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TO: AIAM Technical Committee

FROM: Gregory J. Dana
Vice President and Technical Director

RE: **GLOBAL CLIMATE COALITION (GCC) - Science and Technology Assessment Committee (STAC) - Minutes of April 11, 1996 Conference Call**

Enclosed is a copy of the minutes of the April 11, 1996 conference call of the Science and Technology Assessment Committee (STAC) of the GCC. Also included are copies of two reports refereced in this and other STAC meetings. These are: *the Scientific Uncertainties from the IPCC Second Assessment Report -- Work Group 1 and Work Group II.*

GJD:ljf

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L. S. BERNSTEIN
Manager, Corporate Issues
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FACSIMILE TRANSMISSION COVER SHEET

TO: SCIENCE AND TECHNOLOGY ASSESSMENT COMMITTEE

FROM: L. S. Bernstein - April 15, 1996 (Cover + 17 pages)

Committee Members

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Greg Dana - 703/525-8817
Howard Feldman - 202/682-8270
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Tom Rasmussen - 202/833-9636
Eric Reiner - 612/778-6176
Eric Ridenour - 810/576-7928
Jerrel D. Smith - 314/554-4830 or 314/231-1890
Fred Starheim - 216/384-5433
Mike Stroben - 704/875-5493
Porter J. Womeldorff - 217/422-9174

Information

Chuck Hakkarinen - 415/855-1069
George Lauer - 213/486-2021
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4/9/96

GCC Science and Technology Assessment Committee

April 12, 1996

To: Members of GCC-STAC

Results of GCC-STAC April 11th Conference Call

- Scientific views not adequately addressed by the IPCC - John Kinsman provided a summary of the House Science Committee testimony of scientists who disagreed with the IPCC consensus. Porter Womeldorff provided a list of topics which were sources of the uncertainty in the scientific assessment of climate change. STAC agreed that it would be worthwhile trying to put together write-ups on these topics. The following members volunteered to draft discussions on these topics:

Models	Chuck Hakkarinen
Sea Level Rise	Tom Rasmussen
Solar Variability	Bob Gehri
Carbon Dioxide	Lenny Bernstein
Temp. Record/Measurement	Eric Reiner

These write-ups should be sent to Lenny Bernstein by May 9th for distribution to STAC members prior to our May 16th meeting.

Another topic on Porter's list was the politicization of science in the IPCC process. This issue was addressed in early drafts of the Science Primer, but STAC was unable to come to agreement on how to present the issue. At the May 16th meeting, we will discuss whether the Committee wishes to address this topic as part of the follow-up to the Science Primer.

Bronson Gardner presented a list of eight issues which he felt were inadequately discussed in the IPCC Working Group I report. A written description of these issues is attached. STAC will decide at its May 16th meeting whether to ask Bronson to develop a paper for GCC members elaborating on these issues.

- Review of "Climate Change Assertions and Facts" - We discussed the draft being developed by GCC's Communication Committee in general terms and provided a number of general suggestions to Tom Kirlin who is coordinating development of the piece. Specific comments are due to Tom by fax (202-682-8071) or phone (202-682-8078) no later than the close of business on Thursday, April 18th.

- Bob McFadden informed STAC of GCC's actions in response to a request from the State Department for input on a number of issues which will be discussed at the next round of

UN climate change meetings in July. One of the topics was views on the IPCC Second Assessment Report. This response was put together from a summary developed by Bronson Gardner for the GCC Communications Committee.

- John Kinsman asked whether STAC had reviewed the attached three updated GCC Backgrounders dealing with scientific issues. After the conference call it was determined that STAC had not been involved in the review of these papers. At the May 16th meeting we will discuss both the papers and ways to ensure that STAC review is part of the clearance procedure.

- Bob McFadden also mention an article in the March 29 issue of Science which presented information about climate "surprises." A copy of that article is also attached.

- Eric Reiner reminded STAC members that we need about $500 additional funding to be able to invite Ben Santer, one of the lead authors of IPCC WG I's report to present his arguments for why there is a discernable human impact on global climate at our June meeting.

- Additional items for the May 16th meeting:

  - STAC involvement in the four IPCC Technical Reports scheduled for completion in November, 1996.

  - Status of ACACIA

Lenny

L. S. Bernstein

04119602.wp6

To: GCC STAC
From: Bronson Gardner
Re: Concepts not adequately addressed in the IPCC Second Assessment Report

There are at least 8 issues which I thought were inadequately addressed in underlying chapters of the IPCC's Second Assessment Report. Each of these are items which either generated controversy during the WG I plenary session or which most of the authors of the Synthesis Report wanted to avoid discussing.

Issue #1: Quantification of anthropogenic and natural effects in climatic data. Climate scientists have produced several historical data sets of climate trends. There is inadequate discussion of what scientists need (in terms of data or theoretical advances) to begin quantifying and differentiating between "natural" and "anthropogenic" effects. For example, missing is a good discussion of current temperature trends, e.g., why did the bulk of the temperature rise in the past 100 years occur before the bulk of the CO2 emissions ?

Issue #2: Hypothesis Testing. What do climate scientists need (in terms of data or theoretical understanding) in order to establish the validity of the projections being made by climate models, particularly regional models ? What are the appropriate statistical tests ? If the current data is evaluated with these statistical tests, what do the results show ? What are the "signs" of global warming that should be detected in the data (e.g., a warming arctic) and what tests are needed to verify the existence of these signs ?

Issue #3: Definitions of Key Words: Two phrases generated significant controversy at the WGI plenary and at the Rome Plenary: "climate change" and "global mean temperature". It was clear that delegates could not reach consensus on the meaning of these terms. Part of the problem is a conflict between what scientists may mean when using these terms and what policymakers may mean.

Issue #4: Statistical correlations between observed and modeled data. A great deal has been said about how "broadly consistent" the observed and modeled data are, but there is very limited discussion on the actual statistical relationships. For example, R^2 values are quite low, leading one to believe that natural variability may dominate the historical trends.

Issue #5: Divergent results produced from various models. There is some intermodel comparisons contained within the IPCC report, but much more discussion is needed. This would highlight the weaknesses and uncertainties within the models and allow policymakers a more realistic opportunity to evaluate the credibility of the models for policy purposes.

Issue #6: Discussion of natural warming and cooling trends. The IPCC report clear indicates that there was a significant cooling trend several hundred years ago, but only suggests that one interpretation of the data is that recent warming may be the result of a natural warming trend which began after the cooling trend peaked. For example, why isn't it plausible that most, if not all, of the observed warming is due to natural forces, and that the enhanced greenhouse effect is strictly an issue *for the future ?* Ties back to a discussion on quantification of effects.

Issue #7: Methods of computing global mean temperatures and global mean temperature variations. This is a fundamental issue on which many people, even within the IPCC, are confused. IPCC scientists made it clear that there is no reliable global mean average temperature, since it depends on how one wants to define the mean and what data sets are used. Global mean temperature may vary from 10 to 15 C, depending on how its defined. Departures from the global mean temperature (the parameter generally discussed) is actually a quite complicated parameter to compute. Since "global temperature" trends (meaning deviations from the mean) are one of the central political issues, a clear understanding of how these numbers are derived would seem essential. I question if IPCC would ever want to attempt this, since all the explanation could do is decrease people's confidence in the numbers which they provide.

Issue #8: A clear and detailed explanation of the phrase "discernible human influence." is needed . The Synthesis Report states that the evidence for a discernible human influence comes from "changes in global mean surface air temperature and from changes in geographical, seasonal, and vertical patterns of atmospheric temperature." Missing from the IPCC report are the necessary graphs and statistics which support this point. During the plenary at Madrid, the explanation was offered that the current interpretation is based basically on "visual inspection of the data", leaving the interpretation totally up to the individual scientist making the statement. Clearly, a much more defensible and quantitative justification for this statement is needed.

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BACKGROUNDER

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Science and Global Climate Change: What Do We Know? What are the Uncertainties?

About This Backgrounder

In the past two decades, many scientists have raised concerns about the future of the earth's climate. In 1971, several leading scientists raised concerns about global cooling, leading to predictions of a coming ice age. Some scientists still recognize a cooling potential.

In the mid-1980's, the concern shifted to global warming, with a number of scientists stating their belief that the earth was warming as a result of an increasing concentration of greenhouse gases in the atmosphere. Some scientists predicted dramatic increases in temperature, which would lead to the melting of polar ice-caps, rising of sea levels, and other catastrophic results. Today, after several years of investigation, many of these dire predictions are moderating.

Global climate policy decisions must be made with the benefit of an adequate scientific understanding of how and why climate changes. Scientists remain divided on a number of climate change issues: Are increases of man-made gases contributing to global warming? Have global temperatures increased over the century? How accurate are forecasts based on computer modeling? Are sea levels rising? and How will increases in carbon dioxide (a greenhouse gas) affect the world's plant life?

This backgrounder responds to these questions, which are being debated in the scientific community today, and provides a resource section for additional reading.

Are increases of man-made greenhouse gases contributing to global warming?

Scientists agree that the greenhouse effect is a real, naturally occurring phenomenon. Greenhouse gases trap the sun's warmth in the lowest layers of the atmosphere, keeping Earth warm enough to sustain life. Without the natural greenhouse effect, the average surface temperature on Earth would fall below zero Fahrenheit. Indeed, in the natural greenhouse effect, atmospheric water vapor and clouds play a far greater role than other greenhouse gases. To put this in perspective, even if all other greenhouse gases were to disappear, water vapor and clouds would still leave us with 98 percent of the current greenhouse effect.

Scientists also agree that atmospheric levels of greenhouse gases (such as CO2) are increasing as a result of human activity. But scientists differ on whether the increase in the concentrations of these gases will cause an "enhanced greenhouse effect," or warming of the planet, because the role of greenhouse gases in climate change is not well understood.

As an example of this uncertainty, a recent Gallup poll of climate scientists in the American Meteorological Society and the American Geophysical Union asked whether there has been any identifiable, human-induced global warming to date. Forty-nine percent of respondents said no; 33 percent said they did not know, and only 18 percent thought some warming has occurred.

Have global temperatures increased over the last century?

Average surface air temperature readings appear to have increased about 1 degree Fahrenheit during the last century. Just as the greenhouse effect is a natural phenomenon, so are climate cycles. While temperature records do not extend much beyond the century mark, making it difficult to view the observed temperature change in the context of an overall trend, many scientists believe the observed increase in temperature within the last 100 years is a result of natural fluctuations in climate. Notably, almost all of the temperature increases in this century occurred before 1940, well before any significant increase in man-made CO2 emissions. The effects of man-made gases and natural factors may more completely explain this temperature record.

Analysis of the temperature data records for the last 100 years are subject to several uncertainties, including the urban heat island effect, which can raise temperatures around measurement stations as urban areas expand. Urbanization increases everything from lighting, automobile exhaust and retained heat from buildings and roads. Some scientists say this "heat island" effect must be considered when looking at the long-term temperature record.

Satellite measurements, which have been made for the last 14 years, which are relatively free from the distortions resulting from location, have shown no global temperature trend. The satellite techniques offer the future promise of comparing observational records with global climate model projections.

How accurate are forecasts based on computer modeling?

Computer models are used to project future temperature and climate change scenarios. The fact is, however, that computer modeling is inexact and uncertain. Many of the world's foremost climate modelers concede that insufficient data are available to represent the complex interactions that determine temperature and climate. At this time, modeling is unable to resolve how, where, or even whether potential global climate change can affect specific regions of the planet.

Many scientists believe current climate models are an inadequate basis for policy decisions. The manner in which these models account for water vapor (the major greenhouse gas) and cloud cover, is among their greatest shortcomings. Even small modifications in these factors can dramatically alter model projections. Current climate models cannot credibly predict CO2-induced climate changes. The Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 by the United Nations Environment Programme and the World Meteorological Organization to evaluate the science, potential impacts and potential policies for climate change. Presenting its findings, the IPCC stated, "Climate models are only as good as our understanding of the processes which they describe, and this is far from perfect."

Are sea levels rising?

There has been a great deal of speculation about a potential sea level rise if the global climate gets warmer. Since even the most dire predictions of a warming trend would still leave the polar regions well below freezing, some scientists question the notion of a dangerous melting of the polar ice caps. Several recent studies suggest that warmer air temperatures will increase snowfall, resulting in more, not less, snow cover. While most scientists agree there has been some observed rise in sea level over the last century, there are questions on the accuracy of sea level measurements. Taken primarily through tide gauge records, sea level measurements are difficult to assess because of vertical land movements, atmospheric pressure, winds, ocean currents and lunar cycles.

How will increases in CO2 affect the world's plant life?

While scientists disagree on the link between CO2 increases and any global warming, there is strong scientific evidence pointing to the link between CO2 increases and plant productivity. Plant life "breathes" CO2 as humans do oxygen. Recent studies have suggested, and many agricultural experts believe, that increasing atmospheric CO2 levels may in fact accelerate plant growth, given adequate nutrients in the soil.

In summary

Sound policy making rests on resolving scientific uncertainty. Focused research is critically needed to address the outstanding scientific uncertainties that surround global climate change. The relevance of on-going research will depend in large part on how well it can scientifically clarify answers to the questions facing policy-makers. The research must resolve the questions raised above as well as other key uncertainties such as: 1) What is the role of cloud cover, the oceans, polar ice caps, soil and forests and their interactions? and 2) How can we differentiate natural climate variations from changes attributable to man-made emissions? If the research fails to address these and other issues, the result may be stacks of good scientific articles, but little progress in translating data into information that policy makers can use to make effective decisions.

Recommended Reading

Boettcher, C.J.F. Science and Fiction of the Greenhouse Effect and Carbon Dioxide. The Hague, Netherlands: The Global Institute for the Study of Natural Resources, 1992. *(Copies are available through the Science and Evironmental Policy Project at 703-527-0130.)*

Houghton, J.T., Jenkins, G.J., ed. Climate Change: The IPCC Scientific Assessment. Cambridge University Press, 1990.

Hougton, J.T., Jenkins, G.J., Ed. Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment. Cambridge: Cambridge University Press, 1992.

Lindzen, Richard S. "Global Warming: The Origin and Nature of the Alleged Scientific Consensus." Regulation: Cato Review of Business and Government (Spring 1992): 87-98. *(Copies are available through the Cato Institute at 202-546-0200.)*

Michaels, Patrick J. Sound and Fury: The Science and Politics of Global Warming. Washington, DC: Cato Institute, 1992. *(Copies are available through the Cato Institute at 202-546-0200.)*

Singer, Fred S., ed. The Greenhouse Debate Continued: An Analysis and Critique of the IPCC Climate Assessment. San Francisco: ICS Press, 1992. *(Copies are available fro ICS Press at 1-800-326-0263. Pleas refer to ISBN i-55815-233-4)*

Singer, S. Fred. "Warming Theories Need Warning Label." The Bulletin of Atomic Scientists (June 1992): 34-39.

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Climate Models: Shortcomings and Limitations

General Circulation Models

General circulation models (GCMs) are computer representations of global climate. They are based on mathematical equations derived from our knowledge of the physics that govern the Earth-atmosphere system. By definition, "climate" encompasses a vast number of factors (cloud cover, air and ocean temperatures, rain and snowfall, air and ocean currents, barometric pressure, atmospheric composition, etc.). These models are far from perfect, however. Policymakers should be aware of the limitations of computer models and recognize that while these models are useful tools for scientific research, they are not yet reliable enough to serve as the basis for multi-billion dollar public policy decisions.

Important Weaknesses in GCMs

The IPCC and the GAO have recently identified several important limitations associated with GCMs which clearly indicate that GCMs are not yet ready for use by policymakers. The IPCC has identified 5 major areas of weaknesses in GCMs:

- Poor model representation of cloud processes.
- A coarse spatial resolution (i.e., the grid-scale is too large).
- Problems in the parameterization of regional and local atmospheric processes.
- Generalized topography, disregarding some locally important features.
- A simplified representation of land-atmosphere and ocean-atmosphere interactions. (WGII FSM (Chapter 26, Technical Guidelines), section 6.5.3).

Until these weaknesses are significantly resolved, it is clear that policymakers will be hard pressed to rely on GCM output for policy decisions. The probability that the current output is misleading, or totally incorrect, is simply too high. Key limitations include:

- **Incomplete or inadequate quantification of processes affecting climate.**

  "Specifically, they have not been able to uniquely and quantitatively distinguish the effects of higher concentrations of greenhouse gases from the effects of other factors that can change the

climate. Such factors include natural fluctuations in the global climate system, increases in atmospheric ozone, air pollution, and aerosols emitted into the atmosphere from volcanic eruptions." (GAO, 1995, page 6).

- **Inadequate representation or inclusion of feedback mechanisms.**

  "GCMs include many of the most important feedback mechanisms, such as vegetation, water vapor, ice cover, clouds, and the ocean. However, the models do not yet adequately represent the interactions of these mechanisms with greenhouse gases. Such interactions can amplify, dampen, or stabilize the warming produced by increased concentrations of greenhouse gases." (GAO, 1995, page 8).

It is clear that *feedback mechanisms* (the interaction between the various components of the atmosphere) in GCMs have critical implications for policymakers. The net effect of feedbacks, from a policy viewpoint, is to determine whether a GCM indicates greenhouse gas emissions will be serious or benign. Clearly, the inadequate representation of feedbacks in climate models seriously undermines the usefulness of GCMs for policy purposes. Hence, until climatic feedbacks *are* adequately represented, policymakers should not rely on GCMs.

- **Insufficient computer power**

  "Insufficient computer power affects the accuracy of GCMs' estimates because even the most powerful computers are limited in their ability to store and analyze the vast quantity of data required to accurately simulate changes in the global climate. Modelers have tried to overcome these limitations by introducing assumptions into their models that deliberately oversimplify some operations in order to free the GCMs capacity and time for other, more critical operations." (GAO, 1995, pg 8-9).

The "simplification" of science by introducing assumptions designed simply to increase computational efficiency, raises serious questions about the accuracy of the final result. It is certainly possible that these "simplifications" accomplish their intended purpose (i.e., achieving a reasonable computational speed) while sacrificing the one thing that policymakers really need--an accurate theoretical projection of future climate. The presence of these simplifications, and our current lack of understanding about how they affect projections of future climate, limit the reliability of these projections for policy making purposes.

- **Inability to reliably project regional changes in climate.**

  "Still another limitation affecting the accuracy of GCMs' estimates is the relatively large size of the grids into which the models divide the earth. These grids typically cover an area about the size of South Carolina. Although their use enables GCMs to depict larger-scale regional effects in relatively large homogeneous regions, it does not allow modelers to incorporate detailed regional features. Consequently, the use of large grids prevents the models from accurately forecasting climatic changes for smaller, less homogeneous regions." (GAO, 1995, pg 9).

The IPCC stated the problem this way:

> *"GCM outputs, though physically plausible, often fail to reproduce even the seasonal pattern of present-day climate observed at a regional scale. This naturally casts some doubt on the ability of GCMs to provide accurate estimates of future regional climate. Thus GCM outputs should be treated, at best, as broad-scale sets of possible future climatic conditions and should not be regarded as predictions. (WGII FSM (Chapter 26, Technical Guidelines), section 6.5.3).*

From a policy perspective, projections of regional climate change are *the* most important output of climate models. Yet, it is clear that policymakers can have little confidence in regional climate change projections. In fact, the IPCC recently stated:

> *"Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low." (IPCC Synthesis Report, paragraph 2.9).*

This limitation is critical, since it is potential changes in regional climate which are the basis for virtually all of the impact projections regarding greenhouse gas emissions. The question is naturally raised: If policymakers can have little or no confidence in regional climate change projections, then shouldn't policymakers also have low confidence in any resulting impact projections? Clearly, policymakers should not make multi-billion dollar decisions which are based on impact projections in which scientists, at best, can only express "low confidence".

Improving the Models

General circulation models, particularly regional climate projections, must be improved substantially before policymakers should base decisions on the scenarios they generate. Improvements are needed in several major areas of ongoing research, including the following:

Parameterization: Current parameterization (a mathematical estimate of how natural processes work) schemes are a major source of uncertainty. Improvements are needed in two areas: a) parameterization of cloud formation processes and b) understanding of interactions among the different parameterization schemes being used and portability of parameterization schemes between GCMs. A great deal of testing and development in this area is needed.

> *"At the present time, weaknesses in the parameterization of cloud formation and dissipation are probably the main impediment to improvements in the simulation of cloud effects on climate....There is a great need for observations of cloud-scale dynamics and of the radiative properties of clouds, so that the parameterizations of the physical processes can improve." (WG1 FSM, section 6.7.1.1).*

> *"While a given parameterization scheme may perform well in "off-line" tests, interactions with other parameterizations and with dynamics may not result in an improved simulation in a coupled model. A particular scheme may also perform well in one model but perform poorly when used in another model." (WG1 FSM, section 5.5).*

Paleoclimate Research: Although still inadequate for policy purposes, current GCMs are much improved from those that existed only a few years ago. Still, much work remains to be done to improve confidence in climate projections to the point that they can be relied upon by policymakers. In this regard, the IPCC has made it clear that priority should be given to improving the paleoclimatic data base. Without a significant improvement in paleo data, many uncertainties regarding climate change are unlikely to be resolved.

> *"To build confidence in the decade-to-century time-scale natural variability simulated by models, there is a need to compare model attempts to mimic the climate of the past 1000 years, with variability estimates from paleoclimatic data with comparable time resolution." (WG1 FSM, section 11.7).*
>
> *"Without a better paleoclimatic data base for at least the past millennium, it will be difficult to rule out natural variability for recent observed changes, or to validate coupled model noise estimates on century time scales." (WG1 FSM, section 8.3.2)*
>
> *"Unless paleoclimatic data can help to 'constrain' the century time scale natural variability estimates obtained from CGCMs, it will be difficult to make a convincing case for the detection and attribution of an anthropogenic climate change signal." (WG1 FSM, section 8.3.3.3)*

For these reasons, the GCC supports a coordinated international research program, the continuation of U.S. climate research efforts ($1.8 billion requested for FY 1995), in addition to independent and industry sponsored research. GCC also supports activities to reduce greenhouse gas emissions that make sense in their own right, thus continuing sound business practices that will lead to more efficient use of energy.

References

Global Warming: Limitations of General Circulation Models and Costs of Modeling Efforts. 1995 United States General Accounting Office. Document GAO/RCED-95-164.

Climate Change 1995: The Science of Climate Change. Draft Contribution of Working Group I to the IPCC Second Assessment Report. Accepted by governments at IPCC Working Group I, Fifth Session, Madrid, 27-29 November, 1995. Document: WGI/5th/Doc.3 (9.X.1995). (WG I FSM)

Climate Change 1995: The Science of Climate Change. Draft Contribution of Working Group II to the IPCC Second Assessment Report. Accepted by governments at IPCC Working Group II, Third Session, Montreal, 16-20, 1995. Document: WGII/3rd/Doc.3 (31.VIII.1995). (WGII FSM)

IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations.1995. (Chapter 26 of the WGII FSM). Document CGER-I015-'94. (Published separately).

IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant To Interpreting Article 2 of the UN Framework Convention on Climate Change 1995. Rome, 11-15 December, 1995.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

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BACKGROUNDER

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Understanding Carbon Dioxide (CO_2): Future Trends in Emissions and Emissions Control

Understanding CO_2

At the heart of the global climate change issue is the concern that increasing levels of greenhouse gases in the atmosphere could cause an enhanced greenhouse effect (a warming of the global climate beyond what might occur naturally) or "global warming." Some scientists believe that a man-made enhancement of the greenhouse effect will eventually become significant enough to cause changes in the Earth's climate. Although there are other greenhouse gases including NO_x, methane and HCFC's, CO_2 has been the primary target of efforts to reduce greenhouse gas emissions. Such efforts include proposed emissions limits, targets and timetables for reductions, and taxes on carbon or other energy sources.

It is important to understand that carbon dioxide is not a pollutant. It is a naturally occurring component of the atmosphere and is also a by-product of human, plant and animal respiration, a product of combustion, and a vital component of photosynthesis Of the CO_2 that is emitted as a result of human activities, about half remains in the atmosphere, while the other half is removed by "sinks" which naturally absorb CO_2. Sinks for CO_2 include the ocean, soils and vegetation. Currently, our understanding of these sinks is limited, adding to the uncertainties surrounding predictions of the climate impact of rising CO_2 emissions.

Historical and Future Trends

Understanding the historical data on CO_2 emissions and global temperature provides clues to determining the relationship between increased atmospheric CO_2 levels and possible future changes in global mean surface temperature.

Carbon dioxide levels have varied widely during the Earth's history. Since the mid-1700s, atmospheric concentrations of CO_2 have risen 25 percent. This increase is largely a result of industrialization and the increased burning of fossil fuels as populations grow (resulting in increased living standards). The greatest increases in CO_2 emissions occurred after World War II. For example, between 1950 and 1988, the United States' annual CO_2 output roughly doubled.

Understanding CO_2 Backgrounder
The Global Climate Coalition

Global temperatures can vary significantly with little or no change in greenhouse gas concentrations. For example, global mean temperatures rose 0.46° C between 1900 and 1995, but 67 percent of this increase took place before 1940. It is interesting to note that atmospheric CO_2 concentrations rose only 14.2 ppm between 1890 and 1940. These facts led the IPCC to concluded that this rapid increase in temperature was caused by natural forces.

> *"The rather rapid changes in global temperature seen around 1920-1940 are very likely to have had a mainly natural origin."1*

This means that natural forces, not greenhouse gases, have caused most, if not all, of the observed changes in global temperature during the 20th century.

Many forecasters agree that greenhouse gas levels could double sometime in the next century as a result of a number of factors, including: population growth, increased use of fossil fuels and increased economic activity in developing countries. Yet scientists cannot be certain whether the increased atmospheric concentrations of CO_2 or any other greenhouse gas will cause any significant climate change. One reason for this uncertainty is the inadequate representation of *feedback mechanisms* (i.e., interactions between climatic processes and greenhouse gases) in climate models. According to the IPCC:

> *"GCMs[computer climate models] include many of the most important feedback mechanisms, such as vegetation, water vapor, ice cover, clouds, and the ocean. However, the models do not yet adequately represent the interactions of these mechanisms with greenhouse gases. Such interactions can amplify, dampen, or stabilize the warming produced by increased concentrations of greenhouse gases."2*

Future Sources of Increased CO_2 Emissions

According to the International Energy Agency, as much as 85 percent of the projected increase in manmade global CO_2 emissions will come from developing countries and countries with economies in transition (e.g., Eastern European nations and Russia). In fact, the U.S. contribution of manmade CO_2, which is less than 22 percent of total CO_2 emissions worldwide, has significantly declined over the past twenty years and will continue to decline. Additional reductions in the United States' CO_2 emissions would be relatively insignificant in the context of reducing global greenhouse gas concentration levels.

Policy Efforts to Control CO_2 Emissions

Most industrialized nations, including the United States, already have policies and programs in place that help to significantly reduce emissions of CO_2. In the United States, some studies show that existing programs (such as EPA's Green Lights Program) and policies (such as the Clean Air Act and the National Energy Policy Act of 1992) will come close to reducing CO_2

emissions to 1990 levels by the year 2000. Many economic experts have concluded that the cost of radical reductions in greenhouse gas emissions in the United States would be enormous, perhaps overwhelming enough to cause severe unemployment, decreased international competitiveness of U.S. goods, and other grave economic disruptions.

Some economists believe that carbon dioxide emission reduction policies (i.e., carbon and other energy taxes) will only provide an incentive for carbon intensive industries to migrate to regions without such a tax. They say this movement to developing countries, where environmental regulations are significantly less stringent than the U.S., will result in more greenhouse gas emissions, not less.

As developed nations make progress toward reducing their emissions over the next decade, the greatest opportunities (and needs) for controlling the growth in CO_2 emissions will be in developing countries and countries with economies in transition. International policy efforts will need to be aimed at making the most of these opportunities by encouraging these nations to incorporate clean technologies into their economies. In fueling their economic growth, many developing nations now employ outdated or inefficient energy and environmental technologies and resource management techniques. For more information on reducing emissions in developing countries, see GCC's information backgrounder on Joint Implementation.

1. Climate Change, the 1990 IPCC Assessment. Cambridge University Press, section 7.12.
2. Global Warming: Limitations of General Circulation Models and Costs of Modeling Efforts. 1995. United States General Accounting Office. Document GAO/RCED-95-164. page 8.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

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