EDUCATOR'S GUIDE

Global Climate Change:
Earth's Atmosphere Heats Up

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the Eyes of Nye

For six seasons, millions of students came to understand, appreciate and enjoy the exploration of science through the series, *Bill Nye the Science Guy*. Bill returns with *The Eyes of Nye*, a more in-depth look at science subjects making news, changing lives, and impacting policy. From the future of alternate fuel sources and genetic engineering to population growth trends and issues of race, Bill and his expert cohorts bring science to life right in your classroom, helping you **Motivate** investigation; **Assess** available information; and **Propose** lines of argumentation.

This Educator's Guide includes:

- An **Introduction** that clearly defines the subject and offers an overview of the issue objectives of the guide; how it relates to science from both a social and personal perspective; as well as pertinent questions and insights regarding the topic.
- A listing of all **National Science Education Standards Addressed**.
- Detailed procedures highlighted in the MAP Framework (**Motivate, Assess, Propose**).
- Illustrative **Video Clips** from *The Eyes Of Nye* DVDs with pinpoint chapter cues.
- **Web Site Resources** to help students further investigate and locate research, charts, data as well as experts featured in the program material.
- Easily downloadable **Support Materials** that include articles, transparencies, charts, and much more.

Introduction:

"Global climate change" refers to changes in worldwide climactic conditions, especially temperature. *The Eyes of Nye - Global Climate Change: Earth's Atmosphere Heats Up* describes scientific processes that produce the changes, contributing factors, and questions regarding how society can or should address the situation.

Global climate change claims have been hotly debated for years, especially since the international Kyoto Protocol, rejected by the U.S. in 2001. Disagreements are fueled by questions regarding validity of data produced by opposing camps, interpretations that have

*Check the **MAP Teaching and Learning Framework** to explore the phases (motivate, assess, and propose) used in this guide.*

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been made based on analyses of these data, and the veracity of claims that may or may not point to humans as the cause of the changes. The complexities of the scientific questions surrounding the issue are magnified by the social landscape—the economic costs of putting solutions into place, questions of who *can* or *should* take the risks and pay the costs, and the political clash of nations that hold a stake. The objectives in this guide focus on students' abilities to understand climate change indicators, assess what data is or is not useful for informing relevant action, and gain insight into the role and use of those understandings in international debate.

National Science Education Standards Addressed

Science As Inquiry

- Abilities necessary to do scientific inquiry

  Identify questions and concepts that guide scientific investigations

  Recognize and analyze alternative explanations and models

  Communicate and defend a scientific argument

- Understanding about scientific inquiry

Physical Science

- Structure and properties of matter
- Chemical reactions
- Interactions of energy and matter

Life Science

- Matter, energy, and organization in living systems

Earth and Space Science

- Energy in the earth system

Science and Technology

- Understandings about science and technology

Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

On the DVD:

Global Climate Change: Earth's Atmosphere Heats Up – Chapters

Chapter 1: ***Global Climate Change Preview***
Beginning through 01:34
Ends with title screen.

Chapter 2: ***The Two-Mile Time Machine***
01:56—06:06
Starts with Bill saying, "To answer the difficult question..."

Chapter 3: ***Exploring Past Climate Trends***
06:06—08:58
Starts with Bill saying, "They say this is the world's tallest thermometer."

Chapter 4: ***The Human Factor***
08:59—12:06
Starts with hippie skit.

Chapter 5: ***Politics and Impacts***
12:08—18:48
Starts with Bill saying, "The northwest passage…"

Chapter 6: ***Options and Solutions***
18:49 through end of program
Starts with Bill saying, "In the United States…"

Global Climate Change: Earth's Atmosphere Heats Up – Activity Clips

Global Climate Change: Framing the Issue
14:10—15:46
(referenced in Educator's Guide step 1)
Starts with Bill saying, "Imagine life in the 1800s." Ends with Bill saying "…and as of 2005, has rejected the treaty. Hmmm."

Greenhouse Effect
08:59—10:15
(referenced in Educator's Guide step 5)
Starts with Bill saying, "The same thing that keeps the earth warm enough for us to live here…" Ends with him saying "…when you're a planet."

Back Through the (Ice) Ages
02:16—06:06
(referenced in Educator's Guide step 6)
Starts with images of thermometers. Ends with Bill saying "…it's getting warmer out there."

Record in the Ice: A Correlational Analysis
07:04—08:58
(referenced in Educator's Guide step 7)
Starts with Dr. Hinkley saying, "This is some of the information that we get from ice cores." Ends with Bill saying, "The sky's the limit, I guess."

Thermal Expansion
15:48—18:00
(referenced in Educator's Guide step 8)
Starts with Bill saying, "In the coming decades…" Ends with Bill saying "…the sea will be coming up to us!"

Business As Usual
18:49—21:35
(referenced in Educator's Guide step 10)
Starts with Bill saying, "In the United States…" Ends with Dr. Edmonds saying, "Thank you."

More Sea Routes, More Petroleum
12:08—13:14
(referenced in Educator's Guide step 10)
Starts with Bill saying, "The northwest passage…" Ends with Bill saying "…or just news."

Things You Can Do to Stop Global Chilling
10:32—12:06
(referenced in Educator's Guide step 14)
Starts with caveman saying, "You've heard about global chilling…" Ends with caveman saying, "Just pull it out!"

Procedure: Motivate Phase

1) Play ***"Global Climate Change: Framing the Issue"*** and review historical perspectives provided. Point out a few examples of improvements in technology that have enhanced our standard of

living, and ask what it would be like if we didn't have these things. Note, however, unforeseen consequences often accompany improvements, and give rise to new problems that must be considered.

2) Ask students what they know about "global warming." They have heard of it, but mostly in a superficial manner—primarily media reports. Ask them to recall the news flashes in the segment above regarding the Kyoto Protocol. Note that the U.S. rejected the treaty in 2001 and has not altered that stance. Ask students what they think about that, and explain that we apparently have an international issue of serious magnitude; one that could prove difficult to solve.

3) Ask students to note the climate differences described and the questions raised as you play ***"Chapter 1: Global Climate Change Preview."*** Repeat the question whether the climate changes are because of things we are doing or just part of the natural changes taken place through time, now cycling through a warming trend. Point out this is an important point of contention in the Kyoto dispute—whether we do or do not have evidence that the changes are human-forced, and if we should incur enormous economic costs combating the effect if we cannot be sure. Repeat the question asked "*Should*, or *can*, we do anything about it?" Repeat Bill's response (yes!) as well, but ask students if it appears there are things we need to know first.

4) Ask students to suggest questions that might address our need-to-know, and help them distinguish between questions "scientific" and "social" (e.g., societal, economic, political) in nature. Narrow the questions to a few "scientific" and at least one "social" (see possibilities below).

Potential scientific questions

a) What are the scientific processes involved in producing global warming trends?

b) What do scientific measurements tell us about causes for observed trends, and whether these causes are natural or human-forced?

Potential social question

c) Should, or can, we do anything about it, and what would that be?

Procedure: Assess Phase

5) Explain to students we know something about the principal natural process by which heat is retained in the earth's atmosphere—the *greenhouse effect*. Play ***"Greenhouse Effect"*** and review the role of greenhouse gases (e.g., water vapor, carbon dioxide, methane, and nitrous oxide) in allowing the sun's energy to penetrate to the earth's surface but restrict the escape of heat produced by that energy (see right, Our Atmospheric Greenhouse). Explain these gases comprise very little of our atmosphere, and yet their impact is profound—without them, it would not be warm enough on the earth to sustain life as we know it. Tell students the questions surrounding the effect is not *if there would be* such an effect if

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See **The Eyes of Nye** Issue Support **Our Atmospheric Greenhouse** not for humans, but *to what extent* we artificially, even dangerously, enhance that effect. Suggest that to explore this possibility we must analyze past trends, part of our investigation of the second question we posed in the last step.

6) Tell students that we will start by going *far* back in time. Play ***"Back Through the (Ice) Ages,"*** in which Dr. Todd Hinkley and Dr. Joan Fitzpatrick at the National Ice Core Lab describe ice core samples being collected from a 2-mile deep sheet of ice in Greenland, called the 2-mile time machine because it contains a high-resolution record of atmospheric composition and temperature that goes back 250,000 years. Review Dr. Fitzpatrick's description of the air bubbles trapped as ice layers are deposited and compacted, and how we can analyze that air to determine the CO_2 content at various points in time. Explain that we can also determine temperatures by analyzing the ratio of oxygen isotopes present. Based on the earlier study of the greenhouse effect, ask students to describe what they think we would find if we compared the CO_2 content with the temperature in each case over those many years. Record a few of their responses and ask them to watch closely as we explore that relationship.

Optional – *Core into the ice more deeply. Encourage students to explore geological principles (e.g., uniformitarianism, original horizontality, superposition) on which assumptions are based, relative rareness of regions with undisturbed ice layers, data indicating wide present fluctuations in temperature by region, and difficulties posed by presence of dust in Greenland* CO_2 *analyses. The unquestionable value of what we learn through ice core analyses and the scientific questions that exist form an interesting juxtaposition. Scientific uncertainty—it's just… science.*

7) Play ***"Record in the Ice: A Correlational Analysis,"*** in which Dr. Hinkley presents a graph of lower-resolution (to the century or millennium) CO_2 and temperature changes over the past 400,000 years in Vostok, Antarctica. Ask students to note similarities in the CO_2 and temperature patterns that repeat four times over that span, and that the recent data is represented in the peak of the last trend. Review Hinkley's projection of CO_2 to the present level of 360 parts per million, Bill's question about how high we expect temperature to increase given these levels of CO_2, and the comment that "the sky's the limit." Ask students what this tells us—are we undoubtedly in for a tremendous temperature increase and potential catastrophic situations near coastlines and on islands? And why, then, is the U.S. not taking part in the Kyoto Treaty?

8) Distribute "The Kyoto Protocol: A Summary" and ask students to read the provisions. Remind students of the earlier headline news—the U.S. rejection of the treaty in 2001. Ask students if there are any treaty provisions that raise doubts about whether we should "get on board." Ask students what they think the economic costs would be to reduce average emissions in 2008-2012 to 7% less than those recorded for 1990. Some may note that *developing* nations are raising a similar economic objection. Others may note that the last provision "allows" us to provide financial support to other nations trying to achieve their quota in exchange for points toward our own. Ask, however, if we *know* the situation with global warming is dire then *why* we wouldn't begin right away to repair the problem. Ask what the consequences could be to not do so. Play ***"Thermal***

Read a summary of treaty provisions.

See ***The Eyes of Nye*** *Issue Support* ***The Kyoto Protocol: A Summary***

Expansion," which portrays an often-touted viewpoint of the price of inaction—rising sea level and destruction of coastal areas, even island nations. Ask students, however, to recall the latter part of our second question (step 4) about whether or not this is *human-forced* and if so, to what extent. Ask if this is an important enough question to answer before we incur the expense of Kyoto, or if the wait is not worth the risk. Allow student discourse.

9) Ask students to recall the similar patterns of change in CO_2 content and temperature through the ages. Ask which portion of that graph would contain data that could help us to determine if present warming trends are human-forced. In North America, we can use *direct* measurements to study past temperatures since the 1850s, and in so doing, the National Oceanic and Atmospheric Administration has noted a temperature increase that ranges from .4-.8 degrees Celsius. Ask what this suggests about human influence and changes we now see. Many students will claim a causal relationship—that the increase in gas emissions during the industrial revolution is directly responsible for the increased retention of heat, therefore, our present global warming trend. Explain we do see a correlation, and this is bolstered by other proxy methods (e.g., tree-rings, ocean circulation studies, marine organic matter) as well as certain climate models. Explain also there *may* be a causal connection, but correlational and causal evidence are very different things. Note some well-known climate scientists do *not* believe there is strong causal connection. Ask students to read "Human Contribution to Climate Change Remains Questionable" by Dr. Fred Singer, atmospheric physicist and professor emeritus of environmental sciences at the University of Virginia, and first director of the U.S. Weather Satellite Service.

Teacher Note: *Before proceeding with social and political questions related to climate change claims, discuss the importance of not only assessing evidence but also possible reasons for perspectives provided. The scientific norm of openness can be obfuscated, unintentionally and sometimes intentionally.*

10) Explain that conflicting scientific evidence regarding an issue such as global climate change is not unusual. Ask students if their study of the Kyoto Protocol provisions indicates other forces besides science might be at work. Suggest some believe political expediency can undermine science. Ask students to note the views expressed by Dr. Jae Edmonds of the Pacific Northwest National Laboratory as you play ***"Business As Usual."*** Ask if this influences them to support U.S. ratification of the Kyoto Protocol. Suggest exploring social and political interests that may be involved is important—both ways.

Optional - *Play "More Sea Routes, More Petroleum" for an additional viewpoint on industry/political reasons for opposing Kyoto.*

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Check out the opposing claims.

*See **The Eyes of Nye** Issue Support **Human Contribution to Climate Change Remains Questionable***

*For more, see the **"assess phase"** of the **Map Framework***

11) Distribute "The Press Gets It Wrong", in which Dr. Richard S. Lindzen, professor of meteorology at MIT and member of a National Academy of Sciences panel that prepared a scientific report on climate change used to substantiate the calls for change in Kyoto, speaks out on just that—political expediency. Suggest to students that this creates a rather interesting set of circumstances within which they must address the social question they outlined early in the activity (step 4), "Should, or can, we do anything about it, and what would that be?" Tell them we (they) cannot ignore it. They will have to suggest that we *do* ratify, or that we *do not* ratify. They can, however, accompany their decision with caveats and with steps to take in the near future regardless.

What does a scientist on the team say about how the science was—and was not—used?

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See **The Eyes of Nye** Issue Support **The Press Gets It Wrong**

Procedure: Propose Phase

12) Inform students that often we—our society, our government, the people—must make a decision in the absence of convincing evidence. Such is the decision regarding Kyoto. Though we may attach reservations or suggest that certain additional actions be put into place, we must first decide if *at this moment* we are *for* or *against* ratifying the treaty. Use the following scenario.

Tell students, *"The UN Framework Convention on Climate Change has concluded with a recommitment of support for the Kyoto Protocol by most of the 84 nations that have been signed since 2000. The President has acquiesced to requests from foreign dignitaries, and has submitted the treaty to the U.S. Senate for a decision on ratification. You are to construct an argument 'for' or 'against' ratification, and write it so that it convinces the other Senators to your cause. You will present the case orally before the rest of the Senate prior to a decision being made."*

13) Ask each student to determine what they will strive for—ratification or not—and divide class into groups of 3-4 students with similar preference. Tell them to use the information they have acquired during the course of the lesson to construct a strong case for their stance, and write in a way to be delivered as a speech that will persuade their other classmates (the Senate) to vote in that manner. Allow one class period for groups to prepare their speech, and to select one member from each group to deliver the speech. Follow by allowing each in turn to present their uninterrupted speech, and encourage the other students to take any notes they may feel necessary during the process. Allow any student who wishes an opportunity at the close of all speeches to ask one open question that may be addressed by any speaker who so chooses. Take the "Senate" vote (by hand or ballot), and tell students that they may, again voluntarily, attach additional caveats or requirements along with their vote. Count the votes and report the results to the class. As you do so, separate out the additional requirements, and discuss these as well. Suggest that these additional caveats pose a powerful incentive for further investigation and research into the matter, and in a more realistic and protracted setting, often determine the manner of implementation and the additional measures officially attached to decisions such as these.

See "assess" and "propose" phases in MAP Framework

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Assist students to provide proper emphasis:

- *Scientific arguments are essential, but other concerns (e.g., economy, even politics) cannot be discounted.*
- *Facts and figures are powerful, but can play against you unless sources are credible and data is consistent with acceptable science norms (see "assess" phase of MAP).*
- *Where opinions or inferences are used, good arguments consistently build from specific data to those viewpoints and opinions (see "propose" phase of MAP).*

14) Inform students that as of February 16, 2005, the Kyoto Protocol entered into force. As of April 29, 2005, 150 nations had either ratified, accepted, approved, or acceded to the protocol. The United States was not one of them. Suggest that regardless of whether or not we are part of an official agreement, we have and must exert certain responsibilities —for instance, good stewardship. End on a light-hearted note by playing
"Things You Can Do To Stop Global Chilling."

Final Teacher Note: *The famous physicist and teacher Richard P. Feynman once said, "Science is a way to teach how something gets to be known, what is not known, to what extent things are known (for nothing is known absolutely), and how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgements can be made, how to distinguish truth from fraud, and from show."*

No issue taught properly can more adequately demonstrate these words than the issue of global climate change.
For more, go to eyesofnye.org.

Further Research

Investigating the Issue: Global Climate Change

Making decisions and constructing lines of argumentation related to global climate change requires students to obtain and assess information related to scientific and social aspects of the issue, and especially to claims made regarding the issue and the potential reasons for which claims may have been made. In exploring the global climate change debate, and instances where the debate becomes very public (for instance, the Kyoto Protocol), the latter need extends far beyond most issues, and provides a mechanism for helping students to learn about the rules of scientific engagement through studying how these rules play out and the extent to which they are followed in the socio-scientific arena. Scientific aspects of claims (e.g., data, evidence) are analyzed and assessed according to adherence to accepted scientific norms (*constitutive* criteria such as accuracy, precision, and consistency). Social aspects of claims are analyzed and assessed according to *contextual* criteria such as potential bias and qualifications of "expert" claimants and/or their sponsoring organizations, corroboration of viewpoints, and for this issue more than most, the extent participants in the debate are willing to adhere to the scientific norms above.

In addition to the information and claims presented in *The Eyes of Nye - Global Climate Change*, students may access a variety of informative sources related to climate studies to assist them in assessing both scientific and social aspects of claims that have been made. Teachers may direct them to specific information or leave research tasks as open as they feel is necessary for students to adequately explore and assess information related to analyses of information and climate change data.

Exploring Global Climate Change

The United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration Institutes (NOAA), and the National Aeronautics and Space Administration (NASA) all provide useful information for teachers and students who wish to obtain additional data and/or descriptions regarding climate change. They are joined by a large assortment of other organizations and institutions, however, and students should be encouraged to make full use of these range of sites and organizations in order to obtain the broad perspective needed to make sense of the vastly opposing claims presented. These resources are particularly helpful during the "assess" phase of the educator's guide as students investigate scientific evidence related to the issue of global climate change, and as they construct and communicate persuasive arguments related to potential ratification of the Kyoto Protocol on the
"Senate" floor.

Access these principal sources at:

http://www.usgs.gov

http://www.noaa.gov

http://www.nasa.gov

For the most up-to-date details on the Kyoto Protocol from an international perspective, go to the main United Nations Web site at:

http://www.un.org

Encourage students to access additional information related to:

Climate Science:

- greenhouse effect
- greenhouse gases
- solar radiation
- energy absorption and reflection
- carbon cycle

Climate Change Exploration:

- ice core sampling (Greenland and Antarctica)
- CO2, methane, and nitrous oxide increase
- climate change models
- proxy methods

Conflicting Aspects of Climate Change:

- human vs. natural climate forcing
- regional vs. global climate variation
- satellite and thermometer data
- global cooling crisis
- dust and CO_2 analyses
- role of water vapor in heat retention
- disturbance/diastrophism and ice core data
- CO_2 forcing temp vs. temp forcing CO_2

Climate and Politics:

- Kyoto Protocol
- IPCC
- Petroleum industry
- Russia and Kyoto
- United States and Kyoto
- UN and Kyoto

Exploring Global Climate Change Claims and Claimants

An important aspect of dealing with socio-scientific issues involves looking beneath the scientific evidence and viewpoints by acquiring additional information on the experts themselves as well as organizations for which they work or are affiliated. Through such exploration, students are better able to infer social (contextual) factors that may influence claims. In *The Eyes of Nye - Global Climate Change* and the accompanying educator's guide and support materials, a variety of claimants were

presented. The following list provides the names and institutions with which each are affiliated. Teachers may encourage students to conduct open-ended searches for this type of information, or direct students specifically to the institutes and individuals provided.

Dr. Todd Hinkley, scientist	National Ice Core Laboratory, USGS Denver, CO
Dr. Joan Fitzpatrick, scientist	National Ice Core Laboratory, USGS Denver, CO
Dr. Fred Singer, atmospheric physicist	University of Virginia Science & Environmental Policy Project
Dr. Richard Lindzen, professor of meteorology	Massachusetts Institute of Technology
Dr. Jae Edmonds, chief scientist	Pacific Northwest National Laboratory

ISSUES SUPPORT MATERIAL

Global Climate Change: Earth's Atmosphere Heats Up

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Our Atmospheric Greenhouse: What and Why?

The comfortable temperature of Earth is due to more than its distance from and orientation to the sun. As early as the 1800s scientists have been aware—in no negative sense—of a natural tendency for our atmosphere to allow much of the sun's energy to pass through to the earth's surface and lower levels of the atmosphere, then block it from escaping the atmosphere. Because the effect resulted in retention of life-sustaining warmth, it was likened to a greenhouse—thus the name "greenhouse effect."

Transforming our climate…

Some of the light (about 30%) is scattered or reflected from our atmosphere, some by the surface of the earth (especially those that are lighter-colored, such as areas with a great deal of snow), and most of all, by clouds. The rest of the light, however, is absorbed by our atmosphere, clouds, and (more than half) by the surface of the earth (especially the darker surfaces such as tropical areas, darker desert or prairie soil, and so forth). Upon absorption at the earth's surface, much of the radiant energy is transformed into heat energy and re-radiated back into the atmosphere in the form of invisible infrared radiation. In the atmosphere this infrared radiation is absorbed and re-radiated in all directions by certain types of gas molecules, resulting in a warming of the atmosphere.

What molecules, and why…

The molecules of certain gases, called greenhouse gases because they behave in the manner above, are composed of three or more atoms that are bound just loosely enough to allow them to absorb infrared radiation, to vibrate upon absorption, and to emit the radiation in a different direction. The gases are primarily water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2). They comprise only about 1% of the gases in our atmosphere, but enough to keep the heat circulating!

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The Kyoto Protocol: A Summary

The Kyoto Protocol was opened for signature March 16, 1998, to enter into force upon ratification by 55 nations, provided that these included countries that accounted for at least 55% of total carbon dioxide emissions in 1990. This provision is likely to be hard to meet in the absence of U.S. ratification. On November 12, 1998, the U.S. signed the Protocol, in part because the Clinton Administration wanted to revitalize what was seen by some as loss of momentum. As of February, 2000, 84 countries had signed the treaty, including the European Union and most of its members, Canada, Japan, China, and a range of developing countries. Some 22 countries were reported to have ratified the treaty. Nations are not subject to its commitments unless they have ratified it and it enters into force. The major treaty commitments on the most controversial issues are:

Emissions Reductions. The United States would be obligated under the Protocol to a reduction in its greenhouse gas emissions of 7% below 1990 levels and below 1995 levels, averaged over the commitment period 2008 to 2012.

The required reduction amounts for 39 nations—including the United States, the European Union plus the individual EU nations, Japan, and many of the former Communist nations—are each listed as percentages of the base year, 1990 (except for some former Communist countries), and range from 92% (a reduction of 8%) for most European countries to 110% (an increase of 10%) for Iceland. The United States is committed on this list to 93%, or a reduction of 7%, to be achieved as an average over the 5 years 2008-2012.

Developing Country Responsibilities. The United States had taken a firm position that "meaningful participation" of developing countries in commitments made in the Protocol was critical both to achieving the goals of the treaty and to its approval by the U.S. Senate. This reflects the requirement articulated in Senate Resolution 90, passed in mid-1997, that the United States should not become a party to the Kyoto Protocol until developing countries are subject to binding emissions targets. The developing country bloc argued that the Berlin Mandate clearly excluded them from new commitments in this Protocol, and they continued to oppose emissions limitation commitments. The negotiations concluded without such commitments, and the United States indicated that it will not submit the Protocol for Senate consideration—and therefore will not be able to ratify it—until meaningful commitments are made by developing countries.

Argentina became the first nation to indicate that it will make a commitment to take on a binding emissions target for the period 2008-2012. Kazakhstan also announced its intention to take similar action. It was immediately after these announcements that the United States signed the Kyoto Protocol. However, it is unclear exactly what emissions limitations Argentina will undertake, and how many other developing countries—particularly key large greenhouse gas emitting nations such as China, India and Brazil—will make similar commitments.

The Protocol does call on all parties—developed and developing—to take a number of steps to formulate national and regional programs to improve local emission factors, activity data, models, and national inventories of greenhouse gas emissions and sinks (e.g., oceans, vegetation) that remove these gases from the atmosphere. All parties are also committed to formulate, publish, and update climate change mitigation and adaptation measures, and to cooperate in promotion and transfer of environmentally sound technologies and in scientific and technical research on the climate system.

Emissions Trading and Joint Implementation. Emissions trading, in which a developed country may transfer to, or acquire from, any other country emission reduction units resulting from projects aimed at reducing emissions by sources or enhancing removals of greenhouse gases for the purpose of meeting its commitments under the treaty, is allowed with several provisos. One is the requirement that such trading "shall be supplemental to domestic actions." The purpose of this proviso is to make it clear that a nation cannot entirely fulfill its responsibility to reduce domestic emissions by relying primarily on emissions trading or joint implementation to meet its targets. Joint implementation is project-based activity in which one country can receive emission reduction credits when it funds a project in another country where the emissions are actually reduced.

A major development is the establishment of a "clean development mechanism" (CDM), through which joint implementation between developed and developing countries would occur. The United States had pushed hard for joint implementation, and early proposals were formulated with the expectation that "JI" projects would be primarily bilateral. Instead, negotiations resulted in agreement to establish the clean development mechanism to which developed countries could contribute financially, and developing countries could benefit from financing for approved project activities; developed countries could then use certified emission reductions from such projects to contribute to their compliance with part of their emission limitation commitment. Emissions reductions achieved through this mechanism could begin in the year 2000 to count toward compliance in the first commitment period (2008-2012).

Source: Adapted from the Congressional Service Report 98-2: Global Climate Change Treaty: The Kyoto Protocol. Made available by the National Council for Science and the Environment (NCSE). March 6, 2000. Author: Susan R. Fletcher, Senior Analyst in International Environmental Policy; Resources, Science, and Industry Division. (Accessed at: http://www.ncseonline.org/NLE/CRSreports/Climate/clim-3.cfm

Human Contribution to Climate Change Remains Questionable

By Dr. S. Fred Singer

A Geophysicist Looks at Climate Change: Introduction

What about the association of climate change with atmospheric greenhouse gases? On the time-scale of hundreds of millions of years, carbon dioxide has sharply declined; its concentration was as much as 20 times the present value at the beginning of the Cambrian Period, 600 million years ago (Berner, 1997). Yet the climate has not varied all that much and glaciations have occurred throughout geologic time even when CO_2 concentrations were high.

On a time-scale of decades and centuries, there seems to be an association between temperature and CO_2 concentration, as judged by measurements of Greenland and Antarctic ice cores. (The association is even better for the greenhouse gas methane.) Yet, the causal connection is not at all clear. Only recently has it been possible to obtain sufficient resolution to demonstrate that the increase in CO_2 lags by about 600 years behind the rapid warming that signals deglaciation, the end of an ice age and the beginning of an interglacial warm period (Fischer et al., 1999).

Atmospheric Greenhouse Gases (GHGs)

There is general agreement that the increase in atmospheric GHGs, like CO_2, methane, nitrous oxide, etc., over the last hundred years or so is due to human activities. Attention has focused mainly on CO_2 as the most important anthropogenic GHG. Less than half of the released CO_2 remains in the atmosphere, the rest is absorbed by the ocean and by the biosphere, thereby speeding up the growth of agricultural crops and forests. Informed opinion holds that half of the released CO_2 is absorbed into the shallow oceans within 30 years (Sarmiento, Orr, and Siegenthaler, 1992), that the mean residence time is about 75 years, and that a "tail" may last more than a century (IPCC, 1996, p. 76). The residence time of methane is much shorter, only about 12 years. For reasons as yet unexplained, the rate of increase of CO_2 has slowed considerably in the last decade or so, and methane has stopped increasing altogether (Hansen et al., 1998). This makes it extremely difficult to predict future concentrations of CO_2 and methane, the latter depending primarily on the rate of population growth. With respect to CO_2, estimates of emissions vary greatly, depending on energy scenarios. These are determined not only by population growth and economic growth, but also by the availability of fossil fuels—in turn a strong function of technology and of price. Much to the surprise of many "experts," the price of oil has decreased in the last two decades, even as readily available low-cost resources are being depleted. There is considerable disagreement about the probable date when atmospheric GHG concentration might reach double the pre-industrial level. Estimates vary from the year 2050 all the way to never (Gerholm, 1992; Linden, 1999).

Temperature Data

There is general agreement that the global climate warmed between about 1880 and 1940, following several centuries of the "Little Ice Age," which in turn was preceded by the "Medieval Climate Optimum" around A.D. 1100. There is less agreement about the causes of this recent warming, but the human component is thought to be quite small. This conclusion seems to be borne out also by the fact that the climate cooled between 1940 and 1975, just as industrial activity grew rapidly after WWII. It has been difficult to reconcile this cooling with the observed increases in greenhouse gases. To account for the discrepancy, the 1996 IPCC Report has focused attention on the previously ignored (direct) cooling effects of sulfate aerosols (from coal burning and other industrial activities), reflecting a portion of incident sunlight. But this explanation to support the "discernible human influence" conclusion is no longer considered as valid. Leading modelers (Tett et al., 1996; Penner et al., 1998; Hansen et al., 1998) all agree that the aerosol forcing is more uncertain than any other feature of the climate models. Models have not yet incorporated the much larger indirect cooling effects of sulfate aerosols (by increasing cloudiness), or the quite different optical effects of carbon soot from industrial and biomass burning and of mineral dust arising from disturbances of the land.

The temperature observations since 1979 are in dispute. On the one hand, surface observations with conventional thermometers show a rise of about 0.1°C per decade, less than half that predicted by most GCMs. On the other hand, satellite data, as well as independent data from balloon-borne radiosondes, show no warming trend between 1979 and 1997 in the lower troposphere, and could even indicate a slight cooling (Christy and Spencer, 1999). Direct temperature measurements on Greenland ice cores show a cooling trend between 1940 and 1995 (Dahl-Jensen et al., 1998). It is likely therefore that the surface data are contaminated by the warming effects of "urban heat islands." Some data support this hypothesis (Goodridge, 1996), others do not (Peterson et al., 1999).

While it is certainly true that human life is affected by temperatures at the surface, the GCMs are best validated by observations in the troposphere. It should be noted also that GCMs predict a warming trend that increases with altitude up to about 250 millibars (~12 km), rising to about 0.5°C per decade (Tett et al., 1996)—in clear disagreement with all observations, whether from the surface, balloons, or satellites.

Climate Models

The large discrepancy between model results and observations of temperature trends (whether from satellites or from the surface) demands an explanation. The twenty or so models developed around the world by expert groups differ among themselves by large factors. Their "climate sensitivities" (defined as the temperature increase for a doubling of GHG forcing) vary from as low as 1°C to as high as 5°C; the IPCC gives a conventional range of 1.5°C to 4.5°C. An intercomparison of models has established that a major uncertainty relates to how clouds are treated (Cess et al., 1990, 1996). Since they cannot be spatially resolved, they must be parameterized in some fashion. In many models, clouds add to the warming, but in others, clouds produce a cooling effect. The situation is even more confused with respect to water vapor (WV), the most important greenhouse gas in the atmosphere, contributing over 90% of the radiative forcing. In current climate models, water vapor is taken to produce a positive feedback, thereby amplifying the warming effects of a CO_2 increase. Everyone agrees that a warming produced by an increase in CO_2, or by any other cause, will lead to more evaporation and therefore to a higher level of WV; but it is the WV concentration in the upper troposphere—not in the boundary layer—that determines whether the feedback is positive or negative (Lindzen, 1990; Spencer and Braswell, 1998). On that score, opinions differ widely and probably will continue to do so until the necessary data are at hand.

None of the climate models incorporate the effects of one variable: Sun. It has always been assumed that solar variability is simply too small, but this view is now changing. Even if the radiative forcing from changes in solar irradiance is less than that from GHGs, the variability of the Sun in the ultraviolet is much greater. Evidence is now forthcoming that UV-caused variations of the ozone layer or changes in solar particulate emissions ("solar wind") could (indirectly) influence atmospheric circulation or cloudiness—which in turn can cause significant climate changes (Svensmark and Friis-Christensen, 1997). Climate models generally do not incorporate the large surface albedo changes that have come about through land-clearing for agriculture and, more recently, through reforestation in some parts of the world.

Even though the models are not yet validated as far as temperature trends are concerned, some human influences on climate are already noticeable. Observations indicate that the diurnal temperature range has been decreasing in the Northern Hemisphere and perhaps in the Southern Hemisphere as well (Karl et al., 1991). These could be traced to possible increases in aerosols or cloudiness. There is evidence also for winter warming, but not yet for the expected warming at high latitudes predicted by the climate models. On the other hand, observed stratospheric cooling appears in line with what one might expect from the increase in CO_2, as well as from the ongoing depletion of ozone (Ramaswamy et al., 1996). Yet until GCM climate sensitivity is validated, one cannot accept the predictions of large future temperature increases.

Impacts of Climate Change

If the climate were to change according to model predictions, one would expect to see fewer severe storms, in view of the reduced temperature gradient between the tropics and high latitudes. Model calculations do not indicate an increase of hurricanes, El Niño events, or other kinds of climate oscillations. The empirical evidence displayed in the IPCC Report shows a decline in hurricanes over the last fifty years in both frequency and intensity (IPCC, 1996, p. 170); a future warming is not expected to affect frequency or intensity appreciably (Henderson-Sellers et al. 1998). Observations on El Niño events are not conclusive as yet.

With respect to sea-level rise, it has been assumed, conventionally, that a warming will increase the rate of rise, because of the thermal expansion of ocean water and the melting of mountain glaciers. Certainly, when viewed on a millennial scale, sea level has been rising steadily. But when examined on a decadal scale, which is more appropriate to human intervention, sea-level rise is found to slow during periods of temperature increases, for example, during the temperature rise from 1900 to 1940 (Singer, 1997). Evidently, increased evaporation, linked to warming, results in increased accumulation of ice in the polar regions, thereby lowering sea level. This conclusion seems to be backed by direct observation of ice accumulation, as well as by some modeling studies. A future modest warming should therefore slow down, not accelerate the ongoing rise of sea levels.

Following the publication of the IPCC report in 1996, an increasing number of researchers have adopted the view that much or most of the pre-1940 warming is due to natural causes and represents a recovery from the Little Ice Age. Some would assign a substantial portion to greenhouses gases (Wigley, Jones, and Raper, 1997). Others claim that most of the temperature increase is caused by solar variability (Soon et al., 1996). If one applies the "fingerprint" criterion used by the IPCC, then it can be seen from their data (IPCC, 1996, p.433) that the pattern correlation has a negative trend during the major warming between 1900 and 1940, thereby denying the existence of an appreciable human contribution.

Perhaps the strongest argument against an appreciable human contribution comes from the observed cooling between 1940 and 1975 and the lack of warming since 1979 (in the weather balloon and satellite data).

References

Berner, R. A., The rise of plants and their effect on weathering and atmospheric CO_2, Science, 276, 544-545, 1997.

Cess, R. D., G. L. Potter, et al., Intercomparison and interpretation of climate feedback processes in nineteen atmospheric general circulation models, J. Geophys. Res., 95, 16601-16615, 1990.

Cess, R. D., G. L. Potter, et al., Cloud feedback in atmospheric general circulation models, J. Geophys. Res., 101, 12,791-12,794, 1996.

Christy, J. R., and R. W. Spencer, J. Geophys. Res., 1999 (submitted).

Dahl-Jensen, D., Mosegaard, K, Gundestrup, N., Clow, G. D., Johnsen, S. J., Hansen, A. W., and N. Balling, Past temperatures directly from the Greenland ice sheet, Science, 282, 268-279, 1998.

Fischer, H., M. Wahlen, J. Smith, D. Mastroianni, and B. Deck, Ice core records of atmospheric CO_2 around the last three glacial terminations, Science, 283, 1712-1714, 1999.

Gerholm, T. R., in The greenhouse debate continued, (S. F. Singer, ed.), ICS Press, San Francisco, CA, 1992.

Goodridge, J. D., Comments on regional simulations of greenhouse warming including natural variability, Bull. Amer. Meteorol. Soc., 77, 3–4, 1996.

Hansen, J. E., Sato, M., Lacis, A., Ruedy, R., Tegen, I., and E. Matthews, Climate forcings in the Industrial era, Proc. Natl. Acad. Sci. USA, 95, 12753-12758, 1998.

Henderson-Sellers, A., H. Zhang, G. Berz, K. Emanuel, W. Gray, C. Landsea, G. Holland, J. Lighthill, S-L. Shieh, P. Webster, and K. McGuffie, Tropical cyclones and global climate change: a post-IPCC assessment, Bull. Am. Meteorol. Soc., 79, 19-38, 1998.

IPCC WGI, Climate Change 1995: The science of climate change, (J.T. Houghton, L.G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg and K. Maskell, eds.), Cambridge University Press, Cambridge, UK, 1991.

Karl, T. R., Kukla, G., Razuvayev, V. N., Changrey, M. J., Quayle, R. G., Heim Jr., R. R., Easterling, D. R., and C. B. Fu, Global warming: Evidence for asymmetric diurnal temperature change, Geophys. Res. Ltrs., 18, 2253-2256, 1991.

Linden, H. R, Let's focus on sustainability, not Kyoto, Electricity J., March 1999.

Lindzen, R. S., Some coolness concerning global warming, Bull. AMS, 71, 288-99, 1990.

Penner, J. E., Chuang, C. C., and K. Grant, Climate forcing by carbonaceous and sulfate aerosols, Clim. Dyn., 1998.

Peterson, T.C., K.P. Gallo, J. Lawrimore, T.W. Owen, A. Huang, and D.A. McKittrick, Global rural temperature trends, Geophys. Res. Ltrs, 26, 329-332, 1999.

Ramaswamy, V., Schwarzkopf, M. D., and W. J. Randel, Fingerprint of ozone depletion in the spatial and temporal pattern of recent lower-stratospheric cooling, Nature, 382, 616-618, 1996.

Sarmiento, J. L., Orr, J. C., and U. Siegenthaler, A perturbation simulation of CO_2 uptake in an ocean general circulation model, J. Geophys. Res., 97, 3621-3646, 1992.

Singer, S. F., Global warming will not raise sea-levels, Abstract for 1997 Fall Meeting of the AGU; also S. F. Singer, Hot talk, cold science: Global warming's unfinished debate, The Independent Institute, Oakland, CA, 1997, p. 57.

Soon, W. H., Posmentier, E. S., and S. L. Baliunas, Inference of solar irradiance variability from terrestrial temperature changes, 1880-1993, J. Astrophys., 472, 891-902, 1996.

Spencer, R.W., and W. D. Braswell, How dry is the tropical free troposphere? Implications for global warming theory, Bull. AMS, 78, 1097-1106, 1997.

Svensmark, H., and E. Friis-Christensen, Variation of cosmic ray flux and global cloud coverage: A missing link in solar-climate relationships, J. Atm. Terr. Phys., 59, 1225-1232, 1997.

Tett, S. F. B., Mitchell, J. F. B., Parker, D. E., and M. R. Allen, Human influence on the atmospheric vertical temperature structure: detection and observations, Science, 274, 1170-1173, 1996.

Wigley, T. M. L., Jones, P. D., and S. C. B. Raper, The observed global warming record: What does it tell us? Proc. Natl. Acad. Sci. USA, 94, 8314-8320, 1997.

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The Press Gets it Wrong

By Dr. Richard S. Lindzen

Last week the National Academy of Sciences released a report on climate change, prepared in response to a request from the White House, that was depicted in the press as an implicit endorsement of the Kyoto Protocol. CNN's Michelle Mitchell was typical of the coverage when she declared that the report represented "a unanimous decision that global warming is real, is getting worse, and is due to man. There is no wiggle room."

As one of 11 scientists who prepared the report, I can state that this is simply untrue. For starters, the NAS never asks that all participants agree to all elements of a report, but rather that the report represent the span of views. This the full report did, making clear that there is no consensus, unanimous or otherwise, about long-term climate trends and what causes them.

As usual, far too much public attention was paid to the hastily prepared summary rather than to the body of the report. The summary began with a zinger—that greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise, etc., before following with the necessary qualifications. For example, the full text noted that 20 years was too short a period for estimating long-term trends, but the summary forgot to mention this.

Our primary conclusion was that despite some knowledge and agreement, the science is by no means settled. We are quite confident (1) that global mean temperature is about 0.5 degrees Celsius higher than it was a century ago; (2) that atmospheric levels of carbon dioxide have risen over the past two centuries; and (3) that carbon dioxide is a greenhouse gas whose increase is likely to warm the earth (one of many, the most important being water vapor and clouds).

But—and I cannot stress this enough—we are not in a position to confidently attribute past climate change to carbon dioxide or to forecast what the climate will be in the future. That is to say, contrary to media impressions, agreement with the three basic statements tells us almost nothing relevant to policy discussions.

One reason for this uncertainty is that, as the report states, the climate is always changing; change is the norm. Two centuries ago, much of the Northern Hemisphere was emerging from a little ice age. A millennium ago, during the Middle Ages, the same region was in a warm period. Thirty years ago, we were concerned with global cooling.

Distinguishing the small recent changes in global mean temperature from the natural variability, which is unknown, is not a trivial task. All attempts so far make the assumption that existing computer climate models simulate natural variability, but I doubt that anyone really believes this assumption.

We simply do not know what relation, if any, exists between global climate changes and water vapor, clouds, storms, hurricanes, and other factors, including regional climate changes, which are generally much larger than global changes and not correlated with them. Nor do we know how to predict changes in greenhouse gases. This is because we cannot forecast economic and technological change over the next century, and also because there are many man-made substances whose properties and levels are not well known, but which could be comparable in importance to carbon dioxide.

What we do is know is that a doubling of carbon dioxide by itself would produce only a modest temperature increase of one degree Celsius. Larger projected increases depend on "amplification" of the carbon dioxide by more important, but poorly modeled, greenhouse gases, clouds and water vapor.

The press has frequently tied the existence of climate change to a need for Kyoto. The NAS panel did not address this question. My own view, consistent with the panel's work, is that the

Kyoto Protocol would not result in a substantial reduction in global warming. Given the difficulties in significantly limiting levels of atmospheric carbon dioxide, a more effective policy might well focus on other greenhouse substances whose potential for reducing global warming in a short time may be greater.

The panel was finally asked to evaluate the work of the United Nations' Intergovernmental Panel on Climate Change, focusing on the Summary for Policymakers, the only part ever read or quoted. The Summary for Policymakers, which is seen as endorsing Kyoto, is commonly presented as the consensus of thousands of the world's foremost climate scientists. Within the confines of professional courtesy, the NAS panel essentially concluded that the IPCC's Summary for Policymakers does not provide suitable guidance for the U.S. government.

The full IPCC report is an admirable description of research activities in climate science, but it is not specifically directed at policy. The Summary for Policymakers is, but it is also a very different document. It represents a consensus of government representatives (many of whom are also their nations' Kyoto representatives), rather than of scientists. The resulting document has a strong tendency to disguise uncertainty, and conjures up some scary scenarios for which there is no evidence.

Science, in the public arena, is commonly used as a source of authority with which to bludgeon political opponents and propagandize uninformed citizens. This is what has been done with both the reports of the IPCC and the NAS. It is a reprehensible practice that corrodes our ability to make rational decisions. A fairer view of the science will show that there is still a vast amount of uncertainty--far more than advocates of Kyoto would like to acknowledge—and that the NAS report has hardly ended the debate. Nor was it meant to.

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