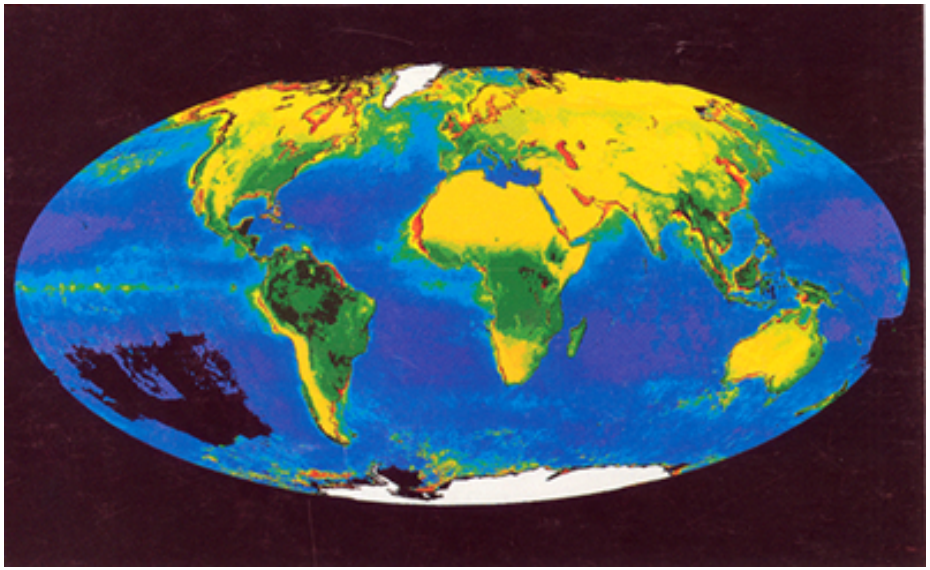
A U. S. Strategy
For Global Change Research



Our Changing Planet:

A U. S. Strategy for Global Change Research

A Report by the Committee on Earth Sciences

To Accompany the
U. S. President's Fiscal Year 1990 Budget

This photograph of the Earth was taken from the Apollo 10 Spacecraft. Much of the Earth is heavily cloud covered. A portion of the United States from the Great Lakes to Southern California, including the Rocky Mountain area, is visible. The North American coastline from Southern Mexico to Alaska can be seen.

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Federal Coordinating Council for Science, Engineering, and Technology

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(See Appendix A for the CES Charter)

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

MEMBERS OF CONGRESS:

I am pleased to forward with this letter the research strategy report of the Committee on Earth Sciences (CES) of the Federal Coordinating Council for Science, Engineering, and Technology. The report, "Our Changing Planet: A U. S. Strategy for Global Change Research ," is the product of an intense interagency effort by experts in various earth sciences and other disciplines. This report, which has benefited greatly from close interaction between CES and the National Academy of Sciences Committee on Global Change, outlines the goals, implementation strategy, and research budget of the U. S. Global Change Research Program. The report accompanies the President's FY 1990 Budget. The strategy will be further expanded into a detailed, comprehensive research plan in 1989.

Changes in the Earth system such as desertification, drought, volcanism, and global warming can have tremendous economic and societal impact. The relative roles of human activity and natural phenomena in global change are of great importance but are, at present, scientifically undefined. Improving our ability to understand and to predict global changes, whether natural or human-induced, is essential for providing our Nation with a sound basis for developing policies and response strategies. An effective and well-coordinated federal research program is crucial to this effort. The program must be both national and international, since global change crosses political as well as physical boundaries.

The Committee on Earth Sciences' report provides an excellent foundation for the comprehensive research plan being developed and provides a keystone for planning for many decades to come. Chairman Dallas Peck and his interagency committee members, associates, and staff have done an excellent job and should be commended.

Sincerely,

William R. Graham

William R. Graham
Director

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Prologue: Our Changing Planet

The Earth is a changing place: over the past million years deserts, forests, and grasslands have migrated across the land, great ice sheets have appeared and disappeared, and wet and dry periods have come and gone.

Until recent times, severe weather, seasonal extremes, and longer term climatological patterns of temperature and precipitation appeared to be driven by unknown forces. It was not easy to discern the influences of even familiar things, like vegetation, the oceans, or the Sun. The focus of human activity was on providing better shelter and improved agriculture.

The industrialization of the planet in the 19th and 20th centuries has given rise to a new set of concerns, namely, that human activity may be adversely affecting the earth system. Recent events, such as the discovery of the Antarctic "ozone hole" and the 1988 North American drought, have led to calls for fundamental change in the economic and social policies of both industrialized and developing nations.

In the past several decades, science has provided increased insight into how the earth and its global environment functions. Science and technology have now evolved sufficiently to begin to unravel the complex processes that dominate the life-sustaining earth, including how human activities may influence life on our planet. The capability to understand how the global earth system will evolve provides the opportunity for a new and more productive partnership with nature and a sound scientific basis for making policy decisions on global change issues.

Executive Summary

- Global changes can have tremendous impact on human welfare. These changes may stem from natural processes that began millions of years ago. Responding to these changes without a strong scientific basis could be futile and costly.

- This report presents an initial strategy for a comprehensive, long-term U. S. Global Change Research Program.

- The goal of the Program is to provide a sound scientific basis for developing national and international policy on global change issues.

- The scientific objectives of the Program are to monitor, understand, and ultimately predict global change.

- The Program is broad in scope, encompassing the full range of earth system changes, including climatic, volcanic, seismic, ecological, and biological changes. The Program addresses both natural phenomena and the effects of human activity. Global warming, an issue that has received much public attention this past year, is an important element of this Program.

- The Program is described in terms of the following seven integrated and interdisciplinary science elements (see Appendix B for amplification) in order to provide a view of global change activities from the interdisciplinary level instead of from the traditional single-discipline or single-agency level:

    1. Biogeochemical Dynamics
    2. Ecological Systems and Dynamics
    3. Climate and Hydrologic System

4. Human Interactions
5. Earth System History
6. Solid Earth Processes
7. Solar Influences

- The Program's goals, objectives, and strategy are consistent with other national and international global change research program plans, including those of the U. S. National Academy of Sciences' Committee on Global Change and the International Council of Scientific Unions' International Geosphere-Biosphere Programme.

- In FY 1989, funding for focused global change research activities totals $133.9 million. The President's FY 1990 budget proposes a funding level of $190.5 million. This budget will enable the Program to expand and accelerate its research activities in all areas of global change.

- A more detailed research plan will be developed in 1989.

- This strategy was developed by a U. S. Federal interagency group, the Committee on Earth Sciences (CES) of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), under the directive of the President's Science Advisor. The CES consists of Federal agencies with programmatic responsibilities related to global change issues. There are thirteen CES members. Seven CES members are Federal agencies conducting research in global change.

Introduction

The Purpose and Scope of this Report

The purpose of this document is to provide an initial research strategy to guide planning and conduct of the U.S. Global Change Research Program. This strategy will be expanded into a more detailed and comprehensive U.S. Global Change Research Program plan in 1989.

The comprehensive research plan will present the details of the U.S. Global Change Research Program, including evaluating how well the current activities address the key scientific questions and program goals, identifying the gaps in knowledge and the priorities among research needs, and defining individual Federal agency roles.

Specifically, this research strategy report will:

- present the overall program goals, objectives, budget, and key scientific questions;
- identify the important national and international global change studies and organizations;
- summarize the research plan and implementation strategy; and
- inventory the current U.S. Federal agencies' research activities.

This research strategy has been developed in close collaboration with other national and international planning groups and activities, including the National Academy of Sciences, the International Geosphere-Biosphere Programme, and the programs outlined in the five year plan of the National Climate Program.

What is Global Change?

Manifestations of global change are numerous and complex: volcanic activity, widespread desertification on some continents, the dramatic changes in many mid-latitude forests

over the past several centuries, changing water tables in numerous regions, earthquakes, the retreat of glaciers, the accumulation of "greenhouse" gases and ozone-depleting chemicals in the atmosphere, the appearance of the Antarctic "ozone hole", acidification of some soils and lakes, and the reduction in genetic diversity of animals and plants.

The earth system is very dynamic and these changes occur on all time and geographic scales. The Earth itself holds testimony of ancient steaming bogs and crushing ice sheets, variations far beyond those known to modern civilization.

Many of these changes are the result of a variety of interrelated natural processes, including changes in the climate system, in solar processes, in the earth's orbit, in volcanic processes, and in the distribution of biological species and land masses that may have been ongoing for centuries. Although human activities may have the potential to alter the earth system, it is clear that variations occur naturally over a wide range. The broad study of all of these interrelated earth processes constitutes global change research.

What is Man's Role in Changing the Environment?

Most humans experience changes as seasonal-to-decadal regional weather and climate changes (e.g., last summer's drought). For this reason these changes, and the influences that human activities might have on them, have dominated public concern. In the past, policymakers have understandably focused on needs perceived as the most immediate, such as weather forecasting, urban smog, and acid rain.

In recent years, the attention of both scientists and policymakers has extended to more global-scale, longer-term changes, such as the question of global warming which may occur when additional heat radiated from the earth is trapped by increases in atmospheric "greenhouse" gases.

Although there are many other "greenhouse" gases, carbon dioxide (CO_2), generated by natural processes and by the burning of wood, coal, oil, gasoline, and natural gas, is currently believed to be the most important contributor to global warming because of its long atmospheric lifetime and ability to trap heat. CO_2 concentration in the atmosphere has increased by 25% over the past two centuries. Part of this increase is a by-product of energy consumption and deforestation to meet human needs.

However, global warming has occurred in pre-industrial eras. The potential for future global warming, and the relative contributions of natural processes and human influences are still poorly known. A better scientific understanding of these changes and an improved predictive capability are important elements of the U.S. Global Change Research Program.

Why is Reliable Global Change Prediction Important?

The effects of natural variability and human activity in the global system can have profound economic, environmental, social, and national security implications. For example, the single 1982-1983 "El Niño" event caused billions of dollars in economic losses worldwide, and this natural fluctuation in the climate system is known to be a recurring event of varying magnitude and periodicity.

Potential changes accompanying a global warming trend might have even greater impact on regional temperature regimes and precipitation patterns. These could result in changes in agricultural policies, modes of energy production and usage, utilization and protection of natural resources, and coastal-zone management. Reliable estimates of the magnitude and rate of these changes would be needed at many decision levels within society: individuals (e.g., farmers), industry (e.g., energy producers), and governments (e.g., regulators).

Improving the capability to predict and respond to such changes, whether naturally-occuring or the result of man's activities, will provide a great benefit to our Nation. A well coordinated Federal global change research program will be critical to realizing these improvements.

The U. S. Global Change Research Program

Key Global Change Scientific Questions. A better predictive understanding of global change requires improved answers to the following four major questions that form the core of the U.S. Global Change Research Program research agenda:

1. What Forces Initiate Global Change? These forces include changes in solar irradiance, in the abundance of atmospheric trace gases and aerosols, in land use, in biota, and in the earth's orbit.

2. How Does the Earth System Respond to Changes in Forcing Functions? These responses or "feedbacks" include interactions among the climate, the ocean, the land, the biota, and the atmosphere.

3. How Has the Earth's Environment Changed in the Past? Differentiating between natural and human-induced global change requires clear documentation of the history of earth system variations over long time scales, especially prior to the influence of human activity. This documentation is provided by fossils, tree rings, pollen, soil composition, and sediments from the ocean, land, and ice.

4. How Well Can Global Change be Predicted? These evaluations include the ability of models to simulate past and present global changes and the biological responses to these changes.

Program Goal. Rational response strategies and sound policy can only be built upon reliable information, predictions, and assessments of the complex phenomena of the global earth system. It is in this context that the U.S. Global Change Research Program goal has been developed.

U. S. Global Change Research Program Goal
To Establish the Scientific Basis for National and International Policymaking Related to Natural and Human-induced Changes in the Global Earth System.

The Program is based on the premise that three developments have converged to make this goal feasible in the 1990's:

1. The science essential to an understanding of global change has matured dramatically in the past several decades and can begin to address the full range of global change research issues.

2. The methodologies and research tools to address the global scales of change are rapidly maturing and can be fully operational in the 1990's (e.g. earth-observing satellites, supercomputers for global scale models and for information management systems, advanced instrumentation and measurement systems, and platforms for ground and ocean-based observations).

3. The national and international infrastructures and commitment to the global change research agenda are basically in place, with such elements as the International Geosphere-Biosphere Programme, the World Climate Research Program, the CES, and the National Academy of Sciences.

Implementation Strategy. The U.S. Global Change Research Program's implementation strategy includes: (1) the identification of three major scientific objectives, (2) the integration of the various scientific disciplines, and (3) the integration of the Program with other national and international global change activities.

(1) Three Major Scientific Objectives

The U.S. Global Change Research Program has three parallel scientific objectives: monitoring, understanding, and predicting global change (see box on page 12 for further details).

The aim of these objectives is to provide detailed assessments of the state of the knowledge of natural and human-induced changes in the global earth system. Appropriate predictions on time scales ranging from years to decades, including projections 20 to 40 years into the future, will be developed periodically. These assessments and predictions will provide information in such areas as: ecosystem dynamics, the biological influence on the climate system, concentrations of significant atmospheric constituents, oceanic and atmospheric circulation, and regionally useful information such as predicted changes in growing seasons, precipitation, and soil moisture. Assessments of uncertainties in these predictions will be an integral part of these predictions.

(2) Integration of Scientific Disciplines

The U.S. Global Change Research Program recognizes the need to achieve a greater level of integration among both single-disciplinary and multi-disciplinary scientific activities. The current foundation of earth science research rests primarily on single-disciplinary activities. However, such individual disciplines have limited capability to explain and predict global and regional scale interactive phenomena. Therefore, multi-

disciplinary programs are a necessary next step to improve the knowledge base and to obtain better predictive capability. Through these interdisciplinary studies, we have recognized the need for an even broader, more integrated view of the global earth system.

The U.S. Global Change Research Program is the national effort to meet that need. It must simultaneously maintain and strengthen the foundation of single-discipline and multi-discipline science, the building blocks of an integrated understanding of the total earth system.

To facilitate this integration process the Program focuses on the following seven interdisciplinary science elements:

- Biogeochemical Dynamics
- Ecological Systems and Dynamics
- Climate and Hydrologic System
- Human Interactions
- Earth System History
- Solid Earth Processes
- Solar Influences

A more detailed discussion of these scientific elements is contained in Appendix B.

The seven science elements were developed in close collaboration with the National Academy of Sciences' Committee on Global Change, which is developing the U.S. component of the International Geosphere-Biosphere Programme. They are designed to maintain a broad and robust research capability, while focusing on those earth system processes and interactions most likely to lead to a practical predictive capability. As a result of this integrating process, each of the agency programs has become increasingly important to the overall success of the U.S. Global Change Research Program.

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U. S. Global Change Research Program Objectives

1. Establish an Integrated, Comprehensive Monitoring Program for Earth System Measurements on a Global Scale

There is no substitute for actual observation of global change. Observations not only provide direct indications of a changing world, but also serve to test models and predictions. Observations sometimes expose surprising phenomena. The Antarctic "ozone hole" and the rapid increase in atmospheric methane are examples.

Knowledge of past global change is essential. Prehistoric changes are recorded in tree rings, sediments, glacier ice, and other parts of the natural record.

Long-term records derived from frequent and well calibrated global measurements of environmentally important parameters are critically needed. Global measurements from satellites and surface-based networks are crucial.

2. Conduct a Program of Focused Studies to Improve Our Understanding of the Physical, Chemical, and Biological Processes that Influence Earth System Changes and Trends on Global and Regional Scales

Substantial progress has been made in understanding the sources, sinks, reservoirs, and fluxes of chemicals and energy through the earth system, but much remains to be learned. The earth systems seem to be capable of adjusting to change, particularly through "feedback" mechanisms. Some global processes tend to amplify change, while others tend to stabilize or oppose further change. Still other processes may respond minimally to changes in the system until a critical magnitude of change is reached, only to trigger and operate in a dramatically different mode. It has been suggested, for example, that ocean circulation may behave this way.

A number of key earth system processes are only beginning to be understood. Examples are: the exchange of heat and chemicals at the ocean-atmosphere interface, ocean circulation, atmospheric heating and cooling effects of clouds, the chemical and climatic effects of atmospheric gases and volcanic products, the general chemical and physical influences on the atmosphere from land plants, and the underlying physiological responses of biological organisms. These processes are the building blocks of earth system models, and their definition requires sophisticated interdisciplinary studies.

3. Develop Integrated Conceptual and Predictive Earth System Models

The rapidly expanding knowledge of earth system behavior permits the development of improved conceptual and computer-based models. The ultimate objective is to produce predictive models (e.g., climate change, environmental response, etc.) that will be useful at both global and regional scales and on many time scales.

While scientific understanding is increasing, there remains much to do if truly integrated models of the earth system are to be developed. Many of the more serious uncertainties arise from limitations in computing capability and from gaps in our scientific understanding of important physical, chemical, and biological processes. Some of the most significant human impacts of global change are expected to be regional in scope, but current climate models cannot forecast at regional scales. Even with enhanced computing capability, scientists modeling the climate have found that the current characterization of the land and of plants to be inadequate for their models' needs and have called upon hydrologists and botanists to provide better descriptions of heat and water transfer.

(3) Integration with National and International Global Change Research Activities

Both U. S. and foreign governments, collaborating closely with researchers at universities and in the private sector, have begun in the last few years to develop a cohesive approach to studying the global earth system. Examples of recent studies that focus on the study of the Earth as a single, integrated system include:

- "Earth System Science: A Program for Global Change" published in 1986 by the National Aeronautics and Space Administration's Earth System Sciences Committee;
- "Global Change in the Geosphere-Biosphere: Initial Priorities for an IGBP" published in 1986 by the National Academy of Sciences; and
- the International Council of Scientific Unions has organized the International Geosphere-Biosphere Programme and recently published a plan of action.

Building on these and related studies, the Program will develop national and international partnerships between governmental bodies, the academic science community, and the private research sector to achieve the specific objectives and long-term goals of the U. S. Global Change Research Program.

Major National and International Organizations Involved in Global Change Research Activities

National Organizations

- FCCSET Committee on Earth Sciences
- National Climate Program
- National Academy of Sciences Committee on Global Change
- Other Boards and Committees of the National Academy of Sciences

International Organizations

- International Council of Scientific Unions: International Geosphere-Biosphere Programme and related activities
- World Meteorological Organization: World Climate Research Program and related activities
- United Nations Educational, Scientific, and Cultural Organization: Intergovernmental Oceanographic Commission and related activities
- United Nations Environmental Programme
- Intergovernmental Panel on Climate Change

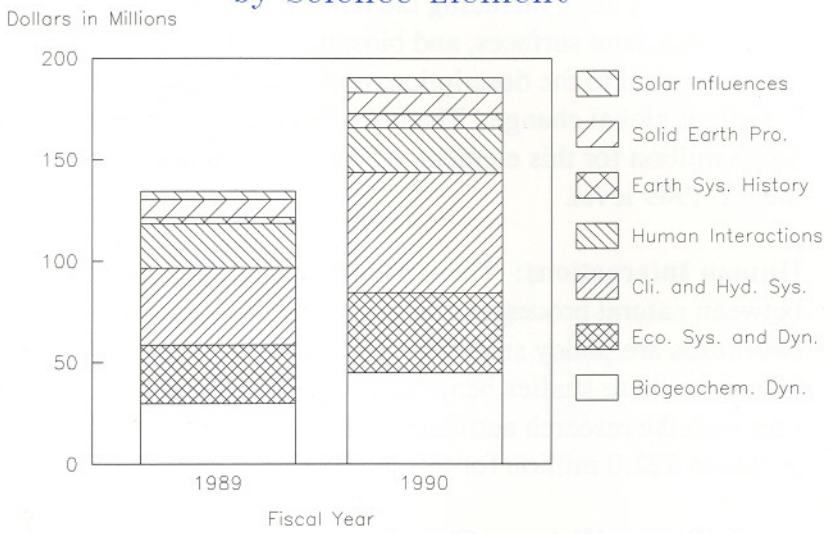
FY 1990 U. S. Global Change Research Program Budget

Over the past year, the CES conducted several interagency global change research budget planning and analysis activities to ensure that the President's Budget includes requests that are well integrated and responsive to the Program's goals and priorities.

The U.S. Global Change Research Program budget includes only research efforts specifically focused on global change issues. Some agency programs that contribute to global change research, but were initiated for and continue to serve other primary purposes, are not included in the focused U.S. Global Change Research Program budget (e.g., the National Aeronautics and Space Administration's Upper Atmospheric Research Program and Topex/Poseidon mission, the National Oceanic and Atmospheric Administration's meterological satellites, and several programs from the Department of Defense). It is anticipated, over the next several years, that some of these contributing programs will be incorporated into the focused Program.

In FY 1989, funding for focused global change research activities totals $133.9 million. The President's FY 1990 budget proposes a funding level of $190.5 million for these programs. (See Table 1 on pages 24 for additional details.) The budget includes important ongoing and new research efforts. Some of these ongoing efforts, like the National Science Foundation's Global Geosciences program and the Department of Energy's carbon dioxide program, have laid the foundation for the proposed FY 1990 effort. This budget will allow the Program to expand and accelerate its research activities across all areas of global change.

Figure 1
U.S. Global Change Research Program
by Science Element



Budget by Science Element

From a scientific perspective, the best way to understand the global change research budget is to examine it by the major science elements. Figure 1 presents the FY 1989 and FY 1990 budgets by science element.

- **Biogeochemical Dynamics:** These programs concentrate on the study of the biogeochemical constituents (e.g., oxygen, carbon, nitrogen, etc.) within the earth system and their influence on the life-sustaining envelope of the earth, including global warming. The FY 1990 budget proposes $44.9 million for this element, a 51 percent increase over the FY 1989 level.

- **Ecological Systems and Dynamics:** These programs focus on how ecological systems both impact and respond to a wide range of global changes. The FY 1990 budget proposes $39.5 million for this element, a 41 percent increase over the FY 1989 level.

- **Climate and Hydrological System:** This research examines the physical processes that govern the climate and hydrologic system, including the atmosphere, hydrosphere, cryosphere, land surfaces, and biosphere. These efforts are clearly central to the description, understanding, and prediction of global change. The FY 1990 budget proposes $59.3 million for this element, a 56 percent increase over the FY 1989 level.

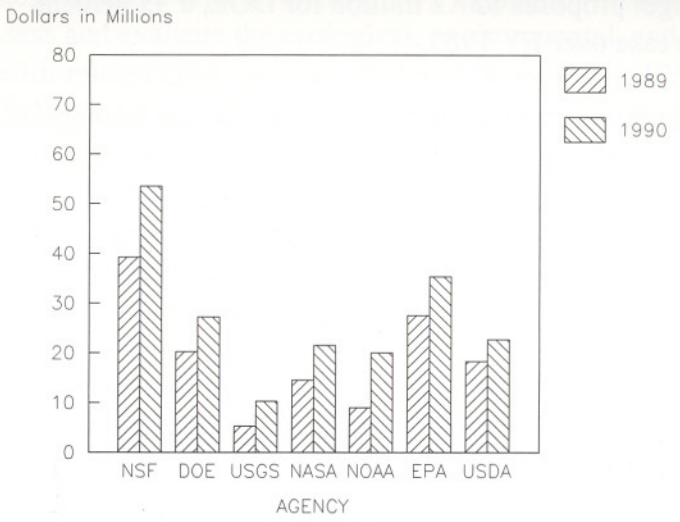
- **Human Interactions:** These programs study the interface between natural processes and human activities. Roughly two-thirds are policy studies and not earth science research. However, these studies benefit greatly from close association with the research activities. The FY 1990 budget proposes $22.0 million for this element.

- **Earth System History:** This element is crucial to documenting past natural changes. Climate information from the past will be very important in distinguishing the relative roles of natural phenomena and human activity in global change. The FY 1990 budget proposes $7.0 million for this element, roughly doubling the FY 1989 level.

- **Solid Earth Processes:** Interactions between the earth's surface and the atmosphere, hydrosphere, cryosphere, and biosphere are the key elements of this program. The FY 1990 budget proposes $10.5 million for this element, an 18 percent increase over the FY 1989 level.

- **Solar Influences:** These programs are designed to study the impact of solar variability on the atmosphere and climate. The FY 1990 budget proposes $7.3 million for this element, a 78 percent increase over the FY 1989 level.

Figure 2
U.S. Global Change Research Program by Agency



Budget by Agency

Figure 2 shows the FY 1989 and FY 1990 proposed budget level by agency. The individual agency efforts reflect their particular mission, and build upon their respective scientific and technical strengths.

- **National Science Foundation (NSF):** NSF primarily supports university-based basic research in all areas of earth, atmospheric, and ocean sciences. NSF's efforts encompass all seven science elements except human interactions. The FY 1990 budget proposes $53.5 million for NSF, a 36 percent increase over FY 1989. This increase reflects Administration and Congressional commitment to doubling the level of NSF's support for university-based basic research over the next five years.

- **Department of Energy (DOE):** DOE maintains a program of research directed at how energy production and use affect global earth systems and how possible responses to such change may affect future energy options. As a result,

the DOE global change program is focused primarily on climate and ecosystem response research. The FY 1990 budget proposes $27.2 million for DOE, a 35 percent increase over FY 1989.

- **Department of the Interior/United States Geological Survey (DOI/USGS):** DOI/USGS carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology. The FY 1990 budget proposes $10.3 million for DOI/USGS, a 94 percent increase over FY 1989.

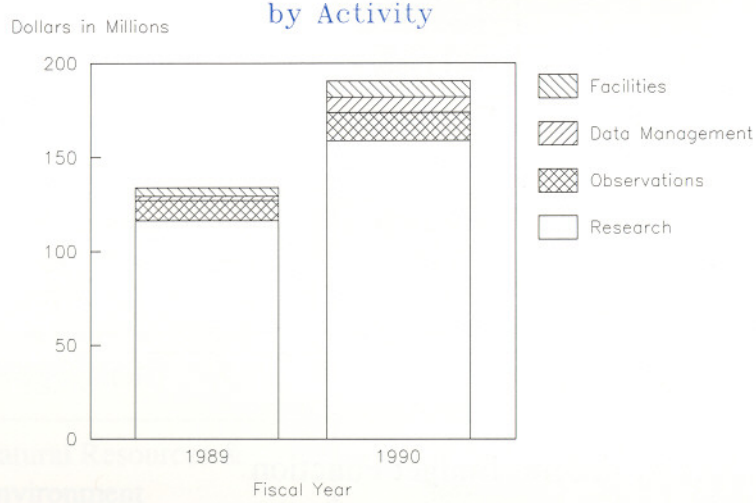
- **National Aeronautics and Space Administration:** (NASA) is responsible for earth sciences research from space, including broad scientific studies of the planet as an integrated system. This research effort supports advanced technology development studies of the Earth Observing System (EOS). These studies will focus on defining the remote sensing instruments, space infrastructure, and data management systems needed to study a broad range of global change processes. EOS is under consideration as a new initiative sometime over the next several years. The FY 1990 budget proposes $21.5 million for NASA, a 48 percent increase over FY 1989.

- **Department of Commerce/National Oceanic and Atmospheric Administration (DOC/NOAA):** Building on its base of oceanic and atmospheric science and services, DOC/NOAA's focused programs emphasize improving predictions of climate change and its regional implications, on time scales from a single season to centuries. NOAA's mission-directed activities include research on physical and biogeochemical processes in the climate system, *in situ* measurements, climate modeling, and diagnostic techniques for detecting global changes. The FY 1990 budget proposes $20.0 million for DOC/ NOAA, roughly doubling the FY 1989 level.

- **Environmental Protection Agency (EPA):** EPA research is focused on ecological systems and human interactions. These research efforts reflect EPA's regulatory mission to assess and evaluate the ecological, environmental, and health-related consequences of global change. The FY 1990 budget proposes $35.3 million for EPA, a 29 percent increase over FY 1989. Roughly 40 percent of the FY 1990 program is for policy studies.

- **United States Department of Agriculture (USDA):** The USDA global change research programs deal with the impact of the climate on agricultural and ecological systems and the impact of these systems on the climate. Many of the USDA vegetation, soils, and ecology research programs are critical to the success of the Program. The FY 1990 budget proposes $22.7 million for USDA, a 24 percent increase over FY 1989.

Figure 3
U.S. Global Change Research Program by Activity



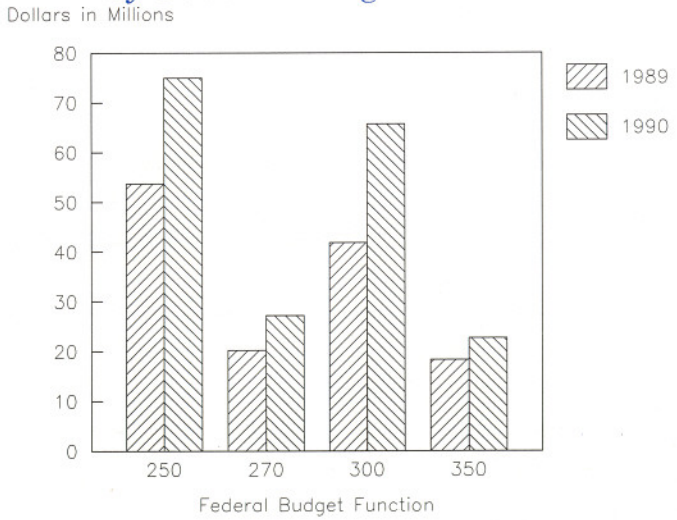
Budget by Type of Activity

The Program has been divided into the four types of activities that are highlighted in Figure 3. The FY 1990 budget

proposes $158.9 million for research, 83 percent of the total FY 1990 budget. However, it is anticipated that the ratio between the four types of activities will change significantly over the next several years. Planning funds have been included for future observing systems, their data management needs, and associated facilities. These planning efforts and the Program's coordination mechanisms will ensure the most efficient use of these capital investments. In particular, the CES is working with the interagency Working Group on Data Management for Global Change to address the future data management needs of the Program. The CES plans to maximize the use of existing archive systems (e.g., DOI/USGS's Earth Resources Observations Satellite Data Center and DOC/NOAA's National Climate Data Center).

Figure 4

U.S. Global Change Research Program by Federal Budget Function



Budget by Federal Budget Function

Scientific, environmental, energy, and agricultural resources are very important to our Nation. All either impact or are impacted by global change.

Figure 4 illustrates the Program's funding level by the Federal budget functions that encompass these national resources. As would be expected, the budget proposes significant increases for budget functions 250 and 300. In FY 1990, $75.0 million is proposed for function 250, a 40 percent increase over FY 1989. For function 300, $65.6 million is proposed for FY 1990, a 57 percent increase over FY 1989.

Despite the broad distribution across these budget functions and, hence, across many Executive Branch and Congressional decision making paths, it is crucial to view the Program as a single integrated research effort. The success of many of the science objectives is dependent on the cooperation and contributions of all the individual agency programs. Thus, decisions concerning these investments should attempt to recognize the full scope and structure of the U.S. Global Change Research Program.

Table 2
1989-1990 U. S. Global Change Research Program Budget by Budget Function
(Dollars in Millions)

Budget Function	Budget Function Number	1989	1990
TOTAL		133.9	190.5
General Science, Space and Technology	250	53.7	75.0
NASA		14.5	21.5
NSF		39.2	53.5
Energy (DOE)	270	20.2	27.2
Natural Resources & Environment	300	41.7	65.6
DOI/USGS		5.3	10.3
EPA		27.4	35.3
DOC/NOAA		9.0	20.0
Agriculture (USDA)	350	18.3	22.7

Table 1
1989-1990 U. S. Global Change Research Program Budget
(Dollars in Millions)

Focused Program	Total Budget		Biogeochemical Dynamics		Ecological Systems and Dynamics		Climate and Hydrologic System		Human Interactions		Earth System History		Solid Earth Processes		Solar Influences	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Agency Totals	133.9	190.5	29.8	44.9	28.1	39.5	38.0	59.3	22.0	22.0	3.0	7.0	8.9	10.5	4.1	7.3
NSF	39.2	53.5	13.5	18.3	1.9	1.9	13.2	17.0	0.0	0.0	2.0	4.7	6.2	6.5	2.4	5.1
DOE	20.2	27.2	6.0	5.5	4.2	6.7	7.0	10.2	2.0	3.6	0.0	0.0	0.0	0.0	1.0	1.2
DOI/USGS	5.3	10.3	0.0	0.0	0.0	0.3	2.3	5.0	1.5	2.0	1.0	2.3	0.5	0.7	0.0	0.0
NASA	14.5	21.5	3.0	4.4	4.3	6.4	4.3	6.4	0.0	0.0	0.0	0.0	2.2	3.3	0.7	1.0
DOC/NOAA	9.0	20.0	0.0	3.0	0.0	0.0	9.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPA	27.4	35.3	0.8	3.5	7.4	13.2	0.7	2.2	18.5	16.4	0.0	0.0	0.0	0.0	0.0	0.0
USDA	18.3	22.7	6.5	10.2	10.3	11.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Activity	133.9	190.5	29.8	44.9	28.1	39.5	38.0	59.3	22.0	22.0	3.0	7.0	8.9	10.5	4.1	7.3
Research	116.4	158.9	26.9	40.1	24.9	35.0	31.6	46.1	22.0	20.8	3.0	3.5	5.4	8.1	2.6	5.3
Observations	10.7	15.0	0.0	1.5	2.0	2.5	5.0	8.5	0.0	0.0	0.0	0.0	3.5	2.2	0.2	0.3
Data Management	2.3	8.1	0.4	0.8	0.2	1.0	1.4	4.7	0.0	1.2	0.0	0.0	0.0	0.2	0.3	0.2
Facilities	4.5	8.5	2.5	2.5	1.0	1.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	1.0	1.5

Epilogue: The Fundamental Rationale

In the coming decades, global change may well represent the most significant societal, environmental, and economic challenges facing this Nation and the world. The national goal of developing a predictive understanding of global change is, in its truest sense, science in the service of mankind.

APPENDIX A

CHARTER
COMMITTEE ON EARTH SCIENCES
of the
Federal Coordinating Council for Science, Engineering, and Technology

The Committee on Earth Sciences (CES) is hereby established by action of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). FCCSET derives its current authority from executive Order 12039 of February 24, 1978.

Purpose and Functions

A goal of earth sciences is to understand, on a global scale, how the highly interactive system comprised of the solid Earth, the oceans, the atmosphere and magnetosphere, and the biosphere has evolved, how it functions today, and how it will evolve in the future. In addition to basic research, earth science R&D includes continued development of the technology needed for observations of the earth system and increased emphasis on collection, analysis, and archiving of data on a global scale from satellite and ground-based measurements needed for long-term research efforts and addressing national policy issues which depend on a characterization of humankind's impact, or potential impact, on the global environment. The purpose of the Committee on Earth Sciences is to increase the overall effectiveness and productivity of Federal R&D efforts directed toward an understanding of the Earth as a global system. In fulfilling this purpose the Committee addresses significant national policy matters which cut across agency boundaries.

Specifically the CES:

a. reviews Federal R&D programs in earth sciences including both national and international programs;
b. improves planning, coordination, and communication among Federal agencies engaged in earth sciences R & D;

c. identifies and defines earth sciences R&D needs;
d. develops and updates long-range plans for the overall Federal R&D effort in earth sciences;
e. addresses specific programmatic and operational issues and problems which affect two or more Federal agencies;
f. provides reviews, analyses, advice and recommendations to the Chairperson of FCCSET on Federal policies and programs concerned with earth sciences R&D, particularly in assessing human kind's impact on the global environment;
g. develops the Administration's response to the call in the NSF Authorization Act of 1987 for a report to Congress, in the NSF Authorization Act of 1987, concerning Federal Government action with respect to the establishment of an International Year of the Greenhouse Effect mandated in calendar year 1991.

Structure

The Chairperson and Vice-Chairperson of the CES are appointed by the Chairperson of FCCSET; the Vice-Chairperson is from an agency other than that which the Chairperson represents. The Executive Secretary is designated by the CES Chairperson. Additional staff assistance is provided by member agencies as required by the Committee. Chairpersons of CES task forces or working groups arrange assistance from their own agencies.

The following departments and agencies are represented on this Committee:

Department of Agriculture
Department of Commerce
Department of Energy
Department of the Interior

Department of State
Department of Transportation
National Science Foundation
Environmental Protection Agency
National Aeronautics and Space Administration
Office of Science and Technology Policy
Office of Managment and Budget
Council on Environmental Quality

Other Federal agencies participate, as appropriate, upon invitation by the Committee Chairperson or the Chairperson of FCCSET.

The CES Chairperson approves the establishment, continuation, or termination of task forces and working groups as necessary to achieve the Committee's purposes. Membership on such task forces and working groups is not restricted to Committee members and is established as the Committee may determine appropriate.

The Committee meets at the call of the CES Chairperson who also approves the agenda. Meetings are held not less than two times a year. Meetings of task forces and working groups are held as necessary to meet their specific objectives. Minutes of meetings are prepared by the Committee Executive Secretary and distributed to all members of the Committee, the leaders of task forces and working groups, and to the Executive Secretary of FCCSET.

Compensation

All members are full-time Federal employees who are allowed reimbursement for travel expenses by their agencies plus per diem or subsistence while serving away form their duty stations and in accordance with standard governmental travel regulations.

Documentation

Agendas and records of actions of Committee meetings are prepared and disseminated to members by the Executive Secretary. Records of actions are submitted to members for approval. Complete records of all committee activities, including those of task forces and working groups, are maintained in the office of the Chairperson. The Committee prepares a report for the Chairperson of FCCSET not later than 60 days after the end of each fiscal year. The report contains, as a minimum, the Committee's functions, a list of members and their business addresses, the dates and places of meetings, and a summary of the Committee's activities and recommendations during the year.

Termination date

Unless renewed by the Chairperson of FCCSET prior to its expiration, the Committee on Earth Sciences of FCCSET shall terminate not later than December 31, 1990.

Determination

I hereby determine that the formation of the Committee on Earth Sciences is in the public interest in connection with the performance of duties imposed on the Executive Branch by law and that such duties can best be performed through the advice and counsel of such a group.

Approved:

March 6, 1987
Date

William R. Graham
Chairman, FCCSET

Appointment of New Member and Amendment to the Charter of the Committee on Earth Sciences (FCCSET)

APPOINTMENT: By my authority as Chairman, Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), I appoint the Department of Transportation as a permanent member of the Committee on Earth Sciences (CES).

AMENDMENT: Charter of the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology as signed and approved on March 6, 1987, by the Chairman, FCCSET, is amended as follows.

Under the Section "Structure," add the following new member:

"Department of Transportation"

August 24, 1988
Date

William R. Graham
William R. Graham, Chairman
Federal Coordinating Council
for Science, Engineering,
and Technology

APPENDIX B:

DEFINITIONS OF SCIENCE ELEMENTS AND TYPE OF ACTIVITY

Definition of Science Elements

1. Biogeochemical Dynamics- The study of (1) the sources, sinks, fluxes, and interactions between mobile biogeochemical constituents within the Earth system, with a particular focus on oxygen, and other key elements, including carbon, nitrogen, sulfur, phosphorus, and the halogens; (2) the cycling of biogeochemical elements in the atmosphere, oceans, terrestrial regions, biota, and other sediments over Earth's history; (3) the influence of biogeochemical elements on the regulation of ecological systems and contribution to potential "greenhouse" constituents (for example CO_2, CH_4, etc.) that might have a direct influence on climate and the life-sustaining envelope of the Earth. Hydrology is excluded here and included in #3. For consistency, ozone studies will be included here.

2. Ecological Systems and Dynamics- The study of the responses of ecological systems, both aquatic and terrestrial, to changes in global environmental conditions and of the influence of biological communities on the atmospheric, climatic, and ocean systems. It includes studies of plant succession, terrestrial and aquatic biodiversity, extinctions, relationship with geological substrate, etc. Contemporary monitoring and specific ecosystem experiments can provide information on multiple stresses influencing the biota and on the biotic response to environmental stresses both natural and cultural; such information is needed to achieve the basic understanding required for the development of models. Identification and study of particularly sensitive and indicative ecosystems will be especially informative.

3. Climatic and Hydrologic System- The study of the physical

processes that govern the climate and hydrologic system--incorporating the atmosphere, hydrosphere (oceans, surface and ground water, etc), cryosphere, land surface, and biosphere. These are clearly central to the description, understanding, and prediction of global change, particularly in terms of impacts on global climate conditions and upon the pervasive and critical hydrologic system.

4. Human Interactions- The study of the impacts of changing global conditions on human activities. The global environment is a crucial determinant of humanity's capacity for continued and sustained development. Research should focus on the interface between human activities and natural processes. An example would be the studies of the impacts on agriculture from changes in length of growing season.

5. Earth System History- The natural record of environmental change is contained in the rocks, terrestrial and marine sediments, glaciers and ground ice, tree rings, geomorphic features (including the record of changes in sea level), and other direct or proxy documentation of past environmental conditions. These archive the Earth's history and document the evolution of life, past ecosytems, and human societies. Past geological epochs with warmer or cooler climates relative to present are of particular scientific interest and should illustrate the range of natural variability. As past analogues of possible future climates, they contribute both to the understanding of the present Earth system and to the prediction of its future.

6. Solid-Earth Processes- The study of solid-Earth processes that affect the life-supporting characteristics of the global environment and especially those processes that take place at the interfaces between the solid earth and the atmosphere, hydrosphere, cryosphere, and the biosphere. Solid-Earth processes that directly affect the environment are of primary interest; processes that have only indirect effects are excluded.

7. Solar Influences- Studies of variability in solar brightness and its impact in atmospheric density, chemistry, dynamics, ionizations, and climate. Studies of the effects of solar variability on biogeochemical cycles as well as the ultraviolet impact on biology and chemistry would be included here. Included are studies of present-day variations and the historical record. This may include examination of causal mechanisms to explain linkages between solar flux variation and subsequent atmospheric responses that have important implications for the biosphere.

Definitions of Type of Activity

1. Research- The research element includes basic and applied science, theory, analysis, modeling, prediction, and assessment which are fundamental to understanding global change or some portion of the Earth system.

Examples are process studies, analyses of processes, exploratory field measurement programs, measurements other than long-term sustained observations, and basic laboratory studies. Also included is applied mission- or problem-oriented research, for example acid rain research. Activities such as policy option studies, emission estimates, and economic modeling would be included here but should be labeled as such.

Model development and use is included here, that is, the development, improvement, and application of quantitative numerical models that simulate processes of the global environment and components of its subsystems, coupled models exploring processes between subsystems, models of human activities and their impacts, assessment models, and predictive models, including operational forecasting models.

2. Long-term Observations- This element includes observations made periodically or continuously over three years or more, and is essentially the documentation of global change. It includes monitoring aimed at developing a long-term observational record of environmental parameters for research on decadal time scales.

Examples: Documentation of variations and changes in the atmosphere's concentration of trace gases; documentation of variations and changes in global atmospheric circulation; satellite measurements of ocean parameters.

Facilities supporting these observations are included along with the actual activities and costs of taking the measurements, developing the algorithms to analyze the data, and the reduction of the data.

3. Data Management- This category includes operational expenses for organizing, archiving, preserving, and making data available for global change research. This includes all activities related to global change data management beyond those short-term activities reported under the research activity.

4. Facilities- Some programs may include major investments in logistics or facilities (satellites, research vessels, supercomputers, telecommunications hardware, etc.) that are essential to the success of a program.

Global patterns of biological productivity showing land and ocean vegetation. Land patterns are determined from measurements taken from the NOAA-7 polar orbiting satellite and ocean patterns from the NASA Nimbus-7 satellite. Ocean productivity patterns represent an average over 18 months and range from red (most productive) to purple (least productive). Land patterns represent the potential productivity averaged over 3 years and range from deep green (representing rain forests) to beige (representing deserts and barren regions).