The Great Climate Change Debate
► Natural or Human?

A lesson in Language Arts and Climate Change Science

Goal: Students will use a debate format to understand the reasons for the controversy over climate change and reach their own conclusions about whether it is caused by human action, natural processes or a combination of the two causes.

Objectives: Students will …
- Develop persuasive arguments
- Practice public speaking skills
- Read and analyze technical information
- Develop a rationale for their beliefs about the cause of climate change

Materials (for a class of 30):
- 30 copies of The Great Climate Change Debate – Articles (Skeptic and Advocate)
- 30 copies of The Great Climate Change Debate – Terms
- 1 The Great Climate Change Debate – Terms Key
- 30 copies of The Great Climate Change Debate – Detailed Sequence
- 15 copies of The Great Climate Change Debate – Advocate Grid
- 15 copies of The Great Climate Change Debate – Skeptic Grid

Time Required: (2) 45-60 minute periods

Standards Met: C3, C5, G5, LA3, LA4, LA5, LA6, LA7, LA11, LA12

Procedure:
- Explain to students that there are generally three schools of thought regarding climate change: one is that the Earth's climate is being influenced by human actions; the second is that any signs of climate change are part of the Earth's natural cycle, and the third is that human actions can contribute to natural cycles to accelerate the process of climate change. For this lesson, a conclusion that human actions can cause climate change would acknowledge the third school of thought, that combined causes are in process as it is a given that climate change has occurred and will continue to occur naturally.
- The topic of the class debate will be whether humans need to change their habits because we are influencing the Earth's climate.
- Pass out The Great Climate Change Debate – Terms.
- Review each term and apply the terms to this topic. Have students fill in the blanks under applicable terms. Use The Great Climate Change Debate – Terms Key.
- Pass out climate change articles and assign students topics, human or natural.
- Allow students time to read each article; they should read both the pro and con to help them better construct their arguments.
- For the advocate, students can also visit the website of the Union of Concerned Scientists: http://www.ucsusa.org/global_warming/global_warming_101/

- For the skeptic, students can also visit the website of the George C. Marshall Institute: http://www.marshall.org/subcategory.php?id=49

- Pass out The Great Climate Change Debate – Detailed Sequence sheets & The Great Climate Change Debate – Advocate or Skeptic Grids.
- Review the sequence and how it relates to the Debater's Grid.

Assessment:
- Participation in debate
- Completion of The Great Climate Change Debate – Terms
- Completion of The Great Climate Change Debate – Advocate or Skeptic Grid

The Great Climate Change Debate ► Terms Teacher Key

Debate: Process whereby two or more individuals take opposing viewpoints on a proposition in an attempt to persuade others to accept or reject a solution to a problem.

- Topic: Climate Change

Resolution: A statement that presents the idea or issue that is under examination. It should be clearly worded, deal with one subject, be timely, be free of emotional or prejudicial phrases, and be phrased from an advocate position.

- Resolution Statement: Humans need to change their habits because we are influencing the Earth's climate.

Advocate: This side tells the importance of adopting changes and why the changes are needed.

Skeptic: The skeptic side presents arguments as to why no changes should take place. They also argue against the advocate points and present the disadvantages of the advocate's plan.

Argument: Argument is the systematic process of relating evidence for the purpose of establishing the case. Argument is your way of presenting evidence that helps to support your side.

Main Points: Statements or points that are offered as being the basic truths upon which a case is built.

Refute: Attack the case of the opposition. The debaters seek out the weaknesses of the opponents' arguments and present a counter argument.

Rebuttal: This is the last opportunity to argue against the opposition and to highlight your main points.

The Great Climate Change Debate
► Terms Student Sheet

Debate: Process whereby two or more individuals take opposing viewpoints on a proposition in an attempt to persuade others to accept or reject a solution to a problem.

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Resolution: A statement that presents the idea or issue that is under examination. It should be clearly worded, deal with one subject, be timely, be free of emotional or prejudicial phrases, and be phrased from an advocate position.

- Resolution Statement: ____

  ____

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The Great Climate Change Debate
► Advocate Grid

Outline of Skeptic Case	Argument You Plan to Use to Refute the Skeptic	What You Plan to Say Against Refutations	Skeptic Refutations to What You Said in Column 3	Final Advocate Rebuttal

The Great Climate Change Debate
► Skeptic Grid

Outline of Advocate Case	Argument You Plan to Use to Refute the Advocate	Advocate Refutation of Your Attack	Argument You Plan to Use in Answer to the Advocate Counter Attacks	Summary Notes

The Great Climate Change Debate
► Debate Sequence

General

1. First Advocate Speaker (2-3 minutes)
2. First Skeptic Speaker (2-3 minutes)
3. Second Advocate Speaker (2-3 minutes)
4. Second Skeptic Speaker (2-3 minutes)
5. Advocate Rebuttal (1 minute)
6. Skeptic Rebuttal and/or Summary (1-2 minutes)
7. Advocate Summary (1 minute)

Detailed

First Advocate Speaker

- Begins with an interesting, attention-getting introduction.
- Gives a brief explanation/history of the problem.
- States the resolution.
- Presents the definition of terms in a clear and meaningful manner. (Make sure that everyone understands the vocabulary being used. Example: Global climate change, chlorofluorocarbons, etc.)
- Announce the major advocate contentions, specifically stating what the advocate team intends to accomplish. The first advocate speaker should tell the listeners which contention will be presented by the First Advocate and the Second Advocate Speakers.
- Present the first major contention. Contentions need to address the need, practicality, and advantages. It must be supported by evidence and reasoning.
- Presents a plan that would bring the change into effect.
- Summarize. Review the major points.

First Skeptic Speaker

- Analyze what the advocate speaker has said. Point out where the Advocate and Skeptic agree and where they disagree.
- Refute the Advocate points. Present evidence, opinion, and reasoning to destroy the opponent's argument.
- Present arguments as to why no changes should take place.
- Summarize. Review the major points.

Second Advocate Speaker

- Analyze the debate. Show clearly the relationship between the Advocate proposal and the Skeptic stand, magnifying the importance of the Advocate points.
- Rebuild your case. Restate points and offer further evidence and reasoning.
- Attack the Skeptic points.
- Summarize. Review the major points.

Second Skeptic Speaker

- Analyze the debate by comparing the two cases again.
- Rebuild your case. Restate your points and offer further evidence and reasoning.
- Attack the Advocate points.
- Present the remaining Skeptic points.
- Summarize. Review the major points.

Advocate Side Questions the Skeptic

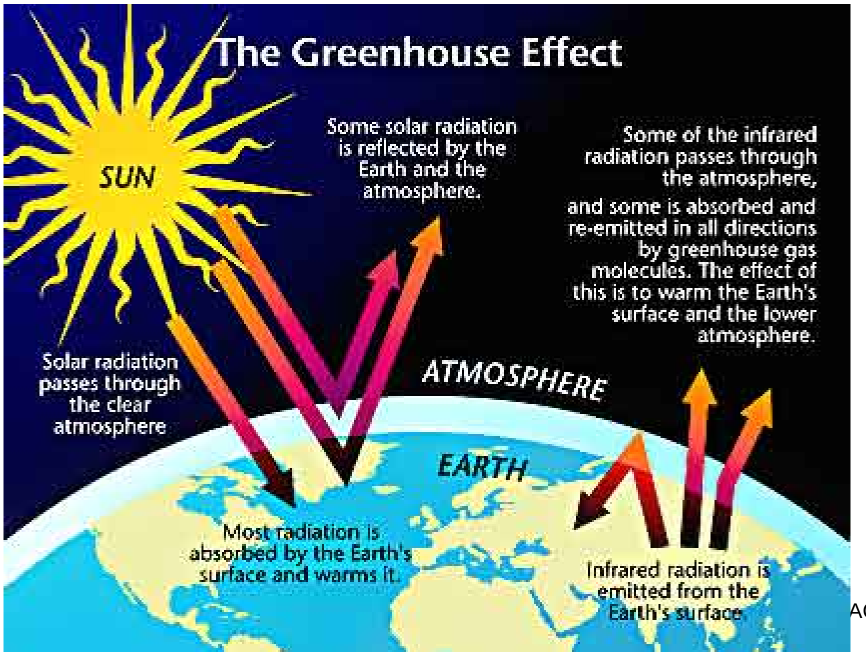
- Skeptic side gives a summary. This is the last time the skeptic side may address the audience.

Advocate Side Concludes with its Summary

The Great Climate Change Debate
► Advocate Article

UNION OF CONCERNED SCIENTISTS
Citizens and Scientists for Environmental Solutions
www.ucsusa.org

Frequently Asked Questions about Global Warming:



ACC/USGCP graphic

What does the greenhouse effect have to do with global warming?
The "greenhouse effect" refers to the natural phenomenon that keeps the Earth in a temperature range that allows life to flourish. The sun's enormous energy warms the Earth's surface and its atmosphere. As this energy radiates back toward space as heat, a portion is absorbed by a delicate balance of heat-trapping gases in the atmosphere – among them carbon dioxide and methane – which creates an insulating layer. With the temperature control of the greenhouse effect, the Earth has an average surface temperature of 59°F (15°C). Without it, the average surface temperature would be 0°F (-18°C), a temperature so low that the Earth would be frozen and could not sustain life.
"Global warming" refers to the rise in the Earth's temperature resulting from an increase in heat-trapping gases in the atmosphere.

What is causing global warming?
Scientists have concluded that human activities are contributing to global warming by adding large amounts of heat-trapping gases to the atmosphere. Our fossil fuel use is the main source of these gases. Every time we drive a car, use electricity from coal-fired power plants, or heat our homes with oil or natural gas, we release carbon dioxide and other heat-trapping gases into the air. The second most important source

of greenhouse gases is deforestation, mainly in the tropics, and other land-use changes.

Since pre-industrial times, the atmospheric concentration of carbon dioxide has increased by 31 percent. Over the same period, atmospheric methane has risen by 151 percent, mostly from agricultural activities like growing rice and raising cattle. As the concentration of these gases grows, more heat is trapped by the atmosphere and less escapes back into space. This increase in trapped heat changes the climate, causing altered weather patterns that can bring unusually intense precipitation or dry spells and more severe storms.

What is the best source of scientific information on global warming?

In 1988, the United Nations Environment Programme and the World Meteorological Organization set up the Intergovernmental Panel on Climate Change (IPCC) to examine the most current scientific information on global warming and climate change. More than 2,500 of the world's leading climate scientists, economists, and risk experts contributed to the panel's most recent report, *Climate Change 2001: The Third Assessment Report.*

Scientists from about 100 countries were involved in this new report – more than in any previous report and with greater participation from developing countries. These scientists reviewed all the published and peer-reviewed scientific information produced during the previous few years to assess what is known about the global climate, why and how it changes, what it will mean for people and the environment, and what can be done about it.

The Third Assessment Report is the most comprehensive and up-to-date evaluation of global warming. As the new benchmark, it serves as the basis for international climate negotiations.

Is global warming already happening?

Yes. The IPCC concluded in its Third Assessment Report, "An increasing body of observations gives a collective picture of a warming world and other changes in the climate system." The kinds of changes already observed that create this consistent picture include the following:

Examples of observed climatic changes:

- Increase in global average surface temperature of about 1°F in the 20th Century.
- Decrease of snow cover and sea ice extent and the retreat of mountain glaciers in the latter half of the 20th Century.
- Rise in global average sea level and the increase in ocean water temperatures.
- Likely increase in average precipitation over the middle and high latitudes of the Northern Hemisphere, and over tropical land areas.
- Increase in the frequency of extreme precipitation events in some regions of the world.

Examples of observed physical and ecological changes:

- Thawing of permafrost.
- Lengthening of the growing season in middle and high latitudes.
- Poleward and upward shift of plant and animal ranges.
- Decline of some plant and animal species.
- Earlier flowering of trees.
- Earlier emergence of insects.
- Earlier egg-laying in birds.

Are humans contributing to global warming?
In 1995, the world's climate experts in the IPCC concluded for the first time in a cautious consensus, "The balance of evidence suggests that there is a discernible human influence on the global climate."
In its 2001 assessment, the IPCC strengthened that conclusion considerably, saying, "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."
Scientists have found significant evidence that leads to this conclusion:

- The observed warming over the past 100 years is unlikely to be due to natural causes alone; it was unusual even in the context of the last 1,000 years.
- There are better techniques to detect climatic changes and attribute them to different causes.
- Simulations of the climate's response to natural causes (sun, volcanoes, etc.) over the latter half of the 20th Century alone cannot explain the observed trends.
- Most simulation models that take into account greenhouse gas emissions and sulphate aerosols (which have a cooling effect) are consistent with observations over the last 50 years.

How much warmer is the Earth likely to become?
The IPCC's Third Assessment Report projects that the Earth's average surface temperature will increase between 2.5° and 10.4°F (1.4°-5.8°C) between 1990 and 2100 if no major efforts are undertaken to reduce the emissions of greenhouse gases (the "business-as-usual" scenario). This is significantly higher than what the Panel predicted in 1995 (1.8°-6.3°F, or 1.0°-3.5°C), mostly because scientists expect a reduced cooling effect from tiny particles (aerosols) in the atmosphere.
Scientists predict that even if we stopped emitting heat-trapping gases immediately, the climate would not stabilize for many decades because the gases we have already released into the atmosphere will stay there for years or even centuries. So while the warming may be lower or increase at a slower rate than predicted if we reduce emissions significantly, global temperatures cannot quickly return to today's averages. And the faster and more the Earth warms, the greater the chances are for some irreversible climate changes.

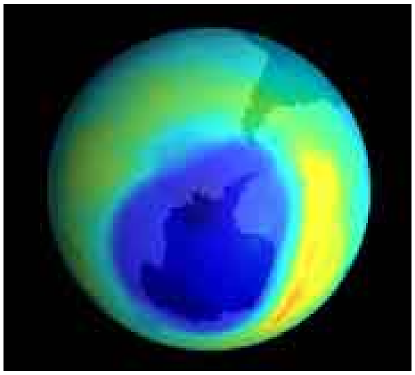
Would a temperature rise of a couple degrees really change the global climate?
An increase of a few degrees won't simply make for pleasantly warmer temperatures around the globe. Even a modest rise of 2°-3°F (1.1°-1.7°C) could have dramatic effects. In the last 10,000 years, the Earth's average temperature hasn't varied by more than 1.8°F (1.0°C). Temperatures only 5°-9°F cooler than those today prevailed at the end of the last Ice Age, in which the Northeast United States was covered by more than 3,000 feet of ice.
Scientists predict that continued global warming on the order of 2.5°-10.4°F over the next 100 years (as projected in the IPCC's Third Assessment Report) is likely to result in:

- a rise in sea level between 3.5 and 34.6 in. (9-88 cm), leading to more coastal erosion, flooding during storms and permanent inundation;
- severe stress on many forests, wetlands, alpine regions and other natural ecosystems;

- greater threats to human health as mosquitoes and other disease-carrying insects and rodents spread diseases over larger geographical regions; and
- disruption of agriculture in some parts of the world due to increased temperature, water stress and sea-level rise in low-lying areas such as Bangladesh or the Mississippi River delta.

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

Global warming and ozone depletion are two separate but related threats. Global warming and the greenhouse effect refer to the warming of the lower part of the atmosphere (also known as the troposphere) due to increasing concentrations of heat-trapping gases. By contrast, the ozone hole refers to the loss of ozone in the upper part of the atmosphere, called the stratosphere. This is of serious concern because stratospheric ozone blocks incoming ultraviolet radiation from the sun, some of which is harmful to plants, animals and humans. The two problems are related in a number of ways, including:



NASA image – Ozone layer hole

- Some human-made gases, called chlorofluorocarbons, trap heat *and* destroy the ozone layer. Currently, these gases are responsible for less than 10 percent 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 no reason to rejoice: 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.

Reducing ozone-depleting gases is crucial to preventing further destruction of the ozone layer, but eliminating these gases alone will not solve the global warming problem. On the other hand, efforts to reduce all types of emissions to limit global warming will also be good for the recovery of the ozone layer.

Is there anything we can do about global warming?

Yes! The most important action we can take to slow global warming is to reduce emissions of heat-trapping gases. Governments, individuals and businesses can all help.

Governments can adopt a range of options for reducing greenhouse gas emissions, including:

- increasing energy efficiency standards;
- encouraging the use of renewable energy sources (such as wind and solar power);
- eliminating subsidies that encourage the use of coal and oil by making them artificially cheap; and
- protecting and restoring forests, which serve as important storehouses of carbon.

Individuals can reduce the need for fossil fuels and often save money by:

- driving less and driving more fuel-efficient and less-polluting cars;
- using energy-efficient appliances;
- insulating homes; and
- using less electricity in general.

Businesses can increase efficiency and save substantial sums by doing the same things on a larger scale. And utilities can avoid building expensive new power plants by encouraging and helping customers to adopt efficiency measures.

Will responding to global warming be harmful to our economy?

Reducing our impact on the global climate ***does not have to hurt*** the world's economies. The answer depends much on the "how" and "when."

The challenge is to strike a balance between responding early enough to avoid major negative (costly) impacts, and responding some time later in order to avoid taking big, expensive steps now which then may turn out to be unnecessary or inappropriate. This type of challenge is typical in business and industry; decision-making under uncertainty is the daily bread of most managers.

Clearly, global warming still involves many unknowns, but the remaining uncertainties in our scientific understanding no longer warrant a "wait and see" stance. Science tells us with increasing certainty that we are in for a serious long-term problem that will affect all of us.

And there is much we can do now that makes sense in terms of the economic bottom line while helping to reduce our impact on the global climate and on our local environment and health. The United States and other developed countries should seize the opportunity to take the lead in developing new, clean, energy-efficient technologies, and help developing countries take a greener path to economic prosperity. All of this can be done in a cost-effective manner, while creating jobs and new business opportunities.

The Great Climate Change Debate
► Skeptic Article

The Marshall Institute — Science for Better Public Policy

Climate Issues & Questions
The debate over the state of climate science and what it tells us about past and future climate has been going on for more than fifteen years. It is not close to resolution, in spite of assertions to the contrary. What is often referred to as a "consensus" is anything but. Many of those making this claim hold a particular point of view that is based on their "expert judgment," not established scientific fact. For others, especially those engaged in advocacy, the claim of consensus is used to advance their agenda. Although humanity has been interested in climate since prehistoric times, climate science is, in fact, a relatively new field. It is only since the 1970s, when models were developed to connect atmospheric and oceanic climate processes, that scientists have had the tools to study climate as a system.

Concerns about climate change have resulted in some scientists entering the policy debate because of alarm about either the potential impacts of climate change or the economic impact of ill-conceived policies. Others, unfortunately, have entered the debate to advance political or economic agendas, gain funding for research, or enhance their personal reputations. To the extent that the debate is carried out in the public policy arena or media, the rigors of the scientific process are short-circuited. This state of affairs creates misunderstandings and confusion over what we know about the climate system, past climate changes and their causes, human impacts on the climate system and how human activities may affect future climate. Policy needs are better served by clarity and accuracy.

The purpose of this document is to address a set of fundamental questions about climate change by summarizing the best available scientific information. The information provided is not intended to rebut claims about human impacts on climate or the potential for adverse impacts later this century. It is intended to separate fact from speculation and to demonstrate that while concerns are legitimate, there is not a robust scientific basis for drawing definitive and objective conclusions about the extent of human influence on future climate. The presentation moves from what is well established, to what is not certain, to what is unknown, and may be unknowable. This is the second edition of *Climate Issues and Questions*.

1. **How is the atmospheric concentration of carbon dioxide (CO2) determined and how accurate are the measurements?** Atmospheric concentrations of CO2 have been measured directly since 1958. The CO2 concentration in air bubbles trapped in ice sheets is used to determine atmospheric concentration for earlier times. The measurements are consistent and accurate.

2. **How much of today's atmosphere is CO2?** The atmosphere is comprised of many gases. CO2, a greenhouse gas, represents 0.038% of today's atmosphere,

while the concentration of water vapor, the most important of the greenhouse gases, varies from near zero in cold, dry polar air to more than 6% in humid, tropical air.

3. **What has been the history of atmospheric CO2 concentrations?** Atmospheric concentration of CO2 has varied greatly over time, from a high of more than 380 parts-per-million (ppm) 25 million years ago, to a low of about 180 ppm during several periods of glaciation over the past 400,000 years. The atmospheric concentration of CO2 was relatively constant at about 280 ppm for 1,000 years before 1750. Since 1750, CO2 concentration has risen, reaching about 380 ppm in 2004.

4. **Do we know why CO2 concentrations are rising?** The increase in CO2 concentration appears to be the result of human activities, though only about half of the CO2 emissions that result from human activity accumulate in the atmosphere. The rest accumulates in the oceans or is stored in the biosphere.

5. **What do we know about the relation between increases in the atmospheric concentrations of CO2 and other greenhouse gases and temperature?** During the 20th century atmospheric concentrations of CO2 and other greenhouse gases rose steadily, but global average surface temperature rose, then fell, then rose again in a pattern that showed no relationship to greenhouse gas concentration. CO2 and other greenhouse gas concentrations were relatively constant from 1000 to 1750, but the Earth experienced a warm period from 800 to 1200, followed by a cold period from 1400 to about 1850.

6. **If temperature changes cannot be correlated with the increase in atmospheric concentrations of CO2 and other greenhouse gases, what is causing them?** The climate system is a complex set of interactions between solar energy, clouds, particulates, water vapor and other greenhouse gases, and the absorption and reflection of solar radiation at the Earth's surface. The general nature of these interactions is understood by climate scientists, but their details are highly uncertain.

7. **Is the Arctic warming faster than the rest of the Earth?** Like the rest of the Earth, the Arctic is warming. The best available evidence suggests that over the 20th century, it warmed at a somewhat faster rate than the global average, but less than would be projected by climate models and less than claimed by the 2004 *Arctic Climate Impact Assessment* (ACIA). Understanding temperature trends in the Arctic is complicated by limited data and the fact that conditions in the Arctic can change much more rapidly than over the rest of the Earth.

8. **Do satellites and surface temperature measurements give different results?** Differences between temperature trends in the lower atmosphere measured by satellites and temperature trends from surface weather stations have been narrowed, but the differences still exist. There are several estimates of both satellite and surface temperature trends. Most temperature trends measured by satellites still show less warming than most temperature trends measured at the surface, but the estimates overlap. In addition, the range of model projections of temperature trends overlaps both sets of measurements.

Both sets of measurements are subject to error, as are the model results, and further data and analyses are needed to resolve the remaining differences.

9. **Is evidence of increased ocean heat storage a "smoking gun" indicating climate change?** Media reports of a paper by James Hansen and 14 co-authors that appeared in the June 3, 2005, issue of *Science*30 claimed that it represented the "smoking gun" evidence for climate change. The smoking gun claim is surprising, since there can be no doubt that climate has been changing. While there is a debate over the amount of change, and an even greater debate over the causes of that change, there is no evidence to argue that the world as a whole is not warmer than it was a century ago. In light of this warming, the authors' conclusion that the Earth is absorbing more energy than it is emitting is obvious. As discussed below, the authors used indirect evidence to test their model, rather than the direct satellite measurements of the Earth's energy balance. Finally, their finding that the Earth is committed to additional warming is also not surprising, since this concept has been well understood since at least 1990.

10. **What influence does the Sun have on global climate?** The Sun provides the energy that drives the climate system. Long-term variations in the intensity of solar energy reaching the Earth are believed to cause climate change on geological time-scales. New studies indicate that changes in the Sun's magnetic field may be responsible for shorter-term changes in climate, including much of the climate of the 20th century.

11. **What is known with a high degree of certainty about the climate system and human influence on it?** We know, with a high degree of certainty, that: 1) the surface of the Earth warmed over the past century; 2) the increases in the atmospheric concentrations of CO2 and other greenhouse gases will have a warming effect; 3) the human emissions of CO2 and other greenhouse gases are responsible for much of the increase in atmospheric concentrations of these gases; and 4) the economic growth trends, particularly in the developing nations, will increase human emissions of CO2, at least over the next few decades because economic growth requires energy use and the dominant source of energy will remain fossil fuels. These facts are the basis for concern about potential human impacts on the climate system.

12. **What major climate processes are uncertain and how important are these processes to understanding future climate?** Key uncertainties in our understanding of the climate system include the details of ocean circulation, the hydrological (water) cycle, and the properties of aerosols. The cumulative effect of these and other uncertainties in our understanding of the climate system is an inability to accurately model the climate system. Since models are the only way to project future climate, our lack of understanding of key climate processes means we lack the ability to accurately project future climate.

13. **What tools are available to separate the effects of the different drivers that contribute to climate change?** Climate scientists use general circulation models (GCMs) to try to separate the effects of the different drivers that affect the climate system. These models use mathematical equations to describe the

different processes known to occur in the climate system. GCMs are extremely complex because they must try to model all of the processes occurring in both the atmosphere and the oceans, neither of which are homogeneous, by dividing them into small grid boxes, then modeling change in small time increments. The resulting computational demand exceeds the capacity of even the best super-computers.

14. **How accurate are climate models?** Current climate models have many shortcomings. They cannot accurately model the atmosphere's vertical temperature profile, their estimates of natural climate variability are highly uncertain, and there are large differences in the response of different models to the same forcing. No climate model has been scientifically validated.

15. **What is the basis for forecasts of large temperature increases and adverse climate impacts between 1990 and 2100?** Forecasts of large temperature increases and adverse climate impacts between 1990 and 2100 are based on the output of climate models using the IPCC SRES (*Special Report on Emissions Scenarios*) Scenarios as input. Concerns about the quality of climate model output have been discussed in Question 11. Large increases in temperature depend on three assumptions, none of which are likely: a) No overt action is taken to control greenhouse gas emissions. However, a variety of actions, some voluntary, some mandatory, are currently being taken to control greenhouse gas emissions. b) Greenhouse gas emissions grow at the high end of the range of the IPCC emissions scenarios, i.e., CO2 emissions in 2100 that were over five times current CO2 emissions. These high emission scenarios have been broadly criticized as unrealistic. c) The climate system shows a high sensitivity to changes in greenhouse gas concentrations. Reports from a recent IPCC workshop indicate that while there is still a great deal of uncertainty, climate modelers now believe that the climate system is less responsive to greenhouse gas concentrations than would be required for a 5.8°C temperature rise.

16. **How accurate are the parameters used in climate models?** The scientific level of understanding of the direct effects of greenhouse gases is high, but the scientific understanding of the other drivers of the climate system is low or very low.

17. **How well have models done in "back-casting" past climate?** Model results that match global average surface temperature for the past 140 years have been published, but they are suspect because of: 1) the quality of the surface temperature data used to determine global average surface temperature; and 2) the quality of the models themselves.

18. **Is the global warming over the past century unique in the past 1,000 years or longer?** The IPCC Third Assessment Report conclusion that the warming of the 20th Century was unique in at least 1,000 years was based on a study (by Mann, *et al.*) that has been shown to be incorrect by three studies recently published in the peer-reviewed literature. These studies show that many parts of the world have experienced warmer temperatures at some time during the last 1,000 years than they did during the second half of the 20th Century and that climate variability is much greater than indicated by the IPCC.

19. **How much does the global climate vary naturally?** Climate scientists don't know the answer to this question, but the available data suggest that there is considerable natural variation on a time-scale of decades to centuries.

20. **What do we know about the extent of human influence on climate? To what extent has the temperature increase since 1975 been the result of human activities?** The best answer to these questions is "We don't know." Human activities have a number of potential impacts on climate. Greenhouse gas emissions contribute to warming, as do some particulate emissions. Other particulate emissions produce cooling. Land-use changes can produce either warming or cooling, depending on the change. The direct effects of greenhouse gas emissions are relatively easy to determine, but their indirect effects, through water vapor and other feedbacks, are poorly understood. The impacts of other human activities – particulate emissions and land-use changes – are poorly understood.

21. **Could climate change abruptly?** Over the last million years, the Earth's climate has shifted dramatically between ice ages and warmer periods like the present one, called the Holocene. The glacial periods, with major advances of ice sheets, have generally lasted about 100,000 years, while the interglacial periods have lasted about 10,000 years. The transition between glacial and interglacial conditions can take place in less than a thousand years – sometimes in as little as decades. Such dramatic climatic shifts occurred near the end of the last major ice age, about 15,000 years ago. First, a brief warming occurred, and then the ice age returned for roughly 1,000 years. Finally, by 11,500 years ago, the climate quickly warmed again. Ice core data indicate that temperatures in central Greenland rose by 7°C or more in a few decades. Other proxy measurements indicate that broad regions of the world warmed in 30 years or less. Recently attention has focused on the potential for the climate to change abruptly as the result of human activities. A common scenario is the onset of an ice age as the result of human greenhouse gas emissions. It is now generally agreed that changes in the Earth's orbit, which result in changes in the amount of solar energy reaching the Earth's surface, are responsible for both ice ages and the warm interglacial periods between them. This theory was first popularized in the 1920s by Milutin Milankovitch, a Serbian astrophysicist. He theorized that three factors controlled the amount of solar energy reaching the Earth's surface: 1) the eccentricity, or shape, of the Earth's orbit, which varies on a cycle of about 100,000 years; 2) the tilt of the Earth's axis, which varies on a cycle of about 41,000 years; and 3) the precession of the equinoxes, which vary on a cycle of about 22,000 years.

22. **Will sea level rise abruptly?** There currently is no scientific evidence to support concern about rapid sea level rise during this century. Longer term, the dynamics of glacier and ice sheet melting are too poorly understood to make reasonable projections.

23. **Will the number of tropical cyclones (hurricanes, typhoons) increase and will they become more intense?** It is well established that tropical cyclones will not form unless the sea surface temperature is 26°C (79°F) or higher. However, tropical cyclone formation depends on a parameter known as

Convective Available Potential Energy (CAPE), which is a function of both sea surface temperature and atmospheric circulation. The atmosphere can either collect the energy available from the warm ocean, leading to cyclone formation, or dissipate it, in which case a cyclone will not form. Since sea surface temperatures are often above 26°C, but tropical cyclones are relatively rare events, dissipative conditions predominate. The same parameter controls tropical cyclone intensity.

24. **Will other extreme weather events, such as heat waves, increase?** If the Earth warms, some types of extreme weather events will increase, others will decrease, and still others will remain unchanged. The occurrence of what is now defined as extreme heat will increase, while extreme cold will decrease.