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THE WHITE HOUSE CONFERENCE
ON
SCIENCE AND ECONOMICS RESEARCH RELATED TO
GLOBAL CHANGE



Global Change

1988-1990

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INTRODUCTION

President Bush's White House Conference on Science and Economics Research Related to Global Change, April 17-18, 1990, in Washington, D.C., will convene ministerial-level officials from seventeen nations, EC, OECD, and the United States, and bring together the essential disciplines of science, economics, and the environment.

The Conference is designed to enhance international cooperation and to build the basis for future joint efforts in addressing changes to these vital areas.

This package is designed to provide each delegation with pre-conference planning information and to solicit your country's responses to the Delegate Information Survey and Conference Content Questionnaire. Your role as a representative of your country's delegation, in the communication and dissemination of these materials to your government counterparts at home, is critical to the success of this international conference.

Enclosed is general background information available on the White House Conference.

We need your input on the Conference Content Questionnaire and information on your delegation NO LATER THAN 29 March 1990.

Respond to Conference Coordinator:

Dr. Franmarie Keel

White House Conference on Global Change
Suite 615
1019 - 19th Street, N.W.
Washington, D.C. 20036

Phone: (202) 653-5980
Fax: (202) 653-2034
Telex: 249118SDAVISUR

THE WHITE HOUSE
WASHINGTON

February 23, 1990

Dear :

On April 17 and 18, 1990, the United States will host a White House Conference on Science and Economics Research Related to Global Change. I take pleasure in inviting you to send an official delegation to this conference.

The meeting will be devoted to advancing the understanding of scientific and economic issues related to global change. Its primary goal is to improve both the state of knowledge in these fields and the analytic tools required to develop potential policy responses. It is my hope that the expertise, experience, and data available in our respective countries can be brought together in a more integrated and coherent fashion. By working together, our nations can enhance international cooperation in these vital areas and contribute to the success of the ongoing IPCC process.

For the conference to be of greatest benefit to all of us, it would be highly desirable if your senior scientific, environmental, and economic officials could attend. The Director of the Office of Science and Technology Policy, the Chairman of the Council of Economic Advisers, and the Chairman of the Council on Environmental Quality will serve as co-chairmen for this meeting.

I look forward to participating personally in and learning from this conference. I hope it will serve as a useful and important step in our joint efforts to address changes in the global environment.

Sincerely,

**EXAMPLE
OF
INVITATION LETTER**

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FACT SHEET

FOR
THE WHITE HOUSE CONFERENCE
ON
SCIENCE AND ECONOMICS RESEARCH
RELATED TO GLOBAL CHANGE

April 17-18, 1990
Washington, D.C.

- On February 5, 1990, the President invited the Heads of State from seventeen countries, the European Community (EC), and the Organization for Economic Cooperation and Development (OECD) to send ministerial-level delegates to a White House Conference on Science and Economics Research Related to Global Change.
- The Conference will be held in Washington, D.C. on April 17-18, 1990.
- The President first indicated his intention to host such a Conference on this subject during his Summit meetings with President Gorbachev, on December 4, 1989, and later on Monday, February 5, 1990, during his speech to the United Nations Intergovernmental Panel on Climate Change.
- The Conference will be devoted to science and economics research issues relevant to policy on global change, including climate. The Conference is designed to address important next steps that substantially enhance and broaden international understanding of science and economics research issues that relate to global change. Further, the Conference seeks to frame the initial steps towards a strategy for implementing joint international science and economics research efforts. It also seeks to integrate and link scientific and economic research results to both the domestic and international policy process and because it seeks for the first time to join research issues central to both the science and the economics related to global change.
- The Conference focuses on "Global Change," a scope of research interest that has evolved out of the science that concerns itself with understanding the fundamental processes that govern the way the global Earth functions. Thus, the research agenda not only includes scientific and economics research issues related to global climate change, but also includes other important global processes.

- The Conference is conceived as an integral part of the ongoing international process of trying to understand changes in the global environment. The need for substantially improved understanding of both the science and economics of global change has been noted by virtually all world leaders. This Conference will focus on scientific and economic research issues as a complementary effort to the on-going Intergovernmental Panel on Climate Change (IPCC) and other upcoming international meetings that seek to address the serious policy issues that evolve out of the concerns for the changes in the global environment, particularly climate change. The President strongly supports the IPCC efforts and expects that the results of the Conference will contribute to the on-going international debate on these issues. For example, the leadership of the Intergovernmental Panel on Climate Change has been invited to take an active role in the Conference.
- The Conference will convene a delegation of three ministerial-level officials from a representative group of nations, each representing one of three disciplines: science, economics, and the environment. The Conference was conceived with the idea that a small representative group of countries would be invited to participate; their selection is based on the simple criteria that the meeting should include countries or representatives of country interests that have substantial populations, large land masses, industrialized economies or heavy future energy needs, substantial research infrastructures, or have provided international leadership on issues related to climate and global change. A representative group of countries has been selected. The President has asked the Heads of State of the following countries and organizations to send a delegation:

1. Australia
2. Brazil
3. Canada
4. Federal Republic of Germany
5. France
6. India
7. Indonesia
8. Italy
9. Japan
10. Mexico
11. Netherlands
12. Nigeria
13. Norway
14. Poland
15. Soviet Union
16. United Kingdom
17. Zaire
18. European Community (EC)
19. Organization for Economic Cooperation and Development (OECD)

DRAFT

It is expected that each country or organization will send a ministerial-level official to represent each of their agencies of science, economics, and the environment, together with no more than two staff associates per official. It is suggested that one delegate in each of the three areas will be an individual who is currently active in scientific or economics research. It is recognized that the delegations are likely to have one "at-large" member. Thus, the total delegation size should not exceed ten per country. Once the delegations are determined, it is planned to consult with these countries on agenda details.

- The U.S. Delegation (total of ten) will be:

- ☐ Secretary of the Treasury - Nicholas F. Brady
- ☐ Secretary of Agriculture - Clayton Yeutter
- ☐ Secretary of Commerce - Robert A. Mosbacher
- ☐ Secretary of Energy - Admiral James D. Watkins (Ret)
- ☐ Administrator, Environmental Protection Agency - William K. Reilly
- ☐ Administrator, National Aeronautics and Space Administration - Richard H. Truly
- ☐ Under Secretary of Commerce for Oceans and Atmosphere; and Director, National Oceanic and Atmospheric Administration - John A. Knauss

Conference Co-Chairmen:

- ☐ Chairman, Council of Economic Advisers - Michael J. Boskin
- ☐ Assistant to the President for Science and Technology - Dr. D. Allan Bromley
- ☐ Chairman, Council on Environmental Quality - Michael R. Deland

- The Conference is designed to be a forum to bring a number of ministerial-level leaders together to enhance international cooperation and to build the basis for joint efforts in these vital areas. It is hoped that the delegates, working together, will agree upon those areas of opportunity for cooperative action in the areas of scientific and economics research. The goal would be to address three major themes:
 - Uncertain Change: The Scientific and Economics Research Challenge
 - Integrating Scientific and Economics Research in the Policy Process; and
 - Building Partnerships for Scientific and Economics Research.

The Conference provides a forum for international leaders to consider and discuss research questions that are critical to the policy process, such as:

- ◆ How well can we predict temperature trends in the decades ahead?
 - ◆ How "good" are our global-scale models, such as models to predict temperature changes?
 - ◆ How well can we predict the interconnections between global environment change and the resulting social and economic impacts?
 - ◆ What are the economic costs of adapting to or mitigating global change?
 - ◆ How "good" are the economic models used to compute these costs?
- (See attached Conference Content Questionnaire)

By addressing such questions, it is hoped that the nations might pledge to support joint international research efforts related to global change that focus on rapid improvement of both scientific and economic knowledge and developing the necessary infrastructure, including:

- Establishing a more formal international mechanism to improve the coordination of global change science and economic research programs, and
 - Participating in cooperative research efforts, such as the World Ocean Circulation Experiment and cooperative economic projects of the OECD.
- The Conference is a White House Conference, initiated by the President. Hence, the President has appointed three members of the Executive Office of the President in the relevant areas, to be the co-chairmen of the Conference. The three co-chairmen are: the Chairman of the President's Council of Economic Advisers, Dr. Michael J. Boskin; the President's Science Advisor and Director of the Office of Science and Technology Policy, Dr. D. Allan Bromley; and the Chairman of the President's Council on Environmental Quality, Mr. Michael R. Deland.
 - The President stated, "this conference is a vital next step in a joint international approach to address changes in the global environment."

**PRELIMINARY AGENDA
FOR
THE WHITE HOUSE CONFERENCE
ON
SCIENCE AND ECONOMICS RESEARCH
RELATED TO GLOBAL CHANGE**

April 17-18, 1990
Washington, D.C.

Monday, April 16, 1990

4:00 PM Registration, Information, and Hosting Desk Opens
7:00 PM Reception for all Delegates at the Air & Space Museum
 (Hosts: Robert A. Mosbacher, Secretary of Commerce & Martin Harwit,
 Director, National Air & Space Museum)

Tuesday, April 17, 1990

7:30 AM Registration, Information, and Hosting Desk Opens
 (Continental Breakfast)

Plenary Session I:

Scientific and Economic Uncertainties: Research Challenges

Chairman: Dr. D. Allan Bromley

8:30 AM Opening Remarks - Nicholas F. Brady, Secretary of the Treasury

8:45 AM Goals and Expectations for the Conference - Conference Co-chairman

Followed by a Welcome by President George Bush

9:15 AM Theme I Presentation:
 "Uncertain Change: The Scientific and Economics Research Challenge"
 - Dr. D. Allan Bromley

9:45 **Adjourn to Working Sessions**

Working Group Session I:

Theme 1: Uncertain Change: The Scientific and Economics Research Challenge

10:00 AM Three Working Groups will address a series of questions that relate to this theme, with each group composed of about seven science, seven environmental, and seven economics ministers. (Each group will be chaired by a member of a visiting delegation.)

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1:00 PM Lunch - Speaker: William K. Reilly, Administrator, Environmental Protection Agency

Plenary Session II:

Integrating Scientific and Economics Research in the Policy Process

Chairman: Michael J. Boskin

2:15 PM Theme II Presentation:
Integrating Scientific and Economics Research in the Policy Process
Michael J. Boskin

2:45PM Adjourn to Working Session

Working Group Session II:

Theme II: Integrating Scientific and Economics Research in the Policy Process

3:00 PM Three Working Groups, as in Session I, will address a series of questions that relate to this theme

5:30 PM Working Sessions Adjourn

Evening - Reception and State Dinner

6:15 PM Shuttle Buses take Delegates to NAS/NAE

6:30 PM Reception, hosted by the National Academies of Science and Engineering, for all delegates and other invited guests

8:00 PM Formal Dinner (Black Tie) - Diplomatic Suite of the Department of State

10:00 PM End of the Day - Shuttle Buses take delegates to hotel

Wednesday, April 18, 1990

7:30 AM Continental Breakfast

9:00 AM An Address by Bert Bolin, Chairman of the IPCC

Plenary Session III:

Building Partnerships for Scientific and Economics Research

Chairman: Michael R. Deland

9:30 AM Theme III Presentation:
"Building Partnerships for Scientific and Economics Research"
Michael R. Deland

10:00AM Adjourn to Working Sessions

Working Group Session III:

Theme III: Building a Partnership for Scientific Research

10:15 AM Three Working Groups, as in Session II, will address a series of questions that relate to this theme

12:30 PM Lunch

Speaker: Admiral James D. Watkins (Ret), Secretary, Department of Energy

Plenary Session IV:

Summary Reports and Closing Remarks

2:00 PM Summary Reports - presented by each Working Group

2:15 PM Summary Remarks - Conference Co-Chairmen

Followed by Closing Remarks by President George Bush

3:00 PM Conference Ends

3:30 PM Closing Reception

Office of the White House Conference on
Science and Economics Research Related to Global Change

COUNTRY DELEGATION

Country: _____

Con-
firmed

Name

Title

Bio

Photo

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DELEGATE BACKGROUND INFORMATION

Country/Organization: _____

Prepared By: _____

Date Prepared: _____

Name: _____

Title: _____

Branch: _____

Address: _____

Branch Phone: _____

Direct Phones: _____

Fax: _____

Telex: _____

OTHER INFORMATION

ASSISTANT INFORMATION

Name: _____

Title: _____

Phone: _____

Fax: _____

Language: _____ English Speaking? (Y/N) _____

What type of accommodations do you prefer? (single, double, king) _____

Are you travelling with security? Are they in addition to the 10 in the delegation? _____

Do you have any dietary requirements or restrictions? _____

How are you travelling? _____

If commercial, what airline, flight number, airport and time of arrival? _____

If government, do you plan to fly into Dulles, National or Andrews Air Force Base? _____

Total number in delegation _____



James D. Watkins
Secretary
Department of Energy



James David Watkins was nominated by the President to be the sixth Secretary of Energy on January 20, 1989. Admiral Watkins was confirmed by the United States Senate and sworn into office on March 1, 1989.

Admiral Watkins was born in California on March 7, 1927, and claims the city of Pasadena as his home. A 1949 graduate of the U.S. Naval Academy, his tours as flag officer included Chief of Naval Personnel; Commander of the Sixth Fleet; Vice Chief of Naval Operations; and, Commander-in-Chief of the Pacific Fleet. Admiral Watkins was selected by President Reagan to become the 22nd Chief of Naval Operations on June 30, 1982. His military decorations include several Distinguished Service and Legion of Merit medals, the Bronze Star with combat "V" and other medals, campaign and service ribbons, and decorations from many foreign nations.

Following his retirement on June 30, 1986, Admiral Watkins devoted his time to issues regarding America's youth, and worked with a number of philanthropic organizations to establish a national program for personal excellence. He also served as a member of advisory boards in both the education and energy fields and has received several honorary doctorates and public service awards.

In October 1987, Admiral Watkins was appointed Chairman of the Presidential Commission on the Human Immunodeficiency Virus (AIDS) Epidemic, submitting the Commission's final report to the President on June 24, 1988.

Admiral Watkins received his master's degree in mechanical engineering in 1958, and is a graduate of the reactor engineering course at the Oak Ridge National Laboratory. He was selected by Admiral Hyman G. Rickover to enter the Navy's nuclear-powered submarine program in 1959, and was qualified as an Engineering Officer of the Watch at one of the Navy's land-based reactor plants. He served for three years in the Atomic Energy Commission as Admiral Rickover's assistant for Naval Nuclear Propulsion and later, in a variety of assignments associated with the management of the nuclear navy. These assignments included Commanding Officer of a nuclear-powered submarine and Executive Officer of the world's first nuclear-powered cruiser.

Admiral Watkins married Sheila Jo McKinney of San Diego, California, in 1950. They have six children: Katherine Watkins Coopersmith, Laura Jo Watkins Kauffmann, Susan, Charles, James Jr., and Edward. Admiral and Mrs. Watkins have eight grandchildren.

SAMPLE

CONFERENCE CONTENT QUESTIONNAIRE

This conference is being designed to promote the sharing of ideas and information. Your answers to this questionnaire will be a vital component of these exchanges and will help to create a successful conference and a better understanding of the global challenges we share. By completing this questionnaire, **in English**, and returning it to us by March 29, 1990, you will assure that your answers are shared among all delegates and that a solid foundation for the conference is established.

Page 17 left intentionally blank,

Theme I: UNCERTAIN CHANGE: THE SCIENTIFIC AND ECONOMICS RESEARCH CHALLENGE

The following questions seek to get a sense of your country's interest and involvement in scientific and economics research related to global change. The term "scientific and economics research related to global change" encompasses all research relevant to global change, including analysis that may originally have been motivated by other concerns. For example, analysis of the impact of consumption in the composition and level of energy uses on economic growth and investment levels should be included in your inventory.

What scientific research related to global change is being conducted or is now planned in your country? Provide a breakdown of this work into the following categories:

- ▼ global/regional forecasts of human activities leading to possible global change;

- ▼ global/regional models of geophysical global change processes;

- ▼ social and economic impact of possible global change, either with or without adaptive responses; and

- ▼ social and economic consequences of specific actions that might be taken to arrest possible global change.

What potential conflicts, if any, between your interest in continued economic progress and your interest in arresting possible undesirable global change have been identified by your existing research? What scientific and economics research is most critical to improving our understanding of relevant tradeoffs and possibly improving the tradeoff themselves?

This image shows a single sheet of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page. There is a vertical margin line on the left side, creating a narrow left margin. The paper appears to be from a notebook or a standard ruled sheet of paper.

What is your government's current and projected budget for scientific and economics research relevant to global change issues? How are your research efforts coordinated across agencies and departments within your government?

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What is the institutional structure for conducting scientific and economics research relevant to global change in your country?

▼ Government agencies and laboratories

▼ Universities

▼ Industry

This image shows a single sheet of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

What studies have been conducted in your country regarding the social and economic consequences of global warming that may occur? How sensitive are these estimates to the assumed rate of warming and to the application of adaptation measures?

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What are the present sources, by percentage, of electrical energy in your country? What are the projected sources, and overall usage levels, in 2000, 2010, and 2020? What technologies are currently under consideration or being planned to increase energy efficiency in generation and utilization in your country?

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Theme II: INTEGRATING SCIENTIFIC AND ECONOMICS RESEARCH IN THE POLICY PROCESS

The need for substantially improved understanding of both the science and economics of global change issues has been noted by virtually all world leaders. The following questions seek to identify how your country integrates such research into its policy decisions.

What mechanisms exist in your country for providing economic and scientific information concerning global change issues to decision makers?

[illegible]

How is scientific and economics information concerning global change used by decision makers in your country to address the environmental ramifications of economic policies and the economic consequences of environmental policies?

[illegible]

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What scientific and economics research questions are most important to answer in order to support the development of domestic and international policies towards global change?

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Theme III: BUILDING PARTNERSHIPS FOR SCIENTIFIC AND ECONOMICS RESEARCH

The conference will be designed to enhance and broaden international understanding of science and economics research issues related to global change. The following questions seek to determine your government's interest in framing the initial steps towards a strategy for implementing joint international research efforts.

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Forecasts of technology advances, their costs, and market penetration necessarily involve both scientific and economic considerations. How can scientific and economic research be integrated to provide the most accurate and closely-bounded technology forecasts possible? How can this research contribute to technology development?

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What are your government's current forecasts of future technologies relevant to mitigation of or adaptation to global change?

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What international mechanisms would be most effective to carry out economic and scientific research on global change?

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Do you anticipate that new entities will be required to carry out joint research efforts? If existing organizations can fill the need, which ones should be used? What changes will be needed in these organizations to produce integrated research?

[illegible]

What are the major barriers to carrying out integrated economic and scientific research on global change?

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What data bases relevant to global change do you have in your country which might be made available for sharing with the international community?

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

Please forward any relevant, previously prepared materials that you wish to distribute to the conference.

Respond to Conference Coordinator:

Dr. Franmarie Keel

White House Conference on Global Change
Suite 615
1019 - 19th Street, N.W.
Washington, D.C. 20036

Phone: (202) 653-5980
Fax: (202) 653-2034
Telex: 249118SDAVISUR

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

May 16, 1989

MEMORANDUM FOR JOHN H. SUNUNU

FROM: WILLIAM R. GRAHAM *WRG*
SUBJECT: BRIEFING ON GLOBAL CHANGE

At the upcoming Economic Summit meeting in Paris, the environment is likely to be a major issue. President Mitterrand is planning a major environmental initiative. Prime Ministers Thatcher and Mulroney as well as Chancellor Kohl also favor a serious discussion of the environment, particularly of global warming. Of course, President Bush's long-standing commitment to environmental matters is a matter of record.

While other countries do not lack for public diplomacy, the U.S. has by far the strongest and most coherent government-wide program aimed at understanding global climate change. This program was formed over two years ago by the Federal Coordinating Council for Science, Engineering and Technology's Committee on Earth Sciences, chaired by Dr. Dallas Peck of the U.S. Geological Survey. The current interagency program plan and budget through 1990 is attached, and the 1991 plan and budget guidance are in final preparation.

I would like to provide you with a status report on global warming issues, and I suggest a one to two hour briefing covering our current understanding of the science related to global change, the extent of U.S. research, and the status of activities and plans for U.S. involvement in international programs related to global change issues. The presenters would be people engaged in the research and planning. Allan Bromley would also join us.

I will also offer the briefing to other White House senior staff members, and would like your guidance on having a shortened version presented to the President. In addition to giving him a status report, such a briefing would also serve to communicate further to the scientific and environmental communities his interest and concern.

Please let me know how you would like to proceed.

(Attached Our Changing Planet)

THE WHITE HOUSE

WASHINGTON

May 9, 1988

MEMORANDUM FOR COLIN L. POWELL
NANCY J. RISQUE

FROM: WILLIAM R. GRAHAM *WRG*

SUBJECT: ADMINISTRATION RESPONSE TO SENATE LETTER
ON GLOBAL CLIMATE CHANGE

We perceive the need for some modifications to the draft EPA response to the March 31, 1988, letter to the President from 42 Senators concerning the raising of global climate change issues at the forthcoming Moscow Summit, as well as the Economic Summit. An interagency review is needed in order to ensure that the Administration's policy is accurately reflected.

Attachments:

Incoming Letter
Draft EPA Response

Special Report:

The U.S. Global Change Research Program;

How the unified research scheme plays out in government dollars

Last week the administration released a report called "Our Changing Planet: The FY 1990 Research Plan." In its nearly 200 pages, it presented the first coherent picture of how the Bush administration would like to target new money next year to assess and cope with the changing face of Planet Earth.

Funding for seven agencies is targeted to research and understand Earth's environment; to research and develop new technologies to adapt to or mitigate environmental changes; and to formulate national and international policy responses required to cope with such pressing problems as deforestation and the depleting ozone layer.

The goal of the unified research program is to provide the scientific basis for making the tough choices that will have to be made to keep the planet habitable.

In his fiscal year 1990 budget request to Congress, the president proposed new funding of \$191.5 million targeted toward global change research. That's a 43% increase from FY 1989 funding but it's only the tip of the iceberg.

Over the course of the next 15 to 17 years, NASA alone — only one of the seven agencies — expects to be spending \$1 billion a year by FY 1993 or FY 1994 for the duration of the program. The \$21.5 million proposed for NASA's contribution to the effort is for research on the proposed Earth Observing System. That's a 48% increase from this year, but so far Congress has been amenable.

The funded studies would further define the sensors, platforms and data management needed to study a broad range of global change processes from space.

NASA already plans for EOS to be a new start for FY 1991. But that budget won't be submitted until Sept. 1 and the agency won't hear the Office of Management and Budget's verdict until around Thanksgiving.

Future related initiatives include payloads attached to the space station, small Earth probes and, further in the

future, geostationary platforms to monitor certain portions of the globe on a constant basis.

Programs run by the Commerce Dept.'s National Oceanic and Atmospheric Administration will emphasize improving predictions of climate change and the regional implications of shifts. The FY 1990 budget proposes \$20 million for that task, twice what the agency got this year.

The Energy Dept.'s programs are focused primarily on climate and ecosystem response research. There is \$27.2 million in the FY 1990 request for this work, a 35% increase.

The Interior Dept.'s U.S. Geological Survey carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity and glaciology. The FY 1990 budget proposes \$11.3 million for this agency, roughly double this year's total.

The Environmental Protection Agency's research is focused on ecological systems and man's effect on them. FY 1990 funds, 29% higher than last year, would continue this work.

The National Science Foundation supports university research on global change. It would receive \$53.5 million for new global change study, 36% more than last year.

Research at the U.S. Dept. of Agriculture deals with the impact of climate on agricultural and ecological systems and the corresponding impact of these systems on the climate. The FY 1990 budget proposes a 24% increase over last year to \$22.7 million.

The table below depicts these funding totals. The one on the next page outlines funding totals by agency as they pertain to specific areas of research. Both appear in the "Changing Planet" report which was made available to *Space Business News* by the White House Office of Science and Technology Policy before its official release as we went to press. It will be available from the Government Printing Office.

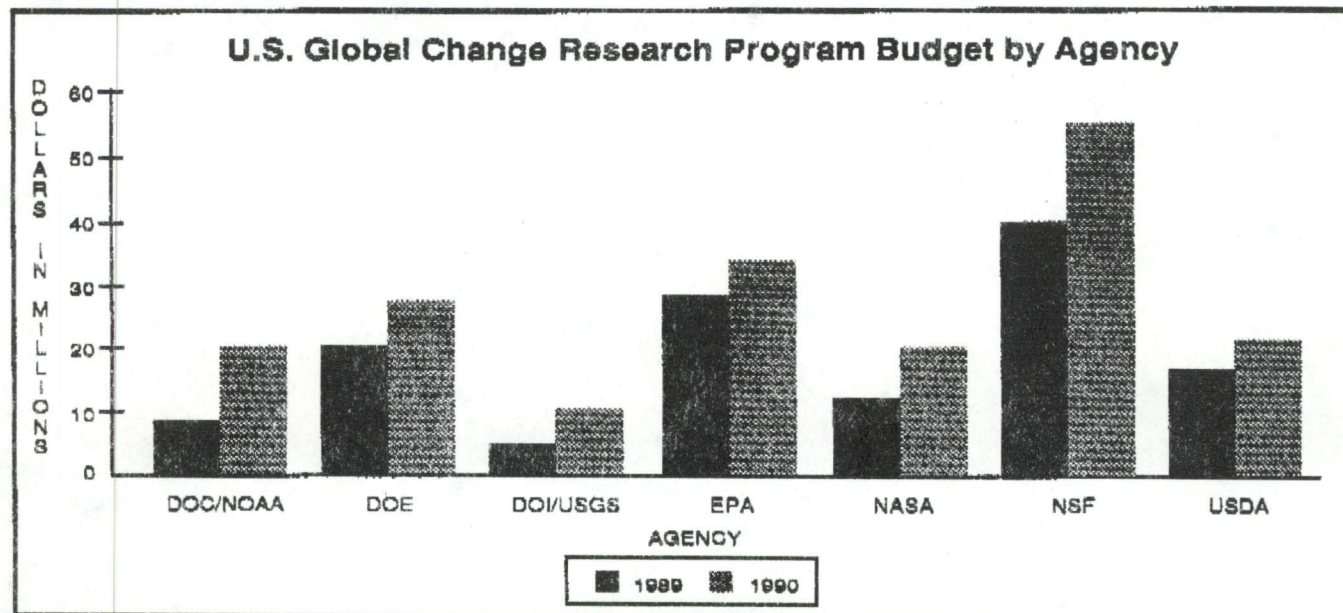


Table 1

U.S. GLOBAL CHANGE RESEARCH PROGRAM BUDGET FOR FISCAL YEARS 1989 AND 1990

(Dollar in Millions)

AGENCY	TOTAL BUDGET		CLIMATE AND HYDROLOGIC SYSTEMS		BIOGEOCHEMICAL DYNAMICS		ECOLOGICAL SYSTEMS & DYNAMICS		EARTH SYSTEM HISTORY		HUMAN INTERACTIONS		SOLID EARTH PROCESSES		SOLAR INFLUENCES	
	FY89	FY90	FY89	FY90	FY89	FY90	FY89	FY90	FY89	FY90	FY89	FY90	FY89	FY90	FY89	FY90
AGENCY TOTALS	133.9	141.5	37.0	38.2	26.1	38.6	32.5	46.9	3.3	0.6	22.0	28.1	8.9	18.4	4.1	7.3
DOC/NOAA	9.0	29.0	0.5	16.5	0.5	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DOE	20.2	27.2	7.0	12.8	6.0	5.5	4.2	7.5	0.0	0.0	2.0	1.2	0.0	6.0	1.0	1.2
DOI *	5.3	11.3	1.8	4.5	0.2	1.1	0.0	0.0	1.3	1.5	1.5	2.5	0.5	8.6	0.0	0.0
EPA	27.4	35.4	0.7	2.2	0.8	3.3	7.4	15.2	0.0	0.0	18.5	16.4	0.0	0.0	0.0	0.0
NSA	14.5	21.5	4.3	6.4	3.0	4.1	4.3	6.4	0.0	0.0	0.0	0.0	2.2	3.5	0.7	1.0
NSF	39.2	55.4	13.2	17.0	13.5	18.7	1.9	1.9	2.0	4.7	0.0	0.0	6.2	6.9	2.4	5.1
USDR	18.3	12.3	1.5	1.5	2.1	3.1	14.7	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* NOTE: FY 1990 Focused Program Total differs from the amount reported in our *Changing Planet: A U.S. Strategy for Global Change Research* due to budget changes made after the printing date.

Global Change and Our Common Future

P A P E R S F R O M A F O R U M

NATIONAL RESEARCH COUNCIL

1989

MATHEMATICAL MODELING OF GREENHOUSE WARMING:
HOW MUCH DO WE KNOW?

J. D. Mahlman

For many decades scientists have known that a buildup of carbon dioxide (CO_2) in the atmosphere has the potential for warming earth's climate through the so-called "greenhouse" effect. Over the past 10 years, awareness has grown that other greenhouse gases can contribute in total to climate warming at a level comparable to that of CO_2 . These include human-produced chlorofluorocarbons (CF_2Cl_2 , CFCl_3 , and others), methane (CH_4), and nitrous oxide (N_2O). The atmospheric concentrations of these gases are currently increasing at a rate sufficient to produce substantial atmospheric consequences over the next century.

These other greenhouse gases are well known to contribute to very significant expected changes in the atmospheric ozone structure and amount. Their potential to add to the CO_2 climate warming effect is not as universally appreciated. Here, I will emphasize only the expected climatic effects of the ensemble of greenhouse gases.

The information that I will present is derived from three-dimensional mathematical models of the climate system. A simplified schematic of the various relevant physical processes is given in Figure 7.1. Such comprehensive global climate models have been under intense development at the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL) for over 25 years. Climate models have grown slowly but steadily in scope, complexity, and computational resolution over that period. Accompanying this growth is an improvement in the ability of the models to simulate the current climate. Accordingly, modeling atmospheric responses to changing conditions (e.g., seasonal and daily cycles, different planets (Mars and Venus), and ice age conditions) has become progressively more accurate.

Unfortunately, substantial uncertainties remain due to deficiencies in scientific understanding and insufficient computer power. However, significant progress is expected on both fronts over the next 10 years. Computer power is increasing while its relative cost is still decreasing. The impact of model dependence on computer power may be seen in Figure 7.2. Deficiencies in scientific understanding of such areas as ocean circulation, cloud processes, land surface processes, and chemical interaction will continue to yield gradually to intense scientific inquiry. In addition to the models, adequate data are necessary to evaluate results of the model calculations.

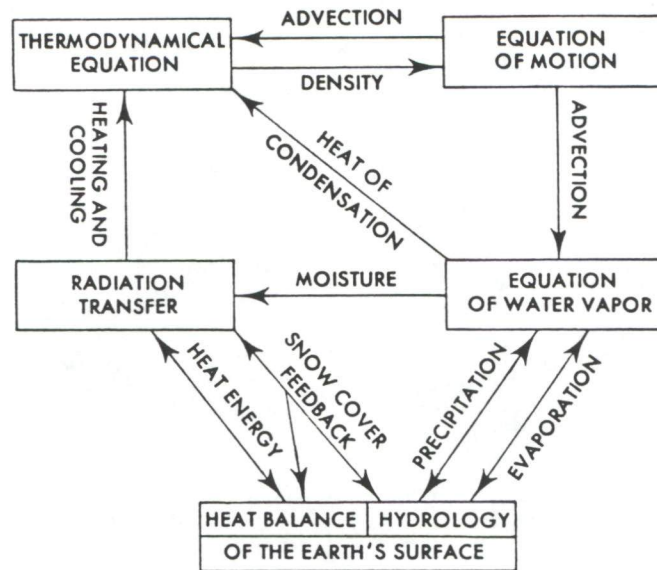


FIGURE 7.1 Simplified schematic diagram illustrating some of the interactive atmospheric processes governing earth's climate system. A proper climate model must account for all of these processes (and more) consistent with the laws of physics at a large number of points on the model "earth."

Current Climate Model Resolution (No Ocean)

5° latitude (300 n miles) X 5° longitude X 10 levels
(36 X 72 X 10 = 25,920 grid points)

Improved Resolution

2.5° latitude X 2.5° longitude X 20 levels
(207,360 grid points X 2) (doubled time steps)
16 times the "cost"

Exploratory Resolution

1° latitude X 1° longitude X 40 levels
(2,592,000 grid points X 5) (quintupled time steps)
500 times the "cost"

FIGURE 7.2 Illustrative example of the strong demands on computer resources as a climate model's grid resolution is increased.

In spite of significant climate model limitations, simulations of the effects of increases in the greenhouse gases permit a number of plausible inferences to be drawn today with considerable confidence. In most model studies to date, atmospheric CO₂ concentrations have simply been doubled (e.g., from 300 to 600 parts per million) and then maintained at that concentration until a new equilibrium climate is established in the model. Typically, such a model includes just the atmosphere; the only effect of the ocean included is its effect as a heat reservoir. We expect such model results to apply reasonably well to a combination of CO₂ and other trace gases where the total effect on the radiation budget is equivalent to a doubling of CO₂. Moreover, because of the now-recognized effect of the other greenhouse gases, calculations using doubling of CO₂ are now thought to be relevant (from a societal impact perspective) for conditions sometime into the middle of the next century. In this presentation, I will avoid detailed greenhouse gas scenarios. Rather, I will emphasize the kinds of expected impacts and my best estimates of their current scientific uncertainties.

Some of the possible climate responses to increased greenhouse gases are regarded to be rather well understood; others remain controversial. Scientific confidence is presented here in general terms. My estimates of confidence levels based on current models can be interpreted according to the following guidelines: By "virtually certain" I mean that there is nearly unanimous agreement within the scientific community that a given climatic effect will occur. Here, "very probable" means greater than about a 90 percent (9 out of 10) chance, and "probable" implies more than about a 67 percent (2 out of 3) chance. By "uncertain" in this context, I refer to an effect that has been hypothesized but for which there is a lack of appropriate modeling or observational evidence. I list below, in decreasing order of my current scientific confidence, some important model-predicted climate changes due to increased greenhouse gases. (This list is similar to that in National Research Council, 1987.)

- o Large stratospheric cooling (virtually certain). A reduction in upper stratospheric ozone by chlorine compounds will lead to reduced absorption of solar radiation and thus to less heating. Increased stratospheric concentrations of radiatively active trace gases will increase infrared radiative heat loss from the stratosphere. Decreased heating and increased cooling will lead to a marked lowering of upper stratospheric temperatures, perhaps by 10 to 20°C (Figure 7.3).

- o Global-mean surface warming (very probable). For a doubling of atmospheric CO₂ (or its radiative equivalent from all the greenhouse gases), the long-term global-mean surface warming is expected to be in the range of 1.5 to 4.5°C (see Figures 7.3 and 7.4). The most significant source of uncertainty arises from difficulties in modeling the feedback effects of clouds on climate change. The actual rate of warming over the next century will be governed by the growth rate of greenhouse gases, natural fluctuations in the climate system, and the detailed response of the slowly responding parts of the climate system, i.e., oceans and glacial ice.

- o Global-mean precipitation increase (very probable). As the climate warms, the rate of evaporation increases, leading to an increase

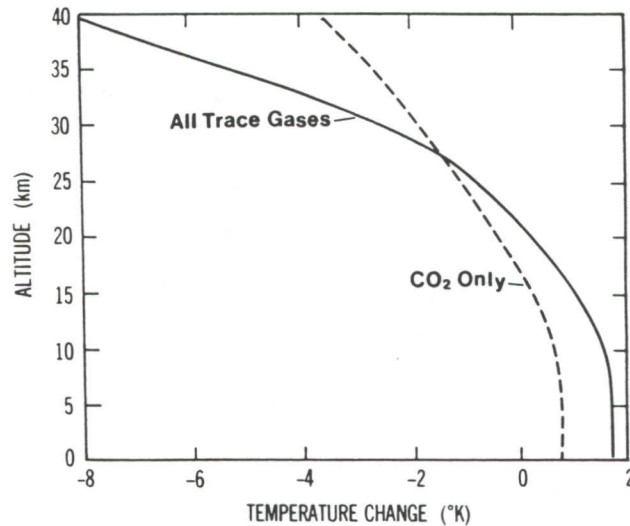


FIGURE 7.3 Estimate of the global-average temperature change ($^{\circ}\text{C}$) for the year 2030 based on projected trace gas trends. "CO₂ Only" includes only effects of changing CO₂; "All Trace Gases" includes effects of changing CO₂ as well as all the other increasing greenhouse gases. (Reprinted from Ramanathan et al., 1987.)

in global-mean precipitation. Despite this increase in global-mean precipitation, local regions might well experience decreases in precipitation.

- o Northern polar winter surface warming (very probable). As the sea ice boundary is shifted poleward, the models predict a significantly enhanced surface warming in winter polar regions (see Figure 7.5). The greater fraction of open water and thinner sea ice is calculated to lead to an effective winter warming of northern polar surface air by more than 10°C relative to the current climate.

- o Reduction of sea ice (very probable). As the climate warms, total sea ice is expected to be reduced in response to warming in high latitudes of the Northern Hemisphere. However, new GFDL model results with a fully interactive ocean indicate little warming at Southern Hemisphere high latitudes over the next century, thus leading to little change in sea ice cover there (Figure 7.6). This new model result thus disagrees with the equilibrium model predictions for the Southern Hemisphere high latitudes as shown in Figure 7.5.

- o Northern high-latitude precipitation increase (probable). As the climate warms, the increased poleward penetration of warm, moist air may increase the annual-average precipitation and river runoff in Northern Hemisphere high latitudes.

- o Summer continental dryness/warming (probable). Several model studies have indicated a marked decrease of the soil moisture over some midlatitude interior continental regions during summer. This drying is

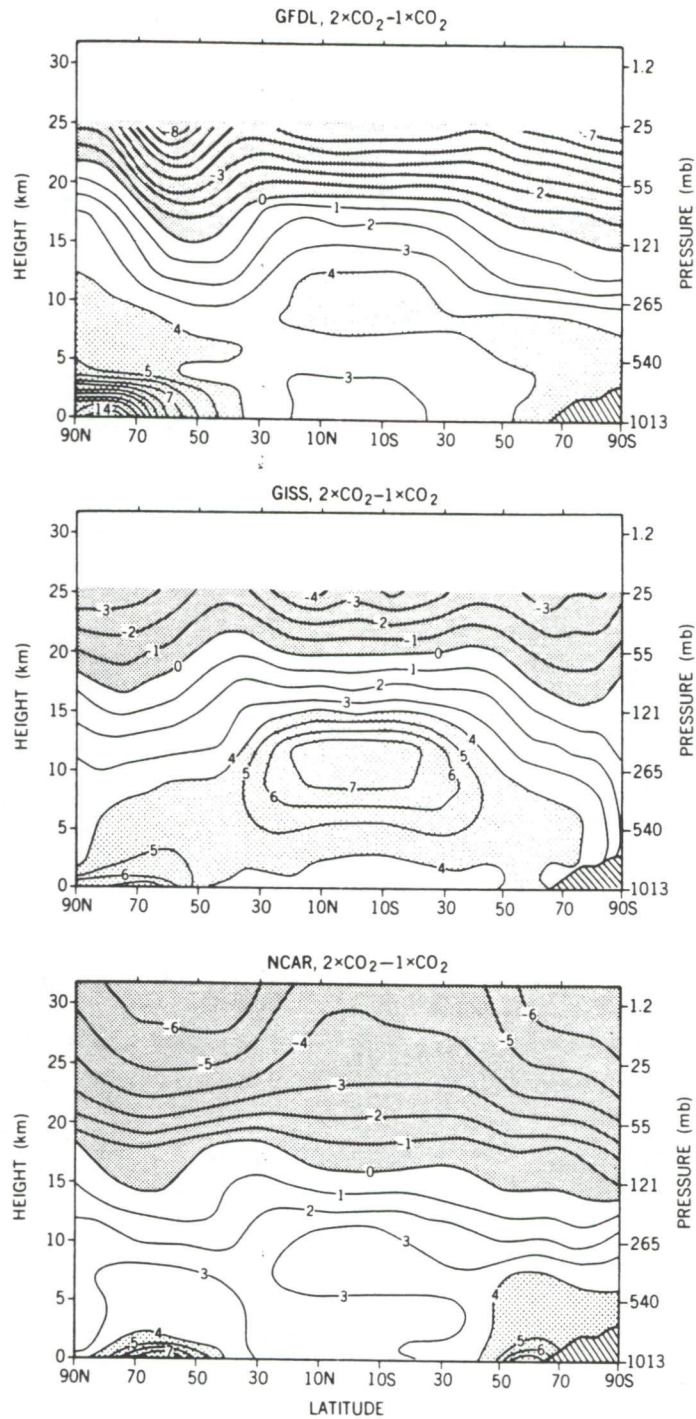


FIGURE 7.4 Latitude-height cross sections of December-January-February mean temperature change (°C) for a doubled CO₂ world compared to today's climate for 3 different models. Top, Geophysical Fluid Dynamics Laboratory (NOAA) model; center, Goddard Institute for Space Studies (NASA); bottom, National Center for Atmospheric Research. (Reprinted from Schlesinger and Mitchell, 1985.)

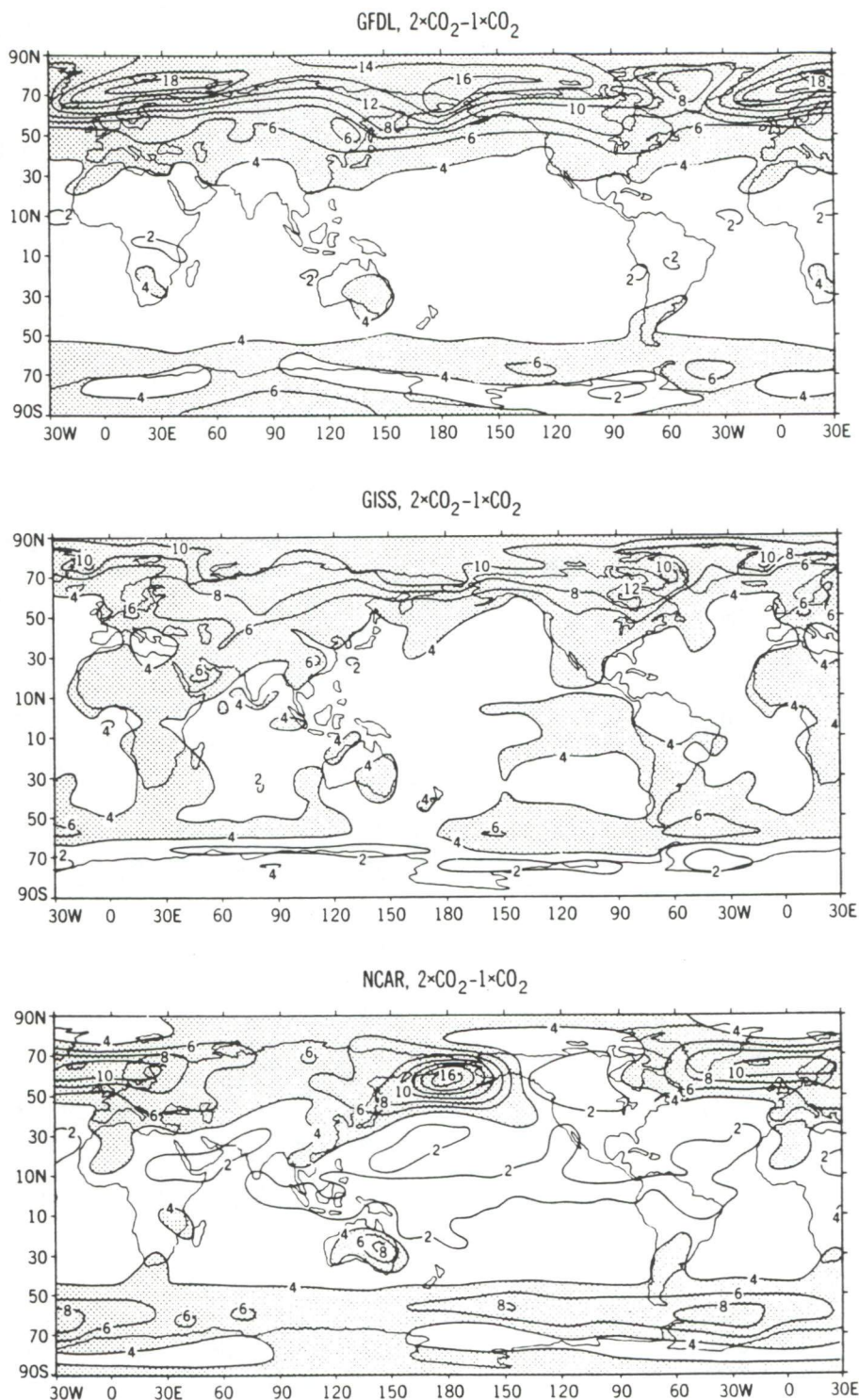


FIGURE 7.5 Latitude-longitude cross sections of December-January-February mean surface temperature change ($^{\circ}\text{C}$) due to a doubled CO_2 as calculated by the three different climate models described in Figure 7.4. (Reprinted from Schlesinger and Mitchell, 1985.)

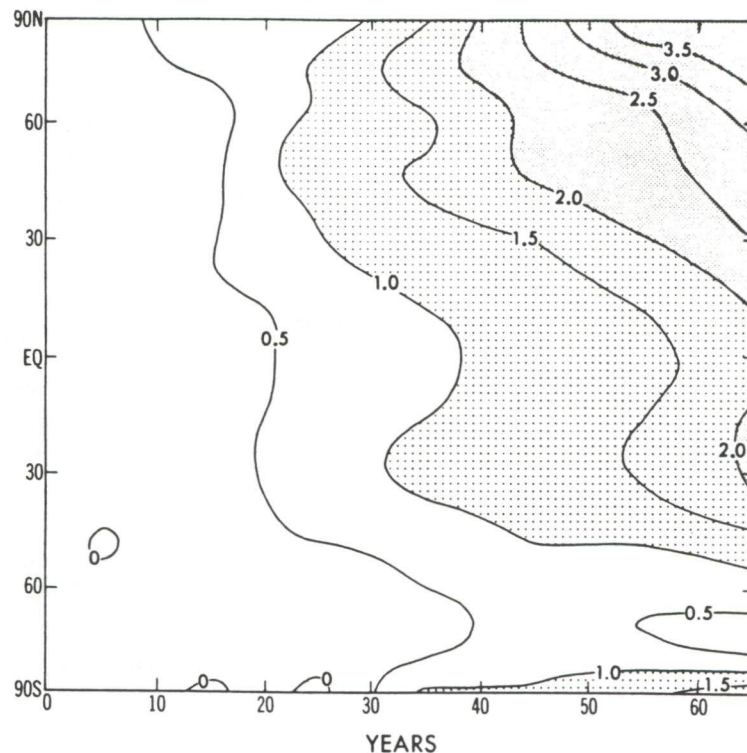


FIGURE 7.6 Time evolution of zonal-mean, decadal averaged temperature change ($^{\circ}\text{C}$) in a GFDL/NOAA coupled atmosphere-ocean model due to a 1.0 percent per year buildup of CO_2 . The resistance of the southern high-latitude region to greenhouse warming illustrates the potential of ocean circulation effects to yield results significantly different from those indicated in the previous generation of models (from Stouffer, R. J., S. Manabe, and K. Bryan, "On the Climate Change Induced by a Gradual Increase of Atmospheric Carbon Dioxide," submitted to *Nature*).

caused mainly by an earlier termination of snowmelt and rainy periods and thus an earlier onset of the normal spring-to-summer reduction of soil moisture. For a comparison of this effect in doubled and quadrupled CO_2 atmospheres, see Figure 7.7.

- o Rise in global mean sea level (probable). A rise in mean sea level is generally expected due to thermal expansion of sea water in the warmer future climate. Far less certain are the contributions due to melting and calving of land ice. In addition, for the next century there now exists the possibility of increased snow accumulation over the antarctic continent. Predictions of actual changes in mean sea level thus remain difficult and controversial.

- o Regional vegetation changes (uncertain). Climatic changes in temperature and precipitation of the kinds indicated above must inevitably lead to long-term changes in the surface vegetative cover. The exact nature of such changes and how they might feed back to the climate remain uncertain.

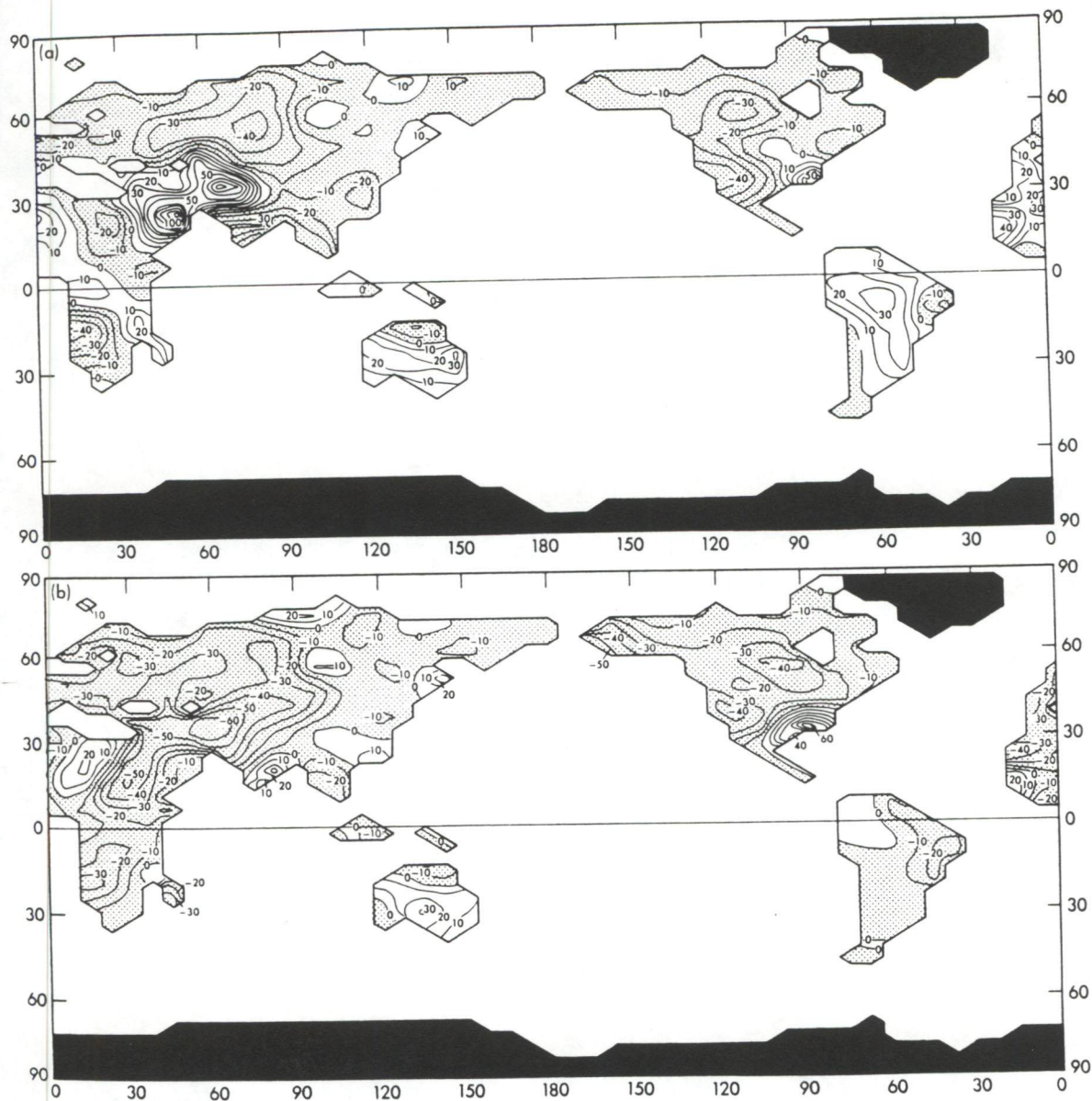


FIGURE 7.7 GFDL model calculation of changed soil moisture (%) for months of June-July-August. Upper picture is for doubled CO_2 ; lower picture is for quadrupled CO_2 . Darkest shading indicates decreases greater than 20 percent. (Reprinted by permission from Manabe and Wetherald, 1987. Copyright (c) by the American Meteorological Society.)

o Tropical storm increases (uncertain). A number of scientists have suggested that a warmer, wetter atmosphere could lead to an increased number and intensity of tropical storms, such as hurricanes. However, tropical storms also are governed by other factors such as local wind structure. At the present time, this effect has not been satisfactorily addressed in the coarse-resolution climate models due to the relatively small size of tropical disturbances.

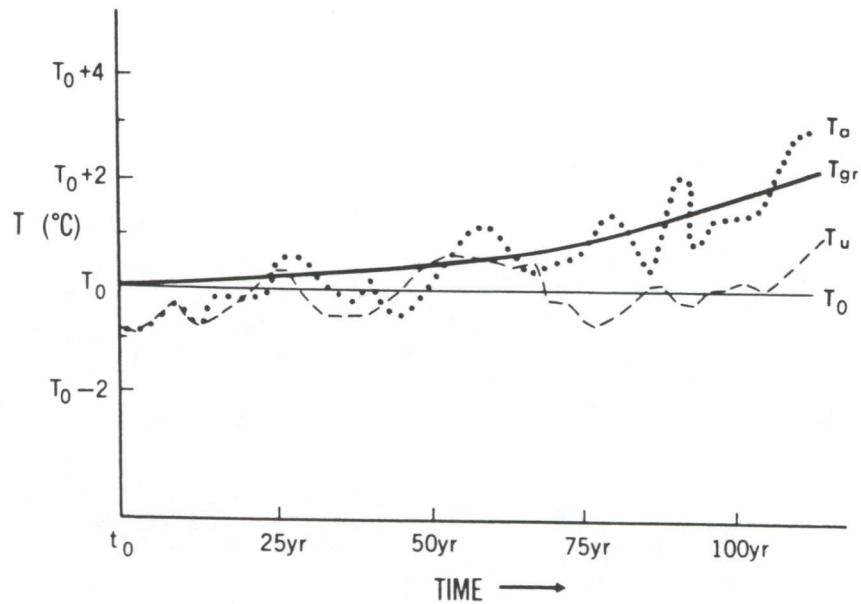


FIGURE 7.8 Schematic illustration of the greenhouse warming detection problem. The thick line (T_{gr}) represents evolution of a hypothetical average gradual greenhouse temperature warming. The thin line (T_0) is an assumed undisturbed time-averaged temperature. The dashed line (T_u) represents the actual temperature variation in an undisturbed climate. The dotted line (T_a) is the actual fluctuating signal for an earth with gradually increasing greenhouse gases. Note that it can take many years to separate the fluctuating greenhouse signal (T_a) from the undisturbed fluctuating signal (T_u).

o Details of next 25 years (uncertain). The results given above describe expected changes in equilibrium climate due to hypothetical large changes in greenhouse gases. In actuality, these gases are increasing gradually with time. Initially, much of the excess heat is absorbed into the oceans, perhaps in complex ways we do not yet understand well. Further, we can expect that natural, decadal-scale climatic fluctuations due to interactions between the atmosphere and the oceans will continue to occur. The midwestern drought in the 1930s and the high water levels of the Great Lakes in the 1980s are good examples of such climatic fluctuations. On these shorter time scales, such natural fluctuations would artificially reduce or enhance the apparent greenhouse warming signals (Figure 7.8). Until such decadal-scale fluctuations are understood or are predictable, it will remain difficult to diagnose the specific signals of permanent climate change as they evolve over the next quarter-century. Moreover, detecting climate change signals becomes even more difficult when smaller regions and/or shorter periods of time are considered.

Even though the above uncertainties are daunting, important advances have already been achieved in the observation, understanding, and modeling of the climate system. The current models are capable of simulating the gross features of geographical and seasonal variations of the global climate. Furthermore, some of these models have achieved successful simulations of the very cold climate of the last glacial maximum and of the extreme temperatures found on the planets. These overall scientific advances have initiated the current public awareness of climate change and its potential implications for the future of the world. This awareness has escalated the need for reliable climate predictions, accurate assessments of the causes of the actual changes occurring, and an ability to distinguish human-produced climate change from longer-period natural variations. Although progress has been made, as noted above, significant deficiencies remain in the capability of the scientific community to address these needs.

Much more effort must be expended worldwide toward providing a climate monitoring and measuring system characterized by careful instrument calibrations and intercomparisons and a commitment to continue measurements over many decades. Focused research into climate processes must be accelerated so that theories can be formulated and reevaluated in the light of newer information. To reduce climate modeling uncertainty, it is imperative that climate modeling efforts receive state-of-the-art supercomputing resources. Additionally, new scientific talent must be developed to exploit those resources.

Through careful, long-term research on observation, modeling, and analysis, our scientific uncertainties will decrease and our confidence for predicting details of the climate system and its changes will gradually improve. A final, very confident prediction is that the societal need for accurate and detailed climate predictions will increase as fast or faster than the scientific community can provide them. The effort to meet these societal challenges will require the combined forces of the world scientific community in a sustained effort spanning decades.

ACKNOWLEDGMENTS

I would like to thank Dr. Syukuro Manabe and his group at the Geophysical Fluid Dynamics Laboratory/NOAA for their contributions to the perspectives offered here as well as for their unrelenting commitment to solving the greenhouse gas modeling problem. I am also indebted for the contributions and cooperative efforts from the other climate modeling groups at the National Center for Atmospheric Research, Goddard Institute for Space Studies/NASA, Oregon State University, and the United Kingdom Meteorological Office.

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