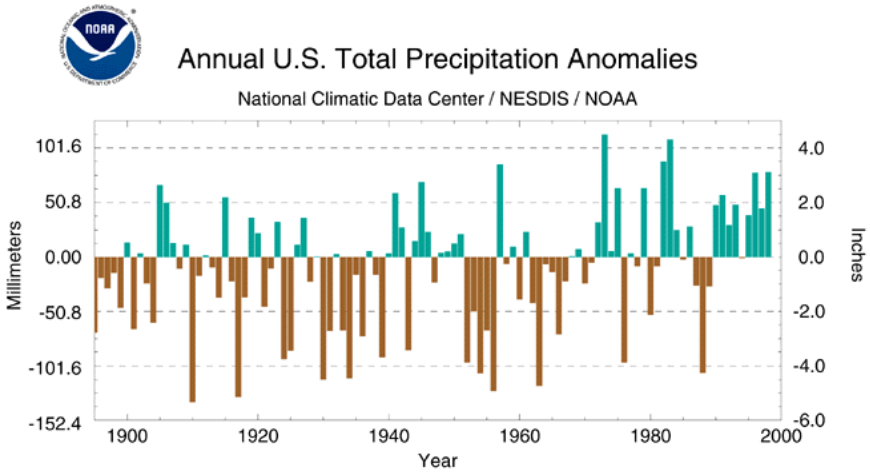

Figure 8: Annual total precipitation anomalies in the United States, 1895-1998

Source: National Climatic Data Center 2000, http://www.ncdc.noaa.gov/ol/climate/research/1998/ann/us_annual.html

Along with increasing global temperatures, sea levels are expected to rise (as glaciers melt). Changes in precipitation and other local climate conditions are also expected. Some of the effects of warming temperatures are observable today as we look at annual precipitation patterns in the United States since 1895 (Figure 8). The national precipitation index expresses precipitation departure from the 60-year mean.

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Answer Question 7 on the Log. (This isn't easy to determine. For a rough estimate, try counting the number of years above and below the long-term average in recent decades.)

The United States had the fifth wettest year on record in 1998, with a national average of 828 millimeters of precipitation. The wettest year was 1973 at 863 millimeters. Considerable regional and seasonal variation in precipitation occurred throughout the year. For example, the Southeast and Great Lakes regions had their wettest January-March in 1998, and the West had its wettest January-June.

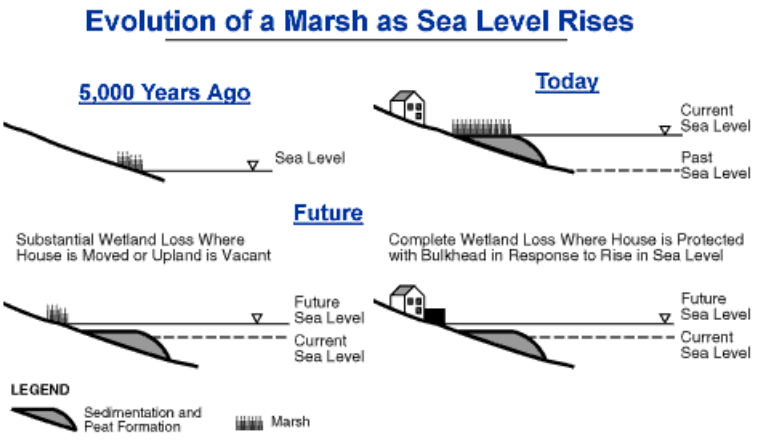

Figure 9: Predicted effect of rising sea levels upon coastal marshes

Source: U.S. Environmental Protection Agency 2000a, http://www.epa.gov/globalwarming/impacts/coastal/index.html

A record dry April-June 1998 resulted in drought conditions from the Southern Plains to the Gulf Coast states. The spring and summer heat and drought led to massive wildfire outbreaks in Florida. Late summer and autumn rains from tropical systems helped abate the dry conditions in the south, while drought intensified in the eastern United States. The region from the central Atlantic Coast to New York experienced the second driest July-November on record, with local water restrictions implemented in many areas.

Increases in precipitation will not be felt equally throughout the world, and it is generally agreed that while flooding may occur in some areas, continental regions are likely to get drier. This will increase the likelihood of drought in various regions. For example, the International Panel on Climate Change (IPCC) for the United Nations reported that climate change could eliminate 85 percent of the wetlands remaining in Spain and Greece (Worldwatch Institute 1997).

Rising sea levels could affect coastal marshes that are important habitats for a variety of birds, fish, and other species. A 0.6 meter rise in sea level could eliminate 17-43 percent of U.S. wetlands (U.S. Environmental Protection Agency 2000a). This effect is depicted in Figure 9.

Global warming could also change ecosystems. Forest ecosystems may be threatened, as rising temperatures reduce the diversity of tree species in forests. Forest fires are likely to become more frequent and severe if soils become drier. Changes in pest populations could further increase the stress on forest ecosystems (U.S. Environmental Protection Agency 2000a). A variety of bird and fish species may have their breeding and migratory patterns changed with changes in regional climate. Some research indicates that the waters off western Canada may warm by 2°C by 2070, which would reduce the summer range of the Pacific salmon species by 50 percent and eliminate the winter range entirely (Worldwatch Institute 1997).

Part 4: How will global warming affect human systems?

There are a number of predicted effects upon human systems from global warming. Global warming may increase the risk of some infectious diseases, particularly from diseases that only appear in warm areas. Diseases that are spread by mosquitoes and other insects could become more prevalent if warmer temperatures enabled those insects to become established farther north. Such "vector-borne" diseases include malaria, dengue fever, yellow fever, and encephalitis (U.S. Environmental Protection Agency 2000a).

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Perhaps the most serious effect of global warming upon human systems is the threat to regional agricultural systems. Rising temperatures and changes in precipitation patterns may radically change current agricultural production around the world. But, as was stated in Figure 4, some areas may benefit from increased CO_2 emissions.

NASA scientists are attempting to predict the impact of global warming upon agricultural production in the Mediterranean (Figure 10). The Mediterranean basin provides a good case study for analyzing regional differences in vulnerability to climate change. Mediterranean agriculture accounts for virtually all olive oil produced worldwide, 60 percent of wine production, 45 percent of grape production, 25 percent of dried nuts (mostly almonds, chestnuts, and walnuts), 20 percent of citrus production, and about 12 percent of total cereal production.

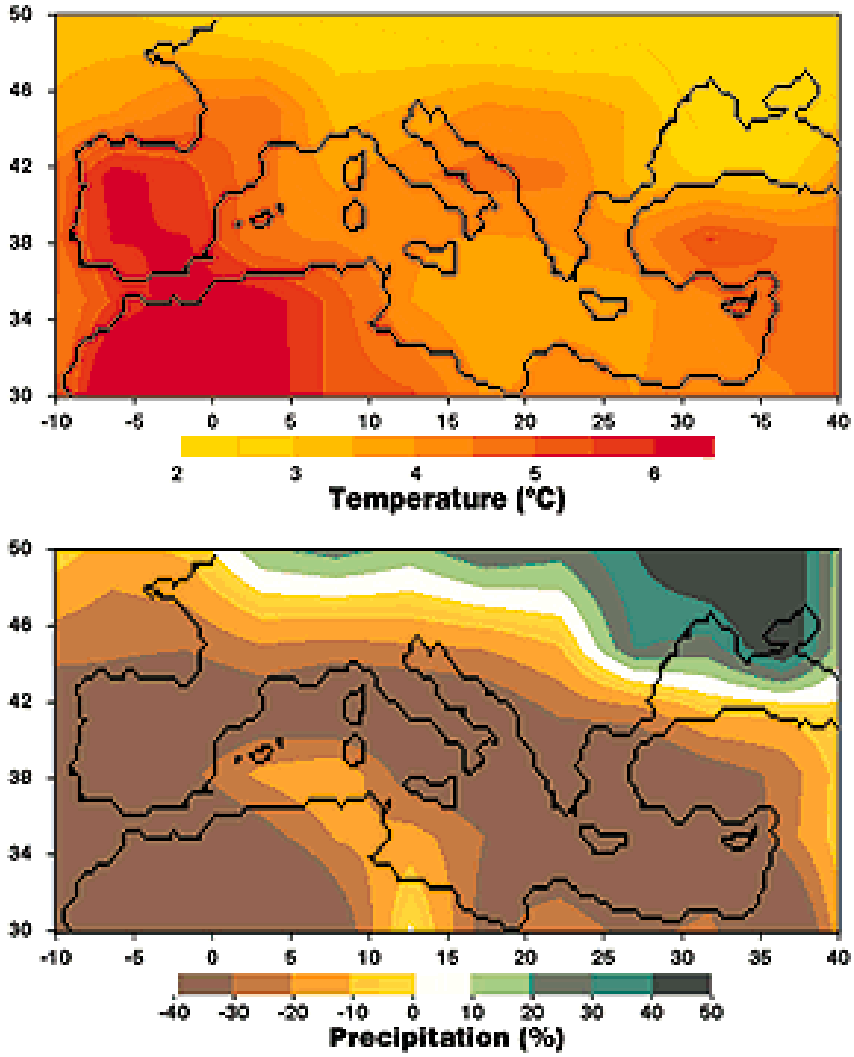

Figure 10: Summer seasonal mean temperature and precipitation changes for the Mediterranean region corresponding to a doubling of carbon dioxide

This climate might occur in the 2050s, if greenhouse gases increase very rapidly.

Source: Rosenzweig et al. 2000, http://www.giss.nasa.gov/research/intro/rosenzweig.01/

Figure 10 is a simulation by the NASA team to predict the effect of rising temperatures and precipitation upon the Mediterranean region. The increased temperatures and lower precipitation simulated for this region by the NASA GISS global climate model is driven by a scenario with rapidly increasing greenhouse gases that would adversely affect crops and water availability, critically influencing the patterns of future agricultural production.

These models predict the climate of the Mediterranean region in 2050 with a rapid increase in greenhouse gases. Although computer models can simulate the possible effects of global warming upon human systems, they are still making predictions. Unless global temperature patterns change, we will have to wait and see how agricultural systems are affected by climate change.

Answer Question 8 on the Log.

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After you have answered Log Question 8, review your answers to all the questions and use that information to help you organize your thoughts before you begin writing your editorial on global warming. Remember to develop your editorial around the following four questions:

1. What facts point to global warming?
2. What are the possible causes of global warming?
3. How might global warming affect physical systems?
4. How might global warming affect human systems?

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1. Using Figure 1, describe the trend in average (mean) global surface temperatures since 1880.

2. Explain why average (mean) temperatures are used in Figure 1, as opposed to “highest” or “lowest” temperatures for that year.

3. Describe any trends that you see in the 100-year temperature record for the United States (Figure 2). Also, note the three highest *and* three lowest recorded years for temperature in the United States since 1895.

4. Describe the past and projected trends in the production of greenhouse gases.

5. Which of the greenhouse gases, documented in Table 1 and Figure 4, increased the most in the atmosphere?

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6. Brainstorm a list of possible effects on physical and human systems from increasing global temperatures.

   Effects on physical systems

   _____

   _____

   _____

   _____

   Effects on human systems

   _____

   _____

   _____

   _____

   _____

7. What is the trend in U.S. precipitation patterns?

   _____

   _____

   _____

   _____

   _____

8. In the climate change models (Figure 10), what happens to temperature and precipitation in the Mediterranean region? How would this information help you if you were a producer of olive oil or grapes?

   _____

   _____

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