Our Changing Planet:
The FY 1990 Research Plan

Executive Summary

THE U.S. GLOBAL CHANGE
RESEARCH PROGRAM

A Report by the
Committee on Earth Sciences

July 1989

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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Office of Science and Technology Policy
Federal Coordinating Council on Science, Engineering, and Technology

Committee on Earth Sciences

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(See Appendix for the CES Charter)

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

Early in 1989, I transmitted to the U.S. Congress a report which accompanied the President's FY 1990 Budget outlining the goals, implementation strategy, and research budget of the U.S. Global Change Research Program. This strategy document, entitled "Our Changing Planet: A U.S. Strategy for Global Change Research," was the product of an intense interagency effort by experts in various earth sciences and other disciplines. This interagency effort was coordinated by the Committee on Earth Sciences (CES) of the Federal Coordinating Council for Science, Engineering, and Technology. The strategy document promised a detailed and comprehensive research plan based on the research strategy to be published in 1989.

I am pleased to forward with this letter the U.S. Global Change Research Program research plan for FY 1990. This research plan focuses on establishing a sound scientific basis for developing national and international policy on global change issues. Global changes such as desertification, drought, volcanism, and global warming can have a tremendous economic and societal impact. The relative roles of human activity and natural processes in these changes are of great importance but are, at present, unknown. In addition, our knowledge is insufficient to reliably predict the likely degree, rate, or timing of these changes. Improving our ability to understand and to ultimately predict global changes, whether natural or human-induced, is essential. The CES research plan represents a well-coordinated federal research program to address these issues and provides a strong foundation for international cooperation.

The scientific objectives of the research plan are to monitor, understand, and ultimately predict global change. The report outlines a priority framework for focusing and integrating the interagency research efforts to ensure that they meet these objectives. This priority framework was derived from numerous research priorities outlined by both the U.S. and international communities. It indicates research areas that require progress to improve our understanding of both natural and human-induced global changes. This research plan provides a solid foundation for future planning and will be updated periodically to reflect our growing understanding of global environmental changes.

I take this opportunity to thank and commend Chairman Dallas Peck and his interagency committee members and staff who have done an outstanding job in preparing this report.

William R. Graham
Director

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THE U.S. GLOBAL CHANGE
AT-A

- Many global changes can have tremendous impact on the welfare of humans. These events may stem from natural processes that began millions of years ago or from human influence. Responding to these changes without a strong scientific basis could be futile and very costly.

- This report presents a comprehensive research plan for the U.S. Global Change Research Program.

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

- The Program's goals, objectives, research priorities, and strategy are consistent with current national and international global change planning and research efforts.

- 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 physical, chemical, geological, social, and biological changes. The Program addresses both natural phenomena, as well as the effects of human activity.

RESEARCH PROGRAM
GLANCE

- The particular research activities which comprise the U.S. Global Change Research Program are grouped into seven interdisciplinary scientific elements:

    1. Climate and Hydrologic Systems
    2. Biogeochemical Dynamics
    3. Ecological Systems and Dynamics
    4. Earth System History
    5. Human Interactions
    6. Solid Earth Processes
    7. Solar Influences

- In fiscal year 1989, funding for focused global change research activities total $133.9 million. The President's FY 1990 budget proposes a funding level of $191.5 million, a 43 percent increase for focused programs. This substantial increase will enable the Program to expand and accelerate its research activities in most areas of global change research.

- This strategy was developed by a U.S. Federal interagency group, the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). The FCCSET is chaired by the Director of the Office of Science and Technology Policy in the Executive Office of the President.

Introduction

The Earth is a changing place. Over the past million years deserts, forests, and grasslands have migrated across the land, seashores have advanced and retreated, and wet and dry periods have come and gone. The dramatic rise in industrial activities during the 19th and 20th centuries has produced a new set of concerns, namely, that human activities may be affecting the Earth system. Consequently, wise use of the Earth for human habitation has become an important political and scientific issue. World population growth, intense industrial and agricultural activities, and the need to maintain man's health and welfare require that each individual and country exercise appropriate environmental care and sensitivity.

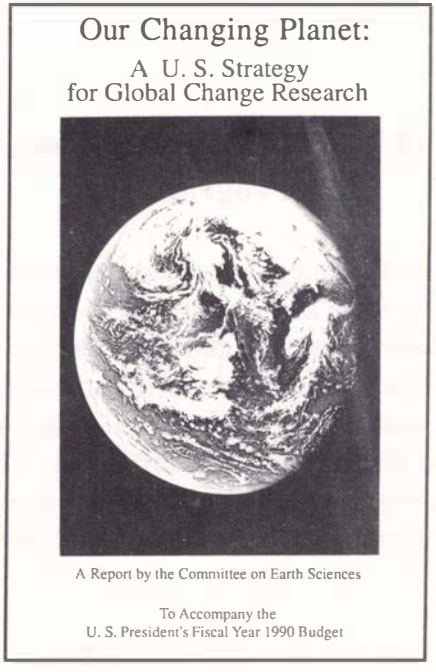
The global changes that may affect both human well-being and the quality of life on this planet include ozone depletion, global climate warming, sea level change, drought, deforestation, desertification, and reduction in biodiversity. While dramatic and complex in and of themselves, these discrete global environmental concerns cannot be fully understood unless they are addressed collectively.

Many of these changes are the result 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 landmasses 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. For many of these changes, current knowledge is insufficient to reliably predict the likely degree, rate, or timing of these changes. To understand and ultimately predict the impact of both natural processes and human activities on these changes, it is necessary to improve our understanding of the underlying physical, geological, chemical, biological, and social processes that control the Earth's environment.

In the past several decades, science has provided increased insight into how the Earth and its global environment function. This capability provides the opportunity for a new and more responsible partnership with nature and a mechanism to improve the scientific basis for making policy decisions on global change issues. An effective and well-coordinated national and international research program will be required to dramatically improve our knowledge of these complex Earth processes — to provide the basis to discriminate between natural and man-influenced changes, and ultimately to predict global change.

The Purpose of This Report

To address this need, the President transmitted to the Congress in early 1989 a report entitled *Our Changing Planet: A U.S. Strategy for Global Change Research.* This report outlined the goals and objectives of the U.S. Global Change Research Program (Program) and recommended that a comprehensive research plan be developed to further integrate Federal global change research activities.



In response to this recommendation, a comprehensive research plan, entitled *Our Changing Planet: The FY 1990 Research Plan*, has been developed for the U.S. Global Change Research Program. This document is the Executive Summary of the Research Plan. All of these documents have been 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). The FCCSET is chaired by the Director of the Office of Science and Technology Policy in the Executive Office of the President.

In addition to information included in the original strategy document, the Executive Summary also includes identification of the key scientific questions, the priorities among research needs, and identification of specific agency roles. Both the strategy document and the Executive Summary cover the Program's FY 1989-1990 activities. The purpose of this Executive Summary and the Research Plan is to present the FY 1990 program in the priority framework that has been developed over the past year. This format will be the basis for the Program in FY 1991 and future years.

The Scope of The U.S. Global Change Research Program

The overall U.S. strategy to address global change issues requires efforts in three areas: research to understand the Earth's environment; research and development of new technologies to adapt to, or mitigate, environmental changes; and formulation of national and international policy response options required for a changing environment. The goal of the U.S. Global Change Research Program is to provide the scientific basis for informed decision making. It is not the role of the Program to formulate policies regarding global change, nor does its mandate cover the research required to develop new

technologies that might be used to mitigate or adapt to a changing environment.

The CES recognizes that, while alternative technologies are not a component of the Program, high priority should be given to this important research. Agencies such as the Environmental Protection Agency (EPA), Department of Energy (DOE), and U.S. Department of Agriculture (USDA) must play a leadership role in the important area of research in adaptation and mitigation technologies. Such research would be complementary to the U.S. Global Change Research Program and to ongoing studies of response strategy formulation.

The U.S. Global Change Research Program

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

Recognizing that effective and rational response strategies to environmental issues can be built only on sound scientific information, the overarching goal of the U.S. Global Change Research Program is:

To gain a predictive understanding of the interactive physical, geological, chemical, biological, and social processes that regulate the total Earth system and, hence, establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts.

In formulating the Research Plan, the CES has drawn upon the national and international research plans and recommendations developed by the scientific community over the past few years that call for a systematic and integrated study of the global Earth system and its susceptibility to change. In particular, the CES relies heavily on the advice and recommendations of the U.S. National Academy of Sciences' (NAS) Committee on Global Change. The goals, objectives, and strategies of the Program are also consistent with the International Council of Scientific Unions' (ICSU) International Geosphere-Biosphere Programme, and the ICSU and World Meteorological Organization's (WMO) World Climate Research Programme.

Key Scientific Questions

Meeting the above goal will require addressing the following three major questions of the U.S. Global Change Research Program:

- *What global changes have occurred in the past and are occurring now?*
    - *Proxy Record*
    - *Direct Measurement*

- *What physical, geological, chemical, biological, and social processes are involved in influencing global change and its environmental impacts?*
    - *Global Change Forcing Agents*
    - *Global System Interactions*

- *How well can global change and its impacts be predicted?*
    - *Model Simulation of the Past*
    - *Model Simulation of the Present*
    - *Model Prediction of the Future*

A central goal in addressing all three of these scientific questions is improving our ability to distinguish between natural and human-influenced changes in the global environment.

Implementation Strategy

The strategy for implementing the U.S. Global Change Research Program requires the identification of scientific objectives, the integration of traditional scientific disciplines, and the establishment of new coordination mechanisms.

Scientific Objectives. The Program has three parallel scientific objectives that address the key questions mentioned above.

These three objectives are the monitoring, understanding, and predicting of global change. Work toward these objectives must proceed simultaneously and in concert, since progress in each of these objectives influences the others. These three objectives are part of the Program priority framework and will be discussed in detail in the following priority framework section.

Disciplinary Integration. The Program recognizes the need to achieve a greater level of integration among both single-discipline and multi-discipline scientific activities. These levels of disciplinary integration include:

- *The Single-Discipline Level.* This fundamental level of activity comprises programs of observations, process studies, theory, and information systems in the basic and traditional Earth and social science disciplines, such as geology, oceanography, meteorology, biology, atmospheric chemistry, hydrology, agronomy, glaciology, economics, geography, and sociology.

- *The Interdisciplinary Level.* The knowledge of global subsystems is developed and tested at this level. Examples include interdisciplinary topics such as atmospheric-biospheric exchange; coupled oceanic-atmospheric dynamics; and chemical, dynamical, and radiative couplings in polar stratospheric ozone processes.

- *The Integrated Level.* Here the conceptual and predictive models of the whole Earth system are developed. Achieving this fully integrated level of perspective and activities is the overarching objective of the U.S. Global Change Research Program.

The Program requires support for activities across all three levels of disciplinary integration. It is this multi-level structure that draws upon the strengths of the existing and separate fundamental disciplines, while building the interdisciplinary

approaches that an integrated Earth picture also demands. The Program's seven science elements reflect the integrated and interdisciplinary nature of such a complex research effort. These science elements are:

- *Climate and Hydrologic Systems*. Includes the study of the physical processes that govern physical climate and the hydrological cycle, including interactions between the atmosphere, hydrosphere (i.e., oceans, surface and ground water, clouds, etc.), cryosphere, land surface, and biosphere.

- *Biogeochemical Dynamics*. Includes the study of the sources, sinks, fluxes, trends, and interactions involving the biogeochemical constituents within the Earth system, including human activities, with a focus on carbon, nitrogen, sulfur, oxygen, phosphorus, and the halogens.

- *Ecological Systems and Dynamics*. Includes the study of the responses of ecological systems, both marine and terrestrial, to changes in global and regional environmental conditions and of the influence of biological communities on the atmospheric, terrestrial, oceanic, and climatic systems.

- *Earth System History*. Includes the study and interpretation of the natural records of past environmental change that are contained in terrestrial and marine sediments, soils, glaciers and permafrost, tree rings, rocks, geomorphic features, and other direct or proxy documentation of past global conditions.

- *Human Interactions*. Includes the study of (i) the social factors that influence the global environment, including population growth, industrialization, agricultural practices, and other land usages; and (ii) the human activities that are impacted by regional aspects of global change.

- *Solid Earth Processes*. Includes the study of geological processes (e.g., volcanic eruptions and erosion) that affect the global environment, especially those processes that take place at the interfaces between the Earth's surface and the atmosphere, hydrosphere, cryosphere, and biosphere.

- *Solar Influences*. Includes the study of how changes in the near-space and the upper atmosphere that are induced by variability in solar output influence the Earth's environment.

The success of the U.S. Global Change Research Program requires progress in all seven scientific elements, as well as the development of data management/information systems to facilitate reduction and analysis of integrated data sets.

Coordination Mechanisms. The planning for and implementation of a broad and comprehensive global change research program will require collaboration and program coordination among many institutions and agencies; these can be broadly grouped into three "communities" that are involved with the science of global change:

- *National and international scientific community*. Including both structured (NAS, ICSU) and informal mechanisms (scientist to scientist) for planning science activities.

- *Government agencies*. Including individual agencies of governments (U.S. and foreign) that support and conduct global change scientific research and the coordinating bodies for these agencies within governments (e.g., CES).

- *Intergovernmental science bodies*. Including the multinational bodies, such as the WMO, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and the United Nations Environment Program (UNEP).

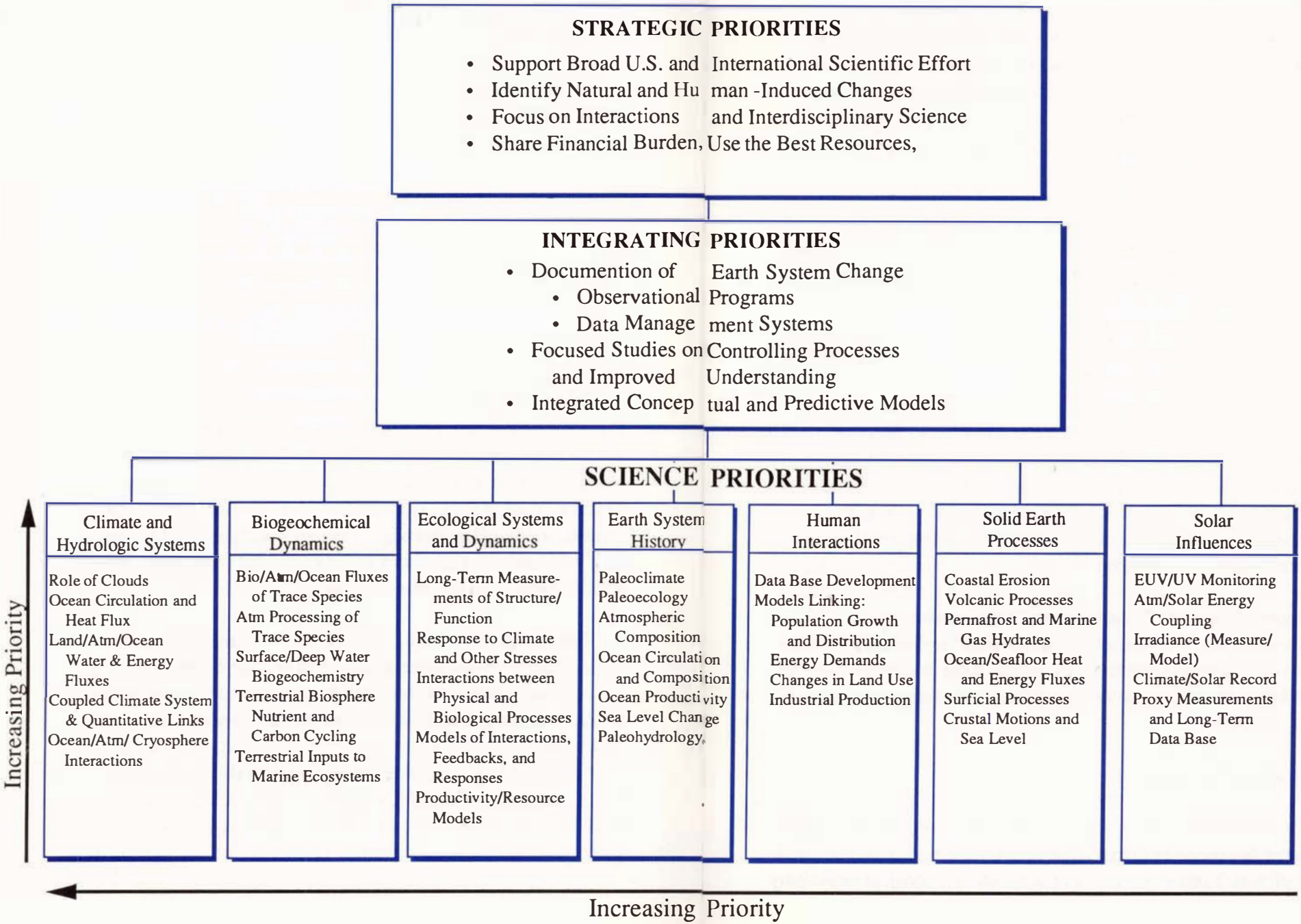
No one Federal agency encompasses the breadth required by the U.S. Global Change Research Program. An effective confederation is required to support and conduct the needed activities, as outlined in the CES Charter (Appendix). Moreover, the complexity and scope of the research required underscores the advantages of an effective interface with coordinating bodies, including the National Academy of Sciences. Furthermore, since such national, and analogous international, interactions are far from being spontaneous or automatic processes, it is of paramount importance to establish and maintain these coordinating mechanisms.

Priority Framework for the U.S. Global Change Research Program

The CES has developed a multi-level priority-setting framework that can be used to focus and integrate program development and budget proposals. In order to address the Program goal of establishing the scientific basis for sound policy formulation, CES has identified several high priority research activities for each of the seven science elements. These represent the current understanding of the most serious intellectual hurdles limiting (i) the knowledge of the controlling processes of global change, and (ii) the capacity to develop comprehensive predictive capabilities.

For any given funding level, the mix of activities both within and between science elements will be determined through an iterative process involving many different participants, including the CES, the National Academy of Sciences, and others. It is likely and expected that these priorities will change as scientific understanding and capabilities evolve. Figure 1 lists the Program's strategic, integrating, and science priorities that are included in the priority framework.

Figure 1
U.S. Global Change Research Program Priority Framework



Strategic Priorities

The major purposes for establishing strategic priorities are to provide an overall framework to help determine the key elements of the U.S. Global Change Research Program, to keep the focus on the most central goals and objectives of the Program, and to compare budget decisions against broad strategic guidelines. The following research program characteristics are deemed to be of high strategic importance:

- *Supports Broad U.S. and International Scientific Effort.* Supports a broad U.S. and international effort to improve the scientific basis needed to address the environmental, societal, and economic challenges related to global change.

- *Identifies Natural and Human-Induced Changes.* Distinguishes natural changes from industrial, social, and other forms of human-induced changes.

- *Focuses on Interactions and Interdisciplinary Science.* Advances the scientific understanding of global change processes through a fundamental research program that focuses on the interactions among physical, geological, chemical, biological, and social processes and emphasizes interdisciplinary science.

- *Shares Financial Burden, Uses Best Resources, and Encourages Full Participation.* Shares the financial burden nationally and internationally, utilizes the best physical and intellectual resources, and encourages the full participation of all nations.

Integrating Priorities

As stated above, the U.S. Global Change Research Program has three parallel and interrelated scientific objectives, one or more of which must be served by any research project or activity

of the Program. These scientific objectives also serve as the following integrating priorities:

- *Establish an integrated, comprehensive long-term program of documenting the Earth system on a global scale through:*
  - *Observational programs*
  - *Data management systems.*

- *Conduct a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales.*

- *Develop integrated conceptual and predictive Earth system models.*

Science Priorities

The science priorities are drawn from numerous sources, including (i) the extensive CES analysis of the current weaknesses in the understanding of global change and what research is needed to address these weaknesses; (ii) the 1988 NAS report entitled *Towards an Understanding of Global Change*; (iii) the 1984 WMO and ICSU report entitled *Scientific Plan for the World Climate Research Programme*; (iv) the 1988 Earth System Sciences Committee (National Aeronautics and Space Administration [NASA] Advisory Committee) report entitled *Earth System Science: A Closer View*; and (v) the 1988 ICSU report entitled *The International Geosphere-Biosphere Programme: A Study of Global Change — A Plan for Action.*

The science priorities are shown schematically in the lower part of Figure 1. The science elements are listed from left to right in descending order of priority. Within each of the seven science elements, the research activities are listed in descending order of priority. These priorities are designed to ensure

that the Program makes rapid progress toward resolving the most significant uncertainties with a given level of support. The CES recognizes that some level of effort is necessary in all the scientific activities to achieve the ultimate goal of reliably modeling the Earth system.

Although the priorities are ordered along each axis of the matrix, the importance of neighboring science elements is similar and virtually interchangeable. In many instances, the research activities shown in the matrix are complementary; hence funding one scientific activity may influence the priority of others, leading to lower priority activities being funded.

These science priorities include:

Climate and Hydrologic Systems. Studies need to be conducted to improve the understanding of (i) the role of clouds in the radiation budget of the atmosphere; (ii) oceanic circulation patterns and the redistribution of energy within the oceans; (iii) the fluxes of water and energy between the atmosphere, biosphere, and land and ocean surfaces; (iv) the quantitative links in the climate system, including feedbacks among atmosphere, ocean, cryosphere, land surface and biosphere; and (v) the influence of polar ice sheets and sea ice on climate and the hydrologic cycle.

Biogeochemical Dynamics. Studies must be conducted to improve the understanding of (i) the fluxes of radiatively and chemically active species between the atmosphere, biosphere, and land and ocean surfaces; (ii) the atmospheric cycling and transformations of radiatively and chemically important trace species; (iii) the biogeochemical processes responsible for the exchange of carbon and nutrients between the surface, deep ocean waters, and sediments; (iv) the cycling and transformation within the terrestrial biosphere of nutrients and carbon; and (v) the terrestrial flux of nutrients and carbon to coastal waters and oceanic ecosystems.

Ecological Systems and Dynamics. Research is required on (i) the structure and function of biological systems on various time scales; (ii) the response of species, ecological communities, and natural and managed ecosystems to carbon dioxide, climate, and physical/chemical stresses; (iii) the interactions between physical and biological processes on varying time and space scales; (iv) modeling ecology and physical climate interactions; and (v) modeling biological productivity of natural and managed ecosystems.

Earth System History. Research needs to be conducted to reconstruct the Earth's past climates and environments on both regional and global scales from evidence preserved in the geologic record, including past (i) natural variability of climate on all time scales, (ii) responses of ecosystems to climate change, (iii) changes in the composition of the Earth's atmosphere, (iv) changes in oceanic circulation and composition, (v) changes in oceanic productivity, (vi) changes in sea level, and (vii) changes in surface water and ground water in response to climate change.

Human Interactions. Research on human interactions in global change must be conducted to (i) establish long-term, comparable, cross-national data bases that encompass human activities such as land-use practices, energy transformations, legal and regulatory requirements, and economic behavior; and (ii) develop models linking population growth and distribution, energy demands, changes in land use, and industrial production.

Solid Earth Processes. Research is required to improve knowledge of (i) coastal erosion and wetland loss caused by sea level changes; (ii) the role of subaerial and submarine volcanism in contributing radiatively important gases, aerosols, heat, and fluids to the atmosphere and the ocean; (iii) how changes in the areal extent of permafrost will alter the quantity of radiatively important gases released to the atmosphere; (iv) the role of mid-ocean ridge systems in releasing heat, volatiles, fluids, and

particulates into the ocean and how these may influence ocean circulation, chemistry, and the carbon dioxide budget; (v) the erosional, transport, and depositional processes on the Earth's surface; and (vi) the Earth's crust and its deformation, both past and present, to establish local versus global absolute sea level change.

Solar Influences. Studies are required to (i) obtain long-term records of solar ultraviolet output; (ii) improve the understanding of the coupling of energy between atmospheric regions, from the thermosphere to the troposphere; (iii) obtain a long-term record of total and spectral solar irradiance; (iv) model climate response to solar inputs and variability; and (v) develop new measurement techniques to determine solar output.

The need for effective data management will be common to all of these science element activities. The studies need to provide these common resources: (i) the management of global-scale, long-term data from observation systems; (ii) the organization of data sets to improve the understanding of global change processes; and (iii) the analyses and preparation of data sets for the development and validation of predictive global change models.

Evaluation Criteria

Within the priority framework, the CES will implement the Program on the basis of the following criteria:

- *Relevance/Contribution.* The research addresses the overall goal and the three key scientific objectives of the Program.

- *Scientific Merit.* The proposed work is scientifically sound and of high priority.

- *Readiness*. The level of planning is high, the capabilities are of high quality and in place, and the research is likely to produce early advances.

- *Linkages*. National and international programmatic connections, including interagency partnerships, are in place.

- *Costs*. The identified resources are adequate, they represent an appropriate share of total available resources, there are prospects for joint funding, and long-term resource implications have been evaluated.

FY 1989-1990 U.S. Global Change Research Program Budget

FY 1989-1990 Budget Summary. Over the past year, the CES conducted several interagency global change research budget planning and analysis activities to ensure that the President's FY 1990 Budget includes requests that are well integrated and responsive to the Program's goals and priorities.

Table 1 presents the FY 1989-1990 Program budget. 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 $191.5 million for this Program. This budget will allow the focused Program to expand and accelerate its research activities across most areas of global change. As a result of subsequent CES discussions, the levels of effort between science elements have changed slightly since the original strategy document.

FY 1990 Initiatives. Based on the priority framework, the Program has identified several new initiatives for FY 1990. The majority (approximately 76 percent) of the resources allocated to FY 1990 initiatives have been directed toward scientific activities within the three higher priority interdisciplinary science elements: Climate and Hydrologic Systems, Biogeochemical Dynamics, and Ecological Systems and Dynamics. These new initiatives include new programs and augmentations to ongoing efforts. In most cases, the research initiatives contain significant elements of all three scientific objectives, i.e., monitoring, understanding, and predicting global change, and are components of coordinated national and/or international programs.

The fact that the FY 1990 initiatives cut across many of the seven science elements and three scientific objectives demonstrates the interdisciplinary and multi-objective nature of the Program. However, this also makes it very difficult to display

the individual agency programmatic contributions. Some examples of these agency initiatives will be presented here along with the budget by science element, by agency, and by Federal Budget Function. The reader is referred to the Research Plan for a thorough listing of the FY 1990 initiatives. The following brief section analyzes the characteristics of some examples of the FY 1990 initiatives:

The Department of Commerce/National Oceanic and Atmospheric Administration (NOAA) Radiatively Important Trace Species initiative focuses on Biogeochemical Dynamics, is a single agency program that contains elements of all three science objectives, complements other ongoing U.S. agency programs (primarily in NASA and NSF), and is part of the high priority research outlined in the ICSU International Global Atmospheric Chemistry Programme.

The NSF and DOE Global Ocean Flux Study initiatives focus on Biogeochemical Dynamics, contain elements in all three science objectives, and are key components of a well-coordinated national (NSF, DOE, NASA, NOAA) and international program.

The proposed NASA Earth Observing System is a broad-based program that contains elements in all three science objectives and will contribute to an improved understanding of five of the seven scientific elements. The Program includes advanced technology definition studies for this future initiative. A significant international contribution has been negotiated through a series of bilateral agreements with the European Space Agency and other nations having major space programs.

Table 1

U.S. GLOBAL CHANGE RESEARCH BUDGET FOR FISCAL YEARS 1989 AND 1990
(Dollar in Millions)

AGENCY	TOTAL BUDGET		CLIMATE AND HYDROLOGIC SYSTEMS		BIOGEOCHEMICAL DYNAMICS		ECOL SYSTE DYNA	OGICAL MS & MICS	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	191.5	37.0	60.2	26.1	38.6	32.5	46.9	3.3	8.0	22.0	20.1	8.9	10.4	4.1	7.3
DOC/NOAA	9.0	20.0	8.5	16.5	0.5	3.5	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	12.0	6.0	5.5	4.2	7.3	0.0	0.0	2.0	1.2	0.0	0.0	1.0	1.2
DOI *	5.3	11.3	1.8	4.6	0.2	0.3	0.0	0.0	1.3	3.3	1.5	2.5	0.5	0.6	0.0	0.0
EPA	27.4	35.3	0.7	2.2	0.8	3.5	7.4	13.2	0.0	0.0	18.5	16.4	0.0	0.0	0.0	0.0
NASA	14.5	21.5	4.3	6.4	3.0	4.4	4.3	6.4	0.0	0.0	0.0	0.0	2.2	3.3	0.7	1.0
NSF	39.2	53.5	13.2	17.0	13.5	18.3	1.9	1.9	2.0	4.7	0.0	0.0	6.2	6.5	2.4	5.1
USDA	18.3	22.7	1.5	1.5	2.1	3.1	14.7	18.1	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.

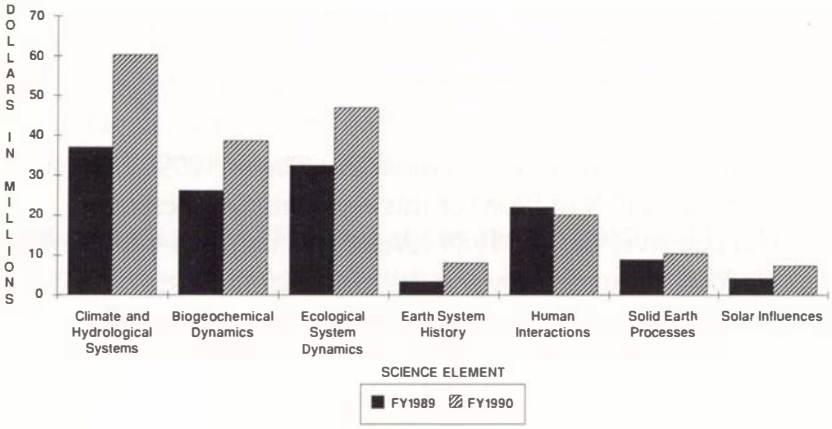
The Tropical Oceans and Global Atmosphere (TOGA) program addresses all three scientific objectives of the U.S. Global Change Research Program. It addresses an important problem in climate prediction, incorporating large-scale observations, intensive process research, and work on predictive models. In the U.S., TOGA involves formally coordinated work by four agencies (NOAA, NSF, NASA, and the Department of Defense [DOD]) advised by a panel from the NAS. Internationally, as part of the World Climate Research Programme (WCRP), 16 nations are cooperating through an intergovernmental board formally established for TOGA implementation. Several important bilateral relationships, which involve the U.S., have also been established to support TOGA.

The DOE Carbon Dioxide Program will initiate focused research on the problem of early detection of global climate change. This initiative seeks to identify the atmospheric and other measurements that appear promising in providing the early warming signals and to develop the analytical methodologies for quantifying the links between the "greenhouse" gas increases and climate change. The initiative spans the first two science elements and will examine the cause and effect relationships involved in global warming.

The National Ozone Expedition is an interagency program (NASA, NOAA, NSF) designed to obtain an improved understanding of the seasonal stratospheric ozone depletion over Antarctica and the biological significance of the resultant changes in ultraviolet radiation reaching the surface of this region of the Earth. Increased monitoring of solar ultraviolet fluxes in Antarctica will be initiated by NSF to help meet the program's objectives.

Budget by Science Element. From the scientific perspective, the best way to understand the Program budget is to examine it by science element. Figure 2 presents the FY 1989 and FY 1990 budgets by science element for focused research efforts.

Figure 2
U.S. Global Change Research Program
Budget by Science Element



- *Climate and Hydrologic Systems.* The FY 1990 budget proposes $60.2 million for this element, a 63 percent increase over the FY 1989 level. This increase will primarily focus on monitoring, understanding, and predicting aspects of (i) ocean circulation through tracer experiments (NOAA and NSF); (ii) interactions between the tropical oceans and the global atmosphere (NSF); (iii) sea level (NOAA); (iv) the exchange of energy and water between the atmosphere and terrestrial ecosystems and the cryosphere (NSF, Department of the Interior/United States Geological Survey [USGS], and NOAA); (v) the quantitative links between radiative and climate change (DOE), and advanced space remote-sensing technology (NASA).

- *Biogeochemical Dynamics*. The FY 1990 budget proposes $38.6 million for this element, a 48 percent increase over the FY 1989 level. This increase will primarily focus on monitoring, understanding, and predicting aspects of (i) the fluxes of radiatively important trace gases between the atmosphere and the oceans and terrestrial ecosystems (NSF, NOAA, EPA, USDA); (ii) fluxes of nutrients and carbon within the oceans (NSF, DOE); (iii) transformations, distributions and trends of trace species within the upper and lower atmosphere (NOAA, NSF), and development of advanced space remote-sensing technology (NASA).

- *Ecological Systems and Dynamics*. The FY 1990 budget proposes $46.9 million for this element, a 44 percent increase over the FY 1989 level. This increase will primarily focus on understanding the response of managed and unmanaged ecosystems to changes in climate, carbon dioxide, ultraviolet radiation and other stress factors (USDA, EPA, DOE); and development of advanced space remote-sensing technology (NASA).

- *Earth System History*. The FY 1990 budget proposed $8.0 million for this element, more than doubling the FY 1989 level. This increase will focus on an improved reconstruction of certain aspects of the Earth's climates and environments (USGS, NSF).

- *Human Interactions*. The FY 1990 budget proposed $20.1 million for this element. While the budget table indicates no new FY 1990 resources for Human Interactions, NSF and USGS will augment efforts in this area through a reprogramming of existing funds in FY 1990.

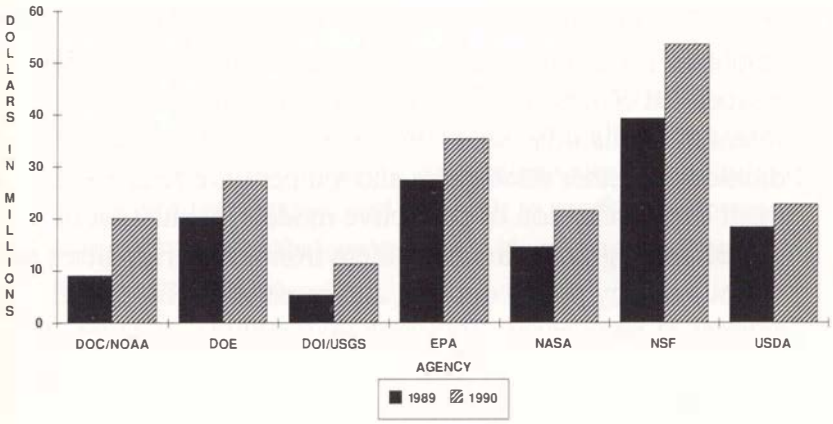
- *Solid Earth Processes*. The FY 1990 budget proposes $10.4 million for this element, a 17 percent increase over the FY 1989 level. This increase will primarily focus on

observations and understanding of crustal motions and dynamics (NSF), and developing advanced space remote-sensing technology (NASA).

- *Solar Influences.* The FY 1990 budget proposes $7.3 million for this element, a 78 percent increase over the FY 1989 level. This increase will primarily focus on monitoring solar ultraviolet fluxes in Antarctica (NSF), understanding and predicting the solar driven energetics and dynamics of atmospheric regions (NSF, DOE), and developing advanced space remote-sensing technology for monitoring and understanding the influences of solar processes on the Earth's environment (NASA).

Budget by Agency. Figure 3 shows the FY 1989 and FY 1990 proposed focused program budgets by agency. The individual agency efforts reflect their particular mission and build upon their respective scientific and technical strengths.

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



- *Department of Commerce/National Oceanic and Atmospheric Administration (DOC/NOAA).* The FY 1990 budget proposes $20.0 million for DOC/NOAA, roughly doubling the FY 1989 level. NOAA maintains a balanced program of observations, analytical studies, climate prediction and information management in the national global change program. NOAA will be responsible for: operational *in situ* and satellite observations and monitoring programs; mission-directed research on physical and biogeochemical processes in the climate system (including their effect on marine ecosystems and resources); development, testing, and application of models and diagnostic techniques for the detection and prediction of natural and human-induced climatic changes; and the acquisition, maintenance, and distribution of long-term data bases and related climate information.

- *Department of Energy (DOE).* The FY 1990 budget proposes $27.2 million for DOE, a 35 percent increase over the FY 1989 level. DOE shall conduct research on carbon dioxide and other emissions from energy supply and end use systems. The research shall include the climate's response to those emissions and shall develop the base of scientific information necessary to assess the climate's response, assuming various energy and industrial policies. Associated efforts may include, but not be limited to, research to quantify the relationships between carbon dioxide and other trace gases and temperature rise, assessment and application of predictive models, evaluation of global and regional climate and environmental responses to various energy policy options, and research on industrial sources of trace gases. Research may include all causes of climate change and how possible responses to change could affect energy options.

- *Department of the Interior/United States Geological Survey (DOI/USGS).* The FY 1990 budget proposes $11.3 million for DOI/USGS, roughly doubling the FY 1989 level. DOI/USGS program efforts address the collection, maintenance, analysis, and interpretation of short- and long-term land, water, biological, and other natural resource data and information. Such efforts include, but are not limited to, monitoring of hydrologic and geologic processes and resources, land use, land cover, and biological habitats, resources, and diversity. Some DOI research areas include: past global change recorded in the physical, chemical, and biological record; the hydrologic cycle; land-surface and solid Earth processes that relate to environmental change; geography and cartography; polar and arid region processes; ecosystem modeling and dynamics; and resource ethnology. The Department utilizes knowledge developed in these and other agencies' programs to evaluate and when necessary respond to potential effects of global change on water, land, biological, and other natural resources.

- *Environmental Protection Agency (EPA).* The FY 1990 budget proposes $35.3 million for EPA, a 29 percent increase over the FY 1989 level. EPA conducts research to assess, evaluate, and predict the ecological, environmental, and human-health consequences of global change, including the feedbacks of these systems on climate change. Additional areas of activity include research to determine emission factors, and inventories for radiatively important trace gases, and research to predict the interactions between global atmospheric change and regional air and water quality.

- *National Aeronautics and Space Administration (NASA).* The FY 1990 budget proposes $21.5 million for NASA, a 48 percent increase over the FY 1989 level. NASA is responsible for Earth science research from space, including those studies of broad scientific scope that study the planet as an integrated whole. Associated efforts include related process studies; sub-orbital and ground-based studies; remote-sensing and advanced instrument development; improvement of techniques for the transmission, processing, archiving, retrieval, and use of data; related scientific models; and other research activities in atmospheric, oceanographic, and land sciences.

- *National Science Foundation (NSF).* The FY 1990 budget proposes $53.5 million for NSF, a 36 percent increase over the FY 1989 level. NSF is responsible for maintaining the health of basic research in all areas of Earth, atmospheric (including solar-terrestrial), and ocean sciences, including the relevant biological and social sciences and research in the polar regions. The basic research program is focused on ground-based studies on regional and global scales; large-scale field programs; interpretation and use of remotely-sensed data and geographic information systems; theoretical and laboratory research; research facilities support; and the development of numerical models, information and communication systems, and data bases.

- *Department of Agriculture (USDA).* The FY 1990 budget proposes $22.7 million for USDA, a 24 percent increase over the FY 1989 level. USDA conducts research to assess the effects of global change on the agricultural food and fiber production systems and on forests and forest ecosystems of the United States and worldwide, including, but not limited to, basic research on the biological response mechanisms to increasing "greenhouse" gases; improvement of plant and animal germ plasm to respond to global change;

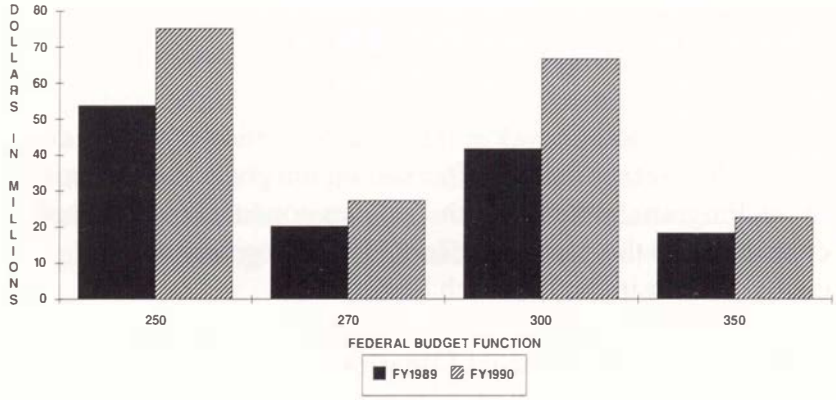
and development and implementation of plans for terrestrial mitigation systems to ameliorate the observed increases of greenhouse gases, including crops and forests. An additional responsibility shall include research on applications of agricultural climatology to improve management decisions and conservation of resources, while maintaining quality and quantity of crop yields.

The DOD and Department of Transportation currently do not conduct research that is focused on the goals and objectives of the Program, although both agencies conduct research that contributes to this research effort. These programs are discussed further in the Research Plan.

Budget by Federal Budget Function. Scientific, environmental, energy, and agricultural resources are very important to the nation. All either impact or are impacted by global change.

Figure 4 and Table 2 illustrate the Program's focused funding levels by the Federal budget functions that encompass these national resources. As would be expected, the budget proposes significant increases for budget functions 250 (General Science, Space and Technology) and 300 (Natural Resources and Environment). In FY 1990, $75 million is proposed for function 250, a 40 percent increase over FY 1989. For function 300, $66.6 million is proposed for FY 1990, a 60 percent increase over FY 1989.

Figure 4
U.S. Global Change Research Program by Federal Budget Function



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 depends 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

U.S. GLOBAL CHANGE RESEARCH PROGRAM BUDGET
by Federal Budget Function for Fiscal Years 1989 and 1990
(Dollars in Millions)

Budget Function	Budget Function Number	1989	1990
Total		133.9	191.5
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	66.6
DOI/USGS		5.3	11.3
EPA		27.4	35.3
DOC/NOAA		9.0	20.0
Agriculture (USDA)	350	18.3	22.7

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

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 the basic research, important components of Earth science R&D include continued development of the technology for needed observations of the Earth system and increased emphasis on collection, analysis and archival of data on a global scale from satellite and ground-based measurements needed for long-term research efforts and also needed to address 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 humankind's impact on the global environment;
g. develops the Administration's response to the call 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 form 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
National Science Foundation
Environmental Protection Agency
National Aeronautics and Space Administration
Office of Science and Technology Policy
Office of Management 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 from 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

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).

The U.S. Global Change Research Program