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U.S. RESPONSE TO CONFERENCE QUESTIONNAIRE

DRAFT AS OF APRIL 10, 1990

**THEME 1: UNCERTAIN CHANGE: THE SCIENTIFIC AND ECONOMICS
RESEARCH CHALLENGE**

- 1.1 WHAT SCIENTIFIC RESEARCH RELATED TO GLOBAL CHANGE IS BEING CONDUCTED OR IS NOW PLANNED IN YOUR COUNTRY? PLEASE PROVIDE A BREAKDOWN OF THIS WORK INTO THE FOLLOWING CATEGORIES:
- 1.1a GLOBAL/REGIONAL FORECASTS OF HUMAN ACTIVITIES LEADING TO POSSIBLE GLOBAL CHANGE;
 - 1.1b GLOBAL/REGIONAL MODELS OF GEOPHYSICAL GLOBAL CHANGE PROCESSES;
 - 1.1c SOCIAL AND ECONOMIC IMPACT OF POSSIBLE GLOBAL CHANGE WITH OR WITHOUT ADAPTIVE STRATEGIES; AND
 - 1.1d SOCIAL AND ECONOMIC CONSEQUENCES OF SPECIFIC ACTIONS THAT MIGHT BE TAKEN TO ARREST POSSIBLE GLOBAL CHANGE.

RESPONSE:

U.S. Government agencies, in concert with the national and international scientific community, have a long history of conducting research into the nature and impacts (including socioeconomic impacts) of environmental change on global, regional and local scales including work to: (i) understand and, where necessary, mitigate changes in air and water quality; (ii) conserve natural resources (including fish, wildlife, forests, and agriculture); (iii) identify and protect unique ecosystems and endangered species; (iv) understand and predict climate change and respond to its regional implications; (v) distinguish between natural variability in the Earth system and the influence of human-induced change, and (vi) assess the value and effectiveness of various mitigation and adaptation technologies and practices (e.g., trace gas emission controls). The principal U.S. agencies engaged in this work include: the Department of Commerce (particularly through its National Oceanic and Atmospheric Administration), the Departments of Agriculture, Energy and Interior, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation. Each of these agencies conduct these scientific activities to support their individual missions and

contribute to a better understanding of the global environment and how human activities may be affecting the Earth system upon which we rely not only for natural resources but for life itself.

Over the past several years, the U.S. Government identified the need to focus the work of these several agencies, in concert with the broad national and international scientific community, into a more integrated program designed to anticipate and respond to the significant economic, social and natural resource implications raised by our increased understanding of current and potential large-scale changes in the global environment (e.g., stratospheric ozone depletion, global climate change, deforestation, and loss of biodiversity). The primary focus of global change science in the United States is now the U.S. Global Change Research Program (USGCRP) which was initiated to improve our understanding of the global Earth system, reduce major scientific uncertainties and ensure a long-term national commitment to continually re-evaluate the effectiveness of policy in the light of new scientific insights and socioeconomic impacts. A brief summary of the history, goal and scientific objectives of the U.S. Global Change Research Program is included as Attachment A. In addition, Attachment B to this Questionnaire provides an annotated bibliography of selected major global change science and economics research studies in the United States.

1.1b GLOBAL/REGIONAL MODELS OF GEOPHYSICAL CHANGE PROCESSES

The U.S. Global Change Research Program, like similar program in other countries, will significantly expand Earth system research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. It includes a carefully-balanced mix of ground- and space-based research efforts that are essential given the variability of the phenomena being studied and the need to scale local processes to regional and global levels. Concerning ground-based activities, the Program will support government-wide (i.e., multi-agency) research thrusts in several critical areas, including the role of clouds in controlling climate, fluxes of greenhouse gases, resource responses to global change, past changes in the Earth system, and the role of human activities in global change. The space-based component of the Program will initiate the development of the NASA Earth Observing System (EOS), a key element in a "Mission to Planet Earth," which will

provide the centerpiece of an integrated international satellite program for monitoring global change, coupled with a comprehensive data and information system.

The USGCRP is designed around seven science elements which characterize the breadth of scientific investigations required to develop a capability to anticipate, assess, and address the issues associated with global environmental change: Climate and Hydrologic Systems; Biogeochemical Dynamics; Ecological Systems and Dynamics; Earth System History; Human Interactions; Solid Earth Processes; and Solar Influences. Within each of these science elements, the USGCRP is designed to provide for a balanced program of documenting, understanding and predicting change. In some cases, projects are designed to provide near-term results by focusing an aggressive, limited duration scientific attack on some key aspect of the Earth system (e.g., stratospheric ozone depletion). In other cases, projects are designed as part of a long-term commitment to the documentation of Earth system changes on a global scale (e.g., the satellite-based Earth Observing System).

With an ultimate focus on the provision of policy-relevant information about the current and anticipated state of the global environment, the USGCRP supports three scientific priorities:

- Establish an integrated, comprehensive program of documenting the earth system on a global scale through observational programs and 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; and
- Develop integrated conceptual and predictive earth system models.

- 1.1a GLOBAL/REGIONAL FORECASTS OF HUMAN ACTIVITIES LEADING TO POSSIBLE GLOBAL CHANGE;
- 1.1c SOCIAL AND ECONOMIC IMPACT OF POSSIBLE GLOBAL CHANGE WITHOUT ADAPTIVE STRATEGIES.

Of particular relevance to the questions raised here, are the research projects planned under the Human Interactions science element. Current and planned activities under this science element recognize that adequate models of the physical and biological processes of change must incorporate an understanding of the relationship between those processes and the human activities that stimulate and mediate changes in the global environment. USGCRP/Human Interactions studies address high-priority observational, research and modelling requirements associated with the following questions:

- What data are needed to verify models of interaction between human (institutions and behavior) and natural systems and to assess the likelihood of changes in those processes?
- How do population dynamics contribute to global environmental change?
- How do institutions influence environmental processes and respond to changes in global environmental conditions?
- How do technological and economic development contribute to global environmental change, and how will changing environmental conditions affect future technological and economic development? and
- How do changing patterns in the use of land, water, energy resources and other natural resources affect global environmental change?

In all cases, these research activities are driven by the need to establish a sound empirical basis upon which to ultimately assess the feasibility and likely results of various policies options.

1.1c SOCIAL AND ECONOMIC IMPACT OF POSSIBLE GLOBAL CHANGE WITH ADAPTIVE STRATEGIES;

1.1d SOCIAL AND ECONOMIC CONSEQUENCES OF ACTIONS THAT MIGHT BE TAKEN TO ARREST POSSIBLE GLOBAL CHANGE.

In addition to the fundamental science program embodied in the USGCRP, major studies of mitigation and adaptation policies are underway throughout the U.S. Federal Government (e.g., in the Departments of Agriculture, Energy and Interior, the Environmental Protection Agency, and the Office of Technology Assessment of the U.S. Congress) and in the private and non-profit sectors (e.g., Electric Power Research Institute, Harvard University, Massachusetts Institute of Technology, and Stanford University). Some of the issues addressed by these studies include:

- Determining the economic obligations and responsibilities to future generations and how to allocate costs for reduction in the rate of global environmental change;
- Global analysis of the potential magnitude and impacts of rising energy costs from global carbon dioxide emissions reductions at various levels; and
- Assessing options for mitigating or reducing tropical deforestation (including methods for sustainable agriculture and other alternatives).
- The role of agricultural practices and techniques in both mitigating and adapting to possible climate change.

Most of the work in this area has focused on possible climate change and in many cases, these and similar studies contribute directly to the deliberations of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change (IPCC). Some specific examples of this work are briefly described below.

The Adaptive Strategies Program of the U. S. Environmental Protection Agency (EPA) is designed to identify resource impacts on both domestic and, where possible, international levels and to examine policy options to mitigate domestic impacts.

The Program builds on the recent EPA Report to Congress entitled POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE IN THE UNITED STATES. The Adaptive Strategies Program sponsors domestic and international studies to examine the social and economic impacts of climate change on agriculture, water resources, coastal resources, forests, biodiversity, fisheries, infrastructure, and human health. Through this program, the implications of possible global warming will be assessed as well as the effectiveness of policy alternatives, such as anticipatory actions to adapt to climate change. The U.S. EPA hopes that these studies will more clearly define national vulnerabilities and provide for the exploration of adaptive strategies with natural resource managers, states and local governments.

The global climate change program in the U.S. Department of Agriculture explores agriculture's role in reducing negative impacts of current technology and production systems, expanding the role of agriculture and forestry in reducing greenhouse gases, and developing stress-resistant crops and livestock to adapt to possible climate changes. Examples include research to reduce methane production from rice paddies and livestock and nitrogen dioxide from crop production by optimizing the use of nitrogen fertilizers. Studies are investigating the use of agriculture and forestry as important sources of carbon-based chemicals, essentially recycling carbon dioxide through photosynthesis as an alternative to fossil fuel sources. Efforts to increase crop and livestock tolerance to environmental stress, such as temperature extremes and drought for example, are being conducted to help the agricultural sector adapt if there are major shifts in climate.

An annotated bibliography of selected major global change studies in the United States, including those addressing the socioeconomic aspects of mitigation and/or adaptation to possible changes in the global environment (particularly climate change) is provided in Attachment B to this Questionnaire.

The U.S. Government has recently taken steps to more carefully design and implement a mitigation and adaptation research strategies program to complement the fundamental science program outlined in the U.S. Global Change Research Program. Additional details on this effort are provided in the response to questions under Theme II -- Integrating Scientific and Economics Research Into the Policy Process.

- 1.2 WHAT POTENTIAL CONFLICTS, IF ANY, BETWEEN YOUR INTEREST IN CONTINUED ECONOMIC PROGRESS AND YOUR INTEREST IN ARRESTING POSSIBLE UNDESIRABLE GLOBAL CHANGE HAVE BEEN IDENTIFIED BY YOUR EXISTING RESEARCH? WHAT SCIENTIFIC AND ECONOMICS RESEARCH IS MOST CRITICAL TO IMPROVING OUR UNDERSTANDING OF RELEVANT TRADEOFFS AND POSSIBLY IMPROVING THE TRADEOFFS THEMSELVES?

RESPONSE:

The United States continues to support a decision-making approach which ensures that environmental considerations are factored into economic development decisions at the earliest possible stage. We believe that sound policy must be justified on the basis of a strong scientific understanding not only of physical and biological processes affected by a proposed action but also the social, economic and environmental consequences of action or inaction; new scientific insights will enable us to more effectively consider the environmental impacts of proposed actions. For example, wildlife researchers in the United States have highlighted the need to consider the effect on species diversity of filling wetlands for agriculture, road construction, housing and industrial development. The degree to which we are successful in identifying and addressing specific environmental considerations associated with potential large-scale changes in the global environment, depends in large part on the level of understanding and certainty associated with the local and regional effects of an anticipated change. In the case of possible global warming due to greenhouse gases, for example, the limitations of our understanding of the timing, nature and magnitude of an integrated Earth system response to increased radiative forcing in the atmosphere constrains the potential effectiveness of policy decisions chosen today. The United States is committed to joining with our international colleagues to reduce these uncertainties and continually re-evaluate the effectiveness of policy in light of new scientific and socioeconomic insights.

The United States believes that uncertainties associated with the timing and magnitude of possible global change mean that policies will vary in their appeal as uncertainties are reduced; an appropriate strategy to address possible global change

based on today's knowledge and in light of today's economic environment may be wholly inappropriate within a decade. The United States encourages economics research which focuses on evaluating the benefits and costs of policies under a broad range of outcomes that reflect the scientific (and related economic) uncertainties of possible global change.

The United States believes that an effective response to potential environmental changes requires the consideration of market mechanisms, including: (i) the development of thorough cost-benefit analyses of possible response options and (ii) the important role of the private sector in the development of new practices and technologies to reduce sources or enhance sinks of greenhouse gases and adapt to possible global environmental changes. Environmental policy in the United States can often be more effective and economically efficient by harnessing market mechanisms, such as by offering incentives to the private sector, than by mandating the use of specific techniques or technologies Government chooses.

Two particular areas of study within the U.S. Global Change Research Program address the scientific and economic aspects of relevant tradeoffs:

- How do institutions influence environmental processes and respond to changes in global environmental conditions?
- How do technological and economic development influence global environmental change, and how will changing environmental conditions affect future technological and economic development?

The United States believes that, perhaps, the most important characteristic of an effective global change research effort is the commitment to continually re-evaluate policy decisions in the light of new scientific insights.

1.3 WHAT IS YOUR GOVERNMENT'S CURRENT AND PROJECTED BUDGET FOR SCIENTIFIC AND ECONOMICS RESEARCH RELEVANT TO GLOBAL CHANGE ISSUES? HOW ARE YOUR RESEARCH EFFORTS COORDINATED ACROSS AGENCIES AND DEPARTMENTS WITHIN YOUR GOVERNMENT?

RESPONSE:

The President's fiscal year (October 1, 1990 through September 30, 1990) 1991 budget proposes to spend \$1.034 billion for global change research by Federal agencies under the U.S. Global Change Research Program (USGCRP). This represents a 57% increase over the current funding level of \$659.3 million for the U.S. Global Change Research Program. In addition, the participating U.S. Federal agencies are expected to continue to support related scientific efforts that contribute indirectly to the goal and objectives of the USGCRP at approximately \$440 million in fiscal year 1991.

The USGCRP is coordinated at the highest levels of government through the interagency Committee on Earth Sciences (CES) which reports directly to the President's Science Advisor. The CES was formed in April 1987 to:

INCREASE THE OVERALL EFFECTIVENESS AND PRODUCTIVITY OF FEDERAL R&D EFFORTS DIRECTED TOWARD UNDERSTANDING OF THE EARTH AS A GLOBAL SYSTEM.

Additional details on the history, membership and activities of the Committee on Earth Sciences with respect to the USGCRP are provided in Attachment A. The coordination of global change research activities by CES is primarily focused in: (i) the Working Group on Global Change which addresses the fundamental science embodied in the USGCRP and (ii) the newly created Working Group on Mitigation and Adaptation Strategies. The CES provides the integrating focus in the United States for scientific input to national and international global change deliberations.

1.4 WHAT IS THE INSTITUTIONAL STRUCTURE FOR CONDUCTING SCIENTIFIC AND ECONOMICS RESEARCH RELEVANT TO GLOBAL CHANGE IN YOUR COUNTRY?

RESPONSE:

U.S. global change research activities are primarily supported through the work of seven Federal government agencies in close collaboration with the academic

scientific community and industry. U.S. Federal agencies and laboratories, universities and private sector research institutions operate in a partnership which allows each to bring their unique talents and capabilities to bear on the scientific challenge associated with documenting, understanding and predicting changes in the global environment and their regional impacts.

The principal Federal funding agencies for global change research are: the Department of Commerce (primarily through its National Oceanic and Atmospheric Administration), the Departments of Agriculture, Energy, and Interior, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation. Investigators at academic institutions across the country, who are funded by these agencies and also by state, industrial, and private organizations, collaborate with their Government counterparts routinely. U.S. Industry is encouraged to bring its expertise to bear on such problems as the development of new practices and technologies to mitigate and/or adapt to potential environmental change.

Additional details on the institutional mechanisms established to coordinate global change research activities in the United States are provided in response to questions under Theme II -- Integrating Scientific and Economics Research in the Policy Process.

1.5 WHAT STUDIES HAVE BEEN CONDUCTED IN YOUR COUNTRY ON METHODS (AND POSSIBLE SOCIAL AND ECONOMIC CONSEQUENCES) OF LIMITING GREENHOUSE GAS EMISSIONS?

RESPONSE:

Several studies have been completed on methods and consequences of limiting greenhouse gas emissions, both within the Federal Government and in the private and non-profit sectors. The Department of Energy (DOE), for example, recently completed a qualitative study of policy options in this area which identified over 160 possible policy measures. These investigations have focussed on methods like: (i) the use of carbon and/or coal taxes as a means to limit emissions; (ii) the shift from fossil fuels to energy that is more environmentally benign; (iii) reforestation; (iv)

improving efficiency standard; (v) deposit refund schemes for carbon dioxide emissions; and (vi) limits of fuel use. An annotated bibliography of selected major global change science and economics research studies is provided in Attachment B.

Effectively limiting the emission of greenhouse gases requires a clear understanding of their sources--both natural and human-induced. Through the U.S. Global Change Research Program, scientists are investigating the sources and sinks of key greenhouse gases including, for example:

- the relative importance of the oceans and terrestrial biosphere as sinks for fossil fuel carbon dioxide and how they change with time; and
- identifying the major sources responsible for current increases in atmospheric nitrous oxide and methane.

1.6 WHAT STUDIES HAVE BEEN CONDUCTED IN YOUR COUNTRY REGARDING THE SOCIAL AND ENVIRONMENTAL CONSEQUENCES OF GLOBAL WARMING THAT MAY OCCUR? HOW SENSITIVE ARE THESE ESTIMATES TO THE ASSUMED RATE OF WARMING AND THE APPLICATION OF ADAPTATION MEASURES?

RESPONSE:

Several studies have examined the social and economic consequences of potential global warming. This work has been supported within the Federal Government, at universities, and in the private and non-profit sector. Completed research has centered on several areas: agriculture, forests, water resources, the implications of a rise in sea level, and human health. The U.S. Environmental Protection Agency recently submitted a report to the U.S. Congress on the potential effect of possible climate change on these resources. Far less research has been completed that examines the social and economic consequences arising from potential effects of global warming on fisheries and biodiversity.

The value of the results of these studies are somewhat limited by the uncertainties associated with the climate models used to project a future climate. Most studies of global warming assume an equivalent doubling of carbon dioxide by the middle of

the next century. Sensitivity of results is very dependent on the rate of warming assumed as well as feedback mechanisms which are difficult to incorporate in models, and which could affect the timing, magnitude and regional nature of any given increase in the concentration of greenhouse gases on observed surface temperature. For example, existing climate simulation models are limited in their ability to adequately represent the role of clouds and ocean circulation in determining the integrated response of the Earth system to atmospheric greenhouse forcing. Further, the spatial resolution of current models limits their ability to accurately predict the regional-scale implications of global climate change.

While several of the studies outline or explore adaptation strategies, the results of the analyses are generally presented as if no adaptation occurs. For example, estimates of changes in agriculture generally do not include factors such as farm management response with existing technology, development of new crop varieties better suited to the new climate and ambient carbon dioxide conditions, irrigation costs and options, and changes in the distribution of agricultural pests and diseases.

An annotated bibliography of selected major U.S. studies related to global change scientific and economics research is provided in Attachment B.

- 1.7 WHAT ARE THE PRESENT SOURCES, BY PERCENTAGE, OF ELECTRICAL ENERGY IN YOUR COUNTRY? WHAT ARE THE PROJECTED SOURCES, AND OVERALL USAGE LEVELS, IN 2000, 2010 AND 2020? WHAT TECHNOLOGIES ARE CURRENTLY UNDER CONSIDERATION OR BEING PLANNED TO INCREASE ENERGY EFFICIENCY IN GENERATION AND UTILIZATION IN YOUR COUNTRY?

RESPONSE:

In 1989, inputs used to generate electricity in the United States were provided by oil (4 percent), natural gas (10 percent), coal (56 percent), nuclear power (20 percent), and hydro/other sources (10 percent). As we move into the next century, we expect oil and natural gas to increase their contribution to electricity generated (to 7 and 15 percent, respectively), while reliance on coal, nuclear, and hydro/other sources may decline slightly.

A variety of new technologies that produce electricity from coal, oil, natural gas, and methane with improved efficiency in the conversion of fossil energy into electrical energy are in various stages of development. Renewable resources, primarily hydropower and wood, provided 8 percent of the nation's energy in 1988. Newer renewable resource technologies, including wind, solar thermal electric, geothermal electric, photovoltaic, and biomass technologies, will make increasing contributions in coming decades.

The future use of nuclear power will be dependent upon many factors, including relative cost, national security considerations, progress in dealing with nuclear waste disposal, continued safe operation of existing nuclear plants, and establishment of a stable and certain licensing process.

Many estimates of conservation potential indicate that new technologies could produce significant savings over expected energy use even by the year 2000. The contributions from new technology to energy efficiency gains are potentially substantial, particularly after 2010. Eventual levels of application, however, depend heavily on fuel prices and the economic lifetimes of capital stock. Because of lower lifetimes, the prospects for near term stock turnover are highest for transportation vehicles, appliances, and some light industrial equipment. Most residential, commercial, industrial, and utility structures and large equipment technologies require much longer time periods to be replaced.

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

- 2.1 WHAT MECHANISMS EXIST IN YOUR COUNTRY FOR PROVIDING ECONOMIC AND SCIENTIFIC INFORMATION CONCERNING GLOBAL CHANGE ISSUES TO DECISION MAKERS?
- 2.2 HOW IS THE SCIENTIFIC AND ECONOMICS INFORMATION CONCERNING GLOBAL CHANGE USED BY DECISION MAKERS IN YOUR COUNTRY TO ADDRESS THE ENVIRONMENTAL RAMIFICATIONS OF ECONOMIC POLICIES AND THE ECONOMIC CONSEQUENCES OF ENVIRONMENTAL POLICIES?

RESPONSE:

Global change science and economics research is conducted by a number of U.S. Federal Government agencies including: the National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), and the U.S. Departments of Agriculture (USDA), Commerce (DOC), Energy (DOE), and the U.S. Interior (DOI).

In fulfilling their individual missions, these Departments and agencies provide scientific and economics research information for policy deliberations within the U.S. Government. In addition, a number of coordination and oversight mechanisms have been established within the Executive Offices of the President to ensure the effective integration into U.S. policy decisions.

In the Executive Branch of the U.S. Federal Government, the Office of Science and Technology Policy (OSTP) advises the President of scientific and technological considerations in several areas, including the environment; monitors the quality and effectiveness of the Federal effort in science and technology; and assists the President in providing leadership and coordination for the research and development programs of the Federal Government.

Within the OSTP, the interagency Committee on Earth Sciences (CES) coordinates the U.S. Global Change Research Program (USGCRP). Additional details on the CES and USGCRP are included in Attachment A, which identifies other U.S. agencies and offices participating in scientific and economic research on global change.

To assist decision makers take account of economic and environmental interactions in policy-making, a Working Group on Global Change has been established within the Cabinet. Members of the Working Group are apprised of new scientific and economic insights so that economic and environmental policies can be continually re-evaluated in light of new information.

In the fall of 1989, the Cabinet Working Group on Global Change established three Task Forces charged with addressing significant obstacles to an effective U.S. response to the social, environmental and economic challenges posed by changes in

the global environment. Of particular relevance to this Conference is the White House Task Force on Economics, chaired by the Council of Economic Advisors, which provided a thorough review and inventory of all work being conducted at universities, think-tanks, U.S. Government agencies, and other nations on the social and economic impacts of possible global change.

2.2 WHAT SCIENTIFIC AND ECONOMIC MODELS ARE USED BY YOUR GOVERNMENT IN ESTIMATING ENVIRONMENTAL AND ECONOMIC CONSEQUENCES OF GOVERNMENT ACTIONS RELATED TO GLOBAL CHANGE?

RESPONSE:

Global climate models used today have their roots in weather prediction models used since the 1960's to make operation global forecasts a few days in advance. The primary climate models, called general circulation models (GCMs), predict a variety of climatic variables such as temperature, precipitation, winds, snow mass, and soil moisture. The GCMs are the only models that provide geographic distributions of these variables and hence, regional predictions, but they have serious limitations. To be used for global change predictions, an atmospheric GCM must be integrated with models of the ocean and land surface and the biotic changes inherent to them.

Various combinations of coupled ocean-atmosphere models have been applied to greenhouse gas-induced warming predictions. Most have been atmospheric GCMs coupled to simpler, mixed-layer ocean models. Although it is possible to couple atmospheric and oceanic GCMs, until now it has been impractical because of the long time required to achieve an equilibrium (steady state) model climate. Non-equilibrium or transient predictions recently have been made with significant new results but the computer time required for these 100-year simulations has limited the number of model runs to date. Integrating with the terrestrial sector and the biosphere in general is yet more primitive. A few coupled atmosphere-biosphere GCMs are in the early stages of development and none have been applied to carbon dioxide-doubling predictions.

Several models are used by the Federal Government to estimate the environmental and economic consequences of policy actions related to global change. The EPA

maintains and applies the Atmospheric Stabilization Framework (Edmonds and Reilly), for evaluating the global consequences of policy options that might be implemented by individual countries or groups of countries. This modelling system has been used extensively to support the IPCC efforts currently underway. A recently completed draft of a study by Montgomery used the Dynamic General Equilibrium Model developed by Jorgenson to explore the implications of a carbon charge on reducing emissions and economic effects. Montgomery also used the Edmonds and Reilly model as well as Global 2100 (developed by Manne and Richels) to explore the long-term implications of policies restricting carbon dioxide emissions. A recent study completed by the Department of Energy evaluated a set of policy options which used: (i) an energy technology demand and supply model (FOSSIL2); (ii) a transportation model (TEEMS); and (iii) a macroeconomic growth model (DRI 25-year model).

2.4 WHAT SCIENTIFIC AND ECONOMICS RESEARCH QUESTIONS ARE THE MOST IMPORTANT TO ANSWER IN ORDER TO SUPPORT THE DEVELOPMENT OF DOMESTIC AND INTERNATIONAL POLICIES TOWARD GLOBAL CHANGE?

RESPONSE:

U.S. research in this area is driven, in part, by our belief that the nations of the world become true stewards of our global resources. Effective global stewardship, in turn, demands a significantly improved understanding of the scientific and socio-economic aspects of providing for life and prosperity in the 21st century. In the seven science elements which comprise the U.S. Global Change Research Program, the following high-priority questions must be addressed to reduce major scientific uncertainties and significantly enhance our ability to predict both natural and human-induced changes in the global Earth system. These questions are:

CLIMATE AND HYDROLOGIC SYSTEMS

- What is the role of clouds in the Earth's radiation and heat budgets?
- How do the oceans interact with the atmosphere in the storage, transport and uptake of heat?

- How do changes in climate affect temperature, precipitation, soil moisture patterns, and the general distribution of water and ice on the land surface?
- How can the reliability of global- and regional-scale climate predictions be improved?
- What is the role of polar regions in global climate change?

BIOGEOCHEMICAL DYNAMICS

- How do the oceans and terrestrial biosphere respond to increases in the introduction of fossil fuel carbon to the atmosphere and how might these responses change with time?
- Why is methane currently increasing in the atmosphere at a rate which may make this the most important greenhouse gas of concern in the future?
- Is the ability of the atmosphere to cleanse itself changing as a result of changing chemical composition?
- Can changes in the natural or anthropogenic sulfur emissions to the atmosphere ameliorate or enhance global warming?
- What are the global consequences of stratospheric ozone depletion in polar regions resulting from increased concentrations of chlorine and bromine in the stratosphere?

ECOLOGICAL SYSTEMS AND DYNAMICS

- What natural and managed systems are most sensitive to global change?
- What are the direct effects of carbon dioxide fertilization on natural and managed ecological systems?

- What are the likely changes and rates of change in natural and managed ecosystems due to global changes other than the direct effects of carbon dioxide fertilization?
- Can current natural and managed ecological systems adapt to rapid rates of change?
- How do ecological systems themselves contribute to processes of global change?
- How can ecological responses to global change be distinguished from natural variability, and other anthropogenic sources of change?

EARTH SYSTEM HISTORY

- What are the natural ranges and rates of change in the climate and environmental systems?
- How rapidly have ecosystems adapted to past abrupt transitions in climate?
- Do past warm intervals in Earth history provide appropriate scenarios to test model predictions of future global warming?
- What unidentified mechanisms of sea-level fluctuation may impede our ability to predict future sea-level change?
- Are there more than one stable mode of atmosphere-ocean circulation?

HUMAN INTERACTIONS

- What data are needed to verify models of interaction between human and natural systems and to assess the likelihood of changes in those processes?
- How do population dynamics influence global environmental change?

- How do institutions influence environmental processes and respond to changes in global environmental conditions?
- How do technological and economic development influence global environmental change, and how will changing environmental conditions affect future technological and economic development?
- How would providing food, shelter, and basic amenities to increasing populations affect natural resources on regional and global scales?
- How do changing patterns in the use of land, water, energy resources, and other natural resources affect global environmental change?

SOLID EARTH PROCESSES

- How do different coastal regions respond geologically and ecologically to higher sea level and how can the contributions from changes in climate (e.g., glacier melting and ocean warming) be differentiated from those due to tectonic processes?
- What are the magnitude, geographic location, and frequency of occurrence of volcanic eruptions and their effect on regional and global climate?
- How do permafrost regions of the northern hemisphere respond to climate warming?
- How and at what rate do climatically sensitive transition regions respond to climate change and human activities?
- What are the causes and consequences of crustal deformation?

SOLAR INFLUENCES

- What aspects of solar variability are influencing the stratospheric ozone layer?
- What impact do other solar inputs, e.g., particles, have on the upper atmosphere and how are they coupled to other atmospheric regions?
- How does the sun's output vary and what is the impact on terrestrial climate?
- What do current upper atmosphere models predict for the impact of greenhouse gases?

The United States believes that economic research on the benefits and costs of proposed policy actions must be evaluated under a broad range of outcomes that reflect the uncertainties that pervade the global change issue, so that decision makers are afforded the highest degree of flexibility in policy options. In responding to the Cabinet, the Task Force on Economic Costs identified several important questions to support the development of policies to respond to potential global change:

- What are the economic effects of possible global change?
- What are the benefits of slowing such change?
- What are the costs and effectiveness of various adaptive and emissions reduction measures?
- What are the effects of such measures on U.S. and world trade and capital flows?
- What are the impacts of such measures on economic growth and employment?

- What opportunities exist for the private sector in the development of new adaptation and mitigation practices and technologies?

THEME III: BUILDING PARTNERSHIPS FOR SCIENTIFIC AND ECONOMICS RESEARCH

3.1 WHAT LESSONS CAN BE LEARNED FROM YOUR COUNTRY'S EXPERIENCE IN INTEGRATING SCIENTIFIC AND ECONOMIC ENERGY-RELATED RESEARCH OVER THE PAST TWO DECADES?

RESPONSE:

The U.S. experience suggests that national leaders and their science, environment, energy, and economic ministers must commit to a long-term program to improve our understanding of the global Earth system, reduce major uncertainties in the decision process, and continually re-evaluate the effectiveness of policy in the light of new insights. In the United States, the National Environmental Policy Act of 1969 requires Federal agencies to assess impacts of their activities on the human environment, including economic as well as environmental impacts.

The U.S. experience has demonstrated that no single agency, or for that matter, no single country, has the expertise or resources to effectively address the issues associated with global environmental change. Effective stewardship of our global resources demands cooperation among nations, government-wide integration within countries, and a deliberate effort to entrain the broadest possible participation of government, academia and industry. The United States believes that when a research program encourages these groups to bring their unique talents and expertise to bear on the problem, the collective result is far greater than the sum of the parts.

In the United States, successful integration of Earth system science, economics research and policy reflective of both science and economics requires government mechanisms or institutions which ensure: (i) a clear problem statement; (ii) programs which will provide the scientific basis for decision-making related to that

problem; (iii) a clearly-identified focus for scientific input to national and international policy deliberations; (iv) full and equal participation by all relevant government bodies with clearly stated roles and responsibilities; (v) close ties with similar efforts in other countries; and (vi) the effective involvement of the full intellectual resources available in projects which demand multi-disciplinary and multi-institutional collaboration.

3.2 FORECASTS OF TECHNOLOGY ADVANCES, THEIR COSTS, AND MARKET PENETRATION NECESSARILY INVOLVE BOTH SCIENTIFIC AND ECONOMIC CONSIDERATIONS. HOW CAN SCIENTIFIC AND ECONOMIC RESEARCH BE INTEGRATED TO PROVIDE THE MOST ACCURATE AND CLOSELY-BOUNDED TECHNOLOGY FORECASTS POSSIBLE? HOW CAN THIS RESEARCH CONTRIBUTE TO TECHNOLOGY DEVELOPMENT?

RESPONSE:

In the United States, technological development in the public interest is best served when a framework exists that creates incentives for the private sector to seek the most cost-effective ways to achieve environmental or other nonmarket goals. Encouraging close collaboration among scientists and economists within the U.S. Federal Government, (such as that sponsored by the USGCRP) as well as with academic and industry counterparts, will assure the development and sharing of scientific, technical, and economic information relevant to environmental quality issues and lead to the most accurate technological forecasts possible.

3.3 WHAT ARE YOUR GOVERNMENT'S CURRENT FORECASTS OF FUTURE TECHNOLOGIES RELEVANT TO MITIGATION OF OR ADAPTATION TO GLOBAL CHANGE?

RESPONSE:

A broad effort is currently underway in the United States to examine and assess the feasibility of technologies relevant to mitigation and/or adaptation in a number of environmental areas. Many of these are technologies that make sense in their own right, but also reduce greenhouse gas emissions:

- Efforts to rehabilitate coastal and freshwater wetland to improve productivity and achieve a "no net loss" of valuable wetlands.
- Protection of biodiversity and the preservation of endangered species.
- Evaluation of the concept of low-input sustainable agriculture (the subject of a recently-completed National Academy of Sciences report which examined the potential to maintain and improve agricultural productivity with changing input and management practices).
- Resource conservation and management efforts in a number of U.S. Federal agencies, including waste minimization through recycling and separation of wastes.
- Reforestation of public and private lands.
- Use of agricultural biomass and forest products as a source of industrial hydrocarbons to recycle carbon dioxide in place of fossil fuel sources.
- Studies to reduce methane production from livestock and rice production.

In the area of global change, the Mitigation and Adaptation Research Strategies (MARS) Working Group of the Committee on Earth Sciences has been charged with identifying an explicit research agenda which will, among other things, address the issue of technology development to either adapt to or mitigate possible global changes. In the area of climate change, for example, this research agenda is likely to contribute to:

- Efforts to evaluate methods and consequences of limiting greenhouse gas emissions including the use of market-based mechanisms such as a carbon tax, tradable emissions and other incentives.
- Improvements in energy efficiency in cars, heating, and industrial uses of fossil fuels, and conservation technologies.

- Technological advancements for increasing the use of renewable energy sources such as solar and geothermal.
- Development of new generation nuclear fission reactors.
- Determining the scientific and technological feasibility of controlled nuclear fusion as a potentially inexhaustible source of heat for electricity generation.
- The development and evaluation of new crop and tree varieties and agricultural and forestry practices, including reforestation.
- Developing management options (e.g. water conservation) for improving the resiliency of water resources to climate changes.
- Methods for adapting to or mitigating the effects of sea level rise on both natural ecosystems and human infrastructure.
- The development of new technologies and practices required to mitigate possible human health effects.

3.4 WHAT INTERNATIONAL MECHANISMS WOULD BE MOST EFFECTIVE TO CARRY OUT ECONOMIC AND SCIENTIFIC RESEARCH ON GLOBAL CHANGE?

3.5 DO YOU ANTICIPATE THAT NEW ENTITIES WILL BE REQUIRED TO CARRY OUT JOINT RESEARCH EFFORTS? IF EXISTING ORGANIZATIONS CAN FILL THE NEED, WHICH ONES SHOULD BE USED? WHAT CHANGES WILL BE NEEDED IN THESE ORGANIZATIONS TO PRODUCE INTEGRATED RESULTS?

RESPONSE:

The United States believes that the following precepts should characterize an effective international global change research effort:

- Countries must give further impetus to scientific research on environmental issues, to developing necessary technologies to support global data acquisition and to evaluate the economic costs and benefits of specific response options.
- Countries must combine their efforts in order to improve observation and monitoring on a global scale. Prime examples of the need and opportunity for such collaboration include: the World Meteorological Organization's (WMO) World Weather Watch; global ocean monitoring efforts such as those currently being coordinated by the International Oceanographic Commission; the global monitoring of atmospheric constituents being coordinated through United Nations Environment Program (UNEP) and WMO; the compilation of standard gridded geophysical data through the UNEP GEMS/GRID program; participation in the Committee on Earth Observations Satellites; international cooperation in satellite-based monitoring programs; and data communication and archiving.
- International cooperation to improve the knowledge base regarding the science and prediction of global change (particularly climate change) will require a commitment to technology development and transfer which will strengthen indigenous capacity and infrastructure in developing countries and will heighten the awareness of decision-makers and the public to the issues.
- Maintaining and improving the quality of international data on human links to global change, e.g., on energy use, resource availability and production costs, agricultural production practices, agricultural technologies and input use, and industrial production. Such efforts should build on existing international data collection efforts of the United Nations organizations.
- Existing mechanisms and institutions should be used wherever possible to foster, coordinate and implement global change efforts. For example:

- Individual nations should continue to support the activities of the World Climate Research Program jointly sponsored by the World Meteorological Organization and the International Council of Scientific Unions (ICSU) as well as enhance support for the evolving ICSU/International Geosphere-Biosphere Programme.
- The WMO/UNEP Intergovernmental Panel on Climate Change should continue to be viewed as a continuing forum for consideration of the issues related to global climate change.
- Recognizing the role of satellites in global environmental monitoring, the Committee on Earth Observations Satellites, a coordinating mechanism for national and regional agency satellite programs, should be strengthened and expanded to more effectively coordinate data management of earth observations from space.
- Individual nations should continue to support the activities of the International Development Association of the World Bank as well as the OECD.
- The United Nations Food and Agriculture Organization (FAO) and Centers for International Agricultural Research should continue to coordinate research on agricultural and forestry practices, with renewed emphasis on impacts and responses to climate change, and integration of such response in coordinated resource management plans such as the Tropical Forestry Action Plan (TFAP).
- The OECD/IEA should continue to develop forecasts of national greenhouse gas emissions and conduct economic research.
- The worldwide network of observatories for greenhouse gases should be strengthened and the World Meteorological

Organization's initiative to establish a global climatological reference network to detect climate change should be supported.

- There should be cooperation in the WMO's Special Fund for Climate and Atmospheric Environment Studies which will initiate scientific activities responding to current international needs.

The U.S. believes that existing bodies such as the WMO, UNEP, and ICSU should be encouraged to enhance mechanisms to gain greater communication and cooperation among the participants in existing and planned global change research programs. Additional mechanisms include continued international support for Mission to Planet Earth, enhanced data exchange, existing bilateral cooperative activities, and the Earth observing, research, and educational activities being organized by the Space Agency Forum on International Space Year for the International Space Year in 1992.

3.6 WHAT ARE THE MAJOR BARRIERS TO CARRYING OUT INTEGRATED ECONOMIC AND SCIENTIFIC RESEARCH ON GLOBAL CHANGE?

RESPONSE:

The U.S. believes that Global environmental problems, and research efforts in this area, can be complicated by the fact that the individuals involved live in many nations. Differences across countries--in incomes, resource endowments, population, and sensitivity to particular environmental changes--mean that countries inevitably have different views on the issues. The United States believes that even if these international differences did not exist, no single agency and no single nation is equipped to address the problem of global environmental change alone. The real challenge, therefore, is to achieve collaboration of all interested parties, each bringing their special expertise and contributions, ensuring scientific and economic progress that no single group could hope to achieve alone.

Other potential barriers include:

- The need to provide long-term stable support for what will undoubtedly be an expensive effort.
- Support to overcome the barrier posed by the current lack of existing computers with sufficient capacity and speed to simulate the entire Earth system as a single system.
- The need to encourage existing government and academic institutions to actively pursue research projects that cross disciplinary and institutional boundaries. Scientists, economists, institutions and nations must be innovative not only in the way they look at earth system science but also in the way that they organize to conduct research.
- The need for free and open exchange of monitoring and other data related to global change and other environmental issues.
- The challenge of technology development and transfer for successful global change scientific and economic efforts. A strong **international** scientific and technological infrastructure is essential.
- The availability of human resources, unless efforts are made to increase the intellectual talent pool through education and technical training programs. Shortages in trained personnel, both as scientists and educators, appears to be particularly acute in the social sciences.

3.7 WHAT DATA BASES RELEVANT TO GLOBAL CHANGE DO YOU HAVE IN YOUR COUNTRY WHICH MIGHT BE MADE AVAILABLE FOR SHARING WITH THE INTERNATIONAL COMMUNITY?

RESPONSE:

The United States believes that an essential ingredient of a successful global change science effort is the free and open exchange of consistent, relevant data and information among all participating parties, including observations from global monitoring networks, field experiments and similar research into Earth system processes, and predictive information derived from modelling efforts.

U.S. agencies, in collaboration with the national and international scientific community, have been conducting research related to global change for several decades. These efforts are producing derived data research products such as global analyses of critically important global change parameters (e.g., clouds, sea level, ocean color, vegetation indexes, trace gas sources and sinks), as well as economic impacts of changes in global climate. These data and information products are available to the broader scientific community. The following examples provide a brief description of some of the existing data currently used by U.S. agencies in global change research:

National Aeronautics and Space Administration (NASA) - Analysis of many different types of existing satellite data bases, including Nimbus, Landsat, Seasat, TIROS, Earth Radiation Budget Experiment (ERBE), International Satellite Cloud Climatology Program (ISCCP), and Advanced Very High Resolution Radiometer (AVHRR) are underway in NASA to assess the current state of the global environment and its variability. Satellite data are used, for example, to better understand: (1) the chemistry and dynamics of the upper atmosphere; (2) the climate effects connected with clouds and radiation; (3) processes affecting global ocean circulation and the interactions between the atmosphere and ocean; (4) the dynamics of terrestrial vegetation in the context of global change; and (5) the role of the ocean in the global carbon cycle.

Department of Commerce/National Oceanic and Atmospheric Administration (NOAA) - The use of existing data sources for studies of climate and global change has a prominent position in NOAA. For example, NOAA has assembled a data base of surface marine observations extending back to 1854. These marine data have been crucial in the compilation of the global mean temperature record upon which many of the global climate change issues rest. Vast numbers of deep ocean observations from 1900 to the present have also been synthesized by NOAA into a climatology of the ocean basins, providing the basis for ocean model integrations and establishing a benchmark for observations in the global ocean. Satellite data are another valuable source of information. Using the satellite data archive, a program to develop historical measures of cloud parameters has been sponsored by NOAA and NASA since 1983. Some near-term improvements in representation of cloud processes in general circulation models can be expected as a result of this effort.

NOAA-sponsored investigators are also active in the use of historical satellite microwave and IN SITU sea ice measurements to assess past fluctuations and trends in polar sea ice extent. Looking backward in time, NOAA is sponsoring an analytical program for the conversion of historical ocean and atmospheric data, spanning several decades, into a homogeneous climate data set for studies of long-term climate change. NOAA also maintains data bases on ocean salinity, the cryosphere, and the means to measure polar vortices.

Department of Commerce/Economic Affairs - This office maintains and makes available data bases which are easily accessible to researchers. The Economic Bulletin Board provides timely access to the most current U.S. economic data, such as Gross National Product (GNP), employment, exchange rates, and international trade. A second data base, Office of Business Analysis (Office of Business Analysis)Data, offers economic time series on U.S. capital stocks, energy, and production, organized by industry. OBAData also contains historical time series for major U.S. economic statistics, such as the National Income and Product Accounts. The National Trade Data Bank, currently under development, will provide detailed statistics on trade between the United States and trade partners by harmonized product code.

Department of the Interior (DOI) - Space-based and ground-based data are being extensively used by the Department of the Interior. For example, Landsat Thematic Mapper data are being used to develop a capability for predicting the hydrologic and water resource responses to climate change. Some operational capabilities exist in DOI and others are being developed for classifying land cover and vegetation types on a regional basis using Landsat data. Changes in land cover and vegetation are also being monitored operationally over time using Advanced Very High Resolution Radiometer (AVHRR) data. Research on characteristics of irrigated lands, snow cover, glaciers, and sea ice as they pertain to climate change are being conducted using remote sensing techniques. In many cases, these ongoing activities have produced data sets that will be useful as baseline reference data against which to assess the impacts of global change.

Department of Energy (DOE) - The DOE is using meteorological data from various sources to evaluate General Circulation Models. Specifically, data from ERBE are used to determine the agreement between the simulated and observed radiation

balance at the top of the atmosphere. The DOE is also participating in the International Satellite Cloud Climatology Program (ISCCP) to establish cloud climatologies necessary to understand relative heat fluxes to and from the Earth. Pilot studies have used satellite data from AVHRR, Landsat, and the French SPOT sensors in studies of deforestation, land use changes, and the exchange of carbon dioxide between the atmosphere and oceans.

National Science Foundation (NSF) - Various divisions of NSF: support the use of satellite data extensively for studying ocean circulation patterns, monitoring geodetic changes related to tectonic activity and sea level change, determining atmospheric structure, radiation budgets and cloud-radiation feedbacks, making ozone measurements to detect and study ozone depletion in polar regions, and studying agricultural drought.

Environmental Protection Agency (EPA) - In support of the U.S. Global Change Research Program, the EPA is using AVHRR, SPOT and Landsat Thematic Mapper data to study seasonal dynamics of vegetation in ecosystems across large regions. Data from these sources are analyzed to provide measurements of vegetation canopy spectral reflectance, temperature, and "greenness" as functions of leaf area and biomass distribution. These characteristics determine the rate of evapotranspiration and trace gas emissions. EPA is also working with the U.S. Geological Survey in studies of the hydrologic cycle and water resource responses to global change.

Department of Agriculture (USDA) - The U.S. Department of Agriculture is using satellite data from Landsat and AVHRR to map snow cover in selected areas of the western United States. The resulting information on snow cover is used as input to hydrologic models to simulate and forecast streamflow. When data bases are developed on particular river basins, the existing or average conditions can be perturbed in the models to approximate the effects of potential global warming or other climate changes. The National Agricultural Library is also expanding its current role in providing bibliographic data on climate change studies.

The United States believes that there is little economic data that is not relevant to studies of human interaction with the natural environment; at the heart of the issue is economic development, industrial and technological development, and the

costs of supplying humankind with basic material needs through alternative strategies for utilizing natural resources. Thus, important basic data include statistics of industrial production and income from the Department of Commerce, current income and household characteristics from U.S. Census data, basic agricultural production, price, and agricultural practice data from the Department of Agriculture, and energy use and price data from the Department of Energy.

The above examples demonstrate the contributions which existing data and data collection systems are already making to global change research in the United States.

ATTACHMENT A

THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

General Background

The U.S. Global Change Research Program (USGCRP) represents an integrated, Government-wide scientific effort designed to document, understand, and predict changes in the global environment and to provide the scientific foundation for national and international policy deliberations.

In March 1987, the White House Office of Science and Technology Policy (OSTP) established a new Committee on Earth Sciences (CES). To a great extent, CES was created in response to the recommendations of a Cabinet Working Group on Climate Change which concluded that improved mechanisms for Government-wide coordination were required for the United States to effectively address the significant economic, social, and environmental issues raised by changes in the global climate system. Thus, the CES was created to:

Increase the overall effectiveness and productivity of Federal research & development efforts directed toward understanding the Earth as a global system.

Participation in the CES includes the principal U.S. Earth sciences funding agencies (National Aeronautics and Space Administration, National Science Foundation, Commerce, Energy, Environmental Protection Agency, and Departments of Commerce, Energy, Interior, and Agriculture) as well as other Departments, Agencies, and Executive Branch offices with interest in the policy implications of such research (the Departments of State, Justice, Transportation, along with the CEQ, OSTP, and Office of Management and Budget). Figure 1 shows the organizational structure of U.S. Government agencies with interest and participation in global change science and economics research. Although the CES has a number of specific areas of responsibility, including coordination of Federal activities in groundwater research, natural hazards reduction, atmospheric research, and the academic oceanographic fleet, the primary focus of CES efforts to date has been the development of the U.S. Global Change Research Program and providing a focus for scientific input to national and international policy deliberations on global change.

The U.S. Global Change Research Program

The USGCRP was formally announced in the January 1989 CES Report: Our Changing Planet: A U.S. Strategy for Global Change Research. That report defined the goal, objectives and scientific framework for the USGCRP.

Activities within the USGCRP are designed to be responsive to the Program's overarching goal:

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.

Thus, projects have been framed as part of a broad national and international scientific endeavor aimed at developing a capability to not only understand but predict both natural and human-induced changes in the global environment in an effort to provide decision-makers at all levels with a strong scientific foundation for policy formulation. In some cases, projects are designed to provide near-term results by focusing an aggressive, limited-duration attack on some key aspect of the earth system--e.g., stratospheric ozone depletion or the role of ocean-atmospheric interactions in the tropical Pacific in determining year-to-year climate variability over North America. In other cases, projects are designed as part of a long-term national commitment to the documentation of changes in the earth system on a global scale. NASA's Earth Observing System and NOAA's ocean observations and global sea level proposals are examples of such initiatives.

Proposed projects are also designed to provide specific contributions to one or more of the three scientific objectives or integrating priorities of the USGCRP:

- Establish an integrated, comprehensive program of documenting the Earth system on a global scale through observational programs and 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.

Again, the ultimate focus is on providing policy-relevant information about the current and anticipated state of the global environment.

Finally, the priority framework established for the U.S. Global Change Research Program provides a relative ranking among the seven interdisciplinary science elements which characterize the USGCRP and within those science elements, identifies the most pressing scientific uncertainties in the context of the Program's ultimate goal of predicting significant changes in the global environment. Improving our ability to anticipate, assess and address the issues associated with climate system changes are given the highest priority in the Program although CES recognizes the need to maintain an appropriate level of effort in all seven science elements including adequate support for the data and information management activities required by the Program. The individual science priorities in the current research plan probably represent the most dynamic feature of the USGCRP. As new insights in earth system processes are gained, and new problems and research needs are identified in response to that new understanding, the details of the science priorities will change. In essence, the evolution of the science priorities will be a measure of the success of the U.S. Global Change Research Program.

The U.S. Global Change Research Program is founded on the premise that international cooperation and coordination are fundamental to the scientific planning and the implementation of a successful effort. Research programs like the International Geosphere-Biosphere Programme and the World Climate Research Program are truly international in scope and design. The complex scientific agenda and the infrastructure needed to address the programs outlined in the USGCRP require a careful assessment and integration of the Program's components with programs of other governments; intergovernmental bodies (e.g., United Nations bodies such as the World Meteorological Organization, and the United Nations Environment Programme); and non-governmental science planning and coordinating mechanisms such as the International Council of Scientific Unions.

ATTACHMENT B
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U.S. Global Change Research Program Priority Framework

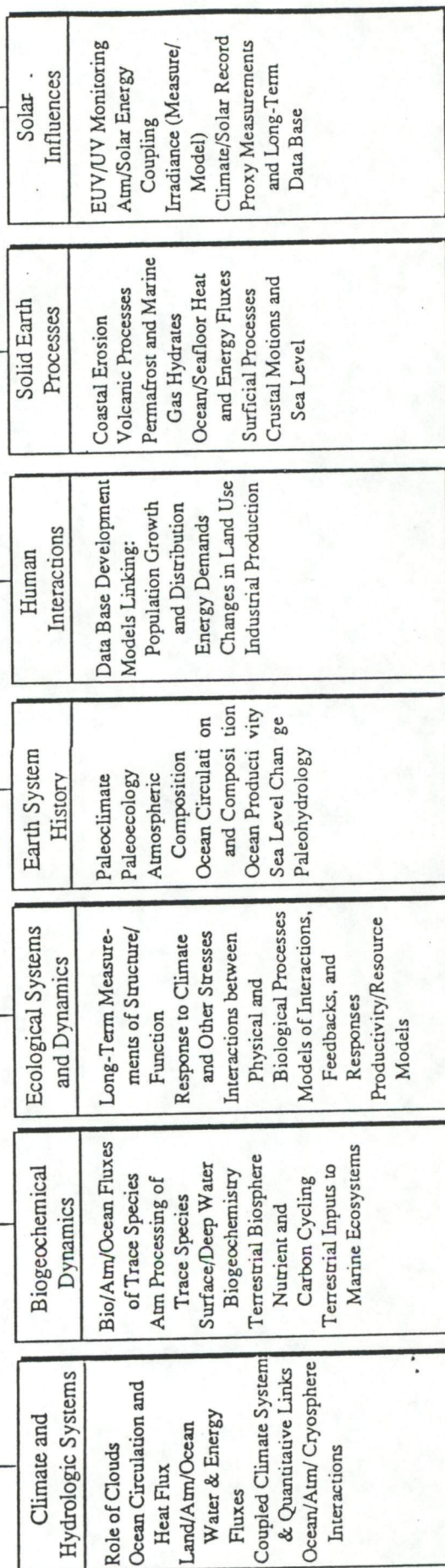
STRATEGIC PRIORITIES

- Support Broad U.S. and International Scientific Effort
- Identify Natural and Human-Induced Changes
- Focus on Interactions and Interdisciplinary Science
- Share Financial Burden, Use the Best Resources, and Encourage Full Participation

INTEGRATING PRIORITIES

- Documentation of Earth System Change
- Observational Programs
- Data Management Systems
- Focused Studies on Controlling Processes and Improved Understanding
- Integrated Conceptual and Predictive Models

SCIENCE PRIORITIES



Increasing Priority

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Climate Change

The Climate System:

The Earth's climate is controlled by the radiative balance of the atmosphere and by internal processes within the climate system. The radiative balance depends upon the input of solar radiation and the atmospheric concentrations of radiatively active trace gases (i.e., greenhouse gases), clouds and aerosols. To predict changes in the climate system requires an understanding of future changes in the atmospheric concentrations of greenhouse gases and aerosols, and the processes that control the response of the climate system to natural and human-influenced changes in the radiation balance.

Changes in the Forcing of the Climate System:

Natural greenhouse gases, primarily water vapor and carbon dioxide, and to a lesser extent, methane, nitrous oxide and ozone, keep the Earth much warmer than it would otherwise be. It is well documented that since the industrial revolution the atmospheric concentrations of carbon dioxide, methane, nitrous oxide and industrially produced chlorofluorocarbons (strong greenhouse gases) have been increasing primarily due to human activities. However, there are many uncertainties concerning the magnitudes of the sources and sinks of these greenhouse gases, hence their residence time in the atmosphere. In particular, the magnitude of the uptake and release of carbon dioxide by the oceans and terrestrial biosphere, and strengths of the individual sources of methane and nitrous oxide are quite uncertain. These uncertainties limit our ability to understand the quantitative consequences of particular emissions control strategies, e.g., it is difficult to relate future emissions of carbon dioxide to growth in its atmospheric concentration. It should be noted, however, that the time taken for atmospheric carbon dioxide to adjust to changes in sources is of order 50-200 years, determined by the slow exchange of carbon between surface waters and deeper layers of the ocean and the response of the terrestrial biosphere. Consequently, carbon dioxide emitted into the atmosphere today will influence the atmospheric abundance of carbon dioxide for centuries into the future, and the atmospheric concentration of carbon dioxide will only respond slowly to changes in emission rates.

Predictions of Climate Change:

General Circulation Models (GCM's) are currently the best tools with which to predict changes in the Earth's climate in response to a change in the atmospheric concentrations of trace gases or aerosols, solar activity, or surface albedo. However, it must be recognized that the current GCM's have certain limitations. In particular, the prediction of global climate change is very sensitive to the treatment of cloud-radiation interactions. Different cloud-radiation parameterizations in GCM models lead to significant differences, up to a factor of three, in the magnitude of the predicted global warming. Prediction of regional climate changes are very uncertain, and are particularly sensitive to the treatment of ocean dynamics and ocean-atmosphere interactions (the exchange of energy and chemicals between the atmosphere and the surface waters, and between the surface waters and the deep oceans controls the rate of predicted warming), and to the terrestrial vegetation-atmosphere interactions (the transfer of energy and moisture between land surfaces and the atmosphere). In addition to our current lack of understanding of several key processes, today's computer capabilities severely limit the spatial resolution of the GCMs. Consequently, while the current GCMs represent the overall climatology of the

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present climate system quite well and all predict that the Earth's climate will warm in response to an increase in the atmospheric abundance of greenhouse gases, it is clear that the predictions of the magnitude and timing of climate changes, especially at the regional level, are somewhat uncertain. In particular, accurate regional predictions of changes in the mean state and variability of climatic parameters needed to assess the impact of climatic change on agriculture, natural ecosystems, coastal regions, and water resources (such as temperature, precipitation, evaporation, soil moisture and the occurrence of severe storms at sub-continental scales) are not possible at this time. Other potentially important uncertainties concern feedbacks between climate change and biogeochemical cycling, and possible non-linear feedbacks within the climate system itself, i.e., a change in ocean circulation.

A key question is what do the GCM's predict for future climate changes based on trace gas emission, recognizing that there are significant scientific uncertainties, and assuming that there will be no long-term changes in solar irradiance or atmospheric aerosol concentrations. Rather than discuss a number of complex emission scenarios it is reasonable to believe that the atmospheric concentrations of carbon dioxide and the other greenhouse gases will continue to increase at a rate such that there will be a radiative equivalent of a carbon dioxide doubling sometime during the middle of the next century. If this occurs then the GCM's predictions that are considered to be most likely are that: (i) the equilibrium increase in global mean surface temperature should lie between 1.5 and 4.5 degrees centigrade (highly sensitive to modeling the feedback between clouds and climate change; recent models with more sophisticated treatments of clouds have tended to predict temperature changes at the lower end of this range); (ii) between 60 and 80% of the equilibrium warming should be realized at the time of "equivalent doubling" (sensitive to the treatment of ocean circulation); (iii) global mean precipitation should increase; (iv) sea-ice extent should decrease; and (v) the predicted warming in the northern polar winter should be greater than the global mean.

There are some consistent GCM predictions of climate change at the continental scale (but not sub-continental scale) such as, (i) land areas are predicted to warm more rapidly than oceans, and (ii) mid-latitude land masses in the northern hemisphere will warm more than the global mean and be accompanied by a decrease in summer precipitation. These results carry important implications, but must be stated with lower scientific confidence than those presented above.

Observations of Temperature Changes:

The instrumental record of surface temperatures suggests an increase of between 0.3 and 0.6 degrees centigrade since the mid-nineteenth century, with an undetermined, but probably small (less than 0.05 degrees centigrade) artificial component due to urbanization. The observation of a marked retreat of mountain glaciers in all parts of the world since the end of the nineteenth century tends to support the notion that temperatures have increased globally over the last one hundred years. However, temperatures have not increased smoothly with time, nor uniformly throughout the world. Several points should be noted: (i) the majority of the temperature increase occurred before 1940, prior to most of the anthropogenic increase in the atmospheric concentrations of greenhouse gases; (ii) there is little evidence that the continental U.S. has warmed since 1900; (iii) the northern hemisphere cooled between 1940 and the early 1970s, while the southern hemisphere continued to warm, albeit at a very slow rate; (iv) there have been significant differences in regional changes, especially in the northern hemisphere since 1950; and (v) from 1975 to 1982 a more general warming occurred, followed by little global warming since 1982. It is

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important to recognize, however, that coupled ocean-atmosphere GCM's predict a highly variable global warming signal, moreover, substantial regional variations are expected.

Detection of the "Anthropogenic Greenhouse" Signal:

The Earth's climate is inherently variable on all timescales, both regionally and globally. Hence, the challenge is to detect an "anthropogenic greenhouse" signal amidst the natural variability of the system. While it can be stated that the observed global mean temperature increase over the past 100 years is broadly consistent with theoretical predictions of climate change, it should be noted that the implied climate sensitivity of the actual system would then be in the lower one-third to one-half of the range predicted by GCM's. In addition, natural variability of the climate system may be as large as the observed changes to date, hence the observed changes could be wholly attributable to natural variability or possibly natural variability could have masked (due to natural variability causing a decrease in temperatures) a larger "anthropogenic greenhouse" signal. Consequently, the current observations cannot confirm the presence or absence of an "anthropogenic greenhouse" signal. Detection of an "anthropogenic greenhouse" signal will require determining trends in both forcing functions and several climatically important parameters, coupled with a quantified understanding of natural variability, and the use of time-dependent coupled ocean-atmosphere GCMs.

Sea Level:

Although the data are difficult to interpret, the best scientific assessment is that over the past 100 years, sea level has risen at an average rate of rise of 1.0-2.0 mm/yr. The uncertainties are large, but the principal causes of this rise are consistent with the expected thermal expansion of the oceans and the melting of mountain glaciers. Regional values differ considerably from global values and predicting future conditions is even more uncertain. If the global mean surface temperature increases, then sea level is predicted to rise, primarily due to the thermal expansion of the oceans and to a melting of some land-ice. The current predicted range of sea level increase, at the time of a radiative equivalent of a carbon dioxide doubling (sometime during the middle of the next century), lies between about 10 and 30 cm. Accurate predictions remain difficult, and somewhat controversial, because of the predicted increased snow accumulation over the Antarctic continent.

Ecological Systems:

Biological Productivity: Where temperature is limiting, warming of soils would increase nutrient availability to plants with potential for increased productivity. Increased temperature will affect respiration more than photosynthesis, possibly reducing carbon stored in terrestrial ecosystems resulting in a positive feedback on atmospheric carbon dioxide concentrations. Higher atmospheric carbon dioxide concentrations can increase photosynthesis with potential increases in net production, but the duration of "carbon dioxide fertilization effects" is unknown. However, while there is some knowledge of the responses of biological production processes to changes in parameters of the physical environment, how these integrate over the life cycle of even one species interacting in a complex of other species is unknown.

Ecosystem Composition: Species will respond differently to changes in temperature, precipitation, and atmospheric carbon dioxide, either singly or in some combination.

Draft: April 10, 1990 at 8 pm

However, exactly what these responses will be is not known. Also unknown are the changes that will occur among species, including plant-animal and plant-microbe interactions-- both beneficial symbioses as well as insect and fungal pathogens, that affect the structure of ecosystems. GCM's predict that global mean surface temperatures may change much more rapidly in response to an increase in greenhouse gases, up to a factor of 100, than they did during ice age cycles. If this were to occur, some species will not be able to migrate or otherwise adapt to the changing climate and become extinct. Offsetting this will be the possible genetic differentiation and expansion that might occur as habitat boundaries are altered, with creation of new barriers to reproduction and dissolution of some old barriers. However, extinction is likely to be more frequent than speciation, further decreasing biological diversity.

Marine Ecosystems: The historic record leaves little doubt that global warming will have an impact on marine planktonic organisms. The structure and productivity of marine ecosystems are strongly influenced by ocean circulation and mixing, physical parameters tightly linked with climate. In high latitudes, the distribution of sea ice is especially important, both for plankton and marine mammals and birds. In sub-polar and temperate regions, physical, chemical and biological parameters are highly variable and the system behavior consequently unpredictable. Thus, effects of warming or other changes are similarly uncertain. Warming affects vertical mixing and in turn nutrient supply, a major determinant of ocean productivity. Again, while there is considerable knowledge of specific processes and specific parts of the global oceans, the integration of this knowledge is incomplete and significant gaps in understanding exist.

Scientific Research Needed to Reduce Scientific Uncertainties:

To improve our current understanding of: (i) the natural and human-influenced processes that control the Earth's climate, and (ii) the impacts of climate change at the regional scale, will require an internationally coordinated program of space-based and ground-based research. This research program will need to: (i) establish an integrated long-term program of systematic observations of the Earth's system; (ii) improve our understanding of the physical, chemical, biological, geological, and social processes that influence the Earth's environment and its responses; and (iii) develop integrated predictive models. In particular, we need to document the natural variability of the Earth's climate, and to improve our understanding and modeling of: (i) cloud-radiation feedbacks; (ii) the exchange of energy between the atmosphere and the surface waters of the ocean, and between the surface and deep waters of the ocean; (iii) the cycling of carbon and other key elements between the atmosphere, land and oceans; (iv) the exchange of water and energy between land surfaces and the atmosphere; and (v) the current structure and functioning of ecosystems, and their response to environmental changes.

Draft: April 10, 1990 at 8 pm

Summary of Areas of Scientific Uncertainty

- a. *Hydrological cycle:* primarily cloud-radiation and land surface-atmosphere interactions. These uncertainties affect the predicted rate (magnitude at a given time) of "climate change".
- b. *Role of the oceans:* the exchange of energy between the ocean and the atmosphere, and between the upper layers of the ocean and the deep ocean. These uncertainties affect the predicted rate of climate change, especially at the regional scale.
- c. *Trace Gases:* quantification of the uptake and release of carbon dioxide by the oceans and terrestrial biosphere, and quantification of the individual sources of methane and nitrous oxide. These uncertainties affect our understanding of how the climate system will be "forced", hence the rate of predicted climate change. These uncertainties also limit the formation of control strategies.
- d. *Predictions of regional climate change:* limitations in computer resources (spatial resolution and physical sophistication), coupled with an inadequate understanding of several key processes (e.g., the exchange of water and energy between vegetative surface and the atmosphere) limit the accuracy of regional climate change predictions at the scale required for impact assessments to be performed (sub-continental).
- e. *Detection of global change:* trends in a number of climatically important parameters, coupled with a quantified understanding of natural variability, is needed to differentiate between human-induced changes in the environment from those that occur naturally. This will require long-term observations of climatically important parameters and forcing functions, as well as careful development of time-dependent coupled ocean-atmosphere GCM's.



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

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





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

April 17-18, 1990

Washington, D.C.





PRE-CONFERENCE MATERIAL FOR DELEGATES



Printed on Recycled Paper



April 5, 1990

Dear Colleague:

On behalf of President Bush, we are honored that you will be coming to the United States April 16-18 to serve as a delegate to the White House Conference on Science and Economics Research Related to Global Change.

By contributing your country's expertise in identifying the critical needs in the fields of science and economics research, you will advance international cooperation and understanding in dealing with the uncertainties of global change.

The United States welcomes a free and open discussion of the science and economics research issues related to global change. As co-chairmen of the Conference, we look forward to joining you in that effort.

Yours Sincerely,

D. Allan Bromley
Assistant to the President
for Science and Technology

Michael J. Boskin
Chairman
Council of Economic Advisers

Michael R. Deland
Chairman
Council on Environmental
Quality



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- Overview of the Conference
- Preliminary Delegation List
- Conference Co-Chairmen Biographies
- U.S. Delegation Biographies
- Hotel/Transportation/Logistics



OVERVIEW OF THE CONFERENCE

GOALS AND OBJECTIVES OF THE CONFERENCE:

President George Bush invited the Heads of State from seventeen nations and the leadership of the E.C. and the OECD to send ministerial-level delegations to the White House Conference on Science and Economics Research Related to Global Change. The Conference is designed to bring together government leaders in science, economics, energy, and the environment concerned with the central research issues of Global Change. The Conference is designed to advance understanding of Global Change phenomena, to enhance international cooperation, and to build the basis for future efforts among nations to integrate more fully science and economics research into the policy process. The Conference adds a new dimension to the international dialogue on Global Change — the proposition that economics, both analysis and research on economic policy and economic consequences, is an essential link between the science of Global Change and policy alternatives. Science and economics research can also serve to identify and develop technologies and policy instruments that relax the tension between growth and Global Change, allowing for greater progress on both fronts. To address these broad goals, the Conference will:

- **Focus on science and economics research** issues relevant to policy on Global Change,
- Address important next steps to substantially **enhance and broaden international understanding** of science and economics research issues that relate to Global Change,
- **Highlight the special role that economics plays** in integrating the science of Global Change with the policy process,
- **Demonstrate linkages between science and economics** research and domestic and international policy processes, and
- Seek to take the initial steps to **implement joint international science and economics research efforts.**

The Conference is conceived as an integral part of the ongoing international process to understand the science of and policy options relating to global environmental issues. The need to improve substantially understanding of both the science and economics of Global Change has been noted by many world leaders. The Conference, therefore, focuses on science and economics research issues as a complement to the ongoing Intergovernmental Panel on Climate Change (IPCC) and other international forums that seek to address the issue of Global Change. It is hoped that the results of the Conference will contribute to the IPCC process and other ongoing international debates and actions.

The Conference focuses on "Global Change," an area of research concerned with understanding the fundamental processes that govern the Earth system functions. Global Change encompasses such diverse and interrelated issues as ozone depletion, greenhouse gases, climate change, food security, water supply, sea level changes, wetlands, deforestation, biodiversity, population change, and energy demand.

The Conference will provide a forum for international leaders to address the complex science and economics research issues central to the policy process, including:

- How well can we predict temperature trends in the decades ahead?
- How "good" are our global scale models, such as models to predict temperature changes?
- How well can we predict the interconnections between global environmental change and the resulting social and economic impacts?
- What are the economic consequences of adapting to or mitigating Global Change?
- How "good" are the models used to assess these economic consequences and their impact on the well-being of humanity?

By addressing such questions, it is hoped that the nations might pledge to enhance joint international research efforts that focus on rapid improvement of both scientific and economic knowledge and development of the necessary infrastructure to implement such efforts.

To address these complex and interrelated issues, President Bush invited heads of state from a small group of nations to send delegations led by ministerial-level officials. The Conference was conceived with the idea that a representative group of countries would be invited to participate. Their selection was based on the simple criteria that the meeting should include countries or organizations of countries that have substantial populations, large land masses, industrialized economies, heavy future energy needs, major research infrastructures, or have provided international leadership on issues related to climate and Global Change. These countries and organizations were selected:

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

THE EXPECTED RESULTS OF THE CONFERENCE

The Conference will provide an opportunity to address the science and economics research issues related to Global Change in the context of the policy process. To accomplish these goals, the Conference will focus on and seek to promote:

- A substantially *enhanced understanding* of science, economics, and environmental research agenda central to the needs of future Global Change policy development.
- A *substantive understanding of the uncertainties* in both science and economics knowledge of changes in the global environment of the planet.
- *Increased mutual understanding* of and sensitivity to the substance of science and economics research between both of those research communities.
- *Increased sensitivity* by the two research communities to the policy needs evolving in such areas as environmental and energy policy, and vice versa.
- A *solid* and well implemented science and economics *research effort* as a prerequisite for a complement to evolving efforts by nations to address the international policy questions of global environmental changes.
- A communication *network among national leaders* concerned with, and responsible for, the research and policy agenda related to Global Change. More particularly, this Conference provides a "first-ever" opportunity to forge a partnership between the science and economics research communities and the policy-makers.

To provide a vehicle to focus on these vital issues, the Conference will include two Plenary Sessions and several concurrent Working Groups, which will address the three major themes of the Conference:

- The Science and Economics Research Challenge
- Integrating Science and Economics Research in the Policy Process
- Building a Partnership for Science and Economics Research

The Conference is expected to produce a Co-Chairmen's Report, which will outline the deliberations of the Conference and set forth common actions designed to expand research and cooperation among nations.

As President Bush stated in his invitation letter, "It is my hope that the expertise, experience, and data available in our respective countries can be brought together in a more integrated and coherent fashion. By working together, our nations can enhance international cooperation in these vital areas and contribute to the success of the ongoing IPCC process."



PRELIMINARY DELEGATION LIST

Current as of April 4, 1990; 12:00 Noon

BRAZIL

(tentative)

Name	Title
Jose Lutzenberger	Environment Secretary
Jose Goldemberg	Science Secretary

CANADA

(tentative)

Name	Title
Lucien Bouchard	Federal Environment Minister
Derek Burney	Ambassador to the U.S.
Dr. Ann White	Director, Canadian Global Change Program
Dr. Arthur W. May	President, the Natural Science and Engineering Research Council

FEDERAL REPUBLIC OF GERMANY

(confirmed)

Name	Title
Professor Dr. Klaus Töpfer	Federal Minister for Environment, Nature Protection and Nuclear Safety
Dr. Gebhard Ziller	State Secretary, Ministry for Research and Technology
Dr. Wilhelm Knittel	State Secretary, Ministry for Transportation
Baldur Wagner	Assistant Secretary, Federal Chancellery
Dr. Mario Graf von Matuschka	Assistant Secretary, Foreign Ministry
Dr. Horst Glatzel	Deputy Assistant Secretary, Federal Chancellery
Walter Lötze	Deputy Assistant Secretary, Ministry of Economics
Professor Dr. Ansgar Vogel	Deputy Assistant Secretary, Ministry for Environment, Nature Protection, and Nuclear Safety
Dietrich Kupfer	Director, Office of International Cooperation, Ministry for Environment, Nature Protection and Nuclear Safety
Professor Dr. Hartmut Grossl	Scientist, Max Planck Society, Hamburg

FRANCE

(tentative)

Name	Title
Minister Hubert Curien	Minister of Research and Technology
Minister Brice Lalonde	Secretary of State for the Environment
Jean Audouze	Science Advisor to the President
Claude Alegre	Special Advisor to the Minister of Education
Ambassador Jean Ripert	Ministry of Foreign Affairs (Environment)
Yves Martin	Chairman of the Interministry Committee on Greenhouse
Madame Borione	Ministry of Foreign Affairs
Andre LeBeau	General Director of the Meteorological Center
M. Nasse	Ministry of Economy and Budget
Sylvie Faucheux	Professor of Economy at Paris I

INDIA

(tentative)

Name	Title
Ms. Maneka Gandhi	Minister of State for Environment and Forests
Vasant Gowarikar	Secretary of Department of Science and Technology
Mahesh Prasad	Secretary of Ministry of Environment and Forests
Dr. A.P. Mitra	Director General of Council for Science and Industrial Research

INDONESIA

(confirmed)

Name	Title
Prof. Dr. Ing. B.J. Habibie	Minister of State for Research and Technology; Chairman of the Agency for the Assessment and Application of Technology
Prof. Dr. Samaun Samadikun	Chairman of the Indonesian Institute of Science
Prof. Dr. John A. Katili	Deputy Chairman of the National Research Council
Prof. Dr. Gunawan Satari	Permanent Secretary, Ministry of State for Research and Technology
Mr. Poedji Kuntarso, MA	Director General for Foreign Economic Relations; Ministry of Foreign Affairs
Prof. Dr. Rustam Didong	Deputy Chairman (Economics), National Development Planning Agency
Prof. Dr. Harsono Wiryosumarto	Deputy Chairman (Technology Development); Agency for the Assessment and Application of Technology
Prof. Dr. S.B. Joedono	Assistant Minister (Industry, Energy and Mining), Office of the Coordinating Minister for the Economy, Finance, Industry and Development Supervision
Dr. M. Alwi Dahlan	Assistant Ministry (Population), Office of the Minister of State for Population and the Environment
His Excellency Abdulrachman Ramly	Ambassador of the Republic of Indonesia to the United States of America

ITALY

(tentative)

Name	Title
Hon. Adolfo Battaglia	Minister of Industry, Head of Delegation
Prof. Umberto Colombo	Director of the National Agency for Nuclear and Renewable Energies
Prof. Giuseppe Biorci	Vice President of the National Research Council
Prof. Giuseppe Bianchi	Director General for Energy Sources, Ministry of Industry
Prof. Antonio Praturlon	President of the CNR Committee on Geological Sciences
Prof. Roberto Frassetto	CNR Institute of the Dynamics of Great Masses
Prof. Emilio Gerelli	Economic Counselor to the Minister of Environment
Dr. Corrado Clini	Director General for Pollution Prevention, Ministry of Environment
Prof. Guido Visconti	Department of Physics, University of L'Aquila
Dr. Giovanni Sacco	Vice Director General of Treasury, Ministry of Treasury

MEXICO

(tentative)

Name	Title
Lic. Patricio Chirinos	Secretary of Urban Development and Ecology
Dr. Jose Sarukhan	Rector, National Autonomous University
Dr. Herminio Blanco	Undersecretary for Foreign Commerce, Secretariat of Commerce and Industrial Development
Ing. Alberto Escofet	Undersecretary for Energy, Secretariat of Energy, Mines and Parastatal Industries
Lic. Jose Angel Gurria	Undersecretary for International Financial Affairs, Secretariat of the Treasury
Fis. Sergio Reyes	Undersecretary for Ecology
Amb. Alberto Szekely	Legal Counsel, Secretariat of Foreign Affairs
Dr. Julian Adem	Director, Center for Atmospheric Studies, National Autonomous University
Dr. Manuel Ortega	Director General, National Council for Science and Technology
Hector Santana	Staff Aide to Secretary Chirinos

THE NETHERLANDS

(tentative)

Name	Title
Hans Alders	Minister for Housing, Physical Planning and Environment
Dr. B.C.J. Zoeteman	Deputy Director-General for Environment
Dr. Pier Vellinga	Coordinator for National Climate Programs
N.D. Van Egmond	Director for Chemistry and Physics, State Institute for Public Health and Environmental Hygiene
I.G. Roos	Directorate-General for European Cooperation, Ministry of Foreign Affairs
Dr. H.M. Fijnaut	Director of the Royal Dutch Meteorological Institute
Dr. A.P.M. Baede	Head of the Department for Dynamical Meteorology
D.F.W.T. Pietermaat	Environmental Coordinator in the Directorate-General for Energy, Ministry of Economic Affairs
Prof. J.B. Opschoor	Professor of Ecology, Free University, Amsterdam

NORWAY

(confirmed)

Name	Title
Kristin Hille Valla	Minister of Environment
Einar Steensnaes	Minister of Education and Research
Ambassador Kjeld Vibe	Norwegian Ambassador to the United States
Oddmund Graham	Secretary General, Ministry of Environment
Kaare Bryn	Director General, Ministry of Foreign Affairs
Dr. Tore Olsen	Director General, Ministry of Education and Research
Per M. Bakken	Coordinator, Air Pollution, Ministry of Environment
Lorents Lorentsen	Director of Research, Central Bureau of Statistics
Professor Dr. Ivar Isaksen	University of Oslo
Leif Westegaard	Science Officer, Norwegian Embassy in Washington

THE OECD

(tentative)

Name	Title
Robert Cornell	Deputy Secretary-General
William L. Long	Director for Environment
John Ferriter	Deputy Executive Director, International Energy Agency
Andrew Dean	Administrator, Department for Economic Affairs and Statistics
George Kowalski	Head of the Division of Economic Analysis, International Energy Agency

POLAND

(tentative)

Name	Title
Jan Janowski	Deputy Prime Minister; Head of the Office of Scientific and Technological Progress
Andreyewski	Deputy Minister of the Environment
Tadeusz Diem	Deputy Minister of Education
Rybicki	Central Planning Office
Kazimierz Duchowski	Department of Economic Cooperation, Ministry of Foreign Affairs
Wiackowski	Chairman, Parliamentary Commission on Environmental Protection
Stakel	Professor, Polish Academy of Sciences
Sadowski	Institute of Metallurgy and Water Management
Wlodzimierz Bojarski	Senator
Jan Kinast	Polish Ambassador to the United States

SOVIET UNION

(tentative)

Name	Title
Nikolay P. Laverov	Chairman of the USSR State Committee on Science and Technology
Yuriy A. Izrael	Chairman of the State Committee on Hydrometeorology
V.F. Kostin	Deputy Chairman, State Committee for Nature Protection
Aleksander A. Metalnikov	Deputy Chairman, State Committee for Hydrometeorology
A.A. Troitsky	Deputy Chairman, State Planning Committee
V.M. Kotliakov	Director, Institute of Geography, USSR Academy of Sciences
Yu. L. Golubev	Assistant to Chairman, State Committee for Hydrometeorology
Yu. V. Vakajuk	Chief, Division of Global Geophysical Problems, Climate Change and Economic Consequences, State Committee for Hydrometeorology
Yu. V. Pikhanov	State Committee for Hydrometeorology, Department of International Cooperation
Mrs. N. Yu. Vail	State Department Committee for Hydrometeorology, Department of International Cooperation

UNITED KINGDOM

(tentative)

Name	Title
David Trippier RD, JP, MP	Minister for the Environment and Countryside
Sir John Fairclough	Chief Scientific Adviser, the Cabinet Office
Sir Crispin C.C. Tickell, GCMG, KCVO	United Kingdom Permanent Representative to the United Nations
Dr. John T. Houghton CBE	Director-General, Meteorological Office
J.G. Odling-Smee	Deputy Chief Economic Adviser; HM Treasury
Dr. David J. Fisk	Chief Scientist, Department of Environment
Dr. W. David Evans	Chief Scientist, Department of Energy
Dr. Eileen Buttle	Secretary, Natural Environment Research Council

UNITED STATES OF AMERICA

(confirmed)

Name	Title
Nicholas F. Brady	Secretary of the Treasury
Manuel Lujan, Jr.	Secretary of the Interior
Clayton Yeutter	Secretary of Agriculture
Robert A. Mosbacher	Secretary of Commerce
Admiral James D. Watkins (Ret)	Secretary of Energy
William K. Reilly	Administrator, Environmental Protection Agency
Richard H. Truly	Administrator, National Aeronautics and Space Administration
John A. Knauss	Under Secretary of Commerce for Oceans and Atmosphere; and Director, National Oceanic and Atmospheric Administration
Erich Bloch	Director, National Science Foundation
Richard Schmalensee	Member, Council of Economic Advisers

ZAIRE

(tentative)

Name	Title
Citoyen Lobo Kanza Kanza	Secretary of State (Deputy Minister); Ministry of Environment and Conservation of Nature



CONFERENCE CO-CHAIRMEN BIOGRAPHIES

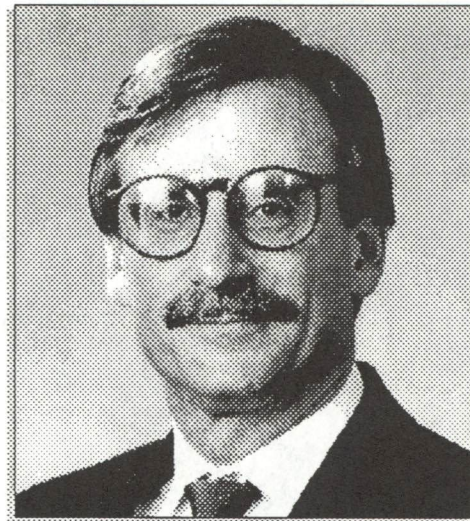
MICHAEL J. BOSKIN

D. ALLAN BROMLEY

MICHAEL R. DELAND



Michael J. Boskin
Chairman
President's Council of
Economic Advisers



Michael J. Boskin is the Chairman of the President's Council of Economic Advisers. He was appointed to this post by the President on February 2, 1989, following unanimous confirmation by the Senate. As Chairman, he provides economic analysis and advice directly to the President and assists in formulating national economic policies. Dr. Boskin is on leave from Stanford University, where he is the Burnet C. and Mildred Finley Wohlford Professor of Economics, and was the founder and Director of the Center for Economic Policy Research. He is also on leave as a Research Associate of the National Bureau of Economic Research.

Dr. Boskin is the recipient of numerous professional awards and citations, ranging from the Chancellor's Award and the Department Citation as outstanding undergraduate at the University of California in 1967 and the first National Tax Association Outstanding Doctoral Dissertation Award in 1971 to the Abramson Award for Outstanding Research from the National Association of Business Economists in 1987 and Stanford University's Distinguished Teaching Award in 1988. He is the author of more than 80 books and articles in the areas of government spending, tax theory and policy, public debt, Social Security, retirement patterns and behavior, U.S. saving behavior, capital formation, U.S. economic growth, and the economic status of the elderly.

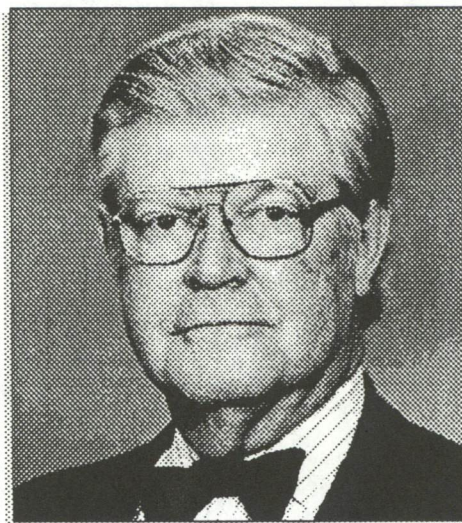
Dr. Boskin received his B.A. degree with highest honors in 1967 from the University of California at Berkeley, where he received his M.A. in 1968 and his Ph.D. in 1971.

Previously, Dr. Boskin had served as a consultant and adviser to the White House, Department of Health and Human Services, Treasury Department, National Science Foundation, and other government agencies, and various congressional committees.

Dr. Boskin is a member of the Economic Education Committee of the American Economic Association. He and his wife Chris moved to Washington, D.C. from California. They both enjoy skiing and tennis.



D. Allan Bromley
Assistant to the President
Science and Technology



D. Allan Bromley is Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. He is on leave from his former position as Henry Ford II Professor of Physics at Yale University, where he was founder and Director of the A.W. Wright Nuclear Structure Laboratory.

One of the world's leading nuclear physicists, he has carried out pioneering studies on both the structure and dynamics of nuclei and is considered the father of modern heavy ion science, one of the major areas of nuclear science. He has also played major roles in the development of accelerators, of detection systems, and in computer-based data acquisition and analysis systems. An outstanding teacher, over the past two decades his laboratory at Yale graduated more Ph.D.'s in experimental nuclear physics than any other institution worldwide. He has published over 450 papers in science and technology as well as edited eighteen books and has received numerous honors and awards, including the National Medal of Science.

For more than two decades, Dr. Bromley has been a leader in the national and international science and science policy communities. As Chairman of the National Academy's Physics Survey in the early 1970s, he contributed in a central way to charting the future of that science in the subsequent decade. As President of the American Association for the Advancement of Science, the world's largest scientific society, and the International Union of Pure and Applied Physics, the world coordinating body for that science, he has been one of the leading spokesmen for U.S. science and for international scientific cooperation.

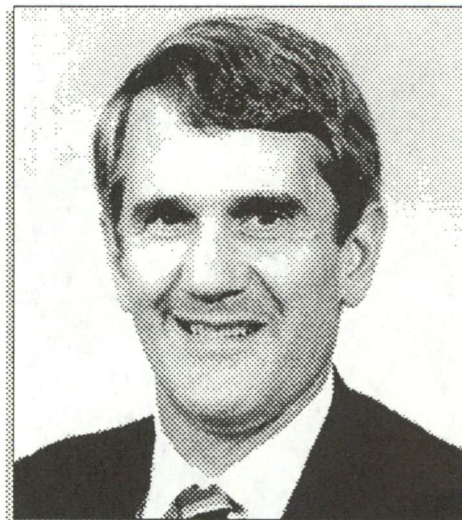
Prior to his present appointment, Dr. Bromley served as a member of the White House Science Council throughout the Reagan Administration and as a member of the National Science Board in 1988-1989. As the U. S. chairman for both the Gandhi-Reagan, Indo/U.S. and the Sarney-Reagan, Brazil/U.S. Science and Technology Initiatives, he led four Presidential missions to conduct negotiations for bilateral cooperation in science and technology.

Born in Westmeath, Ontario, Canada, he received the B.Sc. degree with highest honors in 1948 in the Faculty of Engineering at Queen's University, Ontario, Canada. He received the M.Sc. degree from Queen's University in 1950 and the Ph.D. degree from the University of Rochester in 1952, both degrees in nuclear physics. He subsequently has been awarded ten honorary degrees from universities in Canada, France, Germany, Italy, South Africa, and the United States.

Dr. Bromley is married to the Former Patricia J. Brasseur, and they have two children, David John and Karen Lynn.



Michael R. Deland
Chairman
White House Council
on Environmental Quality



Michael R. Deland was appointed by President Bush to be Chairman of the White House Council on Environmental Quality on August 1, 1989, following unanimous confirmation by the United States Senate. In this capacity he serves as environmental adviser to the President as well as Director of the Office of Environmental Quality which oversees the development of environmental policy, interagency coordination of environmental quality programs and environmental data acquisition and assessment. In addition, Mr. Deland is responsible for overseeing implementation of the National Environmental Policy Act.

Prior to Mr. Deland's appointment as CEQ Chairman, he was the New England Regional Administrator for the U.S. Environmental Protection Agency (EPA). In that capacity, from 1983 to 1989, he administered the federal government's programs dealing with air and water pollution control, hazardous waste management, drinking water, toxic substances, radiation, and pesticides.

Mr. Deland was counsel at Environmental Research and Technology, Inc., a national firm headquartered in Concord, Massachusetts from 1976 to 1983. While in the private sector, Mr. Deland published numerous papers and articles, including the Regulatory Focus monthly column in *Environment, Science and Technology*. Between 1971 and 1976, Mr. Deland served in EPA's Office of Regional Counsel in New England (Region I) in several capacities, including Chief of the Agency's Legal Review Section and Chief of the Enforcement Branch.

Mr. Deland received his Bachelor of Arts degree from Harvard College in 1963 and served as an officer in the U.S. Navy before obtaining his law degree from Boston College in 1969. He is a member of the Massachusetts Bar and the American Bar Association and its Natural Resources Committee. Mr. Deland was President of the Business Associates Club (Boston) from 1981 to 1982 and is a former Director of the Environmental Lobby of Massachusetts and the Center for Environmental Intern Programs, a national non-profit organization headquartered in Boston.

Mr. Deland has received numerous awards and citations, including the Massachusetts Audubon Society Award for his leadership in cleaning up Boston Harbor and the New England Environment Leadership Award for the New England Environmental Network. In 1987, he was honored as "Environmentalist of the Year" by the Massachusetts Association of Conservation Commissions. In March of 1989, he was awarded the National Wildlife Federation's Special Achievement Award for his role in prompting the cleanup of Boston Harbor, for his efforts at protecting valuable fishing areas from off-shore oil drilling, and for his early endorsement of environmentally-based growth controls on Cape Cod. Mr. Deland resides in Washington with his wife Jane and three children.



U.S. Delegation Biographies

As part of the Conference handout materials, we are preparing an information/reference booklet which will include:

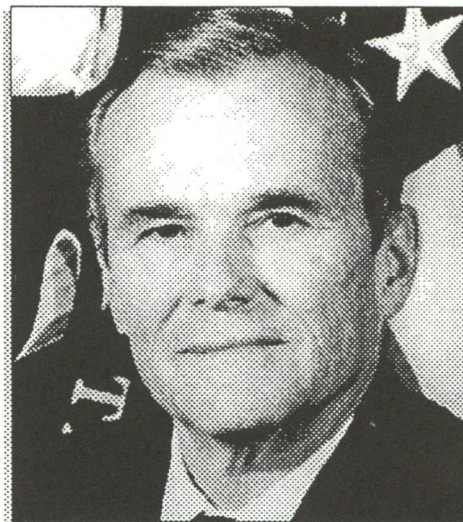
- one-page narrative biography of each delegate
- an 8" x 10" photograph of each delegate
- the delegate's organization's logo/seal

The biographies, logos and photographs of the U.S. delegation included in this section are representative of the materials we are seeking from each foreign delegation member.

Please provide this information to the White House Conference as soon as possible.



Nicholas F. Brady
Secretary
Department of the Treasury



Nicholas F. Brady became the 68th Secretary of the Treasury on September 15, 1988.

Secretary Brady served in the United States Senate from April 20, 1982 through December 27, 1982. During that time he was a member of The Armed Services Committee and the Banking, Housing and Urban Affairs Committee.

In 1984 President Reagan appointed Secretary Brady Chairman of the President's Commission on Executive, Legislative and Judicial Salaries. He has also served on the President's Commission on Strategic Forces (1983), the National Bipartisan Commission on Central America (1983), the Commission on Security and Economic Assistance (1983), and the Blue Ribbon Commission on Defense Management (1985). Most recently, Secretary Brady chaired the Presidential Task Force on Market Mechanisms (1987).

Secretary Brady's career in the banking industry spans 34 years. He joined Dillon, Read & Co., Inc. in New York in 1954, rising to Chairman of the Board. He has been a Director of the NCR Corporation, the MITRE Corporation, and the H.J. Heinz Company, among others.

He has also served as a trustee of Rockefeller University and a member of the Board of the Economic Club of New York. He is a member of the Council on Foreign Relations, Inc. He is a former trustee of the Boys' Club of Newark.

Mr. Brady was born April 11, 1930 in New York City. He was educated at Yale University (B.A., 1952) and Harvard University (M.B.A., 1954). He and his wife, Katherine, have four children.



Manuel Lujan, Jr.
Secretary
Department of the Interior



POLITICAL

President George Bush selected Manuel Lujan, Jr., who had just completed a 20-year career in the House of Representatives, to be his Secretary of the Interior. He was sworn in on February 3, 1989.

The 46th Secretary of the Interior, Lujan was first elected to the House of Representatives from New Mexico in 1968. When he left the Congress on January 3, 1989, he ranked 15th in seniority among all Republicans and 52nd in seniority among all House members.

A member of the House Interior and Insular Affairs Committee since 1969, Lujan was its second ranking Republican. The Committee has jurisdiction over all activity in the U.S. Department of the Interior as well as the Nuclear Regulatory Commission. Lujan was also the senior Republican on the Energy and Environment Subcommittee.

Lujan was the Vice-Chairman of the House Science, Space and Technology Committee. As senior Republican, Lujan was a member of all subcommittees, including Space Science and Applications which has oversight over NASA.

PERSONAL

Born May 12, 1928 in San Ildefonso, New Mexico. Raised in Santa Fe where Lujan's father, Manuel Lujan, Sr., served three elected terms as Mayor.

A graduate of the College of Santa Fe with a B.A. degree, Lujan also attended St. Mary's College in California.

Prior to entering Congress, the Secretary was a partner in a family insurance and real estate business with three offices in New Mexico. His brother, Edward Lujan, is the managing partner of the business.

Married to the former Jean Couchman of Santa Fe, the Lujans have four children; Terra Everett, Jay, Barbara and Jeff. Secretary and Mrs. Lujan maintain residences in both Washington, D.C. and Albuquerque.

LEGISLATIVE

Economy in Government: Lujan was a Congressional leader in the battle against wasteful government spending. *"The effort to stop inflation boils down to a fight against needless government intervention and spending,"* stated Lujan.

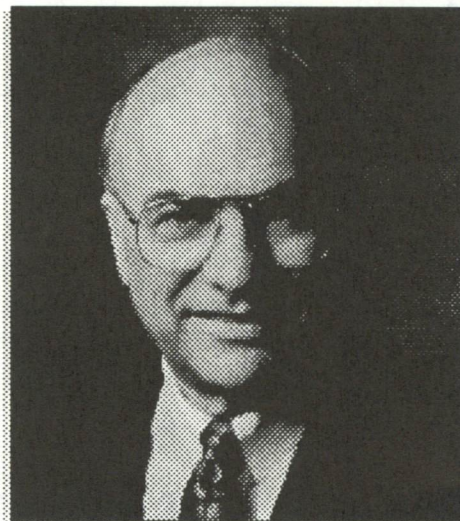
Environmental Protection: Lujan has co-sponsored seven major environmental protection bills including the Clean Air Act of 1970 and the Clean Water Act. More recently, Lujan successfully sponsored legislation setting aside more than 600,000 acres of New Mexico land as wilderness areas, ensuring its beauty and enjoyment for future generations.

Education: Lujan strongly supported student loan programs in the public and private sectors. His work led to New Mexico adopting a student loan program that is a model for other states.

Technology: Lujan believes strongly that scientific research is the key to our future. *"Science and technology can help us meet the challenges of the 21st century,"* said Lujan.



Clayton Yeutter
Secretary
Department of Agriculture



Clayton Yeutter was sworn in as the 23rd United States Secretary of Agriculture on February 8, 1989.

Yeutter's career includes distinguished public and private-sector service in agricultural policy development, law, economics, marketing and trade.

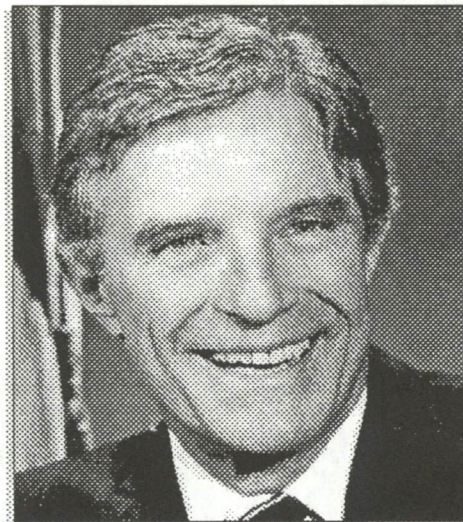
From July 1985 until shortly before his new cabinet appointment, Yeutter served as U.S. Trade Representative. His previous USDA posts include Assistant Secretary for International Affairs and Commodity Programs from March 1974 to June 1975, Assistant Secretary for Marketing and Consumer Service from January 1973 to March 1974 and Administrator of the Consumer and Marketing Service from October 1970 to December 1971.

Yeutter's other career highlights: President and Chief Executive officer, Chicago Mercantile Exchange, July 1978 to June 1985; senior partner, law firm of Nelson, Harding, Yeutter & Leonard, Lincoln, Nebraska, April 1977 to June 1978; Deputy U.S. Special Trade Representative, June 1975 to February 1977; Director, University of Nebraska Mission in Colombia (a large agricultural technical assistance program), September 1968 to October 1970; executive assistant to the governor of Nebraska, January 1966 to September 1968; faculty member, Department of Agricultural Economics, University of Nebraska, January 1960 to January 1966; operator of a 2,500 acre farming-ranching-cattle feeding enterprise in central Nebraska, 1957-1975; and enlistee, later commissioned officer, U.S. Air Force, 1952-1957.

Yeutter was graduated with high distinction from the University of Nebraska in 1952 with a Bachelor of Science degree in animal husbandry. In 1963, he obtained his law degree from the same university, graduating *cum laude* and ranked first in his class. In 1966, he received his Ph.D. in agricultural economics, again from the University of Nebraska, and was named outstanding graduate student in the program.

Yeutter is a former member or chairman of many private and public-sector boards of directors, councils and trusteeships, including: the President's Export Council; the Chicago Association of Commerce and Industry; the Chicago-Tokyo Bank; the U.S. Meat Export Federation; the Chicago Council on Foreign Relations; the Farm Foundation, Oak Brook, Illinois; Tri-Valley Growers, San Francisco, California; and ConAgra, Inc., Omaha, Nebraska.

Yeutter was born in Eustis, Nebraska, December 10, 1931. He and his wife, Jeanne Vierk Yeutter, have four children. He retains ownership of his Nebraska farm, which is currently operated by a tenant. Yeutter's permanent home is in Lincoln, Nebraska, but he currently resides in McLean, Virginia.



Robert A. Mosbacher
Secretary
Department of Commerce

Nominated Secretary of Commerce by President-Elect George Bush on December 6, 1988. He was confirmed 100-0 by the United States Senate on January 31, 1989.

Formerly:

Chief Executive Officer and Chairman of Mosbacher Energy Company

Director of Texas Commerce Bancshares, Houston, Texas

Director, Enron Corporation, Houston, Texas

Director, New York Life Insurance Company, New York

Past Chairman of the National Petroleum Council

Charter member and past Chairman of the All American Wildcatters Association

Member of the Executive Committee and Board of Directors of the American Petroleum Institute

Past Chairman of the Mid-Continent Oil and Gas Association

Twice Past Chairman of the Board of Visitors of the Texas M.D. Anderson Cancer Institute

Former member of Board of Trustees of the Texas Heart Institute

Former National Trustee, Boys Clubs of America Southwest Region

Past Active Trustee of the Aspen Institute for Humanistic Studies

Member of Washington Roundtable and Co-Chair of Houston Roundtable of the Center for Strategic and International Studies

National Finance Chairman for George Bush for President

National Finance Chairman of the Fund for America's Future

Chairman of Victory 88'

Co-Chairman of the Republican National Finance Committee

Member of the Executive Committee for Reagan-Bush

National Finance Chairman for the President Ford Committee in 1976

Won both the North American and World Sailing Championships in the Olympic classes (Dragon and Soling)

Won the Southern Ocean Racing Circuit

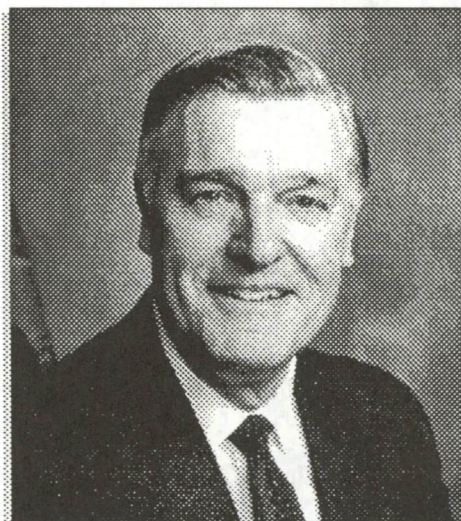
Won the Gold Cup twice

Born in White Plains, New York, Mosbacher has lived in Houston, Texas since 1948. He graduated from Washington and Lee University in Lexington, Virginia in 1947.

Mosbacher is married to the former Georgette Paulsin and is the father of four (Diane, Robert Jr., Kathryn and Lisa) and grandfather of five. The Mosbachers reside in Washington, D.C.



James D. Watkins
Secretary
Department of Energy



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

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

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

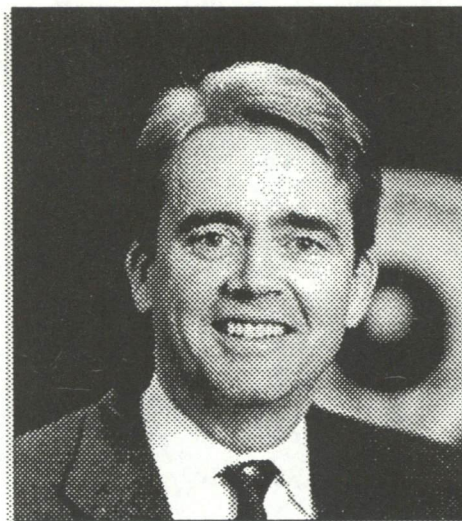
In October 1987, Admiral Watkins was appointed Chairman of the Presidential Commission on the Human Immunodeficiency Virus (AIDS) Epidemic, submitting the Commission's final report to the President on June 24, 1988.

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

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



William K. Reilly
Administrator
Environmental Protection Agency



William Kane Reilly was sworn in as Administrator of the U.S. Environmental Protection Agency by President Bush on February 8, 1989. The President announced his appointment on December 22, 1988, and officially nominated him on January 20, 1989. The U.S. Senate unanimously confirmed his nomination on February 2, 1989.

Prior to becoming EPA Administrator, Reilly held five environment-related positions during the previous two decades. He was President of World Wildlife Fund-U.S. (1985-1989) and President of the Conservation Foundation (1973-1989). Those two organizations joined in a formal affiliation in 1985 and Reilly became President of both organizations. He was Executive Director of the Task Force on Land Use and Urban Growth from 1972-1973. From 1970 to 1972, he was on the staff of the President's Council on Environmental Quality and, from 1968 to 1970, was Associate Director, Urban Policy Center and the National Urban Coalition. He also served as Chairman of the Natural Resources Council of America, an association of all major conservation groups, from 1981-1983.

During his presidency of World Wildlife Fund-U.S., Reilly intensified his mission, the protection of the diversity of life on earth. Between 1961 and 1989, the organization supported 1,371 wildlife and endangered habitat projects in 103 countries. At the Conservation Foundation, he continued its long-standing interest in land programs and initiated new programs in environmental dispute resolution, water toxic substances control, and urban conservation and energy. In 1976, Reilly began a program advocating direct cooperation between business leaders and conservationists in resolving polarizing issues in resources and environmental policy, which resulted in several major consensus-building policy dialogues, including the National Groundwater Policy Forum and the National Wetlands Policy Forum.

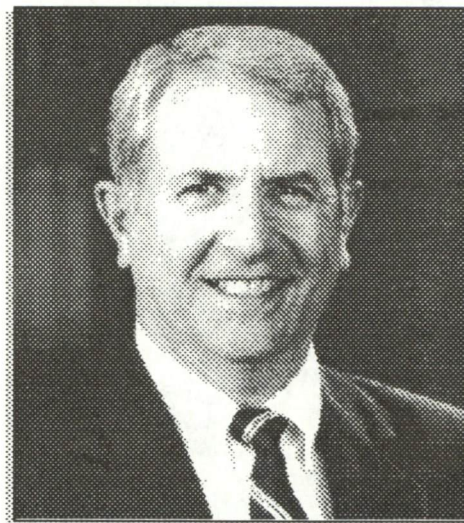
Reilly has written and lectured extensively on environmental issues, has served on the boards of various private and public sector organizations and received the Horace Albright Medal for his contributions to national parks and the Alfred B. LaGasse Medal for his contributions to environmental progress.

An alumnus of Yale University, Reilly holds a law degree from Harvard University and a master's degree in urban planning from Columbia University. He was born in Decatur, Illinois on January 26, 1940, grew up in Fall River, Massachusetts, and served as a U.S. Army captain (1966 to 1967).

He is married to Elizabeth "Libbie" Bennet Buxton Reilly. They have two daughters, Katherine Buxton Reilly, age 19, and Margaret Mahalah Reilly, age 14. The family resides in Alexandria, Virginia.



Richard H. Truly
Administrator
National Aeronautics and
Space Administration



Richard H. Truly became the eighth Administrator of NASA on July 1, 1989. One day earlier, he concluded his naval career of more than 30 years, retiring as a Vice Admiral, United States Navy. He is the first astronaut to head the nation's civilian space agency.

Truly became NASA's associate administrator for space flight on February 20, 1986. In this position, he led the painstaking rebuilding of the Space Shuttle program. This was highlighted by NASA's celebrated "return to flight" on September 29, 1988, when Discovery lifted off from Kennedy Space Center, Florida, on the first Shuttle mission in almost three years.

Before returning to NASA, the former Shuttle astronaut served as the first commander of the Naval Space Command, Dahlgren, Virginia, established October 1, 1983. His career in the U.S. Navy began in 1959, when he was commissioned an ensign. This coincided with his graduation from Georgia Institute of Technology, which he attended as a Naval R.O.T.C. midshipman and earned a bachelor's degree in aeronautical engineering.

Following flight school, he was designated a naval aviator in 1960. His initial tour of duty, Fighter Squadron 33, was aboard USS Intrepid and USS Enterprise, and he made more than 300 carrier landings. From 1963 to 1965, he was a student and then instructor at the U.S. Air Force Aerospace Research Pilot School, Edwards Air Force Base, California.

In 1965, Truly became one of the first military astronauts selected to the Air Force's Manned Orbiting Laboratory program in Los Angeles, California, and transferred to NASA as an astronaut in August 1969. He served as capsule communicator for all three of the manned Skylab missions in 1973 and the Apollo-Soyuz mission in 1975. As a naval aviator, test pilot, and astronaut, Truly has logged over 7,500 hours in numerous military and civilian jet aircraft.

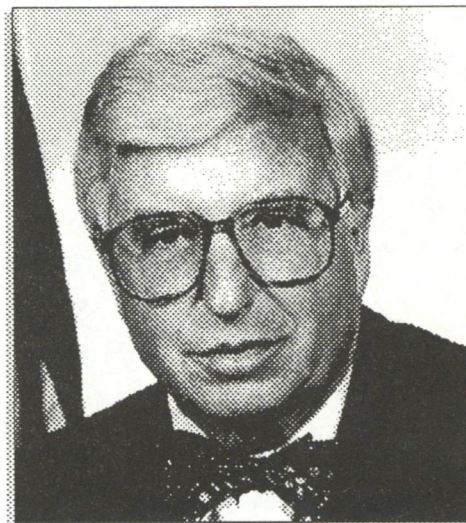
He was pilot for one of the two-man crews that flew the 747/Space Shuttle Enterprise approach and landing test flights during 1977. He then served as backup pilot for STS-1, the first orbital test of the Shuttle. His first flight in space was November 12-14, 1981, as pilot of Space Shuttle Columbia (STS-2), significant as the first manned spacecraft to be reflown in space. His second flight (STS-9, August 30-September 5, 1983) was as commander of Space Shuttle Challenger, the first night launch and landing in the Shuttle program.

On January 18, 1989, Truly was awarded the Presidential Citizen's Medal by President Reagan. His NASA awards include two NASA Distinguished Service Medals, the NASA Outstanding Leadership Medal, two NASA Exceptional Service Medals, and NASA Space Distinguished Service Medal, the Defense Superior Service Medal, two Legions of Merit, the Navy Distinguished Flying Cross, and the Meritorious Service Medal.

Truly was born in Fayette, Mississippi, on November 12, 1937 and attended school in Fayette and Meridian, Mississippi. He is married to the former Colleen (Cody) Hanner of Milledgeville, Georgia. They have three children: Mike, Dan and Lee, and three grandchildren: Ashley, Courtney and Peter.



John A. Knauss
Under Secretary
Department of Commerce



John A. Knauss, Under Secretary for Oceans and Atmosphere and Administrator of the Department's National Oceanic and Atmospheric Administration (NOAA), took office August 7, 1989.

A noted oceanographer and educator, Knauss was a professor of oceanography at the Graduate School of Oceanography at the University of Rhode Island (URI). He also served as dean of the URI Graduate School of Oceanography from 1962 to 1987, and as the university's provost for marine affairs from 1969 to 1982.

Knauss has been a member of two presidential commissions on marine affairs: the Commission on Marine Science, Resources, and Engineering (the Stratton Commission) in 1967 to 1968 and the National Advisory Committee on Oceans and Atmosphere (NACOA), 1978 to 1985. He served as Chairman of NACOA from 1981 to 1985. He has been President of the Association of Sea Grant Program Institutions, Chairman of the Ocean Science Committee of the National Academy of Sciences/National Research Council, and Chairman of the Marine Division of the National Association of State Universities and Land-Grant Colleges.

He has served as President of the oceanographic section of the American Geophysical Union (AGU), Vice President of the Marine Technology Society (MTS), Vice Chairman of the American Association for the Advancement of Science's (AAAS) Atmospheric and Hydrospheric Sciences Section, and a council member of the American Meteorological Society. He was a co-founder of the Law of the Sea Institute and served on its governing board from 1965 to 1976 and 1981 to 1987. He has been elected a fellow of the AAAS, the AGU, and the MTS.

Knauss graduated from Massachusetts Institute of Technology (B.S., 1946), the University of Michigan (M.S., 1949), and the University of California, Scripps Institution of Oceanography (Ph.D., 1959).



Erich Bloch
Director
National Science Foundation



Erich Bloch was confirmed by the Senate to be Director of the National Science Foundation on August 6, 1984. As Director, he is responsible for an agency charged with strengthening the national scientific and engineering research potential and with improving science and engineering education at all levels. The Foundation has an annual budget exceeding \$1.7 billion and the annual award of 12,000 to 14,000 grants for research in all fields of natural, social sciences, and engineering.

Before joining NSF, Mr. Bloch was a corporate Vice President for Technical Personnel Development at IBM Corporation, which he joined in 1952 as an electrical engineer. During his career at IBM, Mr. Bloch was the engineering manager of IBM's STRETCH supercomputer system in the late 1950's and early 1960's. In 1962, he headed development of the Solid Logic Technology program, which provided IBM with microelectronic technology for its System/360 computer. Subsequently, Mr. Bloch was appointed a vice president of the company's Data Systems Division and general manager of the East Fishkill facility, which is responsible for the development and manufacture of semiconductor components used in IBM's product line. He was elected an IBM vice president in 1981.

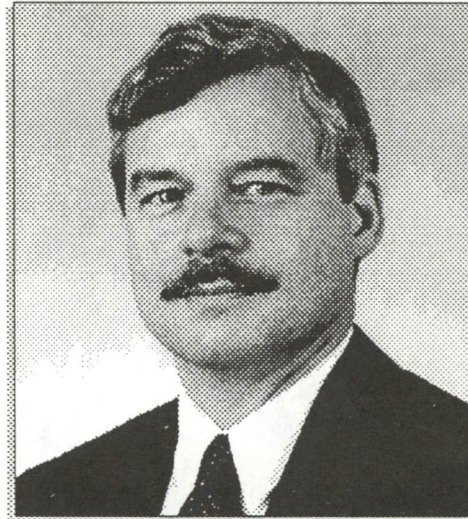
From 1981 to 1984, Mr. Bloch served as Chairman of the Semi-conductor Research Cooperative, a group of leading computer and electronics firms that fund advanced research in universities and shares in the results, and was the IBM representative on the board of the Semiconductor Industry Association.

In February 1985, Mr. Bloch was awarded the National Medal of Technology by President Reagan. The award was made for his part in pioneering developments related to the IBM/360 computer that revolutionized the computer industry. In 1989, Mr. Bloch was the recipient of the IEEE United States Activities Board Award for Distinguished Public Service and the IEEE 1990 Founders Medal. He also received honorary Doctorate of Engineering degrees from the Colorado School of Mines, the University of Notre Dame, and Rensselaer Polytechnic Institute; honorary Doctorate of Science degrees from the University of Massachusetts at Amherst, George Washington University, State University of New York at Buffalo, the University of Rochester, Oberlin College, and Washington College; and an honorary Doctorate of Science and Engineering degree from the Ohio State University.

He is a member of the National Academy of Engineering and is a Fellow of the American Association for the Advancement of Science and of the Institute of Electrical and Electronics Engineers and a member of its Computer Society. He received his education in electrical engineering at the Federal Polytechnic Institute of Zurich, Switzerland, and a Bachelor of Science degree in electrical engineering from the University of Buffalo in 1952.



Richard Schmalensee
Council of Economic Advisers
Office of the President



Richard Schmalensee is a Member of the Council of Economic Advisers. He has primary responsibility for the analysis of microeconomic and regulatory policy. Dr. Schmalensee is on leave from the Massachusetts Institute of Technology (MIT), where he is the Gordon Y. Billard Professor of Economics and Management.

Dr. Schmalensee's research and teaching have focused on industrial organization and on anti-trust and regulatory policy. He has written numerous articles in professional journals and is the author of three books and co-author of three others. He has extensive consulting experience on anti-trust and regulatory matters. He has served on the editorial boards of several economics journals, is co-editor of the *Handbook of Industrial Organization*, and is founding editor of the MIT Press *Regulation of Economic Activity* monograph series. Dr. Schmalensee has also served on various committees of the American Economic Association and the Econometric Society, of which he is a Fellow.

Dr. Schmalensee attended the public schools of Belleville, Illinois and received his B.S. (Economics, Politics and Science; 1965) and Ph.D. (Economics; 1970) degrees from MIT. Prior to joining the MIT faculty in 1977, he taught at the University of California, San Diego. He is married to the former Diane Hawk; they have two sons.



HOTEL/TRANSPORTATION/LOGISTICS

Dr. Franmarie Keel

White House Conference on Global Change

Suite 615

1019 19th Street, N.W.

Washington, D.C. 20036

Phone: (202) 653-5980

Fax: (202) 653-2034

Telex: 249118SDAVISUR

Telemail (OMNET): GLOBAL.CHANGE

HOTEL

The White House Conference is being held at:

The J.W. Marriott Hotel
1331 Pennsylvania Avenue, N.W.
Washington, D.C. 20004
Telephone: 202-393-2000

- The White House Conference has reserved rooms for each official delegation member. **Charges for the hotel room April 16th and 17th, 1990 and for Conference meals served April 17 and 18, 1990, will be paid for by the White House Conference.**
- Hotel room check-in is 3:00 p.m. Conference registration begins at 12:00 noon, Sunday, April 15, for delegates arriving in Washington early. Registration will continue Monday all day and until 12:00 noon on Tuesday, April 17. Special arrangements should be made with White House Conference coordinators for early or late arrivals/departures and check-in.
- To cover any personal incidental expenditures (such as telephone calls, charges at the hotel restaurants and gift shops, and additional room service), each delegation member must present *one* of the following upon registration at the hotel to guarantee incidentals:
 - credit card (American Express, VISA, Master Card, Diners Club, JCV)
 - a letter received by April 14th, 1990 from the delegation's embassy stating embassy will cover its delegation's incidentals prior to delegation's departure from the hotel

TRANSPORTATION

- Delegations will be met by White House Conference personnel at Washington National Airport, Washington Dulles Airport, Baltimore-Washington International Airport, and Andrews Air Force Base and will be escorted to the hotel beginning Sunday, April 15.
- White House Conference personnel meeting flights can be identified by a White House Conference sign. Delegations arriving in Washington domestically will be met at the gate. International arrivals will be met at the exit of the mobil lounge at the entrance to U.S. Immigration and Customs.
- Procedures have been established by the Conference to assist in the facilitation of U.S. Customs.

- Transportation will be provided for delegations' return to those designated airports after the close of the Conference Wednesday, April 18, through Thursday evening, April 19.
- All transportation for official Conference events held outside of the J.W. Marriott Hotel will be provided by the White House Conference.
- All airline arrival and departure times must be confirmed as soon as possible with the White House Conference at 202/653-5980.
- Please inform the White House Conference immediately if flight plans change at departure (i.e. cancelled flight, family emergency, etc.)

SPECIAL REQUIREMENTS

- Any special room, bed, dietary, or medical requirements should be forwarded to White House Conference coordinators as soon as possible.

MISCELLANEOUS

- Simultaneous interpretation in Russian, Spanish, and French will be provided during the Conference meetings.
- Please note the dinner at the State Department, on Tuesday, April 17, is business attire.

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

Delegate Travel Accommodation Registration

PLEASE PRINT OR TYPE

Name: _____

Title: _____

Country Delegation: _____

HOTEL ACCOMMODATIONS:

In order to facilitate your registration upon arrival at the Conference site at the J.W. Marriott Hotel, it will be necessary to provide the information requested in this form. The White House Conference provides each delegate with a hotel room from check-in April 16th to check-out on April 18th. The J.W. Marriott Hotel requires guarantee of payment for incidentals, such as telephone, room service, gift shop, laundry, restaurants, etc., with cash, a credit card or a Letter of Guarantee from your Embassy. A Letter of Guarantee should include delegate's name, check-in date, Embassy Financial Officer, and any stipulations, and must be received by April 14, 1990.

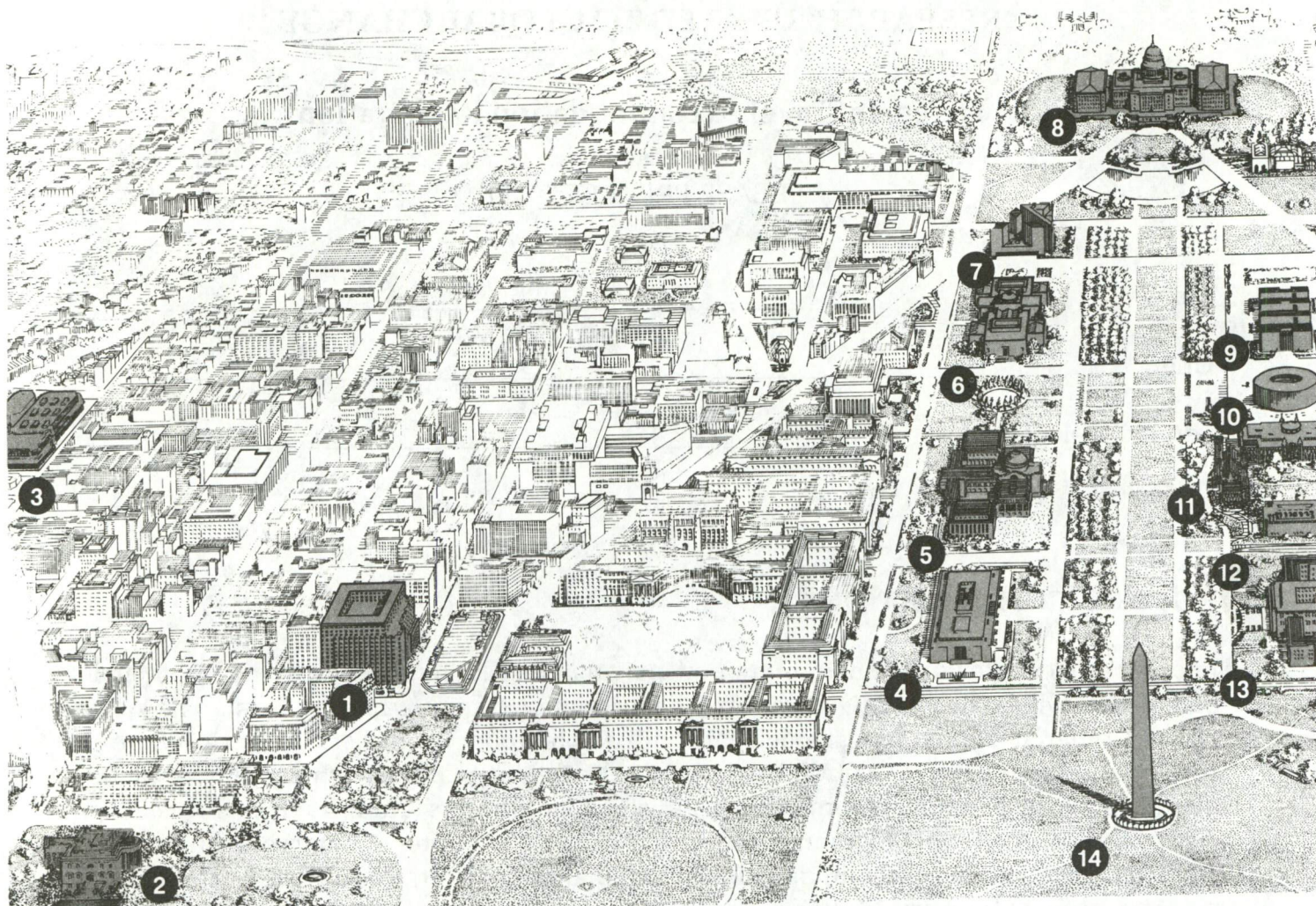
Credit Card # _____ Expiration Date: _____

Type (*American Express, Visa, Master Card, Diners Club, JCV*): _____

Name as it appears on card: _____

Signature: _____ Date: _____

This should be completed and sent by fax (202-653-2034) to Susan Thoren at the White House Conference in Washington, D.C., or delivered by April 12th to 1019 19th Street NW, Suite 615, Washington D.C. 20036



Rendering by S. Finkenberg, New York.

1. JW Marriott Hotel
2. The White House
3. Convention Center
4. Museum of American History
5. Natural History Museum
6. National Gallery of Art
7. National Gallery of Art East Wing

8. United States Capitol
9. Air and Space Museum
10. Hirshhorn Museum
11. Smithsonian "Castle"
12. Freer Gallery
13. Department of Agriculture
14. Washington Monument



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GLOBAL STEWARDSHIP

A STATEMENT OF
THE CONTEXT AND CHALLENGES
FACING THE
WHITE HOUSE CONFERENCE
ON SCIENCE AND ECONOMICS
RESEARCH RELATED TO
GLOBAL CHANGE

SCIENCE AND ECONOMICS RESEARCH FOR GLOBAL STEWARDSHIP

Global stewardship is our shared responsibility and our shared opportunity. We must manage the Earth's natural resources in ways that assure the sustainability of humanity on this planet and in ways that maximize our potential for growth and opportunity for all. Global stewardship is a continuing process of political, economic and social decision-making that meets the needs of the present generation while expanding the opportunities of future generations.

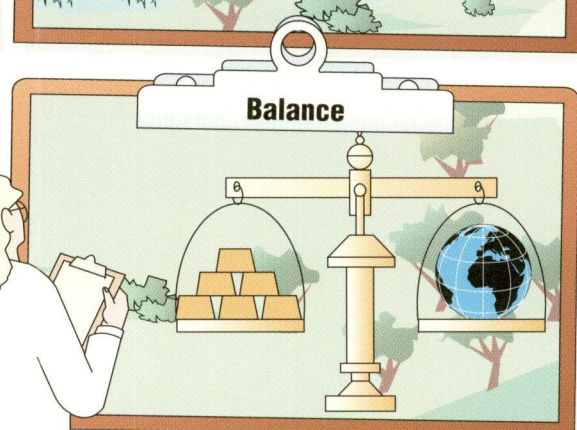
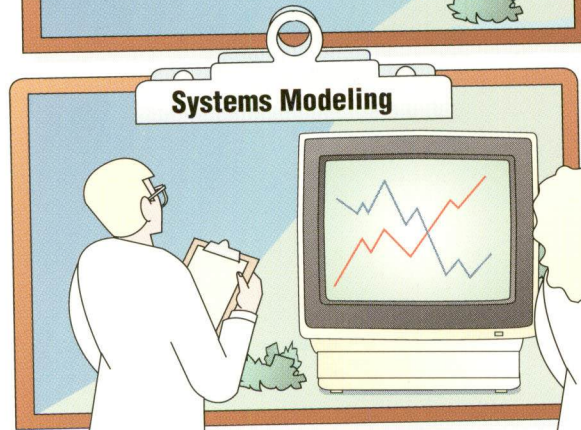
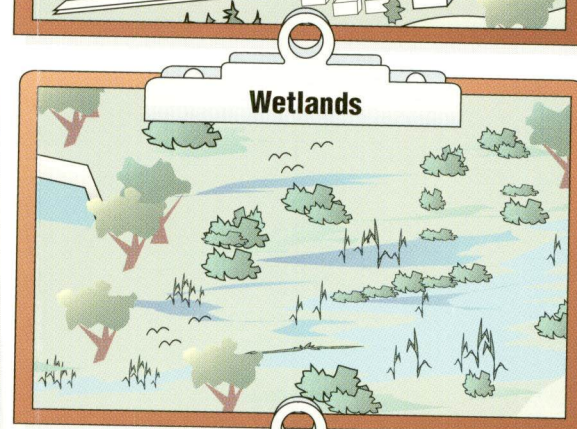
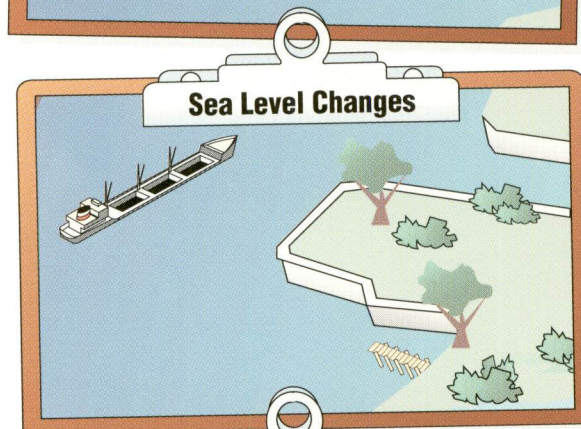
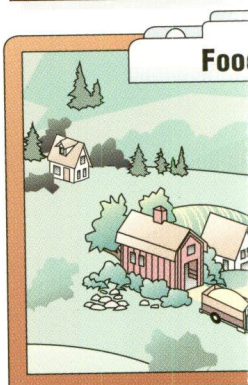
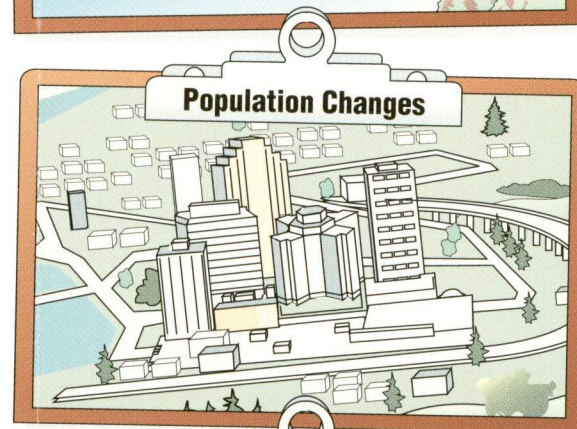
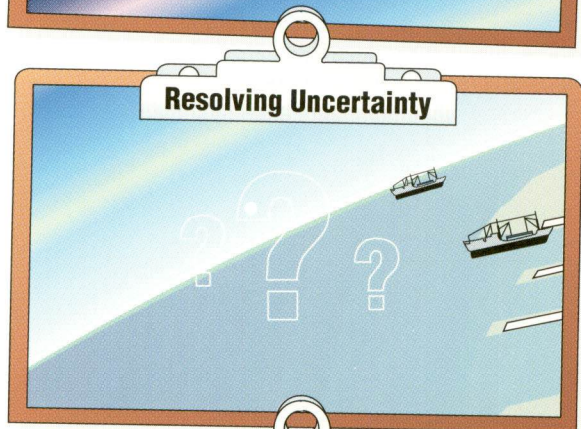
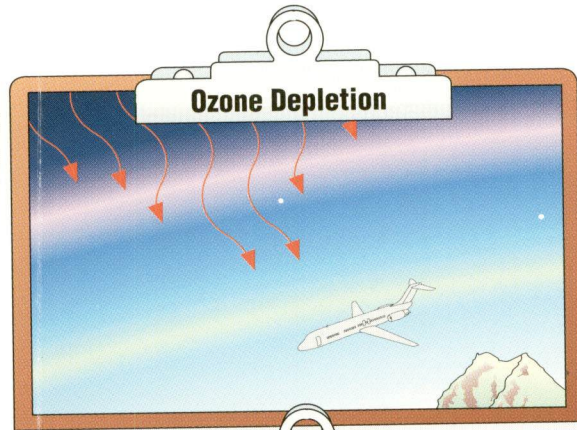
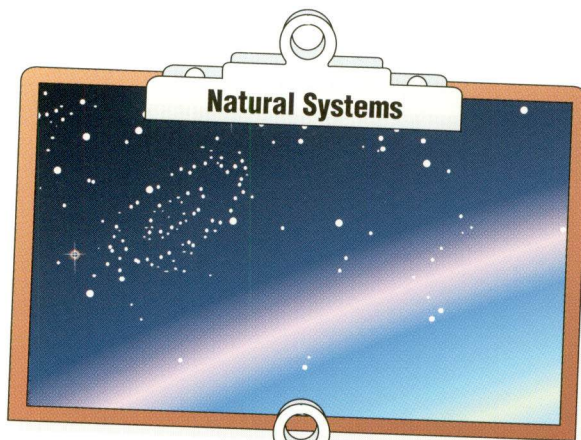
Global stewardship will become a dominant scientific, economic and environmental issue of the 21st century. The experience of the past 45 years has shown that growth can be achieved only through the synergy of democratic political institutions and market economic systems. But just as democratic institutions are expanding, our ability to grow could be limited by changes in our already stressed environment. Solutions must be found which will protect the quality of our natural environment while allowing for the economic growth necessary to sustain and improve the living standards of a growing world population.

For perhaps the first time in human history, we now understand that our progress depends on accounting for our environmental resources and using them wisely. A new understanding of complex environmental systems is emerging. This understanding means that we are now called upon to create new directions for our creative energies and technologies. Global stewardship is the key.

To exercise effective global stewardship, we must advance our knowledge of natural and human systems. We must create solutions that join economic growth with sound management of our environment. Meeting this challenge will require an integration of scientific, economic, and environmental concerns—an integration which moves global stewardship and human sustainability to center stage.

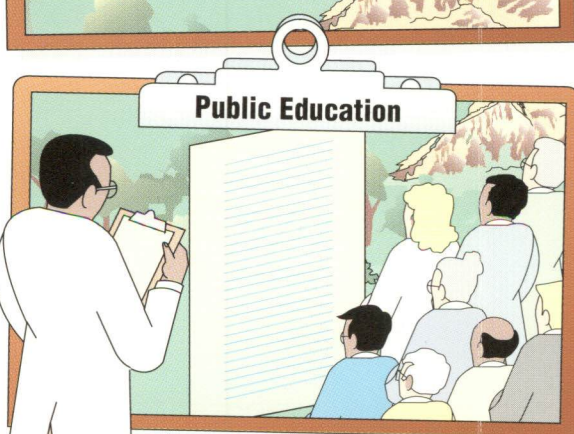
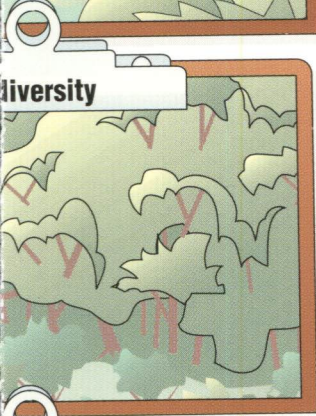
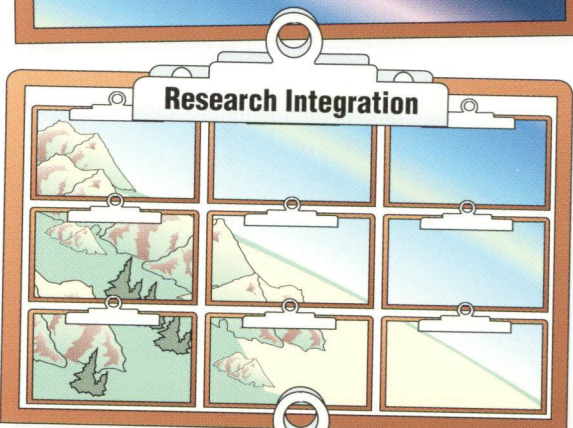
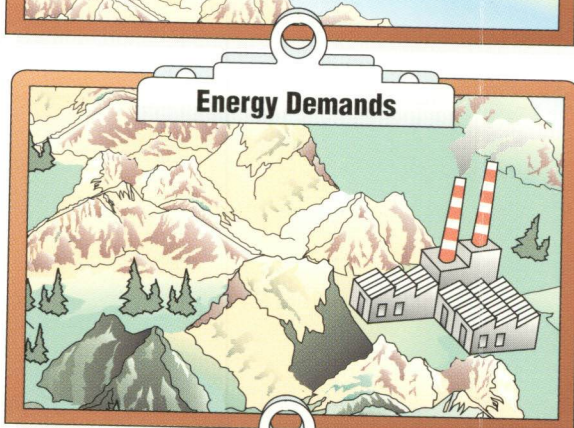
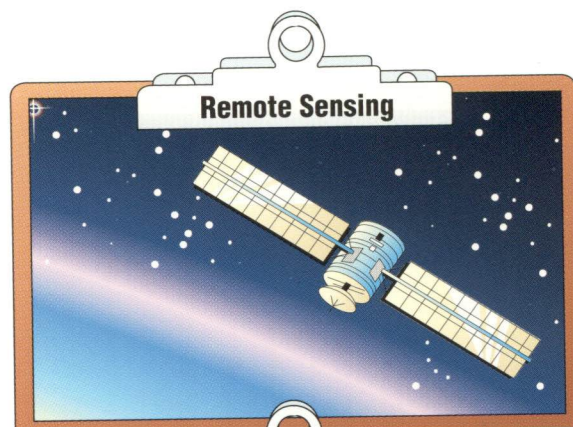
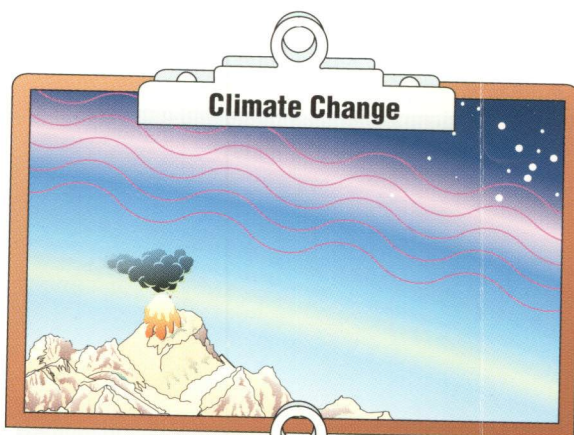
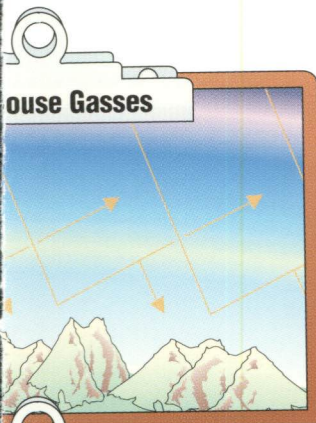
GLOBAL ST

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these systems to assure the prosperity and s



LEADERSHIP

...atural and human systems and manage the integration of
...ustainability of humanity on this planet.





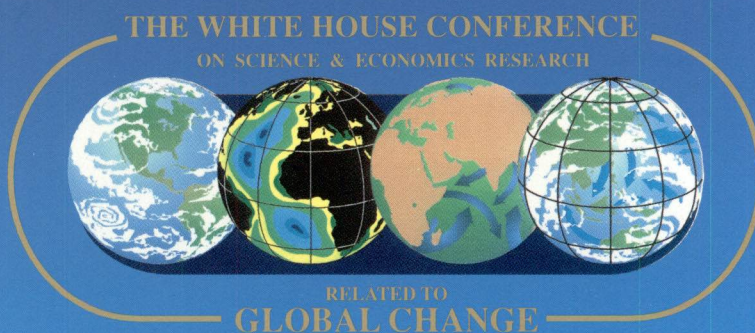
We need new tools to effectively evaluate how to respond to global environmental changes. Science and economics research can provide some of the tools needed to understand and properly manage our changing planet. Global change is concerned with such diverse but interrelated issues as ozone depletion, greenhouse gases, climate change, food security, water supply, sea level changes, wetlands, deforestation, biodiversity, population changes, and energy demands. A common ingredient in each of these issues is the level of uncertainty about the scale at which these changes are occurring and humanity's relative contribution to the change. There is also uncertainty regarding the social and economic consequences of change itself and of policy measures which might be taken to address it. As global stewards we must address these uncertainties by increasing our scientific and economic knowledge and take justifiable actions to manage global change...with due consideration given to the uncertainties which exist.

Therefore, the challenges of global stewardship require agreement in these three areas:

- Science and economics uncertainties—research challenges;
- Strategies for and challenges to integrating economics and science research; and
- Building better international partnerships for economics and science research.

Our existence depends on our ability to draw sustenance from the natural world while supporting the systems that regenerate that world. Building an integrated program of economics and science research is the step we must take today. Global stewardship is not a fixed state, but a process of change in which environmental and economic values are brought into balance to meet human needs and to expand human prospects. Let us join together and accept the challenge of Global Stewardship.

George W. Bush



**The White House Conference
on
Science and Economics Research Related to Global Change**

**CHARTER FOR COOPERATION
in
Science and Economics Research Related to Global Change**

Government officials of Science, Economics, and the Environment from eighteen nations, the European Community (EC), and the Organization for Economic Cooperation and Development (OECD) have gathered in Washington, D.C. on April 16-18, 1990, to attend the White House Conference on Science and Economics Research Related to Global Change. The Conference was designed to address important next steps for substantially enhancing and broadening international understanding of science and economics research related to Global Change. The delegates to the Conference noted that:

WHEREAS:

- o Scientific evidence demonstrates that the Earth and its environment are changing on time and spatial scales not fully known to humankind,
- o Human impacts on the Earth system are closely linked to both the level of economic activity and the selection of technologies that are driven by underlying economic forces,
- o Scientific uncertainty remains as to the contributions made by natural variability in Earth system processes and those made by impacts from anthropogenic sources, hence limiting the ability of science to predict, with acceptable accuracy, the future behavior of the Earth system,
- o Gaps in scientific and economic understanding substantially limit the abilities of nations to gauge the economic and social consequences of policy measures that might be taken to address changes in the global environment,
- o World leaders are considering unprecedented postures and actions to address the potential economic and social implications of these changes, and
- o These national and international developments, taken in total, have placed global environmental issues central on the agenda of international affairs.

THEREFORE:

The delegates gathered at the White House Conference on Science and Economics Research Related to Global Change acknowledge the need to:

- o Increase and coordinate their science and economics research programs related to Global Change,
- o Work together to develop complementary national science and economics research programs that contribute to a coherent international effort,
- o Work to enhance existing international mechanisms for planning and implementing science and economics research programs, and to foster, when necessary and appropriate, new mechanisms to foster cooperation among the world's governments and international agencies in the conduct of Global Change science and economics research,
- o Work toward full participation of all nations in the formulation, refining, and implementation of the science and economics research agenda and work toward developing indigenous research activities relevant to global environmental change research in all participating nations.
- o Encourage the nations of the world to contribute resources and personnel to the research agenda in measure and kind reflecting national capabilities,
- o Collaborate with other nations in support of education, training, and human resources development that contribute to the research agenda and that support full participation by developing countries, and
- o Work toward developing cooperative access to pertinent research facilities and research data and information by all nations.

The White House Conference
on
Science and Economics Research Related to Global Change

INTERNATIONAL INSTITUTES
for
Research on the Science and Economics of Global Change

BACKGROUND:

Government officials of Science, Economics, and the Environment from eighteen nations, the European Community (EC), and the Organization for Economic Cooperation and Development (OECD) have gathered in Washington, D.C. on April 16-18, 1990, to attend the White House Conference on Science and Economics Research Related to Global Change. The Conference provided a forum to consider a new dimension to the international dialogue on Global Change -- the proposition that economics, both analysis and research on broad economic policy and on economic consequences of policy options, is an essential link between the science of Global Change and policy alternatives. The Conference delegates addressed the importance of substantially enhancing and broadening international understanding of the relationship between science and economic research related to Global Change and the international policy process. The delegates also discussed the need to broaden the participation of all nations in fundamental economics and scientific research.

THE PROPOSAL:

It is suggested that interested nations consider the establishment, as joint partnerships between both industrialized and developing countries, of International Institutes for Research on the Science and Economics of Global Change. Institutes, in some cases building on existing "centers," could serve as both focal points of cooperative research activities that address fundamental questions in the economics of Global Change and as vehicles to address those issues in the context of international science and policy interests. The Institutes could stimulate the integration of economics, science and broad policy research. The Institutes, for example, might:

- o Sponsor and conduct research directed at basic economic (including related science and policy) issues central to international interests in Global Change.
- o Provide a "bridge" between economic research, scientific research, and policy studies, adding the perspectives of economic analysis to the scientific research results and adding new scientific results to economic analyses, thereby enriching the fundamental knowledge base available to nations for public policy deliberations.

- o Serve as a conduit for policy-relevant information between the physical, chemical, geological, and biological scientists, on the one hand, and economists and other social scientists on the other.
- o Provide a mechanism for communication and improved understanding of Global Change science and economics research among nations.

Science and economics should be interrelated and interdependent with policy choices being derived from an understanding of both the science and economic implications of changes in the global environment. Policy choices depend on both scientific evidence of risks and economic analyses of the favorable and adverse consequences of policy. By drawing upon each other, the two disciplines will be better able to advance global stewardship of the Earth and its natural resources.

The Institutes could sponsor and conduct, through both internal programs and external grants to international scholars, forward-looking, policy-oriented research. Although present national and international research institutions conduct research independently in science and economics, the challenge for the Institutes is to ensure that the range of scientific and economic aspects of policy choices is studied in an integrated fashion, and that all nations are involved. For example, research within the Institute framework might include:

- o Empirical studies of long-run growth in developing and developed economies, with a focus on linkages to Global Change issues.
- o Efforts to identify the Global Change indicators that have the most significant potential human consequences--so that scientific research can give priority to reducing uncertainty in those areas.
- o Developing new perspectives on the economic implications of changes in the global environment.
- o Studies of the economic and scientific aspects of diverse policy options.
- o Development, refinement and application of techniques for the valuation of environmental amenities.
- o Development and refinement of discounting methods relevant to Global Change issues with a significant time dimension.

The Institutes would be international, involving researchers from throughout the world, and interdisciplinary, bringing the scientists associated with international global change research efforts (e.g., the World Climate Research Program, the International Geosphere-Biosphere Program, and other related international research programs) together with economists and other social scientists in related research efforts. By focusing their efforts on research topics chosen by virtue of their relevance to ongoing policy deliberations, the Institute(s) could provide a bridge between scientific research and the policy process. One possibility is that such Institutes might be founded to address

Global Change research questions from a regional perspective, such as issues facing the countries of the Pacific Basin, the Euro-African region, or the Western Hemisphere. Such regional foci might also provide vehicles for developing the multilateral arrangements to sponsor an Institute as a joint venture between the more highly industrialized countries and those nations with newer economic and industrial programs.

ACTION SUGGESTED

It is proposed that interested nations engage in a set of informal discussions with the goal of developing detailed proposals for the potential establishment of one or more International Institutes for Research on the Science and Economics of Global Change.

The White House Conference
on
Science and Economics Research Related to Global Change

GLOBAL CHANGE DATA AND COMMUNICATIONS NETWORK

BACKGROUND:

The study of Global Change requires the communication, exchange and analysis of large volumes of economic and scientific data and information dispersed throughout the international community. As nations plan to undertake new and expanded Global Change research efforts, including, for example, observational programs on regional, national and global scales, effective data and information management and people-to-people communications become essential elements for success. International cooperation is vital to ensure efficient and effective allocation of resources to support these data exchange and communication efforts. Global Change scientists and economists must have the means to share information and exchange ideas directly with one another to achieve the synergistic potential of this international research effort.

THE PROPOSAL:

With this in mind, a "Global Change Data and Communications Network" is proposed. Part one of this two-part "Network," (the Data Module), would integrate existing international computer networks and provide a mechanism to facilitate various types of data transfer. Part two, a "Communications Module," would apply advanced technologies to electronically link investigators involved in Global Change science and economics research.

In order to provide the widest possible availability of key Global Change data and information for worldwide research efforts, the nations of the world must collaborate in ensuring the availability and exchange of economic and scientific data and information. One of the key purposes of the proposed Global Change Data and Communications Network is to provide an advanced communications capability to developing countries. Some of the infrastructure is already in place through entities such as the Global Telecommunications System of the World Meteorological Organization, which is used to routinely exchange meteorological observations on a global basis. Other regional and point-to-point links have been established on a project-specific basis. In other cases, researchers use commercially available facilities to the extent possible. There are over fifteen existing computer communications networks already in place around the world that could become associated with and benefit from the enhanced capabilities of the Global Data and Communications Change Network.

New technologies, available today, provide capabilities to implement a worldwide network in support of Global Change science and economics research. International Switching Device Network (ISDN), and higher bandwidth technologies, are now being implemented throughout the world and will be available for use in transmitting large amounts of data between institutions handling voice mail, interactive graphics and video conferencing, allowing for the development and use of a new multi-media communications network. The communications module of the proposed network would build upon the solid foundation of communications networks already in place around the world. These existing networks could be integrated into, and be substantially enhanced by, the proposed Global Change Data and Communications Network.

This enhanced communications capability could greatly advance international Global Change science and economics research. Through international cooperation and collaborative planning, this capability can be ensured, and its use made easier and more accessible to all interested nations.

It is important to continue and enhance efforts to collect, control the quality of, and maintain data and data systems (including directories and catalogs) in parallel with the creation of new communications systems/networks. Communications capabilities will only contribute to the goals of Global Change science and economics research if quality data sets are available to be accessed through it and enhancements are provided to facilitate person-to-person communications. This communications system would grow in support of the research endeavor. Through international cooperation and integration of existing systems, the Global Change Data and Communications Network can serve to significantly enhance the research efforts of the international scientific and economic community.

ACTION SUGGESTED:

It is proposed that interested nations engage in a set of informal discussions to develop a strategy for implementing a Global Change Data and Communications Network. It is also proposed that the issues of data and information access and exchange and international communication among economics and science researchers continue to be addressed as appropriate in international forums related to Global Change.

The White House Conference
on
Science and Economics Research Related to Global Change

"STATEMENT OF PRINCIPLES"
for
**Developing a Strategy for Implementing
International Cooperation in Science and Economics Research Related to
Global Change**

BACKGROUND:

Government officials of Science, Economics, and the Environment from eighteen nations, the European Community (EC), and the Organization for Economic Cooperation and Development (OECD) have gathered in Washington, D.C. on April 16-18, 1990, to attend the White House Conference on Science and Economics Research Related to Global Change. The Conference provides a forum to explore the possibility of developing a jointly agreed upon set of principles that could lead to an "implementation strategy" among nations for cooperative international research programs, that includes sharing of scientific and economic data, coordinating the development of international global observing systems, and improving the capabilities of models to predict: baseline emissions trends, costs, rates of market penetration of new energy technologies, the human consequences of Global Change policy measures which may be taken, and controlling global and regional environmental processes.

The United States proposes that delegates consider endorsing a "Statement of Principles" that outlines the essential ingredients for an "implementation strategy," the focus of which would be on research efforts that can be substantially enhanced by joint efforts that build on the collective expertise, experience, and data and information of participating countries. It is suggested that a more fully coordinated international research effort could substantially increase collective knowledge of the science and economics of Global Change, assist the on-going policy debate, and support future international policy forums, such as the Intergovernmental Panel on Climate Change (IPCC) and the Second World Climate Conference.

The proposal builds upon existing discussions initiated by the International Council of Scientific Unions (ICSU), developed during the recent ICSU Annual Meeting in Lisbon, in October 1989. The proposal is intended to fully support the implementation of research programs such as the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP), other international efforts like the "Human Dimensions of Global Change" program, and to support new international research efforts as needed. The proposal suggests that such a "Strategy" could lead to what might be called an "International

Global Change Research Program," an informal agreement among nations to coordinate more fully their national Global Change research programs with other countries.

THE PROBLEM TO ADDRESS

The international research community has recognized the need for a world-wide network of research programs to address the gaps in knowledge and the uncertainties in understanding the Earth system. National and international planning and coordination mechanisms have been established to address the fundamental scientific questions of "Global Change," e.g., the International Geosphere-Biosphere Program, the World Climate Research Program, the U.S. Global Change Research Program and other such national programs, and the G-7 Summit proposal for a multinational global observing and monitoring system.

The process, however, is incomplete. The structuring of planning, implementation, and resource allocation is evolving primarily within the many individual international research programs, good examples of which are the Tropical Ocean Global Atmosphere Program (TOGA), the World Ocean Circulation Experiment (WOCE), the International Satellite Cloud Climatology Project (ISCCP), and the Joint Global Ocean Flux Study (JGOFS). A critical remaining need is to foster international cooperative planning, implementation strategies, and resources allocations among and between the variety of international programs that address the science of Global Change and to foster links between science and economics. For example, emissions trends that are inputs to climate modelling scenarios depend on forecasted levels of economic activity and technology development. Economics research is also essential for translating the output of climate model scenarios into human consequences and for assessing the human consequences of proposed policy actions.

Resolving the need for cooperative planning in science and economics research could lead to a coherent and more fully coordinated international scientific research effort, one that optimizes the allocation of financial, human (i.e. economists and scientists), and major facility (e.g., satellites and ships) resources. The premise is that nations cannot hope to address the complex scientific and economic research questions except through a more fully coordinated international research program. It is out of this context that the U.S. proposal is offered.

THE PROPOSAL:

The United States offers the following "Statement of Principles" as a vehicle for discussions at the White House Conference on Science and Economics Research Related to Global Change, and as a framework that might lead to further discussions among individual national agencies that are responsible for Global Change research programs.

"STATEMENT OF PRINCIPLES"

1. THE PREMISE:

The economic and scientific research efforts that address Global Change are all guided by a fundamental premise that profound uncertainties exist in our understanding of how the total Earth system functions and that carefully-conceived research programs are needed to describe and expand our understanding of the interactive processes that regulate the Earth system, and the roles played by both natural and human-induced changes. Human contributions to Global Change, the human consequences of Global Change and the human consequences of measures that might be taken to address global change involve fundamental questions of economics. An effort to understand the Earth system and its interaction with human activity requires a coordinated international implementation framework for research in both fundamental earth science and economics disciplines. That framework must enjoin the best researchers of the world, the best of resources and scientific facilities of many nations, and the support of national and international organizations and bodies.

2. THE CONTEXT:

There is now a need to consider the establishment and fostering of partnerships among the various international scientific organizations and their adherent national organizations (e.g., ICSU and its various national academies of science and "unions"), intergovernmental bodies (e.g., United Nations specialized agencies like the World Meteorological Organization, UNESCO, and its agencies like the International Oceanographic Commission and the United Nations Environment Program), and individual government coordinating bodies (e.g., the U.S. Committee on Earth Sciences which coordinates the U.S. Global Change Research Program) and agencies of those governments with global environmental science responsibilities.

3. THE RELATIONSHIP TO THE POLICY PROCESS:

There exists a need for strong and well-designed relationships between the policy processes of governments and the science and economics that define the need for policy development. Any international effort that seriously seeks to address the science and economics of Global Change must, by necessity, evolve from the need to dramatically increase our understanding of Earth system processes and human activity and to more adequately support the policy process within and between governments.

4. THE GOAL:

The overarching goal for an international Global Change research program is to substantially improve scientific and economic knowledge in order to reduce the uncertainties in our understanding of and ability to accurately predict global processes and their regional implications as well as forecast human activities and their contributions to Global Change processes. Such knowledge is designed to enable individual nations and international bodies to develop international policy(s) that reflect an

understanding of the roles that both natural and human-induced changes play in Global Change, their attendant regional impacts, and the human consequences of change itself and of policy measures which might be taken to address that change.

5. THE ELEMENTS OF A JOINT INTERNATIONAL RESEARCH PROGRAM

As wider recognition of the need for a comprehensive effort to study Global Change on an international basis grows, nations are establishing their own internal organizations for the coordination and implementation of their national research priorities which, when taken together, could form the beginning of a comprehensive and more coherent international Global Change research program. The funding levels planned and the recognition that no nation alone can mount the required global-scale studies leads inexorably to a need to coordinate among nations and to link with the national and international research communities (e.g., ICSU) and intergovernmental (and regional) bodies (e.g., WMO, IOC, UNEP, and the Organization for Cooperation and Economic Development).

6. THE ELEMENTS OF AN IMPLEMENTATION STRATEGY:

It is suggested that interested countries, through an ad hoc Working Group, develop and produce a draft "Strategy" for an international science and economics research program which brings together the collective expertise, experience, and data available in participating countries in a more integrated and coherent fashion. It is proposed that an ad hoc Working Group of representatives from interested countries prepare a draft "Strategy" document for an international Global Change research program. The draft might include, inter alia:

- a. The rationale and need for a joint strategy for implementing an international program of economics and scientific research on Global Change issues,
- b. The goals, objectives, and expectations for a joint research program,
- c. The conceptual framework for structuring a science and economic research program,
- d. The central and priority economic and scientific questions that must be addressed,
- e. A framework for discussing priorities, mechanisms for implementation, etc.,
- f. The international arrangements to support the program, including linkages between government research agencies; intergovernmental (e.g., WMO, IOC, OECD and others), and non-governmental research bodies (e.g., ICSU),
- g. The linkages to the policy process, and

- h. The identification of products expected from the program, oversight review mechanisms, and the necessary timetables for results that support the policy process.

SUGGESTED ACTION:

It is suggested that the Conference delegations consider the possibility of creating an ad hoc Working Group so that a draft outline of a strategy is produced within a few months after the Conference, including plans for subsequent "in-country" review by all interested countries. The strategy, when completed, could provide the basis for an aggressive and more fully coordinated international research program, and might be a helpful addition to up-coming meetings, e.g., various "Summit" meetings, the meetings of the IPCC, the Second World Climate Conference, and the 1992 "Environment" meeting in Brazil.

RESPONSE STRATEGIES WORKING GROUP
of the
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

FIRST MEETING

WASHINGTON, D.C.

January 30 - February 1, 1989

Speech I
1/30/89

REMARKS BY
THE HONORABLE JAMES A. BAKER III
SECRETARY OF STATE
BEFORE THE
RESPONSE STRATEGIES WORKING GROUP
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
DEPARTMENT OF STATE
JANUARY 30, 1989

Thank you Fred Bernthal, Professor Bolin, ladies and gentlemen. I am very pleased to have the opportunity to join you this morning, however briefly, and to welcome you to the Department of State. You are the first official group that I've had the pleasure of welcoming to the Department.

I would also like to welcome Bill Reilly, who is here with us this morning -- President of the World Wildlife Fund and the Conservation Foundation. Bill has let President Bush talk him into becoming the nominee for the post of Administrator of the United States Environmental Protection Agency, and it's my fervent hope, Bill, that nothing you hear at this conference this morning will cause you to change your mind.

The truth is, though, as I don't need to tell those of you who are here, we face some very difficult problems. It is also true, though, that we now recognize them to be problems, and in my experience in government that is at least half of the battle.

Some months ago President Bush said, "We face the prospect of being trapped on a boat that we have irreparably damaged -- not by the cataclysm of war, but by the slow neglect of a vessel we believed to be impervious to our abuse."

The establishment of the Intergovernment Panel on Climate Change and this meeting of the Panel's Response Strategies Working Group, I think, shows beyond a doubt that this is a transnational issue. We are all in the same boat. And as I put it in my testimony to the Senate recently, "The tides and the winds can spread environmental damages to continents and hemispheres far removed from the immediate disasters."

REPRODUCED AT GOVERNMENT EXPENSE

So, if I may borrow a phrase from the environmentalists, the political ecology is now ripe for action. We know that we need to act, and we also know that we need to act together. That is what this meeting is all about.

But I would take it even a step further. One of the big advantages of being Secretary of State is that because I am not a scientist, I am, therefore, not called upon to assess the evidence, especially on global climate change. Yet it is also clear, I think, that we face more than simply a scientific problem. It is also a diplomatic problem of when and how we take action. And here, if I might, I would like to make four points.

The first is that we can probably not afford to wait until all of the uncertainties have been resolved before we do act. Time will not make the problem go away.

The second is that while scientists refine the state of our knowledge, we should focus immediately on prudent steps that are already justified on grounds other than climate change. These include reducing CFC emissions, greater energy efficiency and reforestation.

The third is that whatever global solutions to global climate change are considered, they should be as specific and cost-effective as they can possibly be.

The fourth is that those solutions will be most effective if they transcend the great fault line of our times, the need to reconcile the transcendent requirements for both economic development and a safe environment.

Without in any way downgrading the difficulty of the task, I would conclude, ladies and gentlemen, by noting that progress generally results when common interests are joined to a common understanding. This meeting and others like it will play a crucial role in moving us all toward that common understanding of what we must do to protect and to preserve our environment.

Thank you very much for having me this morning, and Godspeed.

* * * *

Executive Summary

We are certain of the following:

The greenhouse effect is real; natural greenhouse gases already keep the earth over 30°C warmer than it would otherwise be.

Man made emissions are substantially increasing the atmospheric concentrations of the main greenhouse gases: carbon dioxide, methane, the chlorofluorocarbons, and nitrous oxide. These increases will lead to a warming of the Earth's surface.

Our best tools predict that, in the absence of other effects, man made emissions will lead to the following changes:

By the year 2020, global mean temperatures will have risen 1.8 C above pre-industrial, with a probable range between 1.3 and 2.5 C; global mean precipitation and evaporation will have increased by 3%. By the year 2070, the range of temperature increase will be 2.4 to 5.1 C with a best estimate of 3.5 C, and precipitation will be 7% greater. Areas of snow cover and sea-ice will be smaller.

Regional changes will in most cases be different to the global mean; in general, land surfaces warm more rapidly than the oceans. Examples of regional change are that temperature increases in Southern Europe and North America will be higher than the global mean, accompanied by reduced summer precipitation and soil moisture.

Sea Level is expected to rise mainly due to the thermal expansion of the oceans and the melting of some land ice. Sea level will rise by about 20cm (with a probable range of 10cm to 32cm) by 2030, and by 2070 it will have risen 45cm (with a range of 33cm to 75cm). Within the next century, it is unlikely that there will be a major outflow of ice from the West Antarctic Ice Sheet due directly to greenhouse warming.

Our best judgement is that:

Global - mean surface air temperature has increased by 0.3 to 0.6 C over the last 100 years, with the six global-average warmest years being in the 1980s.

The size of this warming is broadly consistent with predictions of climate models but, because of natural variability and other factors, we cannot say how much of the observed temperature rise to date is due to man-made greenhouse gases.

There is no real evidence that climate has become more variable over the last few decades. However, episodes of high temperatures will become more frequent in the future simply due to an increase in the mean temperature.

Ecosystems will be affected by a changing climate and by increasing carbon dioxide concentrations. Many ecosystems disadvantaged by climate change will be unable to migrate fast enough, and will become prone to extensive damage by exceptional events such as drought and fire.

1
2 **We calculate with confidence that:**

3
4 Some gases are potentially more effective than others at changing climate; the Global
5 Warming Potential index of each gas relates the warming effect of its emissions to
6 those of equal emissions of carbon dioxide. Because carbon dioxide emissions are
7 much larger than those of the other greenhouse gases, it is likely to be responsible for
8 over half the total man-made greenhouse effect.

9
10 To stabilise the atmospheric abundances of most greenhouse gases at present levels
11 would require reductions in man-made emissions of 50-80%; methane would require
12 only a 15-20% reduction.

13
14 There is a long lag between changes in the emission of greenhouse gases and the
15 resultant change in climate. Therefore, reductions in man-made greenhouse gas
16 emissions will take decades to centuries to become fully effective. Emission
17 decreases made sooner will have a greater effect than the same decreases made
18 later.

19
20
21 **To improve our predictive capability, we need:**

- 22
23 • To accelerate the development of numerical models.
24
25 • To undertake experimental and theoretical studies aimed at understanding
26 critical processes within the climate system.
27
28 • To maintain and improve global observing systems, particularly those which
29 are space-based.
30
31 • To increase support for national research activities, and for international
32 programmes under which they can be carried out.
33
34



**INTERGOVERNMENTAL PANEL ON
CLIMATE CHANGE**

**POLICYMAKERS
SUMMARY**

**OF THE
SCIENTIFIC ASSESSMENT OF
CLIMATE CHANGE**

Report to IPCC from Working Group 1

Second Draft, 12 March 1990

**Redraft following discussion at the WGI Lead Authors Meeting
Edinburgh, 26 February - 2 March, 1990**

Prepared by the IPCC Group at the Meteorological Office, Bracknell, UK

Introduction: what is the issue ?

There is concern that man may be inadvertently changing the climate of the globe through the enhanced greenhouse effect, by continuing to emit pollutants which will eventually cause the temperature of the earth to increase - the so called "global warming". If this occurs, consequent changes to sea level and to ecosystems may have a significant impact on society and economies.

The purpose of the Working Group I report, as determined by the first meeting of IPCC, is to provide a scientific assessment of:

- 1) the factors which may affect climate change during the next century especially those which are due to human activity.
- 2) the responses of the atmosphere - ocean - land - ice system.
- 3) current capabilities of modelling global and regional climate changes and their predictability.
- 4) the past climate record and presently observed climate anomalies.

On the basis of this assessment, the report presents current knowledge regarding predictions of climate change (including sea level rise and the effects on ecosystems) over the next century, the timing of changes together with an assessment of the uncertainties associated with these predictions.

This Policymakers Summary aims to bring out those elements of the main report which have the greatest relevance to policy formulation, in answering the following questions:

- What factors determine climate, and how might man change them?
- What are the greenhouse gases, and how and why are they increasing?
- Which gases are the most important?
- How much do we expect the climate to have changed by the year 2020 and beyond?
- How much confidence do we have in our estimation?
- What will be the effects on sea level and ecosystems?
- Are the predicted climate changes unusual?
- Has man already begun to change global climate?
- What should be done to reduce uncertainties, and how long will this take?

1 Throughout the report, we keep in mind the practical needs of the policymaker.
2 The report is not an academic review, neither is it a plan for a new research
3 programme. Uncertainties attach to almost every aspect of the report, yet
4 policymakers are looking for clear guidance from scientists; hence authors have
5 been asked to provide best-estimates wherever possible, together with an
6 assessment of the uncertainties.

7
8 This report is a summary of our understanding as at mid-1990. Although continuing
9 research will deepen this understanding and require the report to be updated at
10 frequent intervals, basic conclusions concerning the reality of the greenhouse
11 effect and its potential to alter global climate are unlikely to change.
12
13
14

15 What factors determine global climate and how 16 might man change them ?

17 The driving force for weather and climate comes from the sun. The earth intercepts
18 solar radiation (mainly in the short-wave, visible, part of the spectrum); about a third
19 of it is reflected, the rest is absorbed by the different components (atmosphere,
20 ocean, ice, land and biosphere) of the climate system. The energy absorbed from
21 solar radiation must be balanced (in the long term) by outgoing radiation from the
22 earth and atmosphere; this terrestrial radiation takes the form of long-wave invisible
23 infra-red energy. As the amount of outgoing terrestrial radiation is determined by
24 the temperature of the earth, this temperature will adjust to emit just the right
25 amount of radiation to balance that coming from the sun.
26

27 There are several important factors which can change the balance between the
28 energy (in the form of solar radiation) absorbed by the earth and that emitted by it in
29 the form of longwave infra-red radiation - the radiative forcing on climate. The
30 most obvious of these is a change in the amount or seasonal distribution of solar
31 radiation which reaches the earth; these changes were probably responsible for
32 initiating the ice ages.
33

34 One of the most important of these factors is the greenhouse effect. Shortwave
35 solar radiation can pass through the clear atmosphere relatively unimpeded. But
36 long-wave terrestrial radiation emitted by the warm surface of the earth is partially
37 absorbed and then re-emitted by a number of trace gases in the atmosphere
38 above. Since the atmosphere is cooler than the earth's surface, the emission to
39 space is reduced. Both the atmosphere and the surface warm until the outgoing
40 long wave radiation balances the incoming solar radiation. This is the basic
41 greenhouse effect. The main greenhouse gases are not the major constituents,
42 nitrogen and oxygen, but water vapour (the biggest contributor), carbon dioxide,
43 methane, nitrous oxide, ozone in the low atmosphere and (in recent years)
44 chlorofluorocarbons. Naturally occurring greenhouse gases keep the earth warm
45 enough to be habitable, but their increase will raise temperatures- and change
46 other aspects of climate, particularly precipitation and evaporation.
47

48 Other factors which affect climate are mentioned later in the Summary, when we
49 discuss uncertainties in climate predictions.
50
51
52

Simple diagram illustrating the greenhouse effect

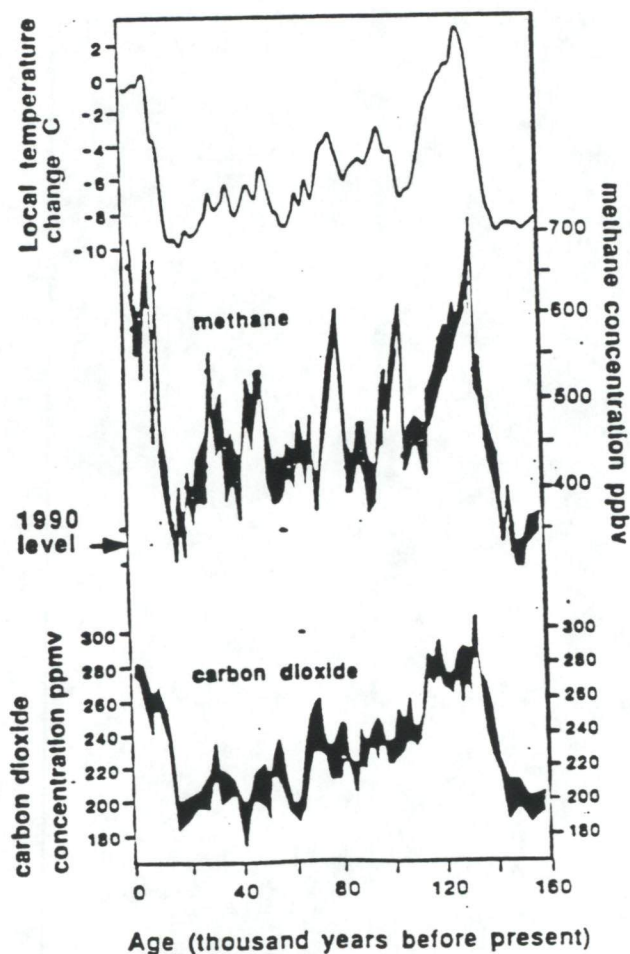
How do we know that the greenhouse effect is real ?

The greenhouse effect is **real**: infrared absorbing gases in the atmosphere make the surface of the earth warmer than it would otherwise be. It is a well understood effect, based on established scientific principles.

We know that the greenhouse effect works in practice, for several reasons. Firstly, the mean temperature of the earth's surface is already about 33 C warmer than it would be if the natural greenhouse gases (mainly carbon dioxide and water vapour) were not present. Satellite observations of the radiation emitted from the earth's surface and atmosphere demonstrate the absorption due to the greenhouse gases.

Secondly, we know the compositions of the atmospheres of Venus, Earth and Mars are very different, and their surface temperatures are in good agreement with greenhouse theory.

Thirdly, measurements from ice cores going back 160,000 years show that the earth's temperature closely paralleled the amount of greenhouse gases in the atmosphere. It is likely that changes in greenhouse gases were part (but not all) of the reason for the large (4 - 5 C) temperature swings between ice ages and interglacial periods.



The enhanced greenhouse effect

We are confident that an increase in concentrations of the greenhouse gases will raise the global, annual-mean surface-air temperature (which, for simplicity, is referred to as the "global temperature"). Strictly, this is an **enhanced** greenhouse effect - above that occurring due to natural greenhouse gas concentrations; the word "enhanced" is usually omitted, but it should not be forgotten. A global warming will cause sea levels to rise, partly due to the thermal expansion of the ocean surface waters, and partly due to the melting of land ice (but not due to the melting of sea ice - such as the north polar sea ice - which is already floating and thus displacing water).

What are the greenhouse gases and how are they changing ?

We know, with certainty, that the concentrations of greenhouse gases in the atmosphere have changed naturally on ice-age timescales, and have been increasing since pre-industrial times due to human activities. The table below summarizes the present and pre-industrial abundances, present rates of change and atmospheric lifetimes of the main greenhouse gases.

SUMMARY OF KEY MAN-MADE GREENHOUSE GASES					
	Carbon Dioxide	Methane	CFC-11	CFC-12	Nitrous Oxide
Atmospheric concentration	ppmv	ppmv	pptv	pptv	ppbv
Pre-industrial	280	0.79	0	0	288
Present day††	354	1.717	280	484	310
Current rate of change	1.6 (0.5%)	0.015 (0.9%)	10 (4%)	17 (4%)	0.8 (0.25%)
Atmospheric lifetime (years)	(50-200)†	10	65	130	150

ppmv = parts per million by volume; ppbv = parts per billion by volume;

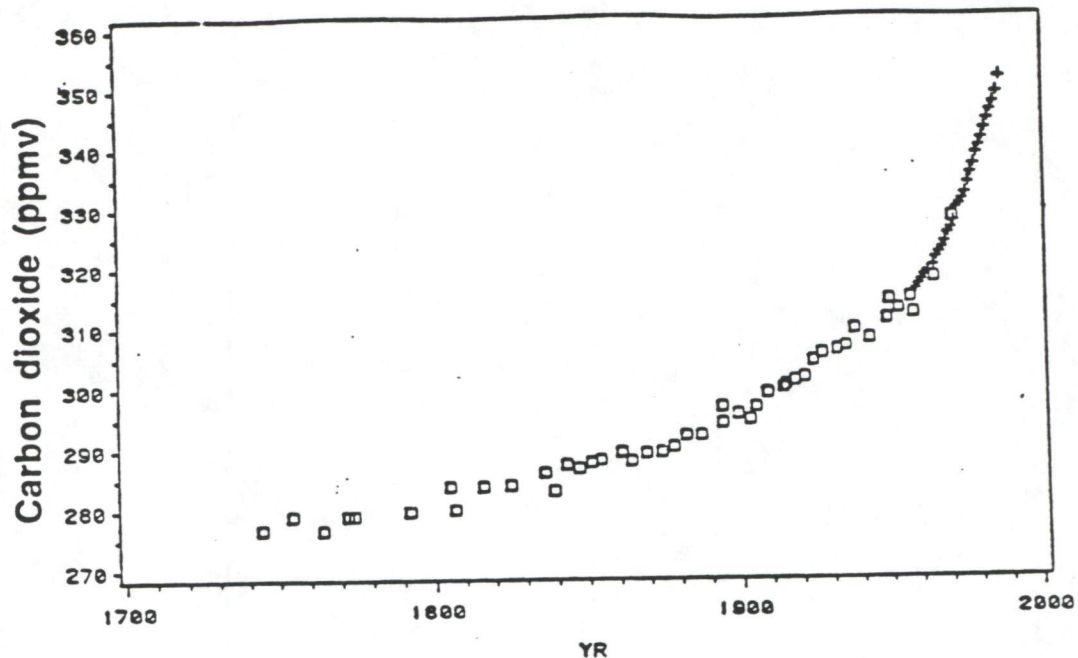
pptv = parts per trillion by volume.

† - The way in which CO₂ is absorbed by the oceans is not simple and a single value cannot be given

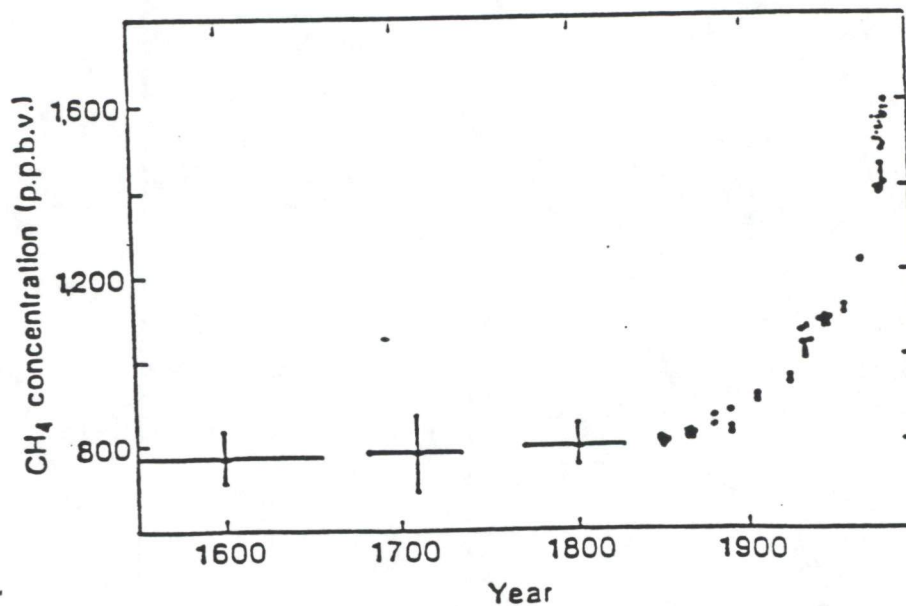
†† - estimated

Carbon dioxide, methane, and nitrous oxide all have significant natural and man-made sources, while the chlorofluorocarbons (CFCs) are purely man-made. Water vapour is also a major greenhouse gas and, although its concentration may also change in future, this will be as a consequence of any global warming and not as a direct result of man-made emissions; we incorporate the effects of this in the estimates of future climate change discussed later.

For a thousand years prior to the industrial revolution, the abundances of these greenhouse gases were relatively constant. However, as the world's population increased, and the world became more industrialized, the abundances of the greenhouse gases increased markedly. The figures below illustrate this for carbon dioxide and methane.



Carbon dioxide concentration from ice cores (squares) and surface observations (Mauna Loa - crosses)

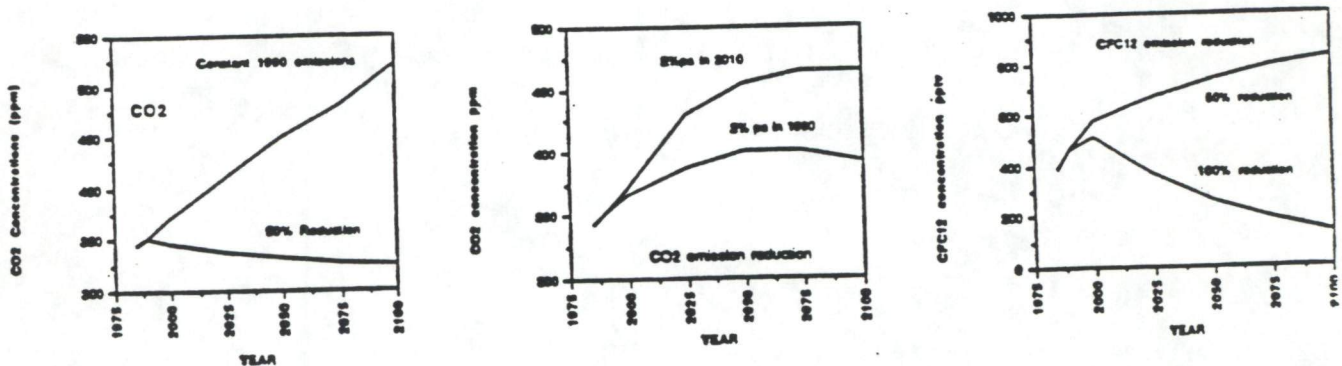


Methane concentration deduced from ice cores and from recent surface observations

We know quite well the reasons for the increased abundances of carbon dioxide, methane, chlorofluorocarbons, and tropospheric ozone, but those for nitrous oxide are less certain. Since the industrial revolution carbon dioxide has increased by 25% because of the combustion of fossil fuels and deforestation practices, in mid-latitudes and in the tropics. Methane has more than doubled because of rice production, breeding domestic ruminants, biomass burning, coal mining and ventilation of natural gas; transport and industry may have also contributed in an indirect way. Low - level ozone has doubled because of increased abundances of carbon monoxide, nitrogen oxides, and hydrocarbons from industry and transport; and nitrous oxide has increased by 8% probably because of fossil-fuel combustion or agricultural practices. Chlorofluorocarbons, which are used as aerosol propellants, solvents, refrigerants, and foam blowing agents were not present in the pre-industrial atmosphere.

Lifetimes and stabilisation of the gases

The lifetimes of the greenhouse gases are determined by their sources and sinks in the oceans, atmosphere and biosphere. Carbon dioxide, chlorofluorocarbons and nitrous oxide have long lifetimes; hence, following a change in emissions, their atmospheric concentrations respond slowly and would not reach a new equilibrium state for many centuries. In contrast, some of the CFC substitutes and methane have relatively short atmospheric lifetimes so that their atmospheric concentrations respond quite quickly and would reach a new equilibrium within a few decades following a change in emissions. This emission-concentration relationship is illustrated below for some of the gases.



It can be seen, for example, even with a complete cessation in the emission of CFC 12 in the year 1990, its atmospheric abundance would still be about a third of today's level in the year 2100. Also shown is the effect on concentrations of continuing man-made emissions of carbon dioxide at 1990 levels, or 50% of 1990 levels, and of a reduction in global emissions of 2% per year from 1990 and from 2010; if there are critical concentration levels that should not be exceeded then it can be seen that earlier emission reductions are more effective than later ones.

The term "atmospheric stabilisation" is often used to describe the limiting at present day values of the concentration of the greenhouse gases. The amount by which man-made emissions of a greenhouse gas must be reduced in order to achieve this is shown in the box below.

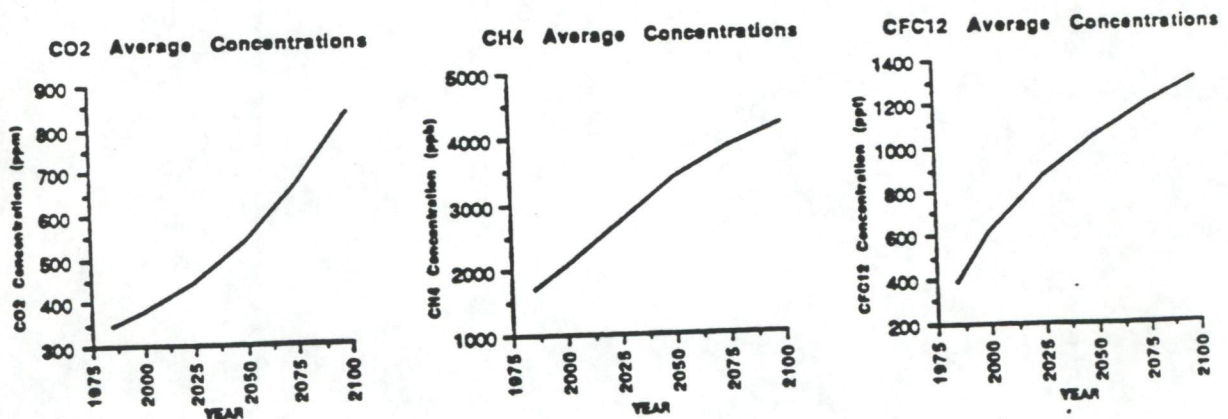
STABILISATION OF ATMOSPHERIC CONCENTRATIONS

Reductions in the man-made emissions of greenhouse gases required to stabilise concentrations at present day levels:

Carbon Dioxide	60 - 80%
Methane	15 - 20%
Nitrous Oxide	70 - 80%
CFC11	70 - 75%
CFC12	75 - 85%
HCFC22	40 - 50%

Natural sources and sinks are assumed to remain unchanged
Note that the stabilisation of each of these gases would have different effects on climate, as explained in the next section.

The same models used for these calculations are also used to determine future concentrations of the greenhouse gases which would arise from scenarios of future emissions generated by IPCC Working Group 3. Shown below are the concentration trends of some of the greenhouse gases expected to result from the High Emissions scenario.

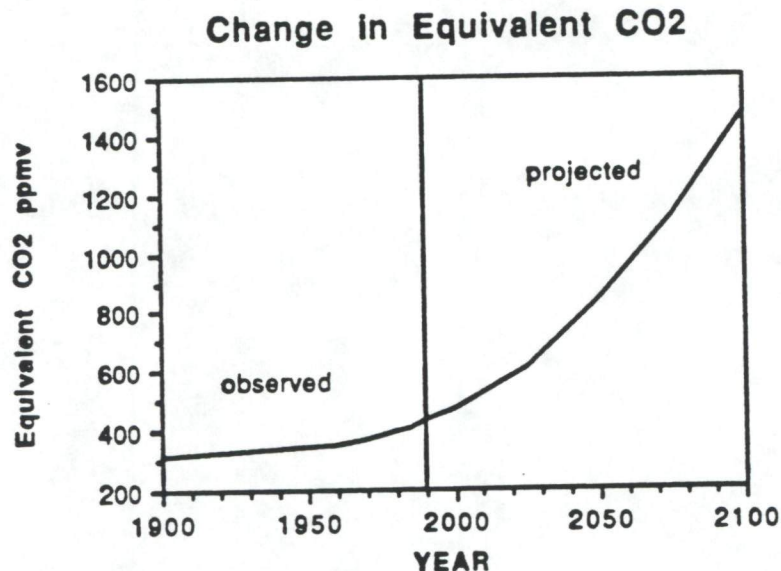


Which gases are the most important?

We know, with certainty, that more greenhouse gases means more radiative forcing and hence a global warming. We can calculate the the radiative forcing due to the increase in concentration of each gas with much more confidence than the calculation of the resulting climate change because the former only involves laboratory measurements of the gases: how strongly, and where in the spectrum,

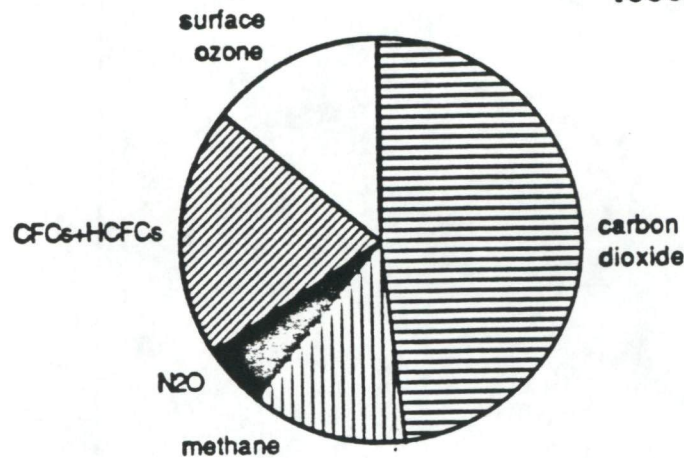
they absorb infra-red radiation. We then have a base from which to calculate the relative effect on climate of an increase in **concentration** of each gas in the atmosphere: both in absolute terms and relative to carbon dioxide. These relative effects span a wide range; methane is about 21 times more effective, molecule-for-molecule, than carbon dioxide, and CFC11 about 12 000 times more effective.

The total radiative forcing at any time is the sum of those from the individual greenhouse gases. For simplicity, we can express total forcing in terms of the amount of carbon dioxide which would give that forcing; this is termed the **equivalent carbon dioxide concentration**. We show how this quantity has changed to date (based on observations of all the greenhouse gases) and how it might change in the future (based on the IPCC Working Group 3 High Emissions scenario) in the figure below. At present, greenhouse gases have increased since pre-industrial times (the mid 18th century) by an amount that is radiatively equivalent to about a 53% increase in carbon dioxide, although carbon dioxide itself has only risen by 26% - other gases have made up the rest.



The contributions of the various gases to the total increase in climate forcing during the 1980s is shown below as a pie diagram; carbon dioxide is responsible for about half the decadal increase.

Contribution to climate forcing change: 1980-90



How can we evaluate the effect of different greenhouse gases?

To evaluate possible policy options, it is useful to know the relative radiative (and, hence, climate) effect of equal emissions of each of the greenhouse gases. The concept of relative **Global Warming Potentials (GWP)** has been developed which takes into account the differing times that gases remain in the atmosphere.

This index allows for the determination of the time-integrated, relative warming effect based on the instantaneous release of a unit mass (1 kg) of a given greenhouse gas. These GWPs are defined for convenience relative to carbon dioxide, the greenhouse gas of most concern. The GWPs in the following table are shown for three time horizons, reflecting the need to consider these cumulative effects on climate over various time scales.

The table indicates, for example, that the effectiveness of methane in influencing climate will be greater in the first few decades after initial release, whereas emission of the longer lived nitrous oxide will affect climate for a much longer period of time. The lifetimes of the proposed CFC replacements range from 1 to 40 years. The longer lived replacements are still potentially effective as agents of climate change. The extreme example of this, HCFC 143a (with a 40 year lifetime), has a very similar effect (when released in the same amount) to CFC11 on a 20 year timescale.

GLOBAL WARMING POTENTIALSThe warming effect of an emission of 1kg of each gas relative to that of CO₂

	time horizon		
	20 yr	100 yr	500 yr
Carbon dioxide	1	1	1
Methane	63	21	9
Nitrous oxide	270	290	190
CFC11	4500	3500	1500
CFC12	7100	7300	4500
HCFC22	4100	1500	510

Global Warming Potentials for a range of CFCs and potential replacements are given in the full text

Although the table shows carbon dioxide to be the least effective greenhouse gas on an equal emissions basis, the warming effect will depend on the size of emissions. In the example shown below, 1990 emissions of carbon dioxide will contribute well over half the man-made warming effect over the next 100 years.

THE RELATIVE CUMULATIVE CLIMATE EFFECT OF 1990 EMISSIONS

	GWP (100yr horizon)	1990 emissions (Tg)	relative contribution over 100yr
carbon dioxide	1	26000†	61%
methane	21	300	15%
nitrous oxide	290	6	4%
CFC11	3500	0.3	2%
CFC12	7300	0.4	7%
HCFC22	1500	0.1	0.4%

Others (including indirect effects, eg that of NO₂ on surface ozone) 10.6%

†26000Tg of carbon dioxide = 7Gt of carbon

There are other criteria which may help policymakers to decide, in the event of emissions reductions being necessary, which gases should be considered. Does the gas contribute in a major way to current, and projected future, climate forcing? Does it have a long lifetime, so that controlling its concentration would require emissions to be reduced sooner rather than later? And are its sources and sinks well enough known to decide which of them could be controlled in practice? The table below illustrates these factors.

GAS	MAJOR CONTRIBUTOR?	LONG LIFETIME?	SOURCES KNOWN?
carbon dioxide	yes	yes	yes
methane	yes	no	qualitatively
nitrous oxide	no	yes	qualitatively
CFCs	yes	yes	yes
HCFCs etc	not at present	mainly no	yes
surface ozone	yes	no	yes

How much do we expect climate to change?

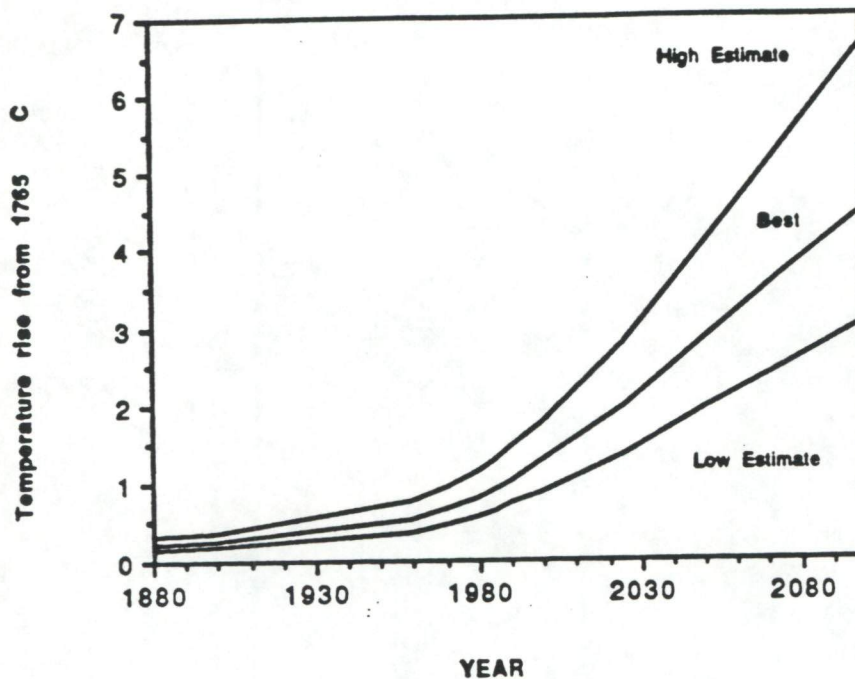
Computer-based numerical models are the best tools we have for making climate predictions; a description of their main features, and how much confidence we can place in their results, are given in the boxes. We outline below the predictions they make for changes at a global and sub-global level.

To estimate the change in climate, we need to know what emissions of greenhouse gases will be over the next decades; in the predictions below we assume the **High Emissions scenario** developed by IPCC Working Group 3. The concentrations and radiative forcing derived from this emissions scenario were shown earlier.

How quickly will global climate change ?

Using this emissions scenario we estimate that, by the year 2020, the increase in global mean temperatures due to man-made greenhouse gas emissions will be 1.8 C above pre-industrial, with a probable range between 1.3 and 2.5 C. By the year 2070, the range is 2.4 to 5.1 C with a best estimate of 3.5 C. The best-estimate projection out to the year 2100 is shown in the diagram below.

IPCC High Emissions Scenario



The global warming will also lead, on average, to increased precipitation and evaporation; perhaps by 3% and 7% by the years 2020 and 2070. Not surprisingly, we expect areas of sea-ice and snow to diminish.

There will be large variations in the magnitude of the warming, and those in precipitation will be even greater, with substantial areas of decreased precipitation within an overall global increase.

What will be the patterns of climate change by about 2020?

Knowledge of the global mean warming and change in precipitation is of limited use in determining the impacts of climate change, for instance, on agriculture. To do this we need to know what these changes will be at a smaller scale. Our best models predict that surface air over land warm faster than that over oceans; the northern hemisphere will warm faster than the southern, and a minimum of warming will occur around Antarctica and in the North Atlantic region.

There are some continental scale changes in which we have relatively high confidence because they are consistently predicted by the most comprehensive models and because we understand the physical reasons for them. The warming is predicted to be 50-100% greater than the global mean in high northern latitudes in winter, and substantially smaller than the global mean in regions of sea ice in summer. Precipitation is predicted to increase in middle and high latitude continents in winter (by some 5 - 10% over 35-55 N).

In the box below are given the changes in temperature, precipitation and soil moisture, which are predicted to occur by 2020, averaged over the 5 regions (each of which are a few million square kilometres in area) selected by IPCC. There may be considerable variations within the regions. In general, confidence in these

1 regional estimates is low, especially for the changes in precipitation and soil
2 moisture, but they are examples of our best estimates. We cannot yet give reliable
3 regional predictions at the smaller scales demanded for impacts assessments.
4

5 **CURRENT BEST ESTIMATES FOR CHANGES BY 2020**
6 **(IPCC High Emissions scenario; changes from pre-Industrial)**
7

8 **Central North America (35 -55N, 85 -105W)**
9

10 The warming ranges between 3 and 4 °C in winter and 2 to 3 °C in summer.
11 Precipitation increases range from 0 to 20% in winter whereas there are
12 decreases of 5 to 10% in summer. Soil moisture decreases in summer by 10
13 to 15%.
14

15 **South East Asia (5 -30N, 70 -102 E)**
16

17 The warming ranges from 1 to 2 °C throughout the year. Precipitation changes
18 little in winter and generally increases throughout the region by 5 to 15% in
19 summer. Summer soil moisture increases by 5 to 10%.
20

21 **Sahel (10 - 20 N, 20 -38 E)**
22

23 The warming ranges from 1 to 2 °C. Area mean precipitation increases and
24 area mean soil moisture decrease marginally in summer. However there are
25 areas of both increase in and decrease in both parameters throughout the
26 region which differ from model to model.
27

28 **Southern Europe. (35 - 50 N, 10 W - 45 E)**
29

30 The warming is about 2 °C in winter and varies from 2 to 3 °C in summer.
31 There is some indication of increased precipitation in winter, but summer
32 precipitation decreases by 5 to 15%, and summer soil moisture by 10 to 25%.
33

34 **Australia (12 - 43 S, 115 - 154 E)**
35

36 The warming ranges from 1 to 2 °C in summer and is about 2 °C in winter.
37 Summer precipitation increases by around 10% , but there the models do not
38 produce consistent estimates of the changes in soil moisture. There are large
39 variations at the sub-continental level within this area.
40

41 **How will climate extremes and extreme events change?**
42

43 Changes in the variability of weather and the frequency of extremes will generally
44 have more impact than changes in the mean climate at a place. With the possible
45 exception of an increase in the number of intense showers, there is no evidence
46 from our work so far that weather variability will change in the future. However, with
47 no change in variability, even for a modest change in the mean, the number of days
48 with temperatures above a given value at the high end of the distribution will
49 increase substantially. Similarly, there will be a decrease in days with temperatures
50
51
52

1 at the low end of the distribution. So the number of very hot days or frosty nights
2 will be substantially changed without any change in the variability of the
3 weather. Changes in the number of days with a minimum threshold amount of soil
4 moisture (for viability of a certain crop, for example) would be even more acute.
5

6 7 Will storms increase in a warmer world?

8
9 Storms can have a major impact on society. Will their frequency, intensity or
10 location increase in a warmer world?
11

12
13 Tropical storms, such as typhoons and hurricanes, only develop at present over
14 seas that are warmer than about 26°C. As the area of sea having temperatures
15 over this critical value will increase as the globe warms, the potential certainly
16 exists for there to be a wider area available for storm development. However, the
17 vertical structure of the atmosphere may also change, and offset this increase.
18 Climate models give no clear indication whether tropical storms will increase or
19 decrease in frequency or intensity as greenhouse gases increase; neither is there
20 any evidence that this has occurred over the past few decades.
21

22
23 Mid-latitude storms, such as those which track across the North Atlantic, are
24 driven by the equator-to-pole temperature contrast. As this contrast will probably be
25 weakened in a warmer world (at least in the northern hemisphere), it could be
26 argued that mid-latitude storms will also weaken. But higher in the atmosphere the
27 thermal contrast strengthens, and in addition the increased amount of water vapour
28 in the atmosphere can supply extra energy to storm development. We do not know
29 which of these factors will be the more influential, and how storms will change in
30 frequency or intensity. Even if changes of this sort do not occur, the tracks they take
31 might move and affect new regions; again, we have no evidence of where, or if, this
32 would happen.
33

34 35 What tools do we use to predict future climate ?

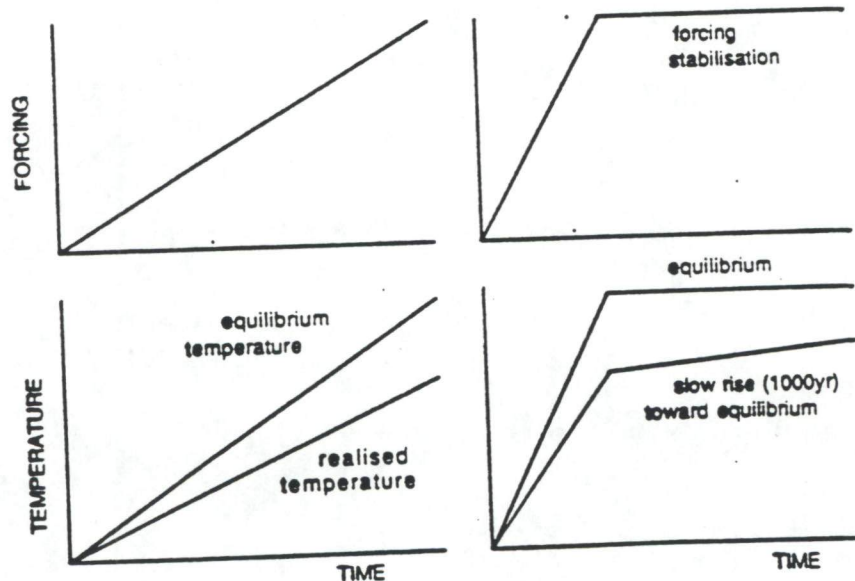
36
37 It is relatively easy to predict the direct effect of the radiative forcing due to increases in greenhouse
38 gases. However, as climate begins to warm, various processes act to amplify (through positive
39 feedbacks) or reduce (negative feedbacks) the warming. The feedbacks are due to changes in
40 water vapour, sea-ice, clouds and the oceans. In making a climate forecast, all these processes
41 have to be taken into account. These are described in three-dimensional mathematical model of
42 the atmosphere and ocean (often known as a general circulation model or GCM). These are
43 based on the equations of motion and use descriptions in simple physical terms (called
44 parameterisations) of the smaller scale processes such as those due to clouds and to deep mixing
45 in the ocean. (The atmospheric component of a climate model is essentially the same as a weather
46 prediction model).
47
48
49

Equilibrium and realised climate change

We have explained that increases in greenhouse gases will (instantaneously) increase radiative forcing. However, the full warming will not occur instantaneously, because of the effect of the oceans. Firstly, the mixed layer of the ocean (about 100m deep) will have to warm at about the same rate as the atmosphere, because transfer of heat from one to the other takes place very efficiently; this will take typically 10 years. Secondly, there are two areas of the oceans (the northern North Atlantic and the Antarctic ocean) where circulation patterns act to draw down water from the warm upper layers into the very deep ocean. Some of the heat from the upper layers is therefore also drawn into the deep ocean, where it remains for a very long time - upwards of a thousand years; on the century timescale we are considering here, the heat is effectively lost.

Consider the case where continuing increases in greenhouse gases is giving a steady increase in radiative forcing at a rate of about 1% per year - this is roughly what is happening at the moment. The first diagram below shows the equilibrium temperature rise which would ultimately occur due to this forcing - this is also the temperature we would experience straight away if there were no oceans. The lower line shows our best estimate of the realised temperature rise; the temperature trend that (in the absence of other forcing and variability) we would observe. The realised temperature trend approximates to the eventual temperature trend reduced (mainly because of the heat sequestered into the deep ocean) by about a third.

The concept of the equilibrium temperature can best be illustrated (as in the second diagram below) by the artificial case of halting and stabilising the radiative forcing at a future date (remembering that this would require a very large reduction in emissions). The realised temperature would then rise slightly over a ten year period as the ocean mixing layer "catches up" with the atmosphere, but then rise further only very slowly, to meet the equilibrium temperature in over a thousand years.



The long term change in **surface air temperature** following from a doubling of carbon dioxide (generally used as a benchmark and referred to as the **climate sensitivity**) is most likely to be somewhere between 1.5 and 4.5°C, with a most likely estimate of 2.5°C. The lowest result from all models so far is about 1.5°C and, although some models give figures higher than 4.5°C (up to 5.2°C), there are good reasons to believe that the less detailed representation of cloud processes in these models leads to an over-estimation of the warming. This range of climate sensitivity deduced from mathematical models is consistent with empirical evidence from paleo epochs.

How do we forecast climate ?

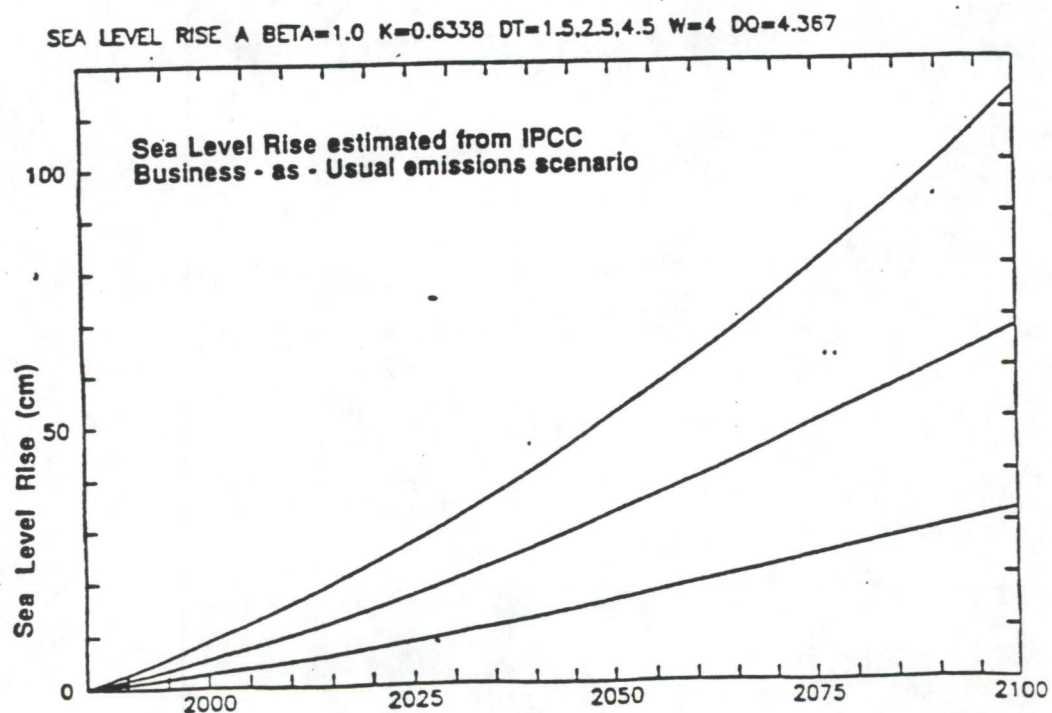
Climate forecasts are derived in a different way from weather forecasts. A weather prediction model gives a description of the atmosphere's state up to 10 days or so ahead, starting from a detailed description of an initial state of the atmosphere at a given time. Such forecasts describe the movement and development of large weather systems, though they cannot represent very small scale phenomena; for example, individual shower clouds.

To make a climate forecast, the climate model is first run for a few (simulated) decades. The statistics of the model's output will be a description of the model's simulated climate which, if the model is a good one, will bear a close resemblance to the climate of the real atmosphere and ocean. The above exercise is then repeated with increasing concentrations of the greenhouse gases in the model. The differences between the statistics of the two simulations (for example in mean temperature and interannual variability) provide an estimate of the accompanying climate change.

A completely different, and potentially powerful, way of predicting patterns of future climate is to search for periods in the past when the global mean temperatures were similar to those we expect in future, and then use the past spatial patterns as analogs of those which will arise in the future. For a good analog, it is also necessary for the forcing factors (eg. greenhouse gases, orbital variations) and other conditions (e.g. ice cover, topography, etc.) to be similar; direct comparisons with climate situations for which these conditions do not apply cannot be easily interpreted. So far, analogs of future greenhouse-gas-changed climates have not been found. We cannot therefore advocate the use of paleo climates as predictions of regional climate change due to future increases in greenhouse gases.

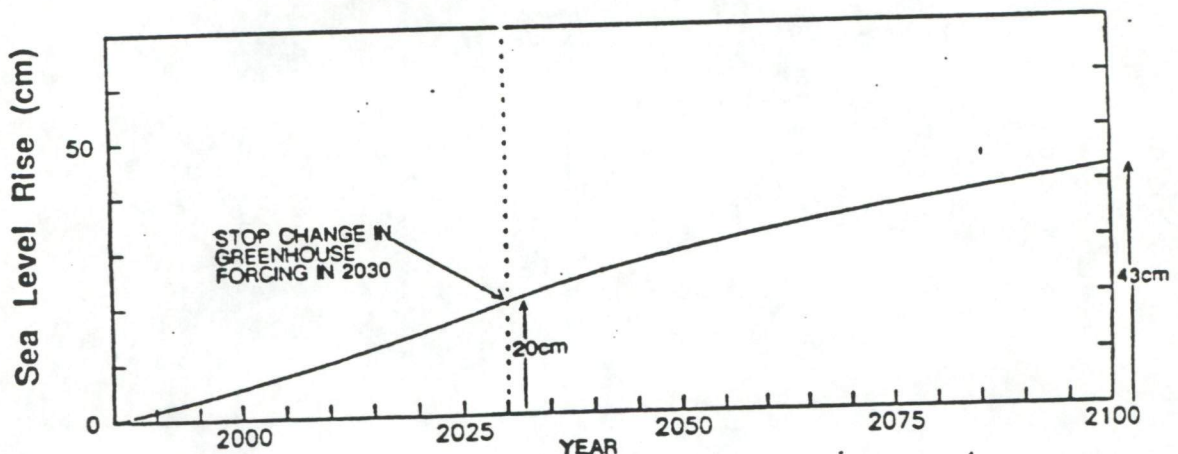
How much will sea level rise ?

Simple models were used to calculate sea level rise to the year 2100 AD; the results are illustrated below. The calculations necessarily ignore any long-term changes, unrelated to greenhouse forcing, that may be occurring but cannot be detected from the present data on land ice and the ocean. For the IPCC High Emissions scenario, sea level is expected to be between 10 cm and 32 cm higher than today by the year 2030, with a best-estimate of 20 cm.



The best estimate is made up of positive contributions from thermal expansion of the oceans (12cm); melting of glaciers (8cm) and the Greenland ice sheet (1cm), with a 1cm negative contribution from Antarctica due to higher ice/snow accumulation in a slightly warmer climate. By the year 2070, sea level is expected to be 45cm higher, with a range of 33cm to 75cm.

By 2030, even if greenhouse forcing increased no further, the world would still be committed to a continuing sea level rise for many decades and even centuries, due to delays in climate, ocean and ice mass responses (see figure below). Sea level would go on rising from 2030 to 2100, by a further 23cm, due to the effects of pre-2030 greenhouse gas increases alone. Moreover, in the longer term, irreversible changes could be triggered with long-lasting effects. For instance, for a persistent 4°C warming, the major part of the Greenland ice sheet would eventually disappear (but over thousands of years), and would not reform even with a return to the present climatic conditions.



SEA LEVEL RISE COMMITMENT. Even if greenhouse gas concentrations were stabilised in 2030, sea level would continue to rise steadily

The West Antarctic Ice Sheet (WAIS) is of special concern, as a large portion of it is grounded far below sea level and it contains an amount of ice equivalent to 5m of global sea level. Recent studies have demonstrated that individual ice streams are changing rapidly on a decadal to century time scale. This variability is not necessarily related to climate, but is important for future sea level change. Within the next century, it is not likely that there will be a major outflow of WAIS ice due directly to greenhouse warming.

Regional rise in sea level is expected to differ substantially from the global mean value. Thermal expansion, changes in ocean circulation, and surface air pressure will vary from region to region as the world warms, but in a yet unknown way. Such regional details await further development of realistic physical models of the ocean circulation. In addition, vertical land movements can be as large or even larger than changes in global mean sea level. For estimates of regional sea level rise, these should be added to climate-related changes in ocean volume.

How much confidence do we have in our predictions?

Uncertainties in the predictions above arise from a number of sources. Firstly, it is obvious that future climate change will depend on the rate at which greenhouse gases (and other gases which influence them) are emitted; this in turn will be determined by various complex economic and sociological factors. Scenarios of future emissions were generated within IPCC by Working Group 3; four such scenarios are explored in the main report, and one of these (corresponding to a Business - as- Usual case) is used to illustrate this Summary.

Secondly, because we do not fully understand the sources and sinks of the greenhouse gases, there are uncertainties in our calculations of future concentrations arising from a given emissions scenario. For carbon dioxide, for example, the concentration calculated for 2070 from the Business-as-Usual emissions scenario ranged from 560ppmv to 720ppmv; we have chosen a best estimate for each gas. Furthermore, because natural sources and sinks of greenhouse gases are sensitive to a change in climate, they may substantially modify future concentrations; ice core records show that methane and carbon dioxide concentrations changed in the same way as temperature between ice ages and interglacials. For example, if wetlands become warmer, methane emissions (and hence concentrations) will increase; if they become drier, methane emissions will decrease. Although these factors are complex, it appears that they are more likely to increase greenhouse gas abundances overall and hence increase the climate change estimates given above.

Thirdly, although we understand quite well the forcing due to changing gas concentrations, other factors apart from these can influence climate. Those which could be important on a decadal timescale are: short term variability of solar radiation output; aerosols from a large volcanic eruption and low level aerosols arising from man-made sulphur emissions. On the timescale of the next century, however, the change in climate due to increasing greenhouse gases is likely to be far more important than that from these other effects.

Because of long period couplings between ocean and atmosphere the earth's climate would still vary without being perturbed by any external influences. This natural variability could act to speed up, or slow down, any man-made warming but on a century timescale would be less than greenhouse gas-induced changes.

Fourthly, models are only as good as our understanding of the processes which affect climate, and this is far from perfect. The range in the climate predictions given above reflects an estimate of uncertainties due to model imperfections; the largest of these is cloud feedback, leading to a factor of two uncertainty in the size of the warming. Nevertheless, for reasons given in the box below, we have substantial confidence that models can predict at least the broad scale features of climate change.

Confidence in predictions from climate models

What confidence can we have that climate change will look anything like what the models tell us? Weather forecasts can be compared with the actual weather the next day and their skill assessed; we cannot do that with climate predictions. There are several indicators that give us some confidence in the predictions from climate models.

When they are run with the present amount of carbon dioxide in the atmosphere their simulation of present climate is generally realistic, capturing the major features such as the wet tropical convergence zones and mid-latitude depression belts, as well as the contrasts between summer and winter circulations. The models also simulate the observed variability; for example, the large day-to-day pressure variations in the middle latitude depression belts and the maxima in interannual variability responsible for the very different character of one winter from another both being represented.

Overall confidence is increased by their generally satisfactory portrayal of aspects of variability of the atmosphere such as that associated with El Niño (the irregular warming of the Eastern tropical Pacific).

In addition, when forced with correct conditions (solar radiation, greenhouse gas forcing, ice caps, etc) they can capture important features of climates 6,000 to 9,000 years ago and the most recent ice age about 20,000 years ago.

It is also worth noting that the weather forecasting models (from which climate models have been developed) predict weather for several days ahead, with generally great success.

Will the predicted changes be unusual?

When considering future climate change, it is clearly essential to look at the record of climate variation in the past. From this record we can learn about the range of natural climate variability, to see how it compares with what we expect in the future, and also look for evidence of recent climate change due to man's activities.

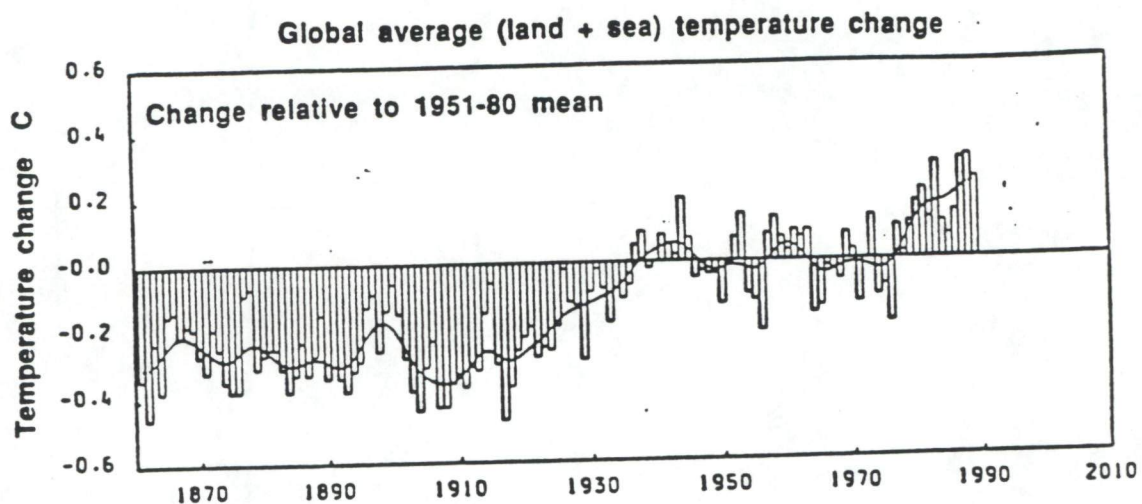
Climate varies naturally on all time scales from hundreds of millions of years down to the year to year. Prominent in the earth's history have been the 100,000 year glacial-interglacial cycles when climate was mostly cooler than at present. Global surface temperatures have typically varied by 5 to 7°C through these cycles, with large changes in ice volume and sea level, and temperature changes as great as 10-15°C in some middle and high latitude regions of the northern hemisphere. Since the end of the last ice age, about 10,000 years ago, global surface temperatures have probably fluctuated by little more than 1°C. Some fluctuations have lasted several centuries, including the Little Ice Age which ended in the nineteenth century and which appears to have been global in extent.

The changes predicted to occur by about 2040 due to man made increases in greenhouse gas concentrations will make global mean temperatures higher than they have been in the last 100,000 years.

Has man already begun to change the global climate?

The instrumental record of **surface temperature** is fragmentary until the mid nineteenth century, after which it slowly improves. Because of different methods of measurement, historical records have to be harmonised with modern ones, introducing some uncertainty. Despite these problems we believe that a real warming of the globe of 0.3 C - 0.6 C has taken place over the last century.

Moreover since 1900 similar temperature increases are seen in three independent data sets: one collected over land and two over the oceans. The figure below shows current estimates of smoothed global mean surface temperature over land and ocean since 1860.



Although overall temperature rise has been broadly similar in both hemispheres, it has not been steady, and differences in their rates of warming have sometimes persisted for decades. Much of the warming since 1900 has been concentrated in two periods, the first between about 1920 and 1940 and the other since 1975. The northern hemisphere cooled between the 1940s and the early 1970s when southern hemisphere temperatures stayed nearly constant. The pattern of global warming since 1975 has been uneven with some regions, mainly in the northern hemisphere, continuing to cool until recently. This regional diversity indicates that future regional temperature changes are likely to differ considerably from a global average.

That there has been a real temperature rise is strongly supported by the retreat of most **mountain glaciers** of the world since the end of the nineteenth century and the fact that **sea level** has risen over the same period by an average of 1 to 2 mm per year.

Estimates of thermal expansion of the oceans, and of increased melting of mountain glaciers and the ice margin in West Greenland over the last century, shows that the major part of the rise appears to be related to the observed global warming. This apparent connection between observed sea level rise and global warming provides grounds for believing that future warming will lead to an acceleration in sea level rise.

1 The magnitude of the warming over the last century is broadly consistent with the
2 theoretical predictions of climate models. If the sole cause of the observed warming
3 were the man-made greenhouse effect, then the implied climate sensitivity would
4 be in the lower half of the range inferred from the models. However, the range of
5 natural variability is almost certainly as large as any change to date due to the
6 man-made greenhouse effect.

7
8 Global-mean temperature alone is an inadequate indicator of greenhouse-gas-
9 induced climatic change. Identifying the causes of any global-mean temperature
10 change requires examination of other aspects of the changing climate, particularly
11 its spatial and temporal characteristics - the man-made climate change "signal".
12 However, we do not yet know what the "signal" looks like because, as we have
13 seen, prediction of many of these detailed characteristics is not yet possible;

14
15 Although we are convinced of the reality of an increasing anthropogenic
16 greenhouse effect, by the time unequivocal detection has been achieved, the
17 commitment to future climate change will be considerably larger than it is today.

18 19 20 What will be the effect of climate change on 21 ecosystems ?

22
23 Our life support system depends on the basic functioning of our ecosystems.
24 Photosynthesis captures atmospheric carbon dioxide and solar energy and stores
25 them in organic compounds which are then utilized for subsequent plant growth,
26 the growth of animals or the growth of microbes in the soil which release CO₂ via
27 respiration into the atmosphere.

28
29 The rates of ecosystem processes are dependent on climatic factors in the short
30 term and carbon dioxide concentration may also modify the rates of
31 photosynthesis and respiration. In the longer term, climate and atmospheric
32 carbon dioxide control the structure of ecosystems by selecting species which
33 together function within them. Changes in climate and atmospheric carbon dioxide
34 concentrations will, therefore, modify both function and structure in our
35 ecosystems.

36
37 Photosynthesis fixes 120-160 Gt of carbon each year (90-120Gt on land and 30-40
38 Gt in the oceans). Most land plants have a system of photosynthesis which will
39 respond positively to increased atmospheric carbon dioxide ("the carbon dioxide
40 fertilization effect"), but the response varies with species and may decrease with
41 time. The response to increased carbon dioxide results in greater efficiencies of
42 water and nitrogen use and may be particularly important in plants of stressed
43 ecosystems (in arid/semi arid and infertile areas). Photosynthesis will also
44 increase as temperature and moisture increase and as nutrient availability
45 increases through the stimulation of the decomposition process by increased
46 temperatures.

47
48 So far there is no incontrovertible proof that net terrestrial ecosystem production
49 has increased. If there were, it would be almost impossible to apportion this
50 between land use effects, fertilization by atmospheric pollutants and climate
51 change. The extent to which ecosystems can sequester increasing atmospheric
52 carbon remains to be quantified.

1 As various species respond differently to various components of the physical
2 environment, some species in a particular location will be more advantaged than
3 others by global change. They will then displace other species and communities
4 and ecosystems will change in structure. Displaced species will be forced to
5 higher latitudes and altitudes, and will be prone to extinction, having no potential
6 habitat while existing where change is predicted to be greatest. Communities will
7 not move en bloc and new assemblages of species will form at new locations.
8 However, a major constraint on the movement of species will be their potential
9 migration rates which will almost always be less than the rates projected for climate
10 change. The result is likely to be unstable ecosystems prone to extensive damage
11 by exceptional events such as drought and fire.

Deforestation and Reforestation

12
13
14
15
16 Man has been deforesting the Earth for millennia since the development of shifting cultivation.
17 During the early part of the century this was mainly in temperate regions, more recently it has been
18 concentrated in the tropics. Deforestation has three potential impacts on climate: through the
19 carbon and nitrogen cycles (where it can lead to changes in carbon dioxide concentrations);
20 through the change in reflectivity of terrain when forests are cleared, and through their effect on
21 the hydrological cycle (precipitation and evaporation).

22
23 The destruction of 100,000 square km of tropical forest has been estimated to release up to 2 Gt
24 of carbon (GtC) to the atmosphere, though allowing for replacement by grassland suggests that
25 nearer 1 GtC is a likely figure. If all the tropical forests were removed, the input is variously
26 estimated at from 150 to 350 GtC; this would increase atmospheric carbon dioxide by 35 to 80
27 ppmv. The rate of loss of forest is difficult to estimate; probably till the mid-20th century,
28 deforestation was a more important contributor to atmospheric carbon dioxide than was the burning
29 of fossil fuels. Since then, fossil fuels have become dominant; one estimate is that around 1980
30 1.7 GtC was being released annually from the clearing of tropical forests, compared with 5 GtC from
31 burning of fossil fuels. Carbon dioxide will be absorbed from the atmosphere during the growth
32 phase of new forests; it is estimated that the planting of 4 million square kilometres of temperate
33 forest would withdraw about 1Gt of carbon from the atmosphere per year for over 100 years.

34
35 Deforestation can also alter climate directly by decreasing the absorption of solar radiation, so
36 weakening the local heat source and decreasing rainfall. Experiments with climate models predict
37 that replacing all the forests of the Amazon basin by grassland reduces the rainfall over the basin
38 by about 20%.

How can we limit climate change?

39
40
41 From studies of how quickly ecosystems can adapt to climate change, it may be
42 relevant to assess what maximum emissions of greenhouse gases would result in
43 global temperatures changing by, say, 0.1°C or 0.2°C per decade.

44
45
46 Even if we were able to stabilise atmospheric concentrations of the greenhouse
47 gases at present day levels (requiring, as we saw above, cutbacks in emissions of
48 50 - 80% in most gases), this would still not keep climate as it is today; we may
49 already be committed to a global rate of change of about 0.1 C per decade. To limit
50 global temperature increase to about 0.2 C per decade, emissions of carbon
51 dioxide would have to be reduced by about XX% (calculation to be finalised),
52 making reasonable assumptions about the effect on CFCs of the Montreal Protocol,
53 and assuming emissions of other gases remain unchanged.
54

What should be done to reduce uncertainties, and how long will this take ?

Policymakers will be aware from this assessment that, although we can say that significant climate change is unavoidable, much uncertainty exists in prediction of global climate properties such as the temperature and rainfall near the surface and the mean sea level. Even greater uncertainty exists in predictions of regional climate change.

To reduce these uncertainties large improvements are required in our capability to model and to observe the global climate system, and to understand it through studies of the processes that need to be represented in the global models. As far as the global modelling is concerned, it is particularly urgent to develop coupled atmosphere -ocean-ice models with increased spatial resolution, incorporating more realistic formulations of relevant physical, chemical and biological processes.

As far as the processes are concerned, the main areas of uncertainty are (1) the role of the clouds which lead to feedback that may amplify or limit the response of the atmosphere to greenhouse forcing, (2) the changes that can occur in the world ocean circulation and in the heat intake of the ocean which acts to reduce and delay surface warming, and (3) the changes that will modify biological activity on land and in the seas. Detailed field studies of these processes are either planned or underway.

As far as the global observational capability is concerned there needs to be increased accuracy and coverage in the observations of the properties of the atmosphere and oceans, especially those directed to the earlier possible detection of climate changes and towards the verification of climate models. The main observational requirements are (1) the maintenance and improvement of observations provided by the World Weather Watch programme of WMO, (2) the development of major new satellite observing systems to obtain global description of properties such as three dimensional cloud distribution and rainfall from polar orbiting platforms, and three dimensional wind fields from a low altitude satellite covering tropical regions, and (3) a new initiative to establish measurements from ships and automatic instrumented vehicles, deep sea moorings and shore stations.

International cooperation to carry out all aspects of this work is concentrated in the World Climate Research Programme and the International Geosphere-Biosphere Programme. These are large and complex endeavours - the largest coordinated international scientific programmes yet attempted. To reinforce existing projects and tackle new scientific problems not only will increased resources be necessary to support existing research teams in each nation, but an increased supply of trained scientists will also be essential; this has implications now at all levels of education. The international community of scientists also needs to be widened to include more participants from developing countries.

As research advances, increased understanding and improved observations will lead to progressively more reliable climate predictions. However considering the complex nature of the problem and the scale of the scientific programmes to be undertaken we know that rapid results cannot be expected. Indeed further scientific

advances may expose unforeseen problems and areas of ignorance. Surprises are possible; for instance it is worth noting that the "ozone hole" resulting from the effects of CFCs was entirely unpredicted. The box below gives some important milestones towards narrowing the uncertainties.

TIMESCALES FOR NARROWING UNCERTAINTIES

PREDICTIONS OF RATE OF CHANGE OF CLIMATE
(as a result of coupled atmos-ocean models
and better understanding of the ocean)

PREDICTIONS OF REGIONAL DIFFERENCES IN
CLIMATE INCLUDING WATER RESOURCES (as
a result of higher resolution models and a
better understanding of the water cycle)

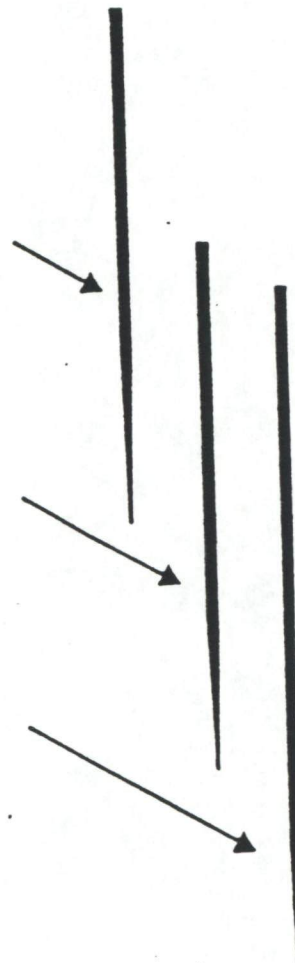
IMPROVED RELIABILITY OF PREDICTIONS &
DEFINITION OF RANGE OF POSSIBLE CLIMATE
VARIATION (as a result of models
containing better representations of
clouds, oceans, ice-sheets, chemistry &
biosphere)

1990

1995

2000

2005





SUMMIT OF THE ARCH

16 July 1989

ECONOMIC DECLARATION

1) We, the Heads of State or Government of seven major industrial nations and the President of the Commission of the European Communities, have met in Paris for the fifteenth annual Economic Summit. The Summit of the Arch initiates a new round of Summits to succeed those begun at Rambouillet in 1975 and at Versailles in 1982. The round beginning in 1982 has seen one of the longest periods of sustained growth since the Second World War. These Summits have permitted effective consultations and offered the opportunity to launch initiatives and to strengthen international cooperation.

2) This year's world economic situation presents three main challenges:

- The choice and the implementation of measures needed to maintain balanced and sustained growth, counter inflation, create jobs and promote social justice. These measures should also facilitate the adjustment of external imbalances, promote international trade and investment, and improve the economic situation of developing countries.

ENVIRONMENT

33) There is growing awareness throughout the world of the necessity to preserve better the global ecological balance. This includes serious threats to the atmosphere, which could lead to future climate changes. We note with great concern the growing pollution of air, lakes, rivers, oceans and seas; acid rain, dangerous substances; and the rapid desertification and deforestation. Such environmental degradation endangers species and undermines the well-being of individuals and societies.

Decisive action is urgently needed to understand and protect the earth's ecological balance. We will work together to achieve the common goals of preserving a healthy and balanced global environment in order to meet shared economic and social objectives and to carry out obligations to future generations.

34) We urge all countries to give further impetus to scientific research on environmental issues, to develop necessary technologies and to make clear evaluations of the economic costs and benefits of environmental policies.

The persisting uncertainty on some of these issues should not unduly delay our action.

In this connection, we ask all countries to combine their efforts in order to improve observation and monitoring on a global scale.

35) We believe that international cooperation also needs to be enhanced in the field of technology and technology transfer in order to reduce pollution or provide alternative solutions.

36) We believe that industry has a crucial role in preventing pollution at source, in waste minimization, in energy conservation, and in the design and marketing of cost-effective clean technologies. The agricultural sector must also contribute to tackling problems such as water pollution, soil erosion and desertification.

37) Environmental protection is integral to issues such as trade, development, energy, transport, agriculture and economic planning. Therefore, environmental considerations must be taken into account in economic decision-making. In fact good economic policies and good environmental policies are mutually reinforcing.

In order to achieve sustainable development, we shall ensure the compatibility of economic growth and development with the protection of the environment. Environmental protection and related investment should contribute to economic growth. In this respect, intensified efforts for technological breakthrough are important to reconcile economic growth and environmental policies.

Clear assessments of the costs, benefits and resource implications of environmental protection should help governments to take the necessary decisions on the mix of price signals (e.g., taxes or expenditures) and regulatory actions, reflecting where possible the full value of natural resources.

We encourage the World Bank and regional development banks to integrate environmental considerations into their activities. International organizations such as the OECD and the United Nations and its affiliated organizations, will be asked to develop further techniques of analysis which would help governments assess appropriate economic measures to promote the quality of the environment. We ask the OECD, within the context of its work on integrating environment and economic decision-making, to examine how selected environmental indicators could be developed. We expect the 1992 UN Conference on Environment and Development to give additional momentum to the protection of the global environment.

38) To help developing countries deal with past damage and to encourage them to take environmentally desirable action, economic incentives may include the use of aid mechanisms and specific transfer of technology. In special cases, ODA debt forgiveness and debt for nature swaps can play a useful role in environmental protection.

We also emphasize the necessity to take into account the interests and needs of developing countries in sustaining the growth of their economies and the financial and technological requirements to meet environmental challenges.

39) The depletion of the stratospheric ozone layer is alarming and calls for prompt action.

We welcome the HELSINKI conclusions related, among other issues, to the complete abandonment of the production and consumption of chloro-fluorocarbons covered by the MONTREAL protocol as soon as possible and not later than the end of the century. Specific attention must also be given to those ozone-depleting substances not covered by the Montreal protocol. We shall promote the development and use of suitable substitute substances and technologies. More emphasis should be placed on projects that provide alternatives to chloro-fluorocarbons.

40) We strongly advocate common efforts to limit emissions of carbon dioxide and other greenhouse gases, which threaten to induce climate change, endangering the environment and ultimately the economy. We strongly support the work undertaken by the Intergovernmental Panel on Climate Change, on this issue.

We need to strengthen the worldwide network of observatories for greenhouse gases and support the World Meteorological Organisation initiative to establish a global climatological reference network to detect climate changes

41) We agree that increasing energy efficiency could make a substantial contribution to these goals. We urge international organizations concerned to encourage measures, including economic measures, to improve energy conservation and, more broadly, efficiency in the use of energy of all kinds and to promote relevant techniques and technologies.

We are committed to maintaining the highest safety standards for nuclear power plants and ~~to~~ strengthening international cooperation in safe operation of power plants and waste management, and we recognize that nuclear power also plays an important role in limiting output of greenhouse gases.

42) Deforestation also damages the atmosphere and must be reversed. We call for the adoption of sustainable forest management practices, with a view to preserving the scale of world forests. The relevant international organizations will be asked to complete reports on the state of the world's forests by 1990.

43) Preserving the tropical forests is an urgent need for the world as a whole. While recognizing the sovereign rights of developing countries to make use of their natural resources, we encourage, through a sustainable use of tropical forests, the protection of all the species therein and the traditional rights to land and other resources of local communities. We welcome the German initiative in this field as a basis for progress.

To this end, we give strong support to rapid implementation of the Tropical Forest Action Plan which was adopted in 1986 in the framework of the Food and Agricultural Organization. We appeal to both consumer and producer countries, which are united in the International Tropical Timber Organization, to join their efforts to ensure better conservation of the forests. We express our readiness to assist the efforts of nations with tropical forests through financial and technical cooperation, and in international organizations.

44) Temperate forests, lakes and rivers must be protected against the effects of acid pollutants such as sulphur dioxide and nitrogen oxides. It is necessary to pursue actively the bilateral and multilateral efforts to this end.

45) The increasing complexity of the issues related to the protection of the atmosphere calls for innovative solutions. New instruments may be contemplated. We believe that the conclusion of a framework or umbrella convention on climate change to set out general principles or guidelines is urgently required to mobilize and rationalize the efforts made by the international community. We welcome the work under way by the United Nations Environment Program, in cooperation with the World Meteorological Organization, drawing on the work of the Intergovernmental Panel on Climate Change and the results of other international meetings. Specific protocols containing concrete commitments could be fitted into the framework as scientific evidence requires and permits.

46) We condemn indiscriminate use of oceans as dumping grounds for polluting waste. There is a particular problem with the deterioration of coastal waters. To ensure the sustainable management of the marine environment, we recognize the importance of international cooperation in preserving it and conserving the living resources of the sea. We call for relevant bodies of the United Nations to prepare a report on the state of the world's oceans.

We express our concern that national, regional and global capabilities to contain and alleviate the consequences of maritime oil spills be improved. We urge all countries to make better use of the latest monitoring and clean-up technologies. We ask all countries to adhere to and implement fully the international conventions for the prevention of oil pollution of the oceans. We also ask the International Maritime Organization to put forward proposals for further preventive action.

47) We are committed to ensuring full implementation of existing rules for the environment. In this respect, we note with interest the initiative of the Italian government to host in 1990 a forum on international law for the environment with scholars, scientific experts and officials, to consider the need for a digest of existing rules and to give in-depth consideration to the legal aspects of environment at the international level.

48) We advocate that existing environment institutions be strengthened within the United Nations system. In particular, the United Nations Environment Program urgently requires strengthening and increased financial support. Some of us have agreed that the establishment within the United Nations of a new institution may also be worth considering.

49) We have taken note of the report of the sixth conference on bioethics held in Brussels which examined the elaboration of a universal code of environmental ethics based upon the concept of the "human stewardship of nature".

50) It is a matter of international concern that Bangladesh, one of the poorest and most densely populated countries in the world, is periodically devastated by catastrophic floods.

We stress the urgent need for effective, coordinated action by the international community, in support of the Government of Bangladesh, in order to find solutions to this major problem which are technically, financially, economically and environmentally sound. In that spirit, and taking account of help already given, we take note of the different studies concerning flood alleviation, initiated by France, Japan, the US and the United Nations Development Program, which have been reviewed by experts from all our countries. We welcome the World Bank's agreement, following those studies, to coordinate the efforts of the international community so that a sound basis for achieving a real improvement in alleviating the effects of flood can be established. We also welcome the agreement of the World Bank to chair, by the end of the year, a meeting to be held in the United Kingdom by invitation of the Bangladesh Government, of the countries willing to take an active part in such a program.

51) We give political support to projects such as the joint project to set up an observatory of the Saharan areas, which answers the need to monitor the development of that rapidly deteriorating, fragile, arid region, in order to protect it more effectively.

DRUG ISSUES

52) The drug problem has reached devastating proportions. We stress the urgent need for decisive action, both on a national and an international basis. We urge all countries, especially those where drug production, trading and consumption are large, to join our efforts to counter drug production, to reduce demand, and to carry forward the fight

THE WHITE HOUSE

Office of the Press Secretary
(Brussels, Belgium)

For Immediate Release

December 4, 1989

FACT SHEET

The President's Initiatives During the Malta Meeting

December 2 - 3, 1989

The President and Chairman Gorbachev exchanged views on a variety of issues during their meetings in Malta, including the remarkable events leading to peaceful and democratic change in Eastern and Central Europe.

The President noted his strong support for perestroika and suggested that the two leaders work to give major new impetus to the U.S.-Soviet relationship. The President conveyed his strong personal commitment to this goal.

In this spirit, the President put forward the following ideas:

Next Steps

1. Holding the Summit in the United States during the last two weeks in June.
2. Having the next meeting of Foreign Ministers next month in the Soviet Union to prepare for the Summit.

Economics and Commercial Relations

1. Targeting the 1990 Summit for completion of a trade agreement granting Most Favored Nation status to the Soviet Union, so that the President can grant a Jackson-Vanik waiver at that time. To reach that goal, the President proposed beginning negotiations on a trade agreement now and urged the Supreme Soviet to complete action on its emigration legislation early next year.
2. Supporting observer status for the Soviet Union in GATT after the Uruguay Round is completed next year. The President urged the Soviet Union to use the intervening time to move toward market prices at the wholesale level so its economy will become more compatible with the GATT system.
3. Expanding U.S.-Soviet technical economic cooperation. The President presented a paper proposing specific economic projects, covering topics such as finance, agriculture, statistics, small business development, budgetary and tax policy, a stock exchange, and anti-monopoly policy.
4. Exploring with Congress the lifting of statutory restrictions on export credits and guarantees after a Jackson-Vanik waiver.

5. Beginning discussions of a bilateral investment treaty that would provide protections for American business people who want to invest in the Soviet Union.
6. Improving ties between the Soviets and the OECD, and East-West economic cooperation through the economic basket of the CSCE process.

Human Rights

Resolving all divided family issues by the time of the 1990 Summit. In this regard, the President handed over a list of people wishing to emigrate.

Regional Issues

Expressed disappointment with Soviet policy on Central America, noting it was out of step with the new Soviet direction domestically in Eastern Europe and in arms control. Nicaragua/Cuba remains the single most disruptive factor in the relationship.

Arms Control

1. Speeding achievement of a chemical weapons ban by offering to end U.S. production of binary weapons when the multilateral convention on chemical weapons enters into force, in return for Soviet acceptance of the terms of our UN proposal to ban chemical weapons.
2. Proposing to sign an agreement at the 1990 Summit to destroy U.S. and Soviet chemical weapons down to 20 percent of the current U.S. level.
3. Suggesting joint U.S.-Soviet support for a CFE Summit to sign a CFE treaty in 1990.
4. Accelerating the START process in order to resolve all substantive issues and to conclude a treaty, if possible, by the 1990 Summit. To this end, the President suggested that Secretary Baker and Foreign Minister Shevardnadze concentrate on resolving at their January meeting three of the outstanding START issues: ALCMs, non-deployed missiles, and telemetry encryption.
5. Completing work on the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET) for signature at the 1990 Summit.
6. Proposing that the Soviet Union join efforts to constrain missile proliferation more effectively by observing the limits developed by the U.S. and its allies in the Missile Technology Control Regime.

Military Openness

Making public more information on military programs. The President suggested that the Soviet Union make public the details of its military budget, force posture, and weapons production figures, just as the United States now does.

Olympics

Suggesting joint U.S.-Soviet support for Berlin as the site of the 2004 Olympic Games.

Environment

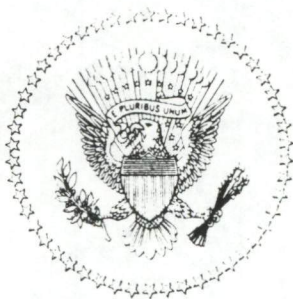
1. Hosting a conference next fall to negotiate a framework treaty on global climate change, after the working groups of the UN-sponsored Intergovernmental Panel on Climate Change submit their final report.
2. Convening an international meeting at the White House next spring for top level scientific, environmental, and economic officials to discuss global climate change issues. The President expressed hope that the Soviets will join us by sending their top officials in the field.

Student Exchanges

Increasing significantly university exchanges so that an additional 1,000 American and 1,000 Soviet college students are studying in each other's country by the beginning of the 1991 school year.

#

Economic Report of the President



Transmitted to the Congress
February 1990

TOGETHER WITH
THE ANNUAL REPORT
OF THE
COUNCIL OF ECONOMIC ADVISERS

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CHAPTER 6

The Economy and the Environment

ECONOMIC PROSPERITY and environmental quality are widely regarded as two of this Nation's most important goals. Some view these as competing goals and argue that economic growth begets environmental degradation. Increasingly, however, this conventional wisdom is being questioned, and a new consensus is emerging that economic growth and environmental quality need not be incompatible. Indeed, economic growth and environmental quality are in many respects complementary. For example, economic growth provides the opportunity for firms to invest in new facilities that are cleaner and more efficient. It is no coincidence that the wealthy societies are the ones that are both willing and able to devote substantial resources to environmental protection.

Compatibility between economic growth and environmental improvement is far from automatic, however; it depends on selection of appropriate goals and careful design of regulatory programs. Environmental goals must balance the associated benefits and costs. The public interest is best served when government provides a framework that creates incentives for the private sector to seek out the most cost-effective way to meet its regulatory goals. Government should *not* be in the business of picking environmental protection technologies and imposing them on firms, their workers, and their customers.

This chapter presents the Administration's principles for environmental regulation and illustrates how they can be put into action to address local, national, and global environmental concerns. The consistent application of these principles will ensure that this Nation's considerable investment in environmental protection—\$81 billion in 1987, about the same as all American households' electricity and natural gas utility bills—will be made in ways that help to achieve *both* a strong economy *and* a healthy environment.

PRINCIPLES FOR ENVIRONMENTAL REGULATION

Market-based economies do not automatically provide the level of environmental quality that consumers desire. Understanding why environmental protection may require government action leads to

an understanding of policies that best serve both the economy and the environment.

MARKET FAILURE

Environmental problems arise in market economies when private individuals and businesses lack incentives to take full account of the environmental consequences of their actions. These market failures, which provide a rationale for government action, can be traced to three sources.

First, individual producers or consumers who pollute the environment generally do not pay for their pollution, even though it may harm others or cause others to incur additional costs. Excess pollution results, just as free electricity would lead firms and households to use electricity without regard to the resources used to produce it.

Second, no single individual can produce tangible evidence of an overall improvement in environmental quality by his or her own actions to reduce or control pollution. When there are some costs and no apparent payoff for individual cleanup effort, rational individuals may be unwilling to act, even in cases where a coordinated effort would yield environmental benefits that exceed the costs of collective action. This problem is analogous to that faced by a stadium full of standing football fans who would all be happier to see the game sitting down if only their actions could be coordinated.

Finally, the private market does not always produce the information needed to solve public problems. Private firms typically do not realize profits from research and development aimed at understanding environmental processes or the relationship between pollution and human health. Government action is often necessary to produce such information to further public policy objectives.

Regulations can also be motivated by factors other than the market failures outlined above. Paternalism, the belief of legislators and regulators that they can improve citizens' overall welfare by taking certain choices out of their hands, can play a significant role. Because the diversity of individual choice generally reflects differences in tastes, needs, and situations among individuals, paternalistic regulation is much more likely to reduce overall well-being than to increase it. Another motive for regulation is the pursuit of private advantage, which can be reflected in the specific design features of regulations that may be broadly grounded in public interest consideration. For example, firms routinely seek to keep their existing products and facilities under the current regulatory regime when more stringent regulations are implemented for new products and facilities.

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First, individual producers or consumers who pollute the environment generally do not pay for their pollution, even though it may harm others or cause others to incur additional costs. Excess pollution results, just as free electricity would lead firms and households to use electricity without regard to the resources used to produce it.

Second, no single individual can produce tangible evidence of an overall improvement in environmental quality by his or her own actions to reduce or control pollution. When there are some costs and no apparent payoff for individual cleanup effort, rational individuals may be unwilling to act, even in cases where a coordinated effort would yield environmental benefits that exceed the costs of collective action. This problem is analogous to that faced by a stadium full of standing football fans who would all be happier to see the game sitting down if only their actions could be coordinated.

Finally, the private market does not always produce the information needed to solve public problems. Private firms typically do not realize profits from research and development aimed at understanding environmental processes or the relationship between pollution and human health. Government action is often necessary to produce such information to further public policy objectives.

Regulations can also be motivated by factors other than the market failures outlined above. Paternalism, the belief of legislators and regulators that they can improve citizens' overall welfare by taking certain choices out of their hands, can play a significant role. Because the diversity of individual choice generally reflects differences in tastes, needs, and situations among individuals, paternalistic regulation is much more likely to reduce overall well-being than to increase it. Another motive for regulation is the pursuit of private advantage, which can be reflected in the specific design features of regulations that may be broadly grounded in public interest consideration. For example, firms routinely seek to keep their existing products and facilities under the current regulatory regime when more stringent regulations are implemented for new products and facilities.

ENVIRONMENTAL R

The Federal Government's environmental protection is relatively recent. Legislation between 1970 and 1980 acted in this era rely heavily on command-and-control regulation. Some use market incentives to reduce emissions charges or trading of the environment and the environmental protection (Box 6-

Box 6-1.—A Glossary of

Command-and-Control—regulative or statutory rules or devices on classes of sources to narrow standards to narrow

Emission Standard—a maximum allowable emission from a source.

Emission Charge—a unit of pollutant emitted

Tradable Emission Allowance—a unit in which all sources of emissions are allocated. The government distributes a number of allowances at a certain emissions level, which can be traded in the private sector.

In the final decade of the 20th century, environmental problems that include stratospheric ozone depletion and climate change are receiving more attention. These problems are also leading to deeper environmental concerns. As the problem grows, policymakers are making progress on several fronts in the economy.

Regulatory goals should be chosen to maximize societal welfare. If it is impossible to remove all of a given pollutant or risk is rising and the incremental benefits often become marginal, then the limit

ENVIRONMENTAL REGULATION

The Federal Government's involvement in environmental protection is relatively recent. The Congress first enacted major legislation between 1970 and 1980. Many environmental programs enacted in this era rely heavily on an approach referred to as command-and-control regulation. Alternative regulatory schemes that use market incentives to further environmental goals, such as emissions charges or tradable emissions allowances, can serve both the environment and the economy by reducing the costs of environmental protection (Box 6-1).

Box 6-1.—A Glossary of Environmental Regulation Terms

Command-and-Control Regulation—a system of administrative or statutory rules that requires the use of specific control devices on classes of selected pollution sources or applies emissions standards to narrowly defined pollution sources.

Emission Standard—a limit, usually expressed as a maximum allowable emission rate, applied to an individual pollution source.

Emission Charge—a fee levied by the government on each unit of pollutant emitted.

Tradable Emission Allowances System—a regulatory regime in which all sources of pollution are required to hold allowances for all emissions of covered pollutants. The government distributes a number of allowances equal to the target emissions level, which can then be freely bought and sold within the private sector.

In the final decade of this century, new environmental issues that include stratospheric ozone depletion and possible global climate change are receiving increased attention. Advances in science are also leading to deeper understanding of problems such as acid rain and pesticide contamination. As the list of environmental concerns grows, policymakers must carefully design programs to make progress on several fronts while minimizing adverse impacts on the economy.

Regulatory goals should be set so that the potential benefits to society from regulation outweigh the potential costs. Specific objectives should be chosen to maximize net benefits to the extent possible. It is impossible to remove all pollution or environmental risks, just as it is impossible to remove all risk of accident or illness. As any given pollutant or risk is reduced, the costs of further reductions rise and the incremental benefits fall. Because these additional benefits often become minuscule and the additional costs become astronomical as the limit of zero pollution or zero environmental

risk is approached, the pursuit of such extreme goals is likely to reduce the overall quality of life. Cost-benefit analysis can be useful both in setting appropriate goals within a particular area of concern and in setting priorities across areas.

Where regulation is necessary, it should wherever possible employ economic incentives to achieve its goals rather than attempt to legislate behavior without changing the underlying structure of private incentives. Where incentive-based approaches such as emissions fees or tradable allowances cannot be used, it is preferable to let each firm decide how best to meet flexible performance standards rather than to impose inflexible design standards that specify how pollution must be controlled. Regulation should also define pollution sources broadly rather than narrowly, to give plants that emit emissions at more than one point flexibility in meeting an overall emissions objective. Regulation of any type should pass a test for cost-effectiveness—reaching its goals at the lowest possible cost. To forsake cost-effectiveness simply wastes resources that could be used for many purposes, including further environmental improvement.

The command-and-control approach generally fails to create incentives consistent with regulatory goals. Indeed, the hallmark of the command-and-control approach is the uniform treatment of pollution sources without regard for the differences in damages they cause or the costs of control. Because command-and-control regulation relies on administrative or statutory rules, flexibility is limited and incentives to firms are distorted. The likelihood that innovation to reduce the costs of pollution control will be met by tighter regulatory requirements presents a particularly large disincentive to innovation (Box 6-2).

Finally, often an insufficient private incentive exists to undertake research that is necessary to understand and rationally address environmental issues. Government support may be required to spur inquiry into environmental problems, benefits and costs of action, and methods of pollution reduction.

In short, the following principles should guide environmental regulation:

- Goals for pollution abatement and risk reduction should be based on a comparison of the costs and benefits involved. Elimination of all risk is almost never a sensible goal.
- Where possible, market-based approaches that provide flexibility, encourage innovation, and support economic growth should be used to achieve environmental goals in a cost-effective manner.
- Government policy should encourage the development and sharing of scientific and technical information relevant to environmental quality issues.

Box 6-2.—Problems with Command-and-Control Regulation

Regulators generally lack the detailed knowledge of individual production facilities and processes and of alternative production and abatement methods that would be necessary to implement an efficient regulatory program by command-and-control.

Firms sensibly expect that any demonstration of potential for environmental improvement or the exploration of new approaches to emission control will increase their risk of being targeted for tougher emission standards. Therefore, there is a disincentive to innovate that magnifies the inefficiency of command-and-control regulation over time. Regulators may try to overcome the incentive problem by incorporating their own forecast of future technology into regulatory requirements. This inflexible approach is a poor substitute for a decentralized innovation process in which many possibilities are pursued at the same time, with winners emerging naturally only as additional information is developed.

Command-and-control regulation also fails to account for private responses that tend to neutralize its impact. For example, a common regulatory practice is to impose new product standards that are tougher than those for existing products and facilities. This practice locks in the continued use of old products or facilities that may actually be more environmentally damaging. Aside from being costly, such standards can actually increase pollution from levels that might have been obtained without a bias against new investment.

Finally, command-and-control regulation sometimes involves issuing threats that are not credible. In 1976, when it became clear that car manufacturers could not meet the automobile emissions standards for the 1977 model year, the Congress quickly revised the standards. The implicit threat to shut down the U.S. auto industry was simply too draconian to be believed.

The rest of this chapter considers the application of these principles in the Administration's proposals to update the Clean Air Act and food safety legislation, in Federal soil conservation programs, and in the Administration's approach to global environmental issues.

THE CLEAN AIR ACT

Prior to 1970, State and local governments held the primary responsibility for determining air quality targets and emission con-

trol strategies. Some States and cities, such as California and Pittsburgh, did address pollution problems. Others, however, were reluctant to impose and enforce strict pollution controls that might drive industry elsewhere.

The Clean Air Act amendments enacted in 1970 expanded the Federal role in clean air issues beyond its previous focus on support for scientific research on air pollution problems. Under its provisions, the Environmental Protection Agency (EPA), which was also established in 1970, sets national air quality standards for major pollutants. These standards, defined as permissible concentration levels of pollutants in the air over a specific time period, are designed to protect the health of the most sensitive members of the population with an adequate margin of safety and without regard to cost. National emission standards for new industrial, utility, and commercial facilities that are significant sources of pollution and new car emission standards are also set and administered at the Federal level. State and local governments retain responsibility, however, for developing plans to reduce emissions from existing utility and industrial pollution sources so that air quality standards are met or exceeded at all locations.

EXPERIENCE UNDER THE CURRENT LAW

Meeting the objectives of the Clean Air Act has been complicated by several factors. One is the sheer number of pollution sources. There are an estimated 27,000 major industrial and utility sources of air pollution in the Nation. Mobile sources of pollution (automobiles, trucks, aircraft, and locomotives) number well over 150 million, and vehicle miles traveled have been steadily increasing. Moreover, because pollutants are transformed and transported in the atmosphere, the selection of control strategies is complicated.

Despite rising levels of economic activity and automobile use, emissions of the most common air pollutants have declined substantially since 1970. For example, emissions of carbon monoxide, particulate matter, and lead fell by 39, 62, and 96 percent, respectively, between 1970 and 1987. Yet, in 1987, 12 years past the original target date for meeting air quality standards, more than 100 million people lived in areas where air quality standards had not all been achieved. Failures to meet the ground-level ozone standard accounted for 90 percent of these exposures. Some have argued, however, that this official measure of air quality status gives little indication of normal air quality in affected areas. For example, air quality monitoring data show that the air quality standards are met more than 99 percent of the time in all areas other than Los Angeles, and 97 percent of the time there, even though it is the city with the most polluted air in the United States.

A major feature in the regulatory approach of the Clean Air Act is the requirement that new facilities meet EPA emission rate standards. This approach can effectively offer grandfather protection to old facilities and slow the rate at which firms replace older, inefficient plant and equipment with newer plant and equipment that meet EPA standards.

This peculiar consequence of regulation is apparent in the utility sector. Concern over the impact of emission standards on mining employment in high-sulfur coal regions led the Congress in 1977 to mandate a design standard for new coal-fired power plants. Sulfur dioxide removal from exhaust gases (via scrubbing technology) was required even when the same emission rate could be reached at lower cost by burning low-sulfur coal. Because such scrubbing may add 20 percent to the capital cost of a new plant, and old generating units can be kept running for 65 years or more, replacement of old generating capacity inevitably slowed. Moreover, because new generating units with scrubbers often have higher operating costs than old unscrubbed units, utilities naturally chose to run the old units as much as possible. Having new, clean plants sit idle while old, dirty ones operated at full capacity was an unintended consequence that vividly illustrates the perverse effects that command-and-control regulation can have.

THE CLEAN AIR INITIATIVE

The Administration has proposed a comprehensive plan for revising and strengthening the Clean Air Act. The Administration's proposal includes initiatives to achieve complete attainment of air quality standards, control toxic air pollutants, address the problem of acid rain, and reduce automobile emissions. The acid rain and automobile emissions programs provide particularly clear applications of the Administration's regulatory principles. The former proposes the use of tradable emissions allowances to reduce sulfur dioxide emissions from utility plants that are a primary cause of acid rain (Box 6-3). The latter uses flexibly applied and carefully targeted standards to limit automobile emissions that are the major source of ground-level ozone pollution.

TRADABLE ALLOWANCES FOR SULFUR DIOXIDE EMISSIONS

The Administration proposes to achieve a permanent 10-million-ton reduction in annual sulfur dioxide emissions in a cost-effective manner, using a system of tradable emissions allowances. The use of tradable emissions allowances is an approach that has been repeatedly advocated in this *Report* for more than a decade. Emission allowances reflecting the required reduction in current emissions

Box 6-3.—Acid Rain and Sulfur Dioxide

Acid rain results from the formation of sulfuric and nitric acids in atmospheric reactions involving sulfur dioxide and nitrogen dioxide. These acids fall to the Earth's surface as dry particles or mixed with rainfall over an area that may extend for hundreds of miles from the location where emissions occur. Thus, emissions from the Midwest can cause acid rain in the Northeast. Rainfall in the most heavily affected areas is eight to nine times more acidic than it would be under pristine conditions.

Sulfur dioxide is regulated as a pollutant under the Clean Air Act. Federal air quality standards for sulfur dioxide are currently met at virtually all locations throughout the country. In some areas, compliance was attained by switching to fuels with lower sulfur content. In others, scrubbing technology was applied to remove sulfur from smokestack gases. Another approach was to build taller smokestacks that spread emissions over a much wider area and allowed standards to be met at all measuring sites near the emission point. Building taller smokestacks was very cost-effective within a local area. But over a larger region, it exacerbated the contribution of sulfur dioxide emissions to the formation of acid rain. The 1977 Clean Air Act amendments limited allowable stack height.

While measured urban sulfur dioxide air quality has improved steadily, aggregate sulfur dioxide emissions, which heavily influence acid rain levels, have declined by only 28 percent since 1970. Almost two-thirds of sulfur dioxide emissions come from electric utility plants, with industrial sources accounting for the bulk of the remaining emissions. Most utility emissions occur at coal-burning power plants—particularly from older plants burning high-sulfur coal without emission controls.

are allocated to existing utility plants. Plant owners, who are required to hold allowances equal to their actual emissions, are then free to trade these allowances among themselves. Thus, the emission rates of individual plants can vary considerably, while overall emissions are automatically held at the target level. An additional requirement that operators of new utility plants hold allowances equal to their emissions after the system is fully in place guarantees against any rise in utility emissions over time.

The allowances trading system has several major advantages over the command-and-control approach. The tradable-allowances approach is estimated to result in cost savings of at least 20 per-

cent annually—totaling billions of dollars over the next two decades—compared with command-and-control regulations. These savings arise from the ability to trade allowances in order to take account of differences in plant access to low- and high-sulfur coal supplies, in expected plant life, and in site constraints that may rule out the installation of scrubbers at some plants. With tradable permits, a plant with low control costs has an incentive to control more and sell its excess allowances to a plant that could only reduce emissions to its original allocation at very high cost. The scope for trading is widened by allowing industrial sources with low control costs to participate in the system and by a provision for the conversion of nitrogen dioxide emissions reductions in excess of required levels into allowances.

Incentives for Conservation and Innovation

Because reductions in electricity generation levels translate directly into a reduced need to hold allowances, the allowances system puts utility energy conservation programs on an equal footing with other emissions reduction strategies. Firms can also economize on allowances by using cleaner plants more intensively. By requiring utilities to buy or hold a costly allowance for each ton of pollution they emit, the allowances system uses the private objectives of cost minimization and profit maximization to promote environmentally sound practices. By ensuring that each pound of actual emissions carries a cost, which will be reflected in the price of electricity, additional conservation is promoted as demand falls in response to higher prices. In sum, a market-based approach sends the proper signals to both consumers and producers, resulting in cost-effective reductions in pollution.

Immediate cost savings are only part of the benefits of the trading program. The possibility of future trading creates strong incentives for further cost reduction and innovation by both utilities and non-utility firms, which could save additional billions of dollars. Utilities can take advantage of the opportunity to carry forward unused allowances for future sale or use. Such banking of allowances would shift emissions reductions from the future toward the present, allowing for more rapid environmental improvement while lowering compliance costs. Firms always stand to gain if they can achieve additional emissions reductions at a cost below the market value of the allowances that would be freed up for external sale. Thus, these firms have a continuing incentive to explore new abatement and combustion technologies, nonconventional energy sources, conservation programs, and other options that emerging technologies and local circumstances may suggest. Because allowances are transferable and continue in force after the retirement of the plant to which they were initially allocated, the investment disincentive implicit in standard regulatory schemes is avoided.

The inherent flexibility of the allowances system, which lets the market choose among competing approaches, is particularly valuable given the impossibility of knowing which technology will prove to be best over the long haul. Several different technologies for burning high-sulfur coal cleanly without scrubbing, as well as improved scrubbers, are currently under development. New concepts will undoubtedly arise over the next decade. The government is no more capable of picking winners in emissions-control technology than in other industrial arenas. By encouraging decentralized innovation and avoiding the pitfalls of centralized technological planning, the allowances system maximizes the potential for the invention and application of new ways to achieve environmental protection.

The Workability of the System

There are several precedents for successful emissions trading and marketable allowances systems. Nationally marketable allowances were used during the phasedown of the lead content of gasoline, with substantial savings. EPA's longstanding bubble policy allows owners of an industrial facility with multiple pollution sources to balance more control at some sources for less control at others to meet emissions targets on a cost-effective facility-wide basis. Since their inception in the 1970s, bubbles have saved billions of dollars compared with a policy of requiring each source to meet its own emissions standard. Trading is also used in EPA's offset policy, which allows construction of new facilities in areas that do not meet air quality standards to be offset by reductions in emissions from existing facilities. Trading in these programs has occurred despite the high air quality modeling costs incurred to verify that proposed trades will not worsen the air quality at any location. Transaction costs for sulfur dioxide emissions trading will be much lower, because local air quality modeling will not be required and continuous emissions monitoring data will be available to verify compliance.

The incentive-based approach to environmental protection offers clear advantages over command-and-control regulation, yet it generates several philosophical and practical criticisms. A common objection is that a marketable allowances system gives industry a right to pollute that it would not otherwise have. This view fails to recognize that command-and-control regulation confers exactly the same sort of pollution right, only in a nontransferable form.

Some observers have raised the concern that trade in allowances will be inhibited by State regulatory actions or manipulated to prevent the entry of new producers into the electric power market. However, facts about market structure and behavioral incentives suggest that the market for allowances will work. The initial distribution of allowances among a large number of utilities means no

one firm or State could exercise market control. Antitrust laws provide an additional safeguard against the possibility of anticompetitive behavior. Existing incentives for cost and rate minimization should lead regulators and utilities with low-cost emissions reduction opportunities to sell sufficient allowances to meet the demand from new plants and new entrants. Of course, there is no guarantee that *every* utility or regulator will seek to minimize costs and electric rates and maximize shareholder returns. But in a competitive situation, cost-minimizing behavior by every participant is not required for the market to work effectively.

AUTOMOBILE EMISSIONS CONTROL

The goals selected in the President's clean air package reflect the careful comparison of benefits and costs that is a fundamental consideration in the Administration's approach to regulatory policymaking. For example, the President's package includes tighter tailpipe emissions standards for new cars and light trucks and other measures to reduce automobile emissions significantly. However, it explicitly rejects a proposal for unreasonably stringent tailpipe standards that has been advocated in some quarters.

EPA estimates that the exotic technologies required to attain such an unreasonably stringent standard would add about \$500 to the cost of each new vehicle. At a projected sales rate of approximately 14 million covered vehicles per year, the additional costs would be more than \$7 billion annually, almost doubling the projected costs of all actions proposed by the Administration to reduce urban ozone pollution. This standard would result in slightly lower emissions from each new car. However, because consumers would undoubtedly respond to higher new car prices by buying fewer new cars, emissions of pollutants that contribute to ozone formation could actually *increase* in the period immediately following adoption of these extreme standards, as consumers would be led to make greater use of old vehicles with significantly higher per mile emission rates. Even after a complete phase-in of vehicles meeting the extreme standard, total reductions in emissions of pollutants that contribute to ozone formation would be only slightly larger than emissions reductions under the President's proposal. Spending \$7 billion or more per year to achieve, at most, very small environmental improvements is simply not sensible.

Flexibility and Targeting

The President's clean air initiative *also* incorporates flexibility in its provisions for automobile emission standards. Automakers can average across their product line to reach applicable standards, opening the possibility of substantial cost savings while achieving exactly the same environmental benefits as a standard applied on a car-by-car basis. Because an automaker who elects to use averaging

must necessarily produce some vehicles that are cleaner than the standard, averaging implicitly encourages advances in emission-control technology.

Cost-effectiveness is also enhanced by tailoring program requirements to local needs rather than using a one-size-fits-all approach. Some areas currently meet air quality standards for ground-level ozone, while others do not. Because air quality standards are set at levels that protect the public health with an adequate margin of safety, areas that already meet standards have little to gain from further reductions in emissions. Cost-effectiveness requires focusing reductions where they are needed. For this reason, the Administration's plan for extra-clean, alternative-fueled vehicles is carefully targeted on the areas with the most severe nonattainment problems. Even within these areas, local authorities are free to opt out of the program if they can achieve equivalent air quality benefits in other ways.

The targeted approach is also evident in the President's proposal for recovery of refueling emissions. Refueling vapors can be recovered using either on-board canisters or gasoline pump recovery systems. The latter approach is preferable because it can be applied selectively in areas with ozone problems without imposing unnecessary costs on new car buyers in clean areas. It also provides more immediate environmental benefits in problem areas, because all pumps can be modified long before all cars on the road are replaced. In this matter, as in many others, environmental and economic interests are convergent.

RISK AND THE REGULATION OF AGRICULTURE

Today the regulation of agriculture involves a complex array of Federal programs—from traditional price support and acreage reduction programs to conservation, environmental, and food safety regulations—administered by the Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration. Some programs, such as the acreage reduction programs, affect a farmer's land-use and crop-choice decisions. Others, such as pesticide regulations, affect choice of production methods. Still others, such as conservation regulations, may affect both land-use and management decisions. The combination of farm production decisions and the physical characteristics of farmers' fields—such as soil type, depth of groundwater, and proximity to surface water—are key factors that determine the impacts agriculture has on the environment.

Two questions arise regarding environmental issues that relate to agriculture. What are the circumstances in agriculture that may justify government intervention? When government action is justi-

fied, how can policies be designed to reduce environmental risks to appropriate levels at least cost?

SOIL CONSERVATION RECONSIDERED

The dust bowl of the 1930s, dramatized by John Steinbeck's *The Grapes of Wrath*, left a public perception that the effects of soil erosion can have dire economic consequences. Because of the dust bowl experience, a principal objective of soil conservation programs since the 1930s has been to prevent the loss of agricultural productivity. Yet, analyses of data on soil erosion indicate that the principal benefits from soil conservation are the prevention of offsite damages such as water pollution, not the prevention of agricultural productivity effects. There is accordingly a need to reconsider the design of soil conservation programs.

Soil Erosion and Productivity

Alarming stories in the press periodically warn that erosive practices are again ruining American farmland and will lead to a food crisis. Such alarmist claims are not supported by the facts. The Department of Agriculture estimates that some 2 billion to 3 billion tons of soil are lost from farmers' fields to erosion each year in the United States. Topsoil is a renewable resource, however, and is replaced as organic matter from crop residues is incorporated into the soil. Because of this replenishment, the rate of net loss of topsoil in the United States as a whole is low.

The gains and losses of soil are not distributed evenly, however. Some areas are net losers and may experience lower productivity as topsoil becomes shallow. These productivity losses are largely offset by gains elsewhere. The Department of Agriculture recently estimated that continuing current rates of soil erosion for 100 years would reduce productivity only about 2 percent (Table 6-1). Because *annual* productivity gains in U.S. agriculture have averaged more than 2 percent for the past 20 years, one year's normal productivity growth will offset the likely effects of erosion on productivity over the next century.

TABLE 6-1.— *Estimated Percent Loss of Productivity From 100 Years of Erosion*

Farming region	Water erosion	Wind erosion
Northeast	7.1	(1)
Lake States	3.9	7
Corn Belt	3.5	(4)
Appalachia	4.7	(4)
Southeast	1.3	(4)
Delta States	1.6	(4)
Northern Plains	6	3
Southern Plains	2	2.1
Mountain States	4	1.4
Pacific States	2.3	2
United States	1.8	5

¹ Less than 0.01 percent.

Source: Department of Agriculture, *The Second RCA Appraisal*, June 1989.

Alarmist claims about soil erosion's effects on agriculture also appear to run counter to basic economics. The farmer who uses erosive practices that cause a decline in current or future expected productivity of the land reduces the value of that land. This loss takes the form of lower farm output and a lower value of the land as an asset. Landowners thus have an economic incentive to limit erosion to the degree that it is profitable to do so. Department of Agriculture research shows that erodibility and topsoil depth do help explain differences in land values. These findings mean that buyers and sellers of farmland are in fact aware of these factors and generally take them into consideration in their decisionmaking. Even if some buyers and sellers of farmland are unable to know the impacts of erosion on productivity precisely, there is no reason to believe the government would be able to do so significantly better.

In short, private gains from soil conservation provide farmers and landowners with adequate incentives to protect soil productivity without government intervention. It is in environmental and other offsite effects of soil erosion that the market fails to account adequately for the effects of erosion, and it is there that government conservation programs are needed.

Pollution Effects of Soil Erosion

There are a host of offsite effects of wind and water erosion. Wind erosion contributes to particulate air pollution in the Western United States that is estimated to cause \$4 billion or more in annual damages in the form of increased cleaning costs, reduced recreational opportunities, and impaired health. Erosion caused by water runoff is a major cause of water pollution that damages reservoirs and navigational channels, harms aquatic and plant life and wildlife, has adverse effects on human health, and reduces the recreational value of lakes and rivers. These damages are estimated to range from \$5 billion to \$18 billion annually.

These damages reflect a classic market failure: farmers typically bear little if any of the cost of the offsite effects of erosion from their fields. Agricultural pollution usually originates on many farms and it is difficult to attribute any specific amount of damage to any one source. Consequently, policies to control agricultural pollution usually must be designed to change farmers' production decisions—such as tillage practices or chemical use—that are related to pollution. The design of efficient environmental policies is complicated by the effects that Federal agricultural subsidies have on farmers' management decisions.

The Conservation Reserve Program

This program was introduced in the 1985 farm bill to accomplish environmental objectives, such as improved water quality, by re-

moving highly erodible land from production. This program was also intended to help curb the production of subsidized commodities and to provide income support to farmers. About 34 million acres are now enrolled, roughly 8 percent of U.S. cropland. In exchange for government payments, farmers must plant grass or trees on the enrolled acres. All farmers can participate in the program, provided their land meets technical criteria for erodibility.

The Conservation Reserve Program illustrates the potential benefits of conservation programs and the problems in designing programs to meet environmental, income-support, and broader policy objectives. In order to attract widespread participation, the program originally allowed farmers to enroll any land in the program that met erodibility criteria, whether or not erosion was likely to cause damages such as water pollution. The program thus provided an incentive for farmers to place low-valued land into the program. Consequently, a disproportionately large share of the acres enrolled—more than 40 percent—is nonirrigated land in the Plains and Mountain States, where most wind erosion occurs but damages are relatively small. Relatively few acres in the program are higher valued land in the Midwest and South, where most water erosion occurs and a large part of the nationwide damages also occur. Because it is estimated that only 30 percent of the most highly erodible land is now enrolled in the program, it can be concluded that an even smaller share of the damage caused by erosion is being prevented.

Federal agricultural policy also strives to maintain and enhance the U.S. position as the major agricultural exporter in the world. Conservation programs that attempt to achieve environmental goals by removing millions of acres of cropland from production are not consistent with this broader policy objective. The inconsistency in U.S. policy is highlighted by the 1985 Food Security Act. The act established the Conservation Reserve Program to remove 40 million to 45 million acres of U.S. cropland from production and simultaneously instituted an export subsidy program—the Export Enhancement Program—to increase U.S. agricultural exports. These conflicts between environmental and trade objectives may increase if current international negotiations, discussed in Chapter 7 of this *Report*, lead to agricultural policy liberalization.

IMPROVING CONSERVATION PROGRAM DESIGN

The targeting problems encountered with the Conservation Reserve Program and its inconsistency with broader U.S. policy objectives both suggest that the Federal Government should reconsider its approach to conservation programs. How can conservation programs be made more effective at meeting conservation objectives and also be consistent with broader policy and trade objectives?

The answer is to target environmental impacts while keeping as much viable land in production as possible. Land retirement could still be used in those special circumstances, such as protection of wetlands, in which there are no viable alternative methods to meet environmental objectives.

Conservation programs are not an efficient means of transferring income to farmers because they do not target those farmers who might be thought to be deserving of income subsidies. Hence, they should not be used as a means to support farm income. Instead, conservation programs should be designed to achieve environmental objectives by targeting land that causes offsite damages and land that needs to be protected for other environmental reasons such as protection of wildlife. The recent changes in the Conservation Reserve Program's eligibility criteria, to include environmentally sensitive lands such as wetlands and areas bordering rivers and lakes, represent a move toward better targeting of environmentally sensitive land. These criteria could be further improved by explicitly linking them to potential damages. If the program enrollment is increased from the current 34 million acres to 40 million as proposed by the Administration, participation should be extended to land meeting criteria that target environmental damages.

Conservation programs could also be made compatible with both environmental and trade objectives by using economic incentives to encourage farmers to invest in conservation improvements that reduce wind and water erosion damages while keeping land in production. Investments such as terracing and windbreaks can be used to reduce wind erosion, and filter strips and grassed waterways can reduce water pollution. Federal conservation programs have long shared the costs of these investments, but not in a way that targets the investments to mitigate offsite damages. Such targeting could be accomplished by linking these investment incentives to the potential for erosion to cause environmental damage.

PESTICIDES: BENEFITS, RISKS, AND REGULATION

Pesticides are believed to have been a major contributor to the growth in the productivity of U.S. agriculture since the 1950s. This growth in productivity—almost 220 percent since the early 1950s—has benefited consumers by making more food available at lower prices. Pesticides are poisons, however, and their widespread use in agriculture has led to growing public concern about detrimental effects on human health and the environment.

Many pesticides have immediate health effects that pose a risk to pesticide users and others from accidental poisonings. Some scientists also believe that low-level exposure to many pesticides may cause delayed health effects. These delayed effects—cancers, birth

defects, and neurological disorders—are much more difficult to demonstrate than immediate effects. Because experimentation on humans is not possible, researchers must infer delayed effects from animal studies or from statistical data on human exposure. Because neither method provides definitive data, regulatory decisions regarding delayed effects are inevitably based on imperfect scientific evidence.

The effects of pesticides on nature may be even more difficult to measure and evaluate than the effects on human health. Countless plant and animal species inhabit the natural world. Plants themselves contain many natural pesticides necessary for survival. The scientific challenge to understand the effects of pesticides is great, even if attention is focused only on those organisms that have immediate economic value. Researchers have only recently begun to construct a framework for systematic quantitative assessment of pesticide impacts.

The Regulatory Process

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) directs EPA to evaluate the effects of pesticides on human health and the environment and to regulate pesticide use as necessary to balance benefits and risks. Pesticides that pass the benefit-risk analysis under FIFRA must also meet a health-risk tolerance for residues in processed foods established by the Federal Food, Drug, and Cosmetic Act (FFDCA). The risk tolerance is to be set in light of the need for “an adequate, wholesome, and economical food supply.” EPA uses available data—including laboratory studies of effects on animals, pesticide use data, and food consumption data—to estimate the risk of an adverse health effect (e.g., the probability of a person developing a cancerous tumor during a lifetime). This risk estimate is then used with other relevant information to make regulatory decisions.

This regulatory scheme is straightforward in principle, but its information requirements are burdensome in practice. Within the next decade, EPA must evaluate hundreds of active ingredients contained in thousands of pesticides. Because many studies and analyses are required on each active ingredient, EPA faces a formidable regulatory task. The current regulatory process takes years to complete. In deciding whether to remove a dangerous pesticide from use, current procedures can take 4 to 8 years. Some of the delays in the regulatory process can be attributed to the way it is organized, and the Administration has proposed reforms to expedite the process. But a major constraint is still the time and cost involved in producing reliable scientific information needed to make responsible decisions.

Negligible Risk and the Delaney Clause

Both risks and benefits of a pesticide are considered in setting most tolerances under FFDCA and in all regulatory decisions under FIFRA. For most decisions, EPA uses the concept of negligible risk. A negligible risk is one below which it is deemed that the public health is not threatened, and is often interpreted to be a lifetime cancer risk in the range of 1 in 1,000,000. When a chemical's risk is estimated to be less than 1 in 1,000,000, its use is not regulated. When a chemical's risk exceeds 1 in 1,000,000, benefits from use are weighed against risks in making a regulatory decision.

A different risk standard is applied in the case of pesticide residues in processed foods, however, because of the Delaney Clause in Section 409 of FFDCA. The Delaney Clause states that a pesticide that has been found to cause cancer cannot be registered for use if *any* residues are found in processed foods. This zero-residue standard implies a zero-risk tolerance for carcinogenic pesticides in processed foods, no matter how small the risk or how large the economic benefit from their use. Thus, benefits are balanced against risks if a carcinogenic pesticide residue is present on fresh produce, but not if it is found in processed food.

The Congress adopted the Delaney Clause's zero-risk standard in the 1950s when laboratory techniques were able to detect residues only in parts per million. With modern techniques, such as gas chromatography, it is possible to detect residues in parts per billion, effectively increasing the stringency of the Delaney Clause's risk standard by a factor of one thousand.

The current negligible-risk standard for pesticides is very stringent—some would say excessively so—and represents a high degree of safety. More stringent pesticide regulations could have little effect on the total number of cancers. To put pesticide health risks into perspective, consider that the risk of cancer in the U.S. population is 300,000 in 1,000,000. Pesticides account for only a small fraction of the 2 percent of cancers attributed to all sources of pollution, whereas tobacco use and diet are believed to contribute to about 65 percent of all cancers. The National Cancer Institute has announced its goal to reduce cancer mortality in the year 2000 by 50 percent through changes in tobacco use, diet, and health care. The Institute's focus on reductions of large risks, rather than ones that are already negligible, is clearly sensible.

THE ADMINISTRATION'S PROPOSALS FOR PESTICIDE POLICY REFORM

The National Academy of Sciences recently studied pesticide regulation extensively and recommended that the inconsistencies between FIFRA and FFDCA be eliminated by abandoning the distinc-

tions now made between residues in processed and nonprocessed foods and by replacing the Delaney Clause with a negligible-risk standard for all pesticides. The National Academy concluded that the consistent application of a negligible-risk standard for carcinogens in food would allow regulatory efforts to be focused on the most dangerous substances and would thereby dramatically *reduce* total dietary exposure to cancer-causing pesticides with modest reduction of pesticide benefits.

The Administration proposes to adopt the National Academy's recommendation that a negligible-risk standard replace the Delaney Clause in FFDCA. Where risk is greater than negligible, the Administration proposes to extend to processed foods the existing regulatory procedures for nonprocessed foods. These procedures allow economic and health benefits of a pesticide to be balanced against risks in all cases. By allowing better targeting of regulatory efforts, this change should *reduce* cancer risks.

The Administration's food safety proposal also would amend FIFRA to strengthen and simplify the pesticide regulation process. The President's plan would establish a periodic review of all pesticides, simplify and make more effective the process of canceling the use of a pesticide found to be harmful to public health, and improve enforcement of pesticide regulations.

Other Regulatory Reforms

Pesticide regulation, like air pollution regulation, is based largely on command-and-control techniques (Box 6-2). Uniform regulatory standards are notoriously inefficient because they fail to take into account the diversity of local conditions. Because pest problems are often location-specific, large production inefficiencies can be caused by uniform pesticide regulations. There is a need for alternative, cost-effective methods of pesticide regulation that allow farmers to adapt production methods to the particular pest problems they face. For example, it may be possible to employ a system of marketable pesticide-use allowances to reduce pesticide contamination of surface and groundwater efficiently. A marketable allowances system (Box 6-1—tradable allowances) would restrict the total use of pesticides in environmentally sensitive areas and would allow those farmers who benefit most from pesticides to use them.

Both Federal and State governments have already financed research into production practices that impose fewer health and environmental risks. For example, many States have developed research programs under the rubric of integrated pest management. Also on the horizon are promising developments in biogenetic research that could enhance pest resistance and reduce the need for chemical pest control. In 1990, the Administration will begin a 5-year interagency research initiative to improve understanding of the process of groundwater contamination, develop safer produc-

tion practices, and disseminate the new practices through the Extension and Soil Conservation Services.

Better data on actual pesticide use, occupational exposure, and environmental contamination are needed to enable regulators to make informed decisions. The Department of Agriculture is currently improving data on pesticide use. The EPA is now conducting the first national assessment of pesticide contamination of well water. Further funding of pesticide data collection and analysis is under consideration.

ENVIRONMENTAL EFFECTS OF FEDERAL FARM PROGRAMS

Federal farm programs may encourage farming practices that increase health and environmental problems. Farm programs may have adverse environmental impacts through several channels. Crop-specific subsidies can encourage farmers to use more fertilizers and pesticides. To limit the costs of programs, farmers can receive subsidies only on those acres that are part of the farmer's program crop base. This criterion for program participation creates a disincentive to rotate crops, even though crop rotation is an important nonchemical technique for pest control. Thus, the programs may further aggravate pesticide pollution by encouraging farmers to substitute chemical pest control for nonchemical control.

When farm subsidies are based on how much land a farmer devotes to particular crops such as wheat and corn, land suitable for those crops becomes more valuable. Higher agricultural land values in turn encourage farmers to bring more land into production. Land that is not already being farmed is generally less productive or more costly to convert to agricultural uses. Such land may be steeply sloped and thus erodible, or it may be wetlands that provide important wildlife habitat. Agricultural subsidies based on land use thus create incentives for farmers to use land in ways that may increase adverse environmental impacts.

Unfortunately, only limited research has addressed the linkages between agricultural policy and environmental quality. Some evidence supporting these linkages is contained in case studies conducted by the National Academy of Sciences in its report, *Alternative Agriculture*. Other research casts doubt on the generality of that evidence, however. Research shows that pollution caused by agricultural chemical use, for example, depends on the physical characteristics of the farmer's field and its proximity to groundwater and surface water. The diversity of conditions under which agricultural production takes place makes it very difficult to draw broad generalizations from limited data.

The potential adverse environmental impacts of Federal agricultural programs could be reduced by breaking the links between agricultural subsidies and farmers' production and land-use decisions. These links could be broken, for instance, by making three changes: continuing the reductions of price-support levels that were begun by the 1985 farm bill; relaxing restrictions on the use of land enrolled in subsidy programs; and changing the criterion for receipt of subsidies from one that is based on crop acreage to one that is not related to production of a specific crop. For example, an income-based safety net could replace the current system of crop-related deficiency payments. These same policy changes would also bring U.S. agricultural policy in line with the broader trade policy goals of this Administration that are discussed in the next chapter of this Report.

GLOBAL ENVIRONMENTAL ISSUES

Like environmental problems at the local or national level, global environmental problems arise because actions taken by one individual have unintended adverse effects on another. Global environmental problems are complicated by the fact that the individuals involved live in many nations. Because one nation cannot impose its wishes on another, international cooperation is required to solve such problems. Differences across countries—in income, natural resource endowments, population, sensitivity to particular environmental changes, and the political strength of environmental movements—mean that countries inevitably have different views on these issues. At the Paris Summit in July 1989, the President joined other heads of state in recognizing the need for cooperation in addressing global environmental concerns. The President has also encouraged international organizations to facilitate international cooperation to solve global environmental problems.

Stratospheric ozone depletion and possible climate change are two global issues that may affect the economy and the environment far into the next century. To evaluate the impact of a policy course chosen today, the impact it will have on the economic well-being of *both* current and future generations and its environmental impact must be assessed.

Scientific evidence of possible stratospheric ozone depletion is stronger than scientific evidence of possible global warming, although significant uncertainties surround both. These uncertainties extend to environmental and economic as well as scientific aspects of these two issues. Because policymakers must understandably make decisions before information on such issues is complete, the government has an important role to play in supporting basic

scientific and economic research that can reduce critical uncertainties in the meantime.

Even when uncertainty cannot be eliminated, identifying a probable range of effects can inform policy choice. For example, a consensus that changes in global climate will lead to at most a small rise in sea level over the next 60 years would make a policy response to protect high-value coastal areas more feasible than if a large rise were expected. Finally, because the regulatory agenda is often influenced by public perceptions that may not accurately reflect available knowledge, the government also has a responsibility to educate the public.

STRATOSPHERIC OZONE DEPLETION

Ozone in the upper layer of the Earth's atmosphere (the stratosphere) provides an essential screen from the Sun's ultraviolet rays. In recent years, evidence has mounted that the stratospheric ozone layer is being depleted. Several chemical compounds, most notably chlorofluorocarbons (CFCs) and bromofluorocarbons (halons) have been identified as sources of the increased atmospheric concentrations of chlorine and bromine that cause ozone depletion. These chemical compounds have long atmospheric lifetimes, so that even if their production were halted immediately, elevated concentrations of chlorine and bromine would persist for decades before subsiding. If production is phased out by 2000, current chlorine concentrations would be likely to increase by 50 percent and then decline slowly to one-half of current levels by 2080. Without any production curtailment, these concentrations would rise indefinitely.

The appearance of a major hole in the stratospheric ozone layer over Antarctica, where no emissions originate, illustrates the global scope of the ozone-depletion problem. Long before the hole was observed, the United States acted in 1978 to ban the use of CFCs as aerosol propellants, a use in which substitutes were readily available. Canada and Sweden followed suit. CFCs and halons are also used in applications such as automotive and residential air-conditioning systems, refrigerators, and fire extinguishers; as blowing agents in the production of insulating board and other foam products; and as industrial solvents. These uses of CFCs and halons have continued to grow.

Protecting the Ozone Layer: Benefits and Strategies

The potential benefits from protecting the ozone layer—improvements in human health and favorable impacts on crops, fish, and materials—arise from lower exposure to solar ultraviolet radiation. Both skin cancer and cataracts are related to cumulative exposure to ultraviolet radiation. A phaseout of CFCs and halons is estimated to reduce the incidence of these health problems in the current

population by 50 to 75 percent from levels that would prevail if there were no curtailment of production. (This estimate is likely to be high, because it assumes that individuals take no offsetting actions to reduce their exposure to increased ultraviolet radiation.) For future generations, which would suffer a greater cumulative exposure to ultraviolet radiation if ozone depletion continued, the health benefits would be even larger.

The geographic distribution of ozone-depleting emissions and their expected growth unless action is taken is such that no single country can act alone and have a significant impact on stratospheric ozone depletion. Individual countries have little reason to act alone. The benefits of national policies to reduce ozone-depleting emissions spill over national boundaries, but costs are concentrated where reductions occur. Thus, the application of cost-benefit criteria on a national level would cause any one country, working in isolation, to reject control measures that may be desirable from a global perspective.

Two international agreements regarding ozone depletion are currently in effect. The 1985 Vienna Convention established a framework for international scientific and technical cooperation. The 1987 Montreal Protocol commits signatories who are major CFC users to freeze production levels by 1989, and then to cut their production in half by 1998. In addition, beginning in 1992 the production of several halons is frozen at 1986 levels. The United States and other major industrialized countries have announced further intentions to phase out production of CFCs and halons completely by the turn of the century if safe substitutes are available. Amendments and revisions to the Montreal Protocol, including extending coverage to other compounds with ozone-depleting potential, are currently under consideration.

Hydrochlorofluorocarbons (HCFCs), the most promising substitutes for CFCs in a wide range of applications, themselves have one-fiftieth to one-tenth the ozone-depleting potential of CFCs. By allowing HCFCs to substitute for CFCs in the near term, the Montreal Protocol rejects the uneconomic approach of barring all new ozone-depleting compounds regardless of their advantage relative to current products and their usefulness during the transition to substitutes with no effect on the ozone layer.

Atmospheric lifetime is one important factor in decisions regarding the coverage of the protocol. Decisions to reduce or eliminate the use of short-lived ozone-depleting compounds, such as methyl chloroform, involve weighing the short-term impact of delay against the opportunity to develop improved substitutes to lower the economic costs of action. Under these conditions, it may be sensible to eliminate their use as good substitutes become available.

Costs of Protecting the Ozone Layer

Preliminary estimates place the U.S. costs of a phaseout of CFCs and halons by 2000 at \$2.7 billion over the next decade if the schedule of intermediate reductions currently incorporated in the Montreal Protocol is maintained. Acceleration of this schedule would drive compliance costs upward significantly. These cost estimates reflect a substitution strategy involving conservation, process changes, and the use of more expensive substitute compounds. The availability of substitutes is critical to avoid economic disruption.

The United States is using transferable allowances to implement the reductions required under the protocol in a cost-effective manner. Manufacturers and importers of CFCs and halons will receive permits in proportion to their base period market shares. As supply is restricted, rising prices will encourage users with available low-cost substitutes to switch, leaving remaining supplies for high-value uses. This approach avoids unnecessary direct regulation of end-use applications, while ensuring compliance with U.S. obligations to reduce production and consumption. Moreover, because there are significant economies of scale in the production of CFCs and halons, the use of permit transfers to concentrate production in a small number of facilities during the phasedown has the potential to increase efficiency on the supply side. Allowing for this kind of flexibility on the international level would yield further cost savings.

GLOBAL CLIMATE CHANGE

Greenhouse gases (carbon dioxide, methane, CFCs, and nitrous oxide, among others) absorb heat that radiates from the Earth's surface and send some of the heat downward, warming the climate. Many scientists believe that fossil fuel burning, certain agricultural practices, deforestation, and other human activities that increase the atmospheric concentration of greenhouse gases will alter the global climate. Scientists are much less confident of the magnitude, timing, location, and character of the greenhouse-induced warming. Many argue that no warming has yet occurred despite a substantial increase in greenhouse emissions; some contend that appreciable future warming is unlikely. Others strongly dispute these views.

Computer models of the Earth's climate system are a principal tool of global climate research. Economic models of energy supply and demand provide the future emissions projections used as input by the climate models. Economic models can also be used to assess the cost and growth impacts of policy actions to change the future emissions profile.

Economic and Scientific Uncertainties

Projections of future emissions of greenhouse gases, a critical input to climate models, are highly sensitive to future rates of population growth, economic growth, and development of new technologies for energy production and use. The inability to place narrow bounds on any of these factors necessarily places very wide bounds on any forecast of future emissions. One recent study could conclude only that actual global carbon emissions from fossil fuel combustion in the year 2050 are likely to be between 50 and 1,100 percent of current annual emissions. This result is typical of the high degree of uncertainty in this area.

Even if estimates of future emission levels are correct, the magnitude of actual climate change will depend on numerous interrelated and, as yet, poorly understood geophysical processes that have both positive and negative feedbacks on warming. For example, an increase in evaporation from a warmer climate will almost certainly increase average cloud cover. Depending on their altitude and configuration, additional clouds can either intensify or counteract warming. Current climate models are incapable of providing reliable estimates of the effect that clouds will actually have if warming occurs.

If the atmosphere begins to warm, a transfer of heat from the air to the oceans is expected to slow the rate at which air temperature actually rises. This effect, which would decrease as ocean temperatures increased, could delay the full effect of any increase in the concentration of greenhouse gases on air temperature for a period ranging from decades to centuries, with wide variations by region. Regional variation in other critical effects such as seasonality, rainfall distribution, and soil moisture is also likely, but current climate models lack sufficient resolution to identify regional differences clearly. This deficiency makes it difficult to specify, among other things, the sea level rise resulting from any degree of average warming.

Considerable resources and effort are being devoted to resolving uncertainties in climate modeling, and in gaining a better understanding of processes that are poorly understood and are not explicitly treated in current climate models. The President's 1991 budget proposal includes \$1.03 billion in funding for global climate change research. This figure reflects an increase of 57 percent over the current funding levels and a 100-percent increase over 1989 expenditures. The United States has also taken a leadership role in the Intergovernmental Panel on Climate Change, the primary international forum for consideration of the scientific, socioeconomic, and policy issues concerning global climate change.

At the Malta meeting with the Soviet President in December, the President of the United States announced his intention to host a

White House Conference on Scientific and Economic Research on the Environment in the spring of 1990. The general purpose of this high-level international meeting will be to advance the quality and understanding of the scientific and economic analytical tools and data necessary to confront international environmental problems, including global climate change. Sound scientific and economic analyses must be the foundation for any policy action in this area. The President of the United States also offered to host the first negotiating session for an International Framework Convention on Global Climate Change in the fall of 1990.

The compounded uncertainties of the projections of future emissions and the climate models present a formidable barrier to accurate forecasting. At present, there is an extremely high level of uncertainty regarding possible future climate change. Some reputable scientists believe that there will be no significant greenhouse warming over the next century. But other reputable scientists believe that a warming of between 1.5 °C and 4.5 °C (with most recent estimates falling into the lower half of this range) could occur by the middle of the next century if emissions grow rapidly. A warming of this magnitude could result in a rise in sea level estimated to range from a little under one foot to about a foot and a half by the end of this period. Both the more optimistic and the more pessimistic judgments are subject to revision as scientific and economic inquiry progresses and additional data are gathered.

If the current understanding of greenhouse processes is correct, some warming could occur by virtue of past emissions. Therefore, some adaptation would be required even if future greenhouse emissions were sharply curtailed. Even though scientists may yet learn that no significant warming is likely, it is nonetheless worthwhile to address two distinct policy questions. First, what actions could be taken now to limit emissions of greenhouse gases and what are the likely costs of those actions? Second, what are the possible economic and other effects of warming that, if these scientists are correct, will occur in any event?

Sources of Greenhouse Gas Emissions

Some steps have already been taken that will reduce greenhouse gas emissions. In addition to their role in stratospheric ozone depletion, CFCs account for 14 percent of total greenhouse emissions from human activities on an impact-weighted basis; the planned phaseout of CFCs is clearly important. In the recently negotiated agreement to replenish the financial resources of the International Development Association, the United States called for preparation of environmental action plans in borrowing countries, expansion of programs for end-use energy conservation and renewable energy sources, and other environmental reforms.

On the domestic front, the Administration's clean air initiative promotes the development of technologies that will improve the efficiency of converting energy stored in coal and other fossil fuels into electricity. The allowances system and the proposed cap on sulfur dioxide emissions may also focus renewed attention on improving efficiency in end-uses of electricity as an alternative to new fossil-fueled generating capacity. Although the measures cited above should reduce net greenhouse emissions, the justification for taking these actions does not depend on resolving the high uncertainties about possible climate change.

Carbon dioxide accounts for about one-half of the current greenhouse gas emissions caused by human activity. The shares of methane, CFCs, nitrous oxide, and other gases are 18, 14, 6, and 13 percent, respectively. Clearly, possible climate change is not a one-gas problem: gases other than carbon dioxide play a significant role. Nonetheless, international attention and current analysis of greenhouse gas limitation policies focus almost exclusively on carbon dioxide.

THE COSTS OF REDUCING CARBON DIOXIDE EMISSIONS

Fossil fuel combustion is the primary source of carbon dioxide emissions. Deforestation accounts for an additional 10 to 30 percent. Other activities such as agriculture and cement manufacturing contribute smaller shares. Although all fossil fuels contain carbon, coal contains about 1.75 times as much carbon per unit of heat energy as natural gas and about 1.25 times that of oil.

In contrast to the situation for CFCs, low-cost substitutes for fossil fuels used in electricity generation, transportation, heating and cooling, and process heat applications are not currently available or on the immediate horizon. Unlike sulfur dioxide, no commercially feasible technology for scrubbing carbon dioxide from combustion waste gases is available. Thus, for the foreseeable future, only lower energy consumption or fuel switching could reduce carbon dioxide that results from fossil fuel combustion. A substantial increase in the price of fossil fuels would likely be required to reduce consumption substantially.

Experience following the 1973 and 1979 oil shocks shows that large increases in the price of energy can reduce the energy intensity of economic activity. The period between 1973 and the sharp decline in oil prices in 1986 saw a significant increase in the relative price of energy. Between 1973 and 1985, the price of energy rose by 47 percent relative to nonenergy products at the consumer level and by more than 80 percent at the industrial level. The ratio of energy use to real gross national product fell by 2.3 percent annually in the United States over this period as consumers and produc-

ers responded to higher energy prices by substituting away from energy and energy-intensive products. With no growth in energy consumption over the period 1973 to 1985, carbon dioxide emissions remained level. The impact on carbon dioxide emissions of the increase in the share of primary fossil energy derived from coal over this period was offset by growth in the use of nuclear power, which produces no greenhouse emissions, and of natural gas. However, the growth rates of output and productivity over this period, 2.3 percent and 1.0 percent, respectively, were far below the corresponding rates of 3.7 percent and 2.9 percent for the 1948-73 pre-shock period.

The relationship between energy prices, energy consumption, and economic growth is also reflected in more recent data covering a period of significant decrease in relative energy prices at the consumer and industrial levels. Between 1985 and 1988, annual growth rates in output and energy use snapped back to 3.6 percent and 2.7 percent, respectively.

Although the slowdown in productivity and output growth between 1973 and 1985 can be attributed to many factors, higher energy prices clearly played an important role. Energy price increases of comparable or larger size would likely be needed to induce the large energy efficiency improvements and demand reductions that must occur to achieve the ambitious targets for carbon dioxide emissions reductions that some have advocated. Although much has changed since 1973—it may be harder now to expand reliance on nuclear power, for instance, even though the regulatory policy errors of that period are less likely to be made—the oil-shock period provides a useful benchmark for consideration of the likely impact of emission reduction policies on output and productivity growth. On balance, there is no reason to believe that an attempt to reduce energy use significantly would be substantially less economically disruptive today.

Modeling the economic effects of policies to curtail carbon dioxide emissions is still in its infancy, and results of modeling efforts remain tentative and controversial. (Even less has been done with regard to other greenhouse gases.) *Recent studies suggest, however, that the costs of policies to stabilize or reduce carbon dioxide emissions from fossil fuel combustion would be high.*

One recent study placed the cost of gradually reducing U.S. carbon dioxide emissions by 20 percent between now and 2100 to range from \$800 billion, under optimistic scenarios of available fuel substitutes and increasing energy efficiency, to \$3.6 trillion under pessimistic scenarios. These present-value estimates, which reflect the discounting of real future costs at a 5-percent annual rate (Box 6-4), are between 35 and 150 times larger than EPA's similarly discounted estimate of the costs that would be incurred over the next

century by consumers and industries forced to use more expensive or less effective substitutes if a complete phaseout of CFCs and halons were implemented by the year 2000.

Box 6-4.—Discounting Over Long Horizons

The costs of reducing greenhouse gas emissions must be borne both now and well into the next century; the benefits of slowing climate change may not be perceptible for many decades. Discounting is required to compare costs and benefits—both market and nonmarket—that occur at different dates.

Suppose, for instance, that a 5-percent real rate of interest is appropriate for these calculations. (If an investment yields a 9-percent rate of interest in dollar terms, but prices rise by 4 percent per year, the real purchasing power of invested funds grows by 5 percent annually.) One dollar invested at 5 percent per year in 1990 will return \$18.68 in purchasing power in 2050 if the interest income between 1990 and 2050 is reinvested. Therefore, it makes no sense to spend \$1 today to obtain benefits worth \$10 in 2050: future generations must receive at least \$18.68 in 2050 benefits to be better off than they would be if the dollar were invested instead.

It is always possible to compare values in either current or future terms. To compare in 1990 terms, one must divide the 2050 value by 18.68. Thus, \$100 billion in 2050 is worth only \$5.35 billion in 1990. To compare in 2050 terms, \$100 billion in 1990 is worth $\$100 \text{ billion} \times 18.68 = \$1,868 \text{ billion}$, or \$1.868 trillion. Either approach will give comparable results; what matters is that all values are placed on a consistent basis.

The costs of carbon dioxide stabilization policies can also be looked at from a future perspective. The present-value estimates cited above reflect reductions in real U.S. output ranging from 1 to 5 percent over the 2010 to 2100 period. Other preliminary estimates place the cost of stabilizing 2050 emissions at 1990 levels in the range of 1 to 2 percent of 2050 gross national product (GNP). To put these estimates in perspective, a 2-percent reduction in GNP in the year 2050 is worth about \$340 billion 1990 dollars, assuming a 2-percent average annual rate of economic growth between now and 2050.

The impact of carbon dioxide stabilization policies can also be considered in terms of growth-rate impacts. A recent estimate based on energy-output balance relationships suggests that global carbon dioxide stabilization could cut world economic growth in half, even after accounting for substitution toward cleaner energy. Other studies and U.S. experience following the oil shocks suggest

substantial if less dramatic impacts. As shown in Chapter 4, even small changes in growth rates can have a large effect on future output levels.

Clearly, economic models as well as climate models are subject to considerable uncertainty. The early estimates of potential costs described above are far from definitive. The critical uncertainty regarding forecasts of the date and cost at which alternative technologies will become available is unlikely to be resolved soon. Meanwhile, the refinement of current estimates and the development and application of new, more detailed economic models would help to provide a stronger foundation for decisions regarding possible actions to limit carbon dioxide emissions.

Other Issues in Reducing Carbon Dioxide Emissions

Reductions in U.S. carbon dioxide emissions on a unilateral basis or in cooperation with other Organization for Economic Cooperation and Development (OECD) countries alone would not significantly alter the projected growth in world carbon dioxide emissions (the OECD is an international organization of industrialized countries that promotes economic growth and trade). Chart 6-1 shows current and projected shares of total carbon dioxide emissions. The emissions share of the United States and other industrialized countries is projected to decline sharply as non-OECD economies experience growth and increasing energy intensity. Developing countries are expected to account for the majority of future emissions increases. Clearly, any significant reduction in emissions growth would require the cooperation of the Soviet Union, Eastern Europe, and the developing countries.

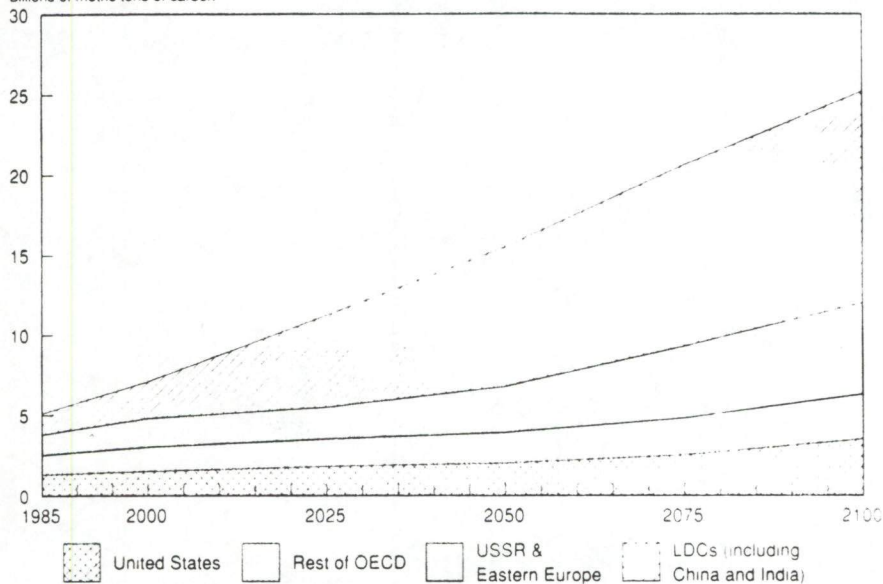
The ratio of carbon dioxide emissions to energy consumption depends on the mix of energy sources employed and thus varies substantially among industrialized nations. This ratio is high for the United States, which depends more heavily on coal than most of its major competitors (Table 6-2), as is energy use per dollar of GNP. *All else equal, uniform international standards or user charges for carbon dioxide emissions are thus likely to have a larger adverse impact on the United States than on its major competitors.* In particular, a fee on carbon dioxide emissions (discussed below) would increase electricity rates in the United States relative to rates in countries that rely more heavily on nuclear and hydroelectric energy, which produce no greenhouse emissions, or in countries relying on fossil fuels with less carbon per unit of energy content. This situation presents a marked contrast to the 1973 and 1979 oil shocks, where greater U.S. self-sufficiency in energy provided an advantage relative to most other industrialized countries.

Other than hydroelectric or geothermal power, which have very limited potential to supply increased electricity within the United States, nuclear power is the only large-scale technology for electric-

Chart 6-1

CARBON DIOXIDE EMISSIONS BY REGION. The LDC share of carbon dioxide emissions is projected to grow rapidly. The U.S. share is projected to decline.

Billions of metric tons of carbon



Source: Environmental Protection Agency, *Policy Options for Stabilizing Global Climate* (Rapidly Changing World Scenario).

TABLE 6-2.—Fuel Share in Electricity Generation, 1986

(Percent)

Country	Coal	Oil	Gas	Nuclear, Hydroelectric, and Geothermal
Canada.....	15.7	1.3	1.5	81.5
France.....	9.7	1.5	8	88.1
West Germany.....	56.9	3.1	6.2	33.8
Japan.....	14.7	28.2	19.3	37.8
Netherlands.....	26.8	5.1	61.8	6.3
Sweden.....	3.0	2.0	1	94.9
United States.....	56.2	5.5	10.1	28.1

Source: Organization for Economic Cooperation and Development, "Energy Policies and Programmes of IEA Countries—1987 Review," Paris, 1988.

ity production that is both benign from a greenhouse emissions perspective and commercially available now. Policies regarding the future role of nuclear power, including the timetable for the development and commercialization of modularized, inherently safe reactor designs, will need to be closely coordinated with policies that affect the future role of fossil-fuel generation.

POLICY TOOLS TO IMPLEMENT A REDUCTION IN GREENHOUSE GAS EMISSIONS

A variety of policy tools, including user charges, correction of market failures, regulatory standards, expanded funding for research on and development of substitutes for fossil fuels and other sources of greenhouse emissions, and efforts to reduce and reverse deforestation, could be used to slow the buildup of greenhouse gases in the atmosphere. These approaches are relevant for nearly all greenhouse gases, not just carbon dioxide. While international attention has naturally focused on carbon dioxide as the single largest contributor to the greenhouse effect, control costs must also be considered in the design of any strategy to reduce net emissions of greenhouse gases. A cost-effective strategy may involve a focus on other gases or on sinks that absorb greenhouse emissions. Different approaches may be suitable for different countries.

A fee, charge, or tradable allowances system for greenhouse gas emissions based on an index of the global climate impacts of each greenhouse gas would provide a least-cost reduction in such emissions. A fee or a tradable allowances scheme would lead firms and individuals to consider the social cost of greenhouse emissions in their private decisions. An emission charge or the need to consider the value of allowances would affect decisions ranging from the choice among alternative technologies for generating electricity, to the energy efficiency of cars, buildings, and industrial equipment, to the demand for automobile travel. Because market-based approaches are flexible and provide incentives that affect decisions at all points along the production-consumption chain and across all industries, they automatically focus on those activities where emissions reductions can be achieved at least cost.

The economic impact estimates for carbon dioxide stabilization discussed above reflect the high costs of reaching very ambitious goals even when efficient market-oriented tools are used. Market-based approaches could also be implemented at a less draconian level to nudge the economy gently and gradually in the direction of greater energy efficiency. Such an approach would test the flexibility of the economy without betting the current way of life on the outcome.

Publicly supported research and development of nonfossil energy sources, including biomass, solar, and next-generation nuclear fission, may contribute to a reduction in greenhouse emissions. It is often noted that the fruits of innovation cannot always be fully captured by the innovator, leading to underinvestment in the development of new technology. This problem is particularly acute for innovations that address a global problem, such as greenhouse emissions. Breakthroughs in environmentally benign technologies hold the promise of lowering the future emissions trajectory while

advancing economic progress. Opportunities also exist outside the energy area. For example, emissions of methane from agriculture might be cut through the development of improved techniques for farming and livestock management.

Reforestation can contribute to reductions in net emissions of carbon dioxide into the atmosphere. Just as tropical deforestation increases carbon dioxide emissions by releasing carbon that is fixed in trees through photosynthesis, reforestation can increase the uptake of carbon dioxide from the atmosphere by increasing photosynthesis. Reforestation potential varies significantly across countries according to their climate and land use patterns. The United States has an abundant supply of urban and rural land suitable for reforestation. Large-scale reforestation efforts could have significant impacts on agricultural and timber production, however, which would in turn affect consumers and producers in those markets.

Correcting Market Failures

In some cases, market failures may serve to increase emissions of greenhouse gases. *Interventions that address market failures directly are generally preferable to direct regulation via standards.* Approaches that merit consideration include public information programs, promotion of efficient appliances by utilities, and changes in mortgage qualification rules to reflect appliance operating costs.

One promising concept to reduce the growth in electricity use is demand-side management. A utility faced with capacity constraints would consider proposals for demand reduction through efficiency improvements and proposals to increase supply on an equal footing, and choose the lowest cost alternative. One barrier to implementing programs of this type is that utility profits under traditional State rate-setting regulation are often linked directly to the level of electricity sales. Regulatory changes at the State level, possibly to permit nonutility companies to bid for demand reduction that can be compared with the costs of increasing supply, are needed to implement demand-side management. Although estimates of the emissions reductions available through widespread application of this approach vary widely, the removal of regulatory barriers and biases in the market for electric power makes economic sense.

The Limitations of Efficiency Standards

Energy efficiency standards can also be used to overcome information barriers and institutional rigidities. However, this command-and-control approach has several significant disadvantages compared with incentive-based systems or alternative approaches that address perceived market failures directly. First, the burden of meeting standards cannot be reallocated across industries or across

the different greenhouse gases in private cost-saving transactions. Second, in the absence of price increases for fossil fuels, standards can increase the demand for energy-using services. Finally, standards reduce the range of products available to meet diverse consumer needs.

The costs of efficiency standards are often hidden. For example, a higher average fuel economy standard might force consumers to buy only the more fuel-efficient and generally cheaper vehicles in the existing product line, thereby actually reducing their purchase and gasoline costs. However, out-of-pocket costs do not reflect costs imposed by denying consumers the option to purchase other valued attributes such as safety, performance, and comfort. Higher fuel efficiency without higher fuel prices also lowers the per mile cost of driving, which encourages more trips, more fuel consumption, and more emissions. Because fuel economy labels already inform consumers about energy consumption, and few apparent institutional rigidities exist, the economic rationale for stringent auto efficiency standards is doubtful at best.

Assertions that efficiency improvements are cost-saving or nearly costless beg the question why these improvements are not automatically taking place. Such assertions must be examined to see if the claimed efficiency gains involve the sacrifice of other product attributes that were excluded from the analysis or market imperfections that could be addressed directly. One must ask whether the analysis considers the entire range of consumer usage rates and energy prices, or is based only on national average values.

In the latter case, efficiency standards may appear to be cost-effective on the national level, while actually restricting the choices of only those consumers who face low energy prices or have low usage rates (and thus energy consumption) for the product. Those with high usage rates or those who face high energy prices would purchase high-efficiency products even in the absence of mandatory standards. Taking this diversity into consideration, an efficiency standard that appears to save money on the national level may actually impose costs.

IMPACTS OF CLIMATE CHANGE

Available assessments of the costs of substantially slowing the rate of greenhouse gas emissions may reach the trillions of dollars. What benefits might be obtained with those costs? This question is difficult to answer, but it is possible to identify several nonmarket impacts of possible future climate change, and to arrive at preliminary estimates of some market effects.

There may be both positive and negative effects of climate change on human health, although these effects are controversial. Temperature extremes—both hot and cold—are associated with higher mor-

tality rates for populations, such as the elderly, that are susceptible to physical stress. These relationships suggest that higher temperatures in winter could reduce weather-related illness and death, whereas higher summer temperatures could increase them. These adverse health effects are not well understood, however, as illustrated by the fact that the average temperature differential between New York City and Atlanta is as large as the most extreme predictions of warming, yet there is no evidence that Atlanta's warmer climate creates a greater health risk than New York's. There could also be changes in the regional distribution of vector-borne diseases, such as those carried by ticks, fleas, and mosquitoes, associated with climate change.

Substantial reductions in economic growth in low-income countries caused by attempts to reduce greenhouse gas emissions could have far greater adverse health consequences than any direct health effects associated with climate change. When one considers the very close relationship around the world between income levels and important health indicators such as infant mortality and life expectancy, it is clear that one of the most important factors affecting health is the ability to afford adequate nutrition and health care.

If global warming occurs, its impact on plants and animals, including humans, is likely to depend on how rapidly it occurs. Both the human and other species' ability to adapt to warming appear to increase if the rate of change is slow. In agriculture, plant breeding and biogenetic techniques can be used to adapt crop varieties to changes in solar radiation, temperature, and moisture. These techniques are more likely to succeed when the incremental changes are small and there is adequate time to undertake adaptive research. In the wild, species can adapt to climate change by moving to suitable environments or adapting to new ones through natural selection. Scientists believe that some wild species of plants and animals may not adapt to rapid climate change and might be lost, thus threatening the biological diversity that has evolved over millions of years. The fact that many medicines contain active ingredients obtained from substances in plants and animals, especially those in the tropics, suggests that a reduction in diversity could represent a significant economic loss.

There is also some reason to believe that extreme weather events may be more important than the increase in average temperature for adaptation to and survival of climate change. A change in the frequency and intensity of hurricanes and tornadoes, for example, could substantially affect their costs, measured in both human life and property.

Sea-level rise is another possible effect of global warming. The U.S. coastline, like the coastlines of other industrial maritime nations, has been extensively developed, with buildings often within

100 feet of the sea. The cost of protecting the entire U.S. shoreline against substantial sea-level rise would be prohibitive, as it would be for many countries with densely populated low-lying areas. The cumulative costs of protecting densely developed shoreline areas from a 20-inch rise is estimated to be between \$37 billion and \$50 billion, or between \$7 billion and \$10 billion in present value under the assumption that all costs were incurred in 2025. If the costs of protecting against sea-level rise were spread over the more distant future, as seems likely, their present value would be lower. If the sea level rises gradually and predictably, a reasonable response strategy might include steps to encourage some population and economic activity to relocate inland to higher ground when existing structures come due for routine replacement.

Most sectors of industrial economies are not climate-sensitive, or could adapt to climate changes. The costs of adaptation depend on how rapidly warming occurs. Useful lives of plant and equipment tend to be shorter than 50 years, so that a slow warming trend would permit change in the location and composition of economic activity without major or unanticipated disruptions. More rapid changes could result in loss of some immobile private assets, abandonment of certain public infrastructure, and reinvestment at new locations.

The most significant impacts on industry are likely to be in activities that involve biological processes that are sensitive to temperature and rainfall such as agriculture, forestry, and fishing—which account for about 2 percent of U.S. GNP. Global climate change could have both positive and negative impacts on productivity. Up to a point, higher carbon dioxide concentrations improve the efficiency of photosynthesis and thus increase agricultural productivity. Warming could change the amount and distribution of precipitation and shift cropping patterns regionally, but regional predictions are now considered highly unreliable.

Preliminary analyses show that global climate change could result in a net loss in agricultural productivity, but no evidence shows that it would threaten the world's food supply even under the most pessimistic scenarios. The Department of Agriculture has made preliminary estimates of the regional and global economic impacts of changes in agricultural production that might be associated with warming. Under one scenario, the net global costs of a doubling of atmospheric carbon dioxide were estimated to range from \$35 billion to \$170 billion annually, with the United States losing \$1 billion annually. Equally plausible but less pessimistic assumptions about yield effects implied small net gains to the global and U.S. economies. Underlying these small net effects would be some redistribution of income from consumers to producers through higher agricultural prices.

These estimated impacts on global and U.S. agriculture can be put into perspective by comparing them with the impacts of agricultural policies discussed in Chapter 7. Using the same economic model, Department of Agriculture researchers estimated that the trade-distorting policies now in place around the world impose a net cost on the world of \$35 billion annually and \$10 billion annually for the United States. Thus, the annual costs of current agricultural policies are estimated to be the same order of magnitude as the estimated agricultural impacts of global warming. However, the agricultural losses from a doubling of carbon dioxide are not likely to occur until well into the next century. For example, using a 5-percent real interest rate, a global loss of \$170 billion in 2050 amounts to about \$9 billion in 1990 dollars (Box 6-4). Thus, the costs of today's agricultural policies are estimated to be more important in economic terms than even pessimistic estimates of the effects of global warming, largely because the former must be borne in the present and the latter may occur, if at all, in the relatively distant future.

SUMMARY

The United States is taking a leadership role in international efforts to reduce scientific and economic uncertainties about global climate change and to build a common understanding about all aspects of the climate change issue from the basic Earth science, to impacts on human activities, to potential response strategies. The data now available on the economic costs of reducing greenhouse gas emissions suggest that it may be as important to improve understanding of the economics of global warming as it is to improve current ability to predict warming itself.

Policies such as the phaseout of CFCs, the President's clean air proposal, and reforestation can significantly reduce global net emissions of greenhouse gases. At the same time, they can be justified on their own merits. Increased research and development funding and modest changes in fuel prices can reflect the broader social interest in promoting energy conservation. Currently available analyses indicate that near-term stabilization or immediate reduction of carbon dioxide emissions from fossil fuel combustion is likely to impose large economic costs on current and future generations. Such measures must be carefully scrutinized, given the current limited understanding of the impacts and likelihood of global warming. The highest priority in the near term should be to improve understanding in order to build a foundation for sound policy decisions.

Until such a foundation is in place, there is no justification for imposing major costs on the economy in order to slow the growth of greenhouse gas emissions. Policies that may result in slower

growth in greenhouse emissions, but can also be fully justified on other grounds, are the best short-run way to address this potential problem while the uncertainties that exist today are reduced. Being justified on other grounds means that a program yields non-greenhouse benefits commensurate with its costs; it cannot mean simply having some non-greenhouse benefits. The adoption of many small programs, each of which would fail a standard cost-benefit test, could significantly slow economic growth and eliminate jobs.

Because the intense research currently underway may reveal that it is desirable to slow the growth of greenhouse gas emissions, it is useful to consider the elements of what would be an economically rational strategy to do so. Any strategy to limit aggregate emissions without worldwide participation would be likely to fail. A cost-effective policy must provide for comprehensive coverage of both sources and sinks of all major greenhouse gases. It must also provide appropriate incentives for emissions reductions and deal directly with market failures. Carbon dioxide emissions, in particular, could be reduced at much lower cost through the use of emissions fees than through government-imposed standards for energy efficiency.

CONCLUSION

There is widespread agreement that both economic growth and environmental quality are desirable policy goals. They need not be incompatible, and are in many respects complementary. Three principles should guide regulation. First, realistic environmental and risk-reduction goals that balance benefits and costs must be set. Second, strategies that work with rather than against market incentives should wherever possible be used instead of less effective command-and-control regulation. Market-oriented approaches, such as marketable air pollution allowances, create incentives for firms to achieve environmental goals in a cost-effective manner. Third, government should support the development and dissemination of scientific and technical information about environmental and health risks.

The Administration's clean air initiative, its proposals to improve pesticide regulation and food safety, and its efforts to improve the understanding of global environmental issues each illustrate how these principles for environmental regulation can be put into action. Other pressing environmental issues will face the Nation in the 1990s and beyond. The application of these principles to all environmental problems will help to achieve both a strong economy and a healthy environment.

of nature. And they must apply this vision in their daily lives—in home and workplace, during leisure time, as family members, as community residents, as producers, as consumers.

What can one individual do? Recycle trash and, if possible, compost garbage and yard waste. Car-pool or take Metro to work, and avoid unnecessary driving. Buy a low-flow shower head and energy-efficient fluorescent light bulbs. Carry groceries home in reusable tote bags (Europeans have been using them for decades). Plant trees. Shop carefully for recycled and recyclable products, and for products without excessive packaging. Avoid "throwaway" products. Drink your coffee or tea from a mug, instead of a styrofoam cup.

And if any of these actions seem like too much trouble, remember this: Our planet's natural systems do not exist just to be exploited or to support human economic activity. Nature has an intrinsic worth that transcends narrow utilitarian values and should be respected. We should all take responsibility for practicing environmental reciprocity, for nurturing and sustaining the planet that nurtures and sustains us.

I sense that just this kind of conservation ethic is on the rise, in the United States and around the world. The millions of people in more than 130 nations who are participating in this weekend's Earth Day celebrations are evidence of a new high-water mark in the rising flood of public concern for nature.

Back in April of 1970, I was a newly hired staff member at the President's Council on Environmental Quality, working for Russell Train. On Earth Day that year, many of us participated in a Potomac riverfront clean-up. Along with other White House staffers, I collected trash along the shore.

No one came into contact with the water, though: In those days a tetanus shot was prescribed for people who fell into the Potomac.

I like to remember that experience now on summer days, as I watch the windsurfers across from National Airport or south of the Wilson Bridge. Like most of the rest of the country, Washington has benefited greatly from the environmental commitments made in the years following Earth Day 1970.

As we celebrate its 20th anniversary, we must take this opportunity to renew our commitment to planet Earth; we must remember that living in harmony with nature is both a practical necessity and a moral obligation. Taking care of the environment is not just important for our future—it is our future.

A WORLD IN OUR HANDS

WASH. POST: 04-22-90

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Forget the Doomsayers— Environmental Action Means Both Progress and Profits

By William K. Reilly 91p

TWENTY YEARS ago, when the original Clean Air Act was being debated in the House of Representatives, one of the bill's opponents took the floor to insist that pollution control is incompatible with economic growth.

The congressman quoted a constituent, a small-town mayor, as saying: "If you want this town to grow, it has got to stink."

Imagine making that kind of argument today! One important legacy of that first Earth Day is the growing recognition that environmental improvements must keep pace with economic growth; that there must be a direct connection between prosperity and environmental progress.

The plight of the newly independent nations of Eastern Europe suggests what can happen when this principle is violated. East Germany, Poland, Hungary, Romania, Czechoslovakia and the Soviet Union have suffered an environmental catastrophe that will take years and billions of dollars to correct. Parts of East Germany, Poland and Romania are virtually uninhabitable. I find it interesting that no one can identify any economic benefits from all the pollution-control costs these countries avoided. Why? Because healthy natural systems are the foundation for all human activity, including economic activity.

This is one lesson we in the United States have been learning, however slowly, over the past 20 years. Here are four more—each of them essential to remember as we move into the "environmental decade" of the '90s:

■ *The money we spend on sound environmental programs is an investment in the nation's well-being.*

There's no question that compliance with environmental laws has an enormous impact on the economy. This will be true, for example, with the Clean Air Act amendments now pending in Congress, just as it was true with the original clean air law. That's why the Bush administration has been so careful to analyze every measure in our clean air bill, in order to ensure that for every cost, there is a commensurate benefit.

And just look at the benefits we already have realized from our pollution control investments. Over the past two economically robust decades, while the nation's gross national product grew by 70 percent, we have made great progress in cleaning up our air and water, lowering the levels of toxic substances, removing many dangerous and persistent pesticides from the marketplace and improving control over hazardous wastes.

Environmental programs have saved or prolonged tens of thousands of human lives; prevented birth defects and other damage to human and animal health; preserved thousands of natural areas; and avoided billions of dollars in health costs, lost workdays and crop damage.

Look, for example, at the nation's phase-out of leaded gasoline. Over an eight-year period, it will

have cost refiners about \$3.6 billion. But the quantifiable benefits add up to more than \$50 billion, including nearly \$42 billion in medical costs avoided for both children and adults; \$1.6 billion in pollution-related environmental damage avoided; nearly \$5.8 billion in lower vehicle maintenance costs; and \$1.1 billion in improved fuel economy. And those figures don't count the truly priceless value of saving more than 5,000 lives and avoiding 8,000 heart attacks, strokes and cases of high blood pressure in 1986 alone.

■ *Environmental protection is a sound economic investment.*

The nation spends more than \$80 billion a year to comply with federal environmental regulations, mostly in private funds, and the trends are up. Our capital and operating expenditures on pollution control and clean-up, as a percentage of gross domestic product, are higher than all of the other Western industrial nations for which data are available—in the range of 1.5 to 1.7 percent. Those expenditures could double in the 1990s as the revised Clean Air Act takes effect and the multi-billion-dollar cleanups of hazardous-waste sites and government nuclear facilities go forward.

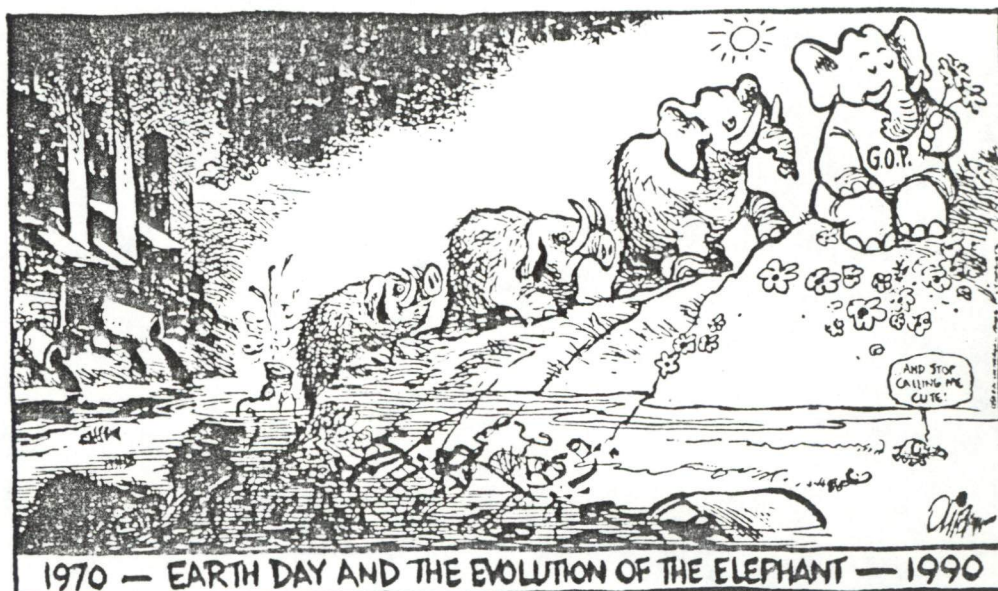
Some analysts suggest that the environment will be the growth industry of the 1990s. Many large pollution-control companies are now trading on the stock market at price-to-earnings ratios of more than 20-to-1, compared to a Wall Street norm of about 12-to-1.

The star corporate performers of the 1990s will be the companies that are ahead of the environmental power curve. Their customers, employees, stockholders and boards will increasingly demand a positive environmental performance—not only out of concern for the environment, but also because pollution is a sign of poor management, waste and inefficiency.

A pollutant, after all, is nothing more than a misplaced resource. It's no coincidence that our principal economic challengers, Japan and West Germany, produce less waste and consume less energy than we do. West Germany creates half as much solid waste per capita as we do and generates about 60 percent as much carbon dioxide. Germany is more energy-efficient than we are largely because its population is less

dispersed than ours, its railroads and other mass transit more convenient and more widely used, and its automobiles more efficient (partly a reflection of Europe's higher fuel costs).

Japan now uses one-third as much energy per capita as the United States. Between 1973 and 1984, as Japan began to clean up its historic legacy of pollution and to emerge as a global economic power, the energy and raw materials used in Japanese production decreased, astoundingly, by 40 percent.



To remain competitive internationally, the United States will have to achieve substantial increases in efficiency in our industrial processes and our use of energy; and we will need to recycle many of the materials and byproducts we now throw away. It can be done. The Borden Chemical Co.'s Fremont plant, near San Francisco, reduced the level of toxic organic pollutants in its wastewater by 93 percent in the 1980s using pollution-prevention techniques.

One major reduction came when the company changed its method of rinsing large chemical reactor vessels. Borden had been using a single rinse that produced wastewater that was too dilute for recycling but too polluted to dispose of easily. The company switched to a two-stage process: A small first rinse cleans out most of the residual chemicals, which are then recycled; the second rinse produces dilute wastewater which is readily handled by existing treatment systems. Moreover, the company is saving money by recycling raw materials that it had been paying to eliminate.

Strong environmental programs, especially those that encourage the prevention of pollution before it's generated, can help stimulate the improvements needed to increase efficiency, productivity and competitiveness. One important benefit of the acid rain provisions of President Bush's Clean Air Act proposals is that they will encourage electric utilities to improve energy efficiencies and promote conservation in order to cut back on their sulfur dioxide emissions.

■ *The marketplace is environmentally neutral; it can damage the environment or it can help protect it.*

We have known for some time that unregulated economic markets don't always protect public health and environmental quality; nor do they ensure that environmental costs of air and water pollution are paid by those doing the polluting.

In response, society imposed wide-ranging "command-and-control" regulations to force accountability and action. While the regulations were successful in cleaning up the most obvious pollution, they did little to encourage enterprise and innovation; they offered few incentives to go beyond the minimum standards set by law. And since most of the regulations were based on controlling emissions at the "end of the pipe," they neglected the prevention of pollution as part of the industrial process.

Today, as consumers increasingly demand clean industrial practices and "green" products—and as the costs of regulations, waste disposal and liability continue to climb—we can build on the traditional command-and-control programs with economic incentives to harness the dynamics of the marketplace on behalf of the environment.

Using a combination of incentives and tough enforcement of existing laws, we can engage the marketplace in environmental protection without having to rely exclusively on the kind of cumbersome government intervention that we relied on in the past. Marrying the environment and the economy is essential to deal effectively with the vastly more subtle and complex environmental problems of the 1990s. These are often caused by small, widely scattered sources which are not easily amenable to federal regulation—problems like municipal and hazardous wastes, toxic substances in the air and water, groundwater contamination from agricultural and urban runoff, and global atmospheric changes.

Many of the provisions in the Clean Air Act amendments proposed by the president already reflect this market-based approach. The bill would cut millions of tons a year from the sulfur dioxide that causes acid rain

by giving electric utilities a limited number of "allowances," or marketable permits, designed to reduce their sulfur dioxide emissions by about half. EPA will monitor emissions to ensure that they do not exceed the allotted levels. If a company finds that cleanup costs are particularly high at one plant and that purchasing additional allowances would be less expensive, it will be able to buy allowances from other utilities.

On the other hand, a company could cut its emissions so far that it would be able to sell its extra allowances or bank them to provide for future growth. And it will be able to pursue the cheapest available method of pollution control—energy conservation, different fuels, new technology—provided only that it gets the pollution reductions the country needs.

This flexibility will achieve our air-quality goals at the lowest possible cost—cutting the price tag of acid rain reductions by about one-fifth.

■ *Environmental protection is as much an individual duty as it is a responsibility of government and industry.*

Ultimately, the environmental problems of the 1990s and the next century will require cooperation among governments, and between government and the private sector, on an unprecedented scale. Yet what government and industry can achieve by way of conserving energy, slowing the generation of waste or reducing the emission of gases that cause ozone depletion and climate change, will depend to a great extent on people's readiness to change their habits, to buy new products and to safeguard nature from their own practices.

People everywhere, in developed and developing nations alike, must embrace a new ethic of conservation and stewardship



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
WASHINGTON, D.C. 20500

Michael R. Deland
Chairman

May 18, 1990

(202) 395-5080

MEMORANDUM TO

Kenneth P. Gale

FROM: Michael R. Deland

SUBJECT: Attached memorandum, "Bush Administration Environmental Initiatives and Accomplishments"

We have prepared the enclosed memorandum for your use, entitled "The Bush Administration and the Environment: Initiatives and Accomplishments." Please circulate it to all relevant personnel.

This memorandum summarizes all Administration actions which promise to have a beneficial result for environmental quality and conservation of natural resources. We hope it is helpful to you and your staff as you prepare speeches and respond to inquiries. It was not prepared for release to the news media, but it has been rigorously reviewed to ensure its factual integrity.

In the past year, several summaries or "scorecards" have been prepared by various EOP offices, Federal departments and agencies, and outside groups. These have been consulted and this summary incorporates many of those items.

We would welcome your comments, suggestions or additions. The memorandum will be kept up to date and distributed at least quarterly by my assistant, Dale Curtis, who can be reached on 395-5750.



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
WASHINGTON, D.C. 20500

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Chairman

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The Bush Administration and the Environment:

Summary of Initiatives and Accomplishments

May 1990

President George Bush, continuing a life-long record of concern for the environment, has demonstrated a commitment to environmental protection, conservation, and wise management of our natural resources. What follows is a summary of the Administration's initiatives and accomplishments.

1. General leadership
2. Air pollution
3. Environmentally-sensitive budget policy
4. Pollution prevention and recycling
5. Asbestos ban
6. Water pollution, water projects and wetlands
7. Energy
8. Global climate change
9. International environmental initiatives
10. Alaskan oil spill
11. Future oil spill prevention
12. Food safety
13. Hazardous wastes and Superfund
14. Clean oceans and coastlines
15. Radon
16. Defense & the Environment Initiative
17. Endangered species
18. Earth Day
19. Environmental education
20. Enforcement
21. Deterring conflicts of interest

1) **General leadership:**

President Bush appointed William K. Reilly to be Administrator of the Environmental Protection Agency (EPA), the first professional conservationist to hold the post.

The President named Michael R. Deland, former Administrator of EPA's Boston regional office, to be chairman of the President's Council on Environmental Quality (CEQ). The President is committed to revitalizing CEQ's advisory role and requested funding to increase the staff of CEQ from 10 to 34 positions over two years.

The President supports elevating EPA from sub-Cabinet to full Cabinet status, and approved the elevation of EPA's International Activities Office to the assistant administrator level.

President Bush has directed all Cabinet officers to incorporate consideration of environmental impacts into all agency decisions. More departments are embarked on substantive environmental policy initiatives than ever before (see below). The President has devoted dozens of speeches, news conferences, and events to environmental themes, and the White House Domestic Policy staff has devoted thousands of hours to ambitious environmental quality initiatives.

2) **Air pollution:**

After a decade of policy gridlock, President Bush's Administration crafted amendments to the U.S. Clean Air Act to reduce the emissions that cause acid rain, urban smog and toxic air pollution. Thanks in large measure to the President's personal commitment, a bill recently passed the Senate and it appears likely this complex reform package will be enacted in 1990.

Among several other administrative actions on clean air, EPA issued rules that lower gasoline volatility (which contributes to smog) in summer months; and rules to reduce industrial emissions of the hazardous pollutant benzene by 90 percent. EPA proposed standards to require source separation by municipal waste handlers to effectively reduce overall air emissions from municipal waste incinerators by 90 percent.

The Administration has taken important strides forward on global air pollution issues (see #8 and #9).

Related actions on automobile fuel efficiency, energy efficiency and renewables, and clean coal technology are listed below.

3) **Environmentally-sensitive budget policy:**

The Administration's budget request for 1991 continued a trend begun with the President's first budget in 1990: substantial funding increases for most environmental programs, and greater sensitivity to the impact of federal actions on the environment. Notable areas include:

-- Increases for EPA's operating budget, especially for enforcement (more than 500 new staff) and cleanup at Superfund and federal sites (see #10)

-- **"America the Beautiful":** a three-pronged effort to acquire lands with high environmental or recreation value (up to \$1 billion over four years); restore threatened natural resource and recreation areas ("Legacy '99"); and a new program to expand and accelerate national reforestation to a rate of one billion trees annually

-- concerning global climate change, sharply higher funding for the "Mission to Planet Earth" space-based Earth observation system, solar and renewable energy, energy conservation (see #7), and basic research

-- research, protection and enhancement of the nation's wetlands; termination or mitigation of certain water projects (see #5)

-- proposed demonstration projects to terminate wasteful "below-cost" timber sales at nine national forests and provide improved recreational facilities in those areas

-- an increase of almost \$800 million, or 21 percent above 1990 levels, for Federal facility cleanups

-- full funding for the Clean Coal Technology program

4) **Pollution prevention and recycling:**

The Administration seeks reforms to move beyond costly end-of-the-process cleanups, toward an emphasis on pollution prevention.

Within EPA, two percent of every program's budget has been set aside to fund specific pollution prevention demonstration projects.

EPA has launched a nationwide "early warning system" to prevent municipal sewage treatment plants from violating Clean Water Act standards.

Legislation and administrative actions are under development to spur federal and private pollution prevention efforts. The legislation would set numerical goals and timetables, enhance data collection, improve municipal solid waste minimization and management, and create helpful new market incentives.

5) **Asbestos ban:**

EPA announced a ban on almost all uses of asbestos in the United States by 1997. Asbestos is a carcinogen linked to lung and chest cancer.

6) **Water pollution, water projects, and wetlands:**

EPA Administrator Reilly blocked issuance of a permit that would allow construction to begin on the Two Forks Dam in Colorado. President Bush seeks termination of uneconomic and destructive projects such as the Garrison Diversion Unit in North Dakota. EPA rejected the proposed Big River reservoir project in Rhode Island, based on unacceptable adverse effects on wetlands, wildlife and recreation.

EPA issued proposals to regulate 17 pesticides and 21 other contaminants in drinking water, almost doubling the number of pollutants subject to federally enforceable standards. The proposals also call for monitoring 110 currently unregulated contaminants.

The Bureau of Reclamation has been given new direction and proposed doubled funding to pursue mitigation of adverse impacts of certain large water projects already constructed.

Concerned by the rapid loss of American wetland habitats, the President directed an interagency task force to report by late 1990 on ways to implement a policy of "no net loss" of wetlands. EPA and Army Corps of Engineers signed an agreement to clarify wetlands protection policy; the Bureau of Reclamation and the U.S. Fish and Wildlife Service signed an agreement to cooperate in expanding the wetlands breeding habitat for numerous species.

The President's FY91 budget seeks a 24 percent boost (to \$460 million) for research, protection and enhancement of wetlands, including acceleration of the national wetlands inventory. This follows a 32 percent increase in 1990.

For related actions on ocean pollution, see #14.

7) **Energy:**

The Department of Energy is preparing a National Energy Plan which emphasizes, among other things: energy conservation and efficiency; alternative and renewable energy sources; and nuclear power safety.

DOE announced eleven initiatives in energy efficiency and renewables, including: more efficient lighting for federal buildings; regulatory and legislative changes to stimulate efficiency improvements in the utility, commercial and construction sectors; and using the government-industry technology transfer process to speed promising energy technologies into widespread use.

In a reversal of previous policy, DOE proposed rules to centralize and significantly strengthen compliance with the environmental assessment process under the National Environmental Policy Act.

The Department of Transportation raised the corporate average fuel economy (CAFE) standard for autos to 27.5 mpg.

The President postponed lease sales and oil and gas development in sensitive areas off the shores of California and Florida, and will make a final decision on these leases in 1990.

The President has requested all of the necessary funds to complete the \$2.5 billion Clean Coal Technology program.

To address waste cleanup at DOE facilities, funding was increased by \$500 million in FY90; an increase of \$600 million is sought for FY91. DOE released a five-year, site-by-site cleanup plan, and a five-year research and development plan to reduce outyear costs.

8) **Global climate change:**

The Bush Administration has demonstrated a willingness to confront the complex and important question of global climate change.

The Secretary of State's first major address in January 1989 expressed the President's intention to take comprehensive action in this area. In February 1990, the President became the first and only head of state to address the U.N.-sponsored Intergovernmental Panel on Climate Change (IPCC), the leading global forum for climate change policy.

The U.S. agreed in November 1989 to stabilize U.S. carbon dioxide emissions and study further reductions; the President proposed two major international conferences on the issue in 1990. The first conference, held April 17-18, addressed scientific and economic questions. The second conference would open negotiations toward a multilateral framework treaty once the IPCC has completed initial assessments of the scientific evidence, potential impacts, and policy options.

The President supports efforts to build upon the Montreal Protocol and phase-out all uses of chloro-fluorocarbons (CFC's) and halons by the turn of the century. The Administration supports financial and technical assistance to developing countries to make the transition to non-CFC technologies.

The FY91 budget request seeks \$1 billion for research into global climate change, up 57 percent from 1990. That research includes work on the "Mission to Planet Earth" orbiting observation system, renewable and solar energy sources, and energy efficiency/conservation.

The Administration's clean air bill, National Energy Strategy and increased CAFE standard also will have the effect of stabilizing/reducing "greenhouse gas" emissions.

9) **Other international environmental initiatives:**

The President banned imports of African elephant ivory (see #18).

During his 1989 trips abroad, the President pledged financial and technical aid to Poland and Hungary to control air and water pollution, draft environmental statutes, and establish an East European environmental center.

President Bush led efforts to make the environment a major focus of the "G-7" Summit in Paris. In Tokyo, the President held meetings with leaders of Japan and Brazil to discuss the problem of rapid rainforest depletion.

The Administration helped develop and then signed the Basel Convention, which governs transboundary shipments of hazardous wastes in an environmentally sound manner.

President Bush supported and signed a bill to prohibit U.S. support for foreign development loans unless environmental impacts are studied first.

The Administration persuaded Japan, Taiwan and Korea to enter into agreements to monitor driftnet fishing. This will allow the U.S. to monitor the incidental take of birds, seals, whales, dolphins and other marine mammals.

In 1990, for the first time, Peace Corps volunteers will be trained by EPA in water pollution prevention, waste disposal, reforestation and pesticide management.

The President's plan to elevate EPA to full Cabinet status will give the U.S. Environment Secretary commensurate status with his counterparts from other nations. The plan would also enhance "USDE" authority to offer technical assistance to foreign environmental programs. In early 1989, EPA's International Activities Office was elevated to the assistant administrator level.

10) **Alaskan oil spill:**

The President sent Vice President Quayle and a Cabinet-level team to assess the situation; the Department of Transportation is overseeing cleanup by Exxon, while EPA is coordinating an interagency task force on long-range restoration of Prince William Sound.

After negotiations broke down, the Justice Department issued a five-count criminal indictment against Exxon with potential penalties of up to \$600 million.

11) **Future oil spill prevention:**

The President proposed, and Paris Summit leaders accepted, a call for increased international efforts on oil spill prevention and cleanup. In May 1989, President Bush sent Congress comprehensive oil pollution liability and compensation legislation. The Interior Department began a \$6 million, 3-year joint project with the American Petroleum Institute to research and develop new cleanup technology.

12) **Food safety:**

The Administration proposed legislation to improve food safety by streamlining regulations to allow faster removal of dangerous substances from the market. EPA prohibited all sales, distribution and use of "Alar" products labeled for use on food products, and stepped up its efforts against other suspect pesticides. EPA blocked the sale of roughly 100 million apples that had been illegally treated with the fungicide "Botran."

13) **Hazardous wastes and Superfund:**

After an intensive management review, the Administration reoriented the "Superfund" hazardous waste dump cleanup to an "enforcement first" program to get more responsible parties to undertake cleanups. EPA added 500 new enforcement staff to this program.

The Administration fought Congressional attempts to cut the Superfund budget and in 1989, exceeded Congressionally-mandated targets for cleanup starts and site studies.

The Administration commenced a similar review of the Resource Conservation and Recovery Act (RCRA), expected to yield proposals for upcoming legislative reauthorization.

14) **Clean oceans and coastlines:**

EPA implemented the first step of the President's commitment to prevent medical wastes from washing up on beaches: a pilot medical waste tracking system to serve as a model for further action. The program involves the states of Connecticut, Louisiana, New Jersey, New York and Rhode Island, as well as the District of Columbia and Puerto Rico.

EPA negotiated agreements with local jurisdictions to stop ocean dumping of sewage sludge by late 1991, an initiative that also resulted in penalty actions against 61 cities in 1989. The President proposed legislation to require criminal felony penalties for illegal ocean dumping.

15) **Radon:**

EPA released data showing high levels of cancer-causing radon to be widespread in housing throughout the country, and undertook public education efforts to urge Americans to test and safeguard their homes, schools and businesses.

16) **Defense & the Environment Initiative**

The Department of Defense established a five-point initiative intended to forge long-term partnerships in defense-environmental matters well beyond mere compliance. An autumn 1990 conference will attempt to: finalize a near-term DOD environmental action plan; activate an enhanced DOD environmental decision-making structure; and discuss how global strategic policy might encompass environmental challenges.

17) **Endangered species:**

The President has rejected the suggestion of amendments to the federal Endangered Species Act.

The President banned imports of African elephant ivory products in an effort to save that endangered species; and he requested funding from Congress to assist African countries with management and protection of this species.

The Department of Interior issued an emergency listing of the Desert Tortoise as an endangered species in Southern California, Utah and Nevada. DOI acquired additional habitat for endangered panthers in Florida.

The Two Forks Dam and Big River decisions (see #6) protected thousands of acres of wildlife habitat. And the President reversed a proposal to cap the outlay of funds under the Wallop-Breaux Trust Fund used for fisheries protection and development.

18) **Earth Day**

The Council on Environmental Quality coordinated actions by all federal agencies to celebrate the 20th anniversary of Earth Day, including an exhibition on the Mall in Washington, and various activities by more than a dozen Federal agencies.

19) **Environmental education**

The President proposed a program of cash awards of up to \$5,000 to elementary and secondary school teachers in the 50 states, the District of Columbia and the territories who develop innovative, effective environmental education curricula.

20) **Enforcement**

EPA's aggressive enforcement program levied civil and administrative penalties totaling just under \$35 million in fiscal year 1989, including \$13.6 million from over 4,000 administrative actions, two record highs.

EPA referred 364 civil judicial cases of alleged environmental law violation to the Department of Justice for prosecution in FY89, just short of the 1988 record of 372. EPA referred 60 criminal cases to Justice in FY89.

Notable enforcement actions include:

--Proposed fines of \$1.65 million on 42 companies that failed to report toxic chemical discharges as required by law.

--Civil lawsuits against 34 companies and individuals to halt violations of rules protecting the public from unlawful asbestos demolition and renovation practices.

--Civil lawsuits against 61 cities (including Detroit, El Paso, Phoenix and San Antonio) for violations of the Clean Water Act.

--A civil penalty of \$15 million against the Texas Eastern company for toxic substance violations at up to 89 sites along a 1,000 mile-long natural gas pipeline. The fine was the largest ever for violation of any environmental statute.

--A coordinated campaign to protect the Chesapeake Bay included charges against 26 facilities in the watershed for violations of the Clean Water Act.

After negotiations broke down, the Justice Department issued a five-count criminal indictment against Exxon with potential penalties of up to \$600 million.

21) **Deterring conflicts of interest:**

EPA has set a strict new policy on the agency's use of contractors, barring them from involvement 17 specific activities and warning of improper conflicts of interest in 15 additional areas.

Our Changing Planet:

The FY 1991

U.S. Global Change Research Program



A Report by the Committee on Earth Sciences

To Accompany the
U.S. President's Fiscal Year 1991 Budget

This photograph of the Earth was taken from the Apollo 16 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.

Our Changing Planet:
The FY 1991
U.S. Global Change Research Program

A Report by the Committee on Earth Sciences

To Accompany the
U.S. President's Fiscal Year 1991 Budget

**Office of Science and Technology Policy
Federal Coordinating Council for Science,
Engineering, and Technology**

Committee on Earth Sciences

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Dallas L. Peck, Department of the Interior, United States
Geological Survey

Vice-Chairman

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Executive Secretary

Paul V. Dresler, Department of the Interior, United States
Geological Survey

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 "Our Changing Planet: The FY 1991 U.S. Global Change Research Program," a report by the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology to accompany the President's Fiscal Year 1991 Budget.

The report outlines an accelerated, focused research strategy designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound policies and responses to global change can be based. Because of the importance of this area, the President is proposing a 57 percent increase in the budget for this effort for FY 1991.

The research program presented here is a key component of the President's overall approach to the global change issue. This approach has, as its central goal, the provision of a sound scientific basis for developing national and international policy on global change. The President has called for an expanded schedule of international collaboration on research, monitoring, data exchange, and a new Framework Convention on climate change. This comprehensive approach recognizes the profound economic and social implications of responding to global environmental changes and maintains U.S. leadership on this issue.

The Committee on Earth Sciences' report outlines a careful blend of ground- and space-based efforts in research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. The report has benefited from close interaction with the National Academy of Sciences, the International Council of Scientific Unions' International Geosphere-Biosphere Programme, and the World Meteorological Organization's World Climate Research Programme. As such, I believe the report and the process which produced it provide an exemplary model of a coordinated, integrated research strategy and a sound basis for planning. Chairman Dallas Peck, Vice Chairman Robert Corell, and their interagency committee members, associates, and staff have done an excellent job and are to be commended.

Sincerely,

A handwritten signature in dark ink, reading "D. Allan Bromley". The signature is fluid and cursive, with the first name "D. Allan" and last name "Bromley" clearly distinguishable.

D. Allan Bromley
Director

To obtain a copy of this document – send request to:

Committee on Earth Sciences
c/o U.S. Geological Survey
104 National Center
Reston, VA 22092
(703) 648-4450

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Executive Summary

- Although the Earth has been changing for millions of years, dramatic recent changes such as antarctic ozone depletion demonstrate that human activities are affecting the Earth system.
- Recognizing the profound economic and social implications of responding to global environmental changes, the President has set in motion a comprehensive process designed to continue U.S. leadership on this issue. This includes an accelerated, focused research effort; active participation in international collaborative efforts intended to culminate in a Framework Convention; and a comprehensive review of potential policies and their implications.
- As the research component of this process, the U.S. Global Change Research Program is designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound policy strategies and responses can be based.
- An improved predictive model of the integrated Earth system and a better understanding of human interactions with this system will provide direct benefits by anticipating and planning for impacts on commerce, agriculture, energy, resources utilization, and human safety.
- Because of the high priority attached to the U.S. Global Change Research Program, the President is proposing \$1,034 million for this research effort in the FY 1991 budget, a \$374.8 million or 57 percent increase over the FY 1990 level.
- This proposed budget will significantly expand research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. It includes a carefully balanced mix of ground- and space-based

research efforts that are essential given the variability of the phenomena being studied and the need to scale local processes to regional and global levels.

- For the ground-based program, the proposed budget will initiate multi-agency research thrusts in several critical areas, including the role of clouds in controlling climate, fluxes of greenhouse gases, resource responses to global change, past changes in the Earth system, and the role of human activities in global change.
- For the space-based program, the proposed budget will initiate the development of the NASA Earth Observing System, a key element in "Mission to Planet Earth," which will provide the centerpiece of an integrated international satellite program for monitoring global change, coupled with a comprehensive data and information system.
- This report summarizes the key features and budget of the proposed U.S. Global Change Research Program for FY 1991. A more detailed FY 1991 research plan will be released in the spring of 1990.
- The research program was developed by the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology, in close interaction with the National Academy of Sciences, the International Council of Scientific Unions' International Geosphere-Biosphere Programme, and the World Meteorological Organization's World Climate Research Programme.

Introduction

World leaders are taking an increased interest in the economic and social implications of global environmental changes, both natural and human-induced. The 1988 midwestern U.S. drought underscored the potential effects of a warm, dry summer, just as the climate in recent decades in the Sahel starkly reveals the human tragedy that can occur in marginal-subsistence zones of a changing planet. Furthermore, the very recent linking of the antarctic ozone "hole" to man-made chlorofluorocarbons and the current debate over humanity's role in the greenhouse effect have placed the environment high on the national and international agenda.

In virtually all of these issues, the salient feature is the significant scientific uncertainty associated with predicting the behavior of the coupled ocean-atmosphere-land system. The formidable costs associated with addressing environmental change require that policy decisions be based on adequate scientific knowledge. To provide this knowledge, the U.S. Global Change Research Program has been created as a key component of the President's overall approach to global environmental change. Because of the priority attached to this issue, the President is requesting \$1,034 million for the research program in FY 1991, an increase of \$374.8 million or 57 percent over the FY 1990 level.

The present document is the second in a series of overviews that accompany the President's annual budget to the Congress. It highlights the Program's FY 1991 research activities and budget developed by the Committee on Earth Sciences (CES) of the Federal Coordinating Council for Science, Engineering, and Technology.

The CES activities of the past year began with the publication in January 1989 of *Our Changing Planet: A U. S. Strategy for Global Change Research*. Following this strategic plan, the CES prepared *Our Changing Planet: The FY 1990 Research Plan* (July 1989), which reviewed the Earth system changes that have occurred in the past; the forces that are at work today;

and the strengths and weaknesses in current scientific understanding. It also described the highest priority interdisciplinary research needs, agency roles, and new FY 1990 research initiatives.

The FY 1990 Research Plan was reviewed by the National Academy of Sciences, the American Geophysical Union, and others, all of whom strongly endorsed the Program's holistic approach to understanding the Earth system. The *Plan* is also consistent with the concepts outlined by the International Geosphere-Biosphere Programme and the World Climate Research Programme.

While recognizing the need for a comprehensive research and modeling effort, the FY 1991 Program also focuses on the scientific issues underlying current and future policy questions, including: Should the "Montreal Protocol on Substances that Deplete the Ozone Layer" be strengthened? Has a global warming signal been detected, and what are the relative contributions from natural processes and human activities? What will the climate of the coming century be like, and how will it impact agriculture, forestry, habitation, and water and energy supply and use?

Furthermore, the present document shows how this integrated interdisciplinary program has begun to address such crosscutting activities as understanding the carbon cycle, data management, education, and emerging disciplines.

A comprehensive FY 1991 research plan will be published in the spring of 1990.

Planning the FY 1991 Program

In *The FY 1990 Research Plan*, the CES established the following goal and objectives for the U.S. Global Change Research Program:

Goal:

To establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system.

Objectives:

To establish an integrated, comprehensive long-term program of documenting the Earth system on a global scale.

To 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.

To develop integrated conceptual and predictive Earth system models.

Planning Framework

Each year the CES will review the Program to ensure that it continues to aggressively address its goal and objectives. This process began in mid-July 1989, when CES evaluated individual agency initiatives relative to ongoing programs and the priority and evaluation framework outlined later in this section.

At a series of meetings over the ensuing months, agency representatives developed a final recommendation on the content and resource requirements for the FY 1991 Program. Subsequently, during the fall of 1989, there were extensive program reviews and discussions that led ultimately to the FY 1991 Program and budget summarized herein.

As part of these deliberations, the CES has forged increasingly effective partnerships among the Federal agencies and with the scientific community. These partnerships, the need to integrate science into the policy process, and the focus on interdisciplinary science have become the "Basic Tenets" (see box on page 7) of the CES cooperative planning process.

Priority Framework

In the preparation of *The FY 1990 Research Plan*, the CES created and implemented a multi-level priority-setting framework that was used to focus and integrate the program development and budget proposals. This framework contains three levels of priorities for the U.S. Global Change Research Program, diagrammed in Figure 1. These strategic, integrating, and science priorities focus on those research questions that will produce significant early improvements in understanding and modeling the interactive Earth system. For example, there is little disagreement that a major shortcoming of existing general circulation models is their inability to simulate the role of clouds and convective processes accurately; hence, that research is the highest priority in the Climate and Hydrologic Systems element. However, concurrent progress in high priority activities in all science elements is necessary for the Program to achieve its overall goal, although not all will receive equal emphasis.

Evaluation Criteria

Within each science element, the CES evaluated FY 1991 research initiatives, taking into account the priorities and several evaluation criteria (see box on page 10). These criteria provided a framework for designing the specific project-by-project structure that constitutes the Program (see Appendix for project listing).

The CES Process: Basic Tenets

- ***Integrate Science into the Policy Process.*** The need for effective relationships between the policy processes of governments and the underlying science of environmental issues has always been recognized and central to the U.S. Global Change Research Program. A process for policy development has evolved within the Executive Branch that directly involves the CES, including (i) it being the focal point for the development and coordination of U.S. scientific programs for global change, both domestically and internationally, and (ii) ensuring that the results of these scientific efforts provide the foundation for rational policy debate and effective action.
- ***Maintain a Partnership Among All Participants.*** A partnership has evolved among the CES members and between CES and the non-Federal research community through the relevant Committees and Boards of the National Academy of Sciences (NAS), notably the Committee on Global Change (CGC). Within CES, there has been a conscious effort not to designate "lead" agencies. Leadership is distributed among the agencies, with each contributing its strengths to the planning, documentation, review, and implementation process. This partnership concept is fundamental to the operation of the CES. The same philosophy is operative in the parallel planning relationship with the NAS, including joint meetings, program reviews, and exchange of ideas for developing implementation strategies. In addition, the CES has interacted with (i) the international scientific community and agencies of other governments, (ii) several intergovernmental bodies with global change concerns, (iii) the environmental community, and (iv) the private sector.
- ***Focus on Interdisciplinary Science and Interactions.*** The CES science program is founded on the premise that the essential scientific questions can only be addressed through interdisciplinary research on the interacting components of the Earth system. This is also the scientific strategy of the CGC and its international counterpart, the International Geosphere-Biosphere Programme (IGBP), thereby further strengthening the interactions of the CES and CGC.

Figure U.S. Global Change Research

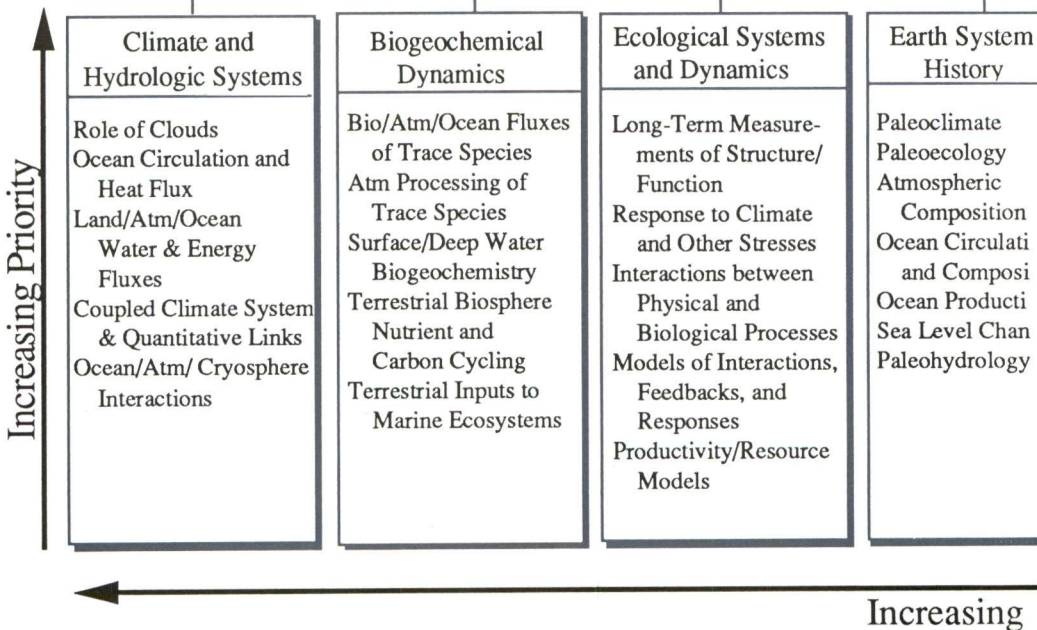
STRATEGIC

- Support Broad U.S. and
- Identify Natural and Hu
- Focus on Interactions
- Share Financial Burden, and Encourage Full

INTEGRATING

- Documentation of
 - Observational
 - Data Manage
- Focused Studies on and Improved
- Integrated Concep

SCIENCE



1

Program Priority Framework

PRIORITIES

International Scientific Effort
man -Induced Changes
and Interdisciplinary Science
Use the Best Resources,
Participation

PRIORITIES

Earth System Change
Programs
ment Systems
Controlling Processes
Understanding
tual and Predictive Models

PRIORITIES

	Human Interactions	Solid Earth Processes	Solar Influences
on tion vity ge	Data Base Development Models Linking: Population Growth and Distribution Energy Demands Changes in Land Use Industrial Production	Coastal Erosion Volcanic Processes Permafrost and Marine Gas Hydrates Ocean/Seafloor Heat and Energy Fluxes Surficial Processes Crustal Motions and Sea Level	EUV/UV Monitoring Atm/Solar Energy Coupling Irradiance (Measure/ Model) Climate/Solar Record Proxy Measurements and Long-Term Data Base

Priority

The CES Evaluation Criteria

- *Relevance/Contribution.* The research must address the overall goal and one or more of the three key scientific objectives of the Program.
- *Scientific Merit.* The proposed work must be scientifically sound and of high priority, and be the product of a documented scientific planning and review process.
- *Readiness.* The level of planning must be mature, of high quality, and the research likely to produce vital and needed advances.
- *Linkages.* The CES looks for established inter-agency, other national, and international connections.
- *Costs.* The CES considers whether the identified resources are adequate; if they represent an appropriate share of total available resources (e.g., a balance between space- and ground-based program elements); prospects for joint funding; and the degree to which long-term resource implications have been evaluated.
- *Enhancements to Existing Program Research.* The highest priority existing programs will receive adequate support before new initiatives are funded.
- *Agency Approval.* The proposed program or activity must have policy-level approval by the submitting agency.

Agency and Organizational Roles

At the outset of the Program, the CES developed a set of role statements that specifically define each agency's respective role in the Program (see *The FY 1990 Research Plan*, Appendix A). In developing the FY 1991 Program, that process of role definition has been extended. The current status of participation in the Program by CES agencies and other Federal organizations has three categories:

- (1) *Agencies whose budget initiatives are in the "focused" category and hence are detailed in this document.*** These are the Department of Commerce, National Oceanic and Atmospheric Administration (DOC/NOAA), Department of Energy (DOE), Department of the Interior (DOI), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and the United States Department of Agriculture (USDA).
- (2) *Agencies whose programs fall into the "contributing" category.*** These agencies' programs support many of the science elements, but were initiated for reasons other than the focused Program goal. They include the agencies with focused programs and the research agencies of the Department of Defense (DOD) (including the Office of Naval Research, the Oceanographer of the Navy, and the U.S. Army Corps of Engineers).
- (3) *Agencies and offices of the Executive Branch that contribute to the overall guidance of the Program.*** These agencies and offices contribute to the architecture of the Program and are key vehicles for coordinating and linking the Program with overall national and international policy on global change. These include the Council on Environmental Quality (CEQ), Departments of State (DOS) and Transportation (DOT), Office of Management and Budget (OMB), Office of Science and Technology Policy (OSTP), and the White House Office of Policy Development.

Benefits

The U.S. Global Change Research Program is founded on the premise that effective strategies to address environmental issues can be built only on sound scientific information.

Therefore, a hallmark of the Program strategy is linking the U.S. scientific program for global change to the policy process, including:

- Predicting the magnitude and timing of environmental variations, thereby providing the means to plan or avoid their impacts.
- Separating natural changes from human-induced changes, thereby balancing regulatory needs with economic and social development and providing the ability to focus on those parts of the problem that are traceable to human intervention.

Specifically, this is accomplished by supporting a robust, prioritized research effort that can address important policy issues (see box on page 13) and address public needs for predicting and dealing with environmental change through:

- (i) ***Providing Timely Information*** – making available the results of scientific research through special briefings and other information products for the Congress, the Executive Branch, and others immediately after new insights are obtained;
- (ii) ***State of the Science Assessments*** – providing periodic assessments of the "state of the science" in the critical areas of global change (as has been done regarding the stratospheric ozone layer), employing both domestic and international mechanisms, such as the Committees of the NAS and the Intergovernmental Panel on Climate Change (IPCC);

***Benefits of the U. S. Global Change Research Program:
Examples***

- ***Greenhouse Gases.*** A better understanding of the processes, both natural and human-influenced, that govern the sources and fates of greenhouse gases will provide a basis for analyzing integrated control strategies and cost-benefit analyses.
- ***Ozone Depletion.*** Maintaining the "Montreal Protocol on Substances that Deplete the Ozone Layer" will require an improved knowledge of the mechanisms controlling the stability of the stratospheric ozone layer.
- ***Energy.*** Establishing links between carbon dioxide emissions and atmospheric abundances with energy policy scenarios will facilitate the assessment of different energy technologies.
- ***Agriculture/Ecosystems.*** Better knowledge of the linkages of crops, forests and other ecosystems to environmental conditions will enhance the ability to make sound decisions regarding food security, forest management, and conservation of natural resources, including crop selection, reforestation, and deforestation practices.
- ***Water Policy.*** A more complete knowledge of the interaction of the climate and hydrological cycles will help resolve issues involving water supply and demand and will allow better planning for the allocation of water resources during extreme events.
- ***Sea Level.*** Elucidation of the processes that control sea level will provide the predictive capability to guide policies regarding coastal human settlements and wetlands.

(iii) **Regular Prediction/Forecasting Products** - providing a line of information products that address three time scales: seasonal, interannual, and interdecadal.

- **Seasonal Projections** - It is expected that research already under way (including developments from the sciences associated with weather forecasting) will lead to seasonal forecasts (i.e., 30- to 60-day projections) within three to five years. These products will likely be derived from the existing weather forecasting systems operating throughout the countries of the world. Ocean forecasting is in an earlier state of development and will require increased effort to achieve this goal.
- **Interannual Projections** - The advent of a greatly improved understanding of how the tropical ocean induces changes in heating patterns within the atmosphere (El Niño and the Southern Oscillation) is leading toward one of the next realizable lines of predictive products. It is expected that within about 10 years regular assessments and forecasts will be produced quarterly, each providing three- to six-month forecasts, a one-year prognosis, and a two-year outlook of interannual climate variability for selected climatic processes.
- **Interdecadal Projections** - It is expected that prediction of selected climatic processes on interdecadal (ten to twenty years) time scales will emerge during the coming decade. The products will consist of interpretive reports and model predictions. This process is beginning with the science assessment of the IPCC and the Second World Climate Conference in late 1990.

In summary, the overall benefits of the Program are substantial: (i) providing critical data to minimize economic or other adverse impacts by supporting prudent near-term actions where justified, while accelerating the development of more

reliable scientific understanding on which to base long-term policies; (ii) contributing to the Nation's environmental leadership and credibility, both domestically and internationally; and (iii) serving as a catalyst for similar scientific commitments from other nations.

Research Program and Budgets

The following sections summarize the FY 1991 activities and budgets of the U.S. Global Change Research Program in the seven interdisciplinary science elements, by agency, by scientific objective including data management, by Federal budget function, and by the balance between space- and ground-based components. Because of the complex nature of the Program, examples of important research, data collection, and modeling activities will be mentioned along with how they address the research priorities and related policy-relevant questions.

Budget Overview

Table 1 shows the U.S. Global Change Research Program budget proposal by science element, by agency, and by scientific objective. In FY 1990 funding for the U.S. Global Change Research Program is \$659.3 million.* The President's FY 1991 budget proposes a funding level of \$1,034 million, a \$374.8 million (57 percent) increase over the FY 1990 level. Table 2 shows the budgets for programs that contribute to global change research and provide important support to the Program objectives but were initiated for reasons other than the focused Program goal.

* The FY 1990 Program as outlined in the President's FY 1990 Budget to Congress was \$190.5 million (see *Our Changing Planet: A U.S. Strategy for Global Change Research*, January 1989). The FY 1990 Program was adjusted to \$659.3 million over the past year reflecting subsequent FY 1990 Appropriations actions by the Congress and the reevaluation of "focused" and "contributing" programs. The bulk of this increase is due to the transfer of several NASA programs from the "contributing" category.

Budget by Science Element

This section summarizes the FY 1991 activities in the seven interdisciplinary science elements and data management. Figure 2 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by science element. At this time the U.S. Global Change Research Program focuses primarily on the three highest priority science elements: Climate and Hydrologic Systems, Biogeochemical Dynamics, and Ecological Systems and Dynamics. However, the Program maintains an appropriate level of effort in all seven science elements consistent with the policy needs, science priorities, and the current state of scientific program development.

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

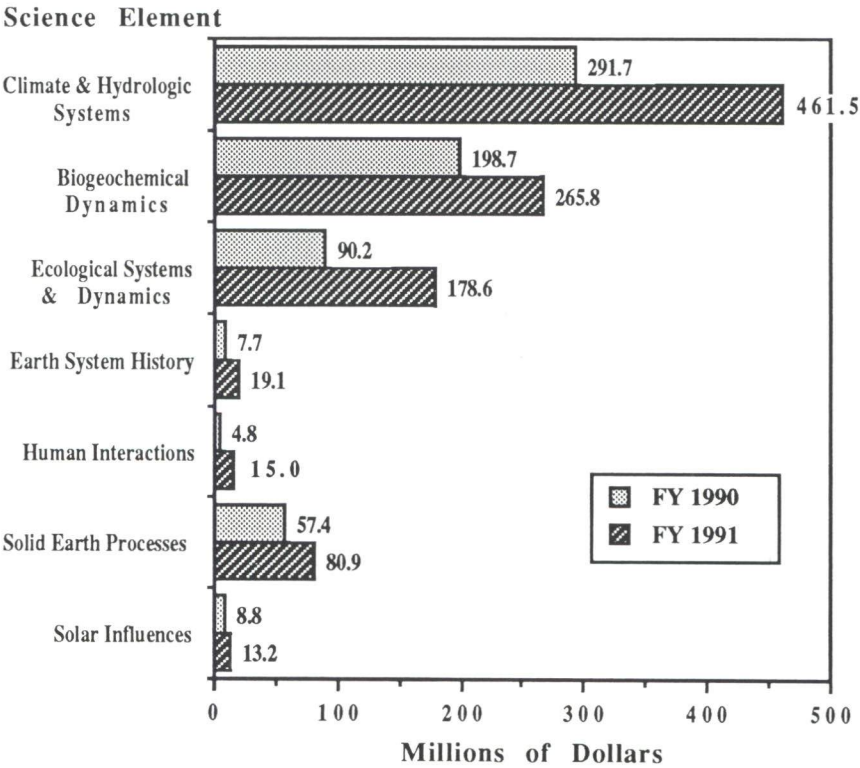


Table
FY 1990-1991 U. S. Global Change
(Dollars)

Focused Program	Total Budget		Climate & Hydro- logic Systems		Biogeochemical Dynamics		Ecological and
	FY90	FY91	FY90	FY91	FY90	FY91	FY90
Agency Totals	659.3	1034.1	291.7	461.5	198.7	265.8	90.2
DOC/NOAA	18.0	87.0	14.2	67.6	3.3	13.5	0.0
DOE	50.0	66.0	32.0	44.0	7.0	9.0	9.0
DOI	13.3	43.7	4.9	12.2	0.8	2.0	0.9
EPA	13.2	26.0	1.0	3.3	2.5	3.1	9.7
NASA	488.6	661.0	221.4	302.5	162.2	198.3	51.0
NSF	55.0	103.0	16.8	29.8	20.2	32.2	3.5
USDA	21.2	47.4	1.4	2.1	2.7	7.7	16.1
Scientific Objective							
Observations	137.2	255.0	89.1	148.9	17.2	38.9	14.1
Data Management	65.2	129.4	32.9	64.0	21.2	34.7	5.5
Understanding	409.7	560.0	143.1	200.3	148.1	176.2	65.5
Prediction	47.2	89.7	26.6	48.3	12.2	16.0	5.1

1

Research Program Focused Budget

(in Millions)

Systems Dynamics	Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
178.6	7.7	19.1	4.8	15.0	57.4	80.9	8.8	13.2
4.9	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0
10.3	2.4	8.0	0.9	5.3	3.4	5.9	0.0	0.0
19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90.0	0.0	0.0	0.0	0.0	47.7	63.0	6.3	7.2
8.5	4.5	9.0	1.2	5.5	6.3	12.0	2.5	6.0
35.3	0.3	1.1	0.7	1.2	0.0	0.0	0.0	0.0
39.6	0.0	0.2	0.0	2.2	13.1	20.8	3.7	4.4
17.7	0.5	2.2	0.4	1.0	3.8	8.8	0.9	1.0
103.2	6.1	13.1	2.9	10.6	40.5	50.1	3.5	6.5
18.1	1.1	3.6	1.5	1.2	0.0	1.2	0.7	1.3

Table
FY 1990-1991 Budget of Contributory Programs
(Dollars)

Contributing Program	Total Budget		Climate & Hydrologic Systems		Biogeochemical Dynamics		Ecological and
	FY90	FY91	FY90	FY91	FY90	FY91	FY90
Agency Totals	853.8	918.2	432.4	443.1	63.6	80.1	209.1
DOC/NOAA	300.6	315.9	254.2	268.0	10.4	10.4	36.0
DOD	31.2	31.0	22.3	22.1	1.1	1.1	6.0
DOE	39.3	39.5	0.0	0.0	21.8	22.4	8.6
DOI	225.1	227.7	97.4	91.0	2.7	2.9	51.4
EPA	83.3	50.6	11.0	8.3	1.6	2.0	70.7
NASA	24.7	25.3	0.0	0.0	0.0	0.0	0.0
NSF	124.2	132.5	45.2	47.2	23.1	26.6	18.9
USDA	25.4	95.7	2.3	6.5	2.9	14.7	17.5

2

to the U.S. Global Change Research Program

(in Millions)

Systems Dynamics	Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
234.4	24.3	25.7	71.4	77.4	44.9	47.3	8.1	10.2
37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.0
8.4	0.0	0.0	0.0	0.0	7.9	7.7	1.0	1.0
54.9	0.4	0.4	65.1	70.4	6.1	6.1	2.0	2.0
40.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	24.7	25.3	0.0	0.0
20.8	23.8	24.3	4.6	4.9	3.5	3.6	5.1	5.1
66.5	0.1	1.0	1.7	2.1	0.9	2.8	0.0	2.1

Climate and Hydrologic Systems

Table 1 shows that the FY 1991 request for this element is \$461.5 million, a \$169.8 million or 58 percent increase over the FY 1990 level.

The increasing abundances of greenhouse gases in the Earth's atmosphere are altering the radiative balance of the planet. However, the impact on the climate is uncertain. The response of the Earth's climate is strongly tied to the natural variability of the climate and hydrologic systems, including the atmospheric, oceanic, cryogenic, and land surface processes that govern the distribution of temperature, moisture, clouds, and rainfall. Effective policy formulation requires quantification of the natural and human-induced variability in the climate and hydrologic systems, and reliable predictions of the magnitude and timing of regional and global changes in response to the increasing abundances of greenhouse gases.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What is the role of clouds in the Earth's radiation and heat budgets?

Clouds and water vapor play a pivotal role in the Earth's radiation and heat budgets. They control the amount of solar energy absorbed by the climate system as well as the infrared radiation emitted to space, and they strongly influence the redistribution of heat throughout the climate system. A change of a few percent in global mean cloud cover or type could either dramatically enhance or counteract the radiative effects of anthropogenic greenhouse gas emissions.

To understand the role of clouds in controlling the Earth's radiative and heat budgets requires knowledge of their distribution, radiative properties, and cloud-radiation feedback

mechanisms. For example, ongoing and new research programs that are focused on this area include: NASA's Earth Radiation Budget Experiment; the NASA, NOAA, and NSF International Satellite Cloud Climatology Project (ISCCP) and associated field campaigns; and a broad range of proposed studies and measurements (NASA's Earth Observing System [EOS] and DOE's Atmospheric Radiation Measurements [ARM] program).

(2) How do the oceans interact with the atmosphere in the storage, transport, and uptake of heat?

The oceans and atmosphere play a vital role in the transport of energy from the equator to the polar regions. The rate at which the oceans exchange heat with the atmosphere controls the magnitude and timing of the predicted global warming due to greenhouse gases.

The prediction of climate change will require ocean observation systems analogous to the existing atmospheric systems used to predict the weather. Understanding the role of the oceans in exchanging energy with the atmosphere requires knowledge of ocean circulation and air-sea energy fluxes.

Numerous ongoing and new research programs contribute to these areas. *In situ* (NOAA, NSF, and DOI) and remote (NASA scatterometer [Earth Probes] and altimeter [TOPEX]) ocean observation systems will contribute to studies of ocean circulation and the coupling of the ocean and the atmosphere. Interannual climate change (Tropical Ocean-Global Atmosphere [TOGA]: NOAA, NSF, and NASA), and the general circulation of the oceans (World Ocean Circulation Experiment [WOCE]: NSF, NOAA, and NASA) are critical investigations. Other key research includes the NOAA Atlantic Climate Change Project, and the proposed new generation of space-based measurements of ocean altimetry, temperature, and wind stress (NASA EOS).

(3) How will changes in climate affect temperature, precipitation, and soil moisture patterns, and the general distribution of water and ice on the land surface?

Changes in seasonal temperatures, precipitation and soil moisture patterns could have significant ramifications for water resources, agricultural productivity, natural ecosystems, and the exchange of water between oceans and glaciers.

Understanding the distribution of precipitation and the impacts of a changing climate on the distribution of water and ice on land surfaces requires knowledge of the fluxes of energy and water within the Earth system, water resources on the land, and changes in the area and volume of glaciers.

Ongoing and new research programs that will contribute to these areas include: the Global Energy and Water Cycle Experiment (GEWEX: NOAA, NSF, DOI, and NASA); the proposed new generation of space-based measurements of precipitation, winds, water vapor, clouds, and ice extent (NASA Earth Probes and EOS); long-term observational networks of water resources (DOI, NOAA, and DOE); field and modeling studies of the climate sensitivity of watersheds (DOI and USDA); continental-scale hydrologic processes (NSF and DOE), water budgets in managed and manipulated ecosystems (USDA) and in temperate and arctic regions (DOE); and compilation of glacier extent worldwide, but especially in the Arctic and Antarctic, using ground-based and satellite data (NSF, DOI, and NASA).

(4) How can the reliability of global- and regional-scale climate predictions be improved?

Accurate predictions of climate change, whether natural and/or human-induced, are vital for evaluating environmental and socioeconomic impacts. The current generation of climate prediction models is inadequate to confidently predict the magnitude and timing of climate change. This is particularly true at the regional scale.

Improving the reliability of model predictions will require the development of climate diagnostics, model assimilation of climatic data, modeling shorter space and time scales, and an improved parameterization of key Earth system processes.

Ongoing and new research programs that will contribute to these areas include: enhanced climate modeling and diagnostics efforts (NOAA, NASA, NSF, and DOE); mechanistic studies of climatic change through analysis of observations (NOAA and NSF); development of climate modeling data assimilation techniques (NOAA and NSF); a critical review of data needs both for detection of climate change and for climate modeling (DOE); development of regional climate and hydrology models linked to global climate models (EPA and USDA); and the development of the capability to forecast seasonal conditions through coupled ocean-atmosphere modeling and extension of conventional weather prediction techniques (NOAA). Results from a number of process-oriented studies will be utilized to parameterize key interactions in models, including cloud-radiation interactions (NASA, NOAA, NSF ISCCP, and DOE ARM), and land-ocean-cryosphere-atmosphere interactions, including land surface hydrology (NSF, NOAA, DOI, and NASA).

Biogeochemical Dynamics

Table 1 shows that the FY 1991 request for this element is \$265.8 million, a \$67.1 million or 34 percent increase over the FY 1990 level.

There is compelling scientific evidence that the atmospheric concentrations of several key radiatively and chemically active gases are increasing, due both to natural processes and human activities. The rates of increase of these gases depend not only on their emissions, but also on the fate of these gases, which involves the cycling of carbon and other key nutrients between the ocean, atmosphere, and terrestrial biosphere. Currently, there are significant uncertainties in understanding

these processes, thus limiting the ability to quantitatively predict future increases in atmospheric trace gas concentrations. This restricts the formulation of effective policies regarding trace gas emissions.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What is the relative importance of the oceans and terrestrial biosphere as sinks for fossil fuel carbon dioxide, and how do they change with time?

Increasing atmospheric concentrations of carbon dioxide are predicted to contribute to global warming. Presently some portion of the emissions from the combustion of fossil fuels and deforestation stay in the atmosphere, with the remainder being taken up by the oceans and the terrestrial biosphere, but the proportions and responsible processes are not well understood. For a given anthropogenic emission scenario, the prediction of atmospheric growth rates of carbon dioxide depend upon an understanding of this sequestering of emitted carbon dioxide.

To understand the relative importance of the oceans and terrestrial biosphere as sinks for fossil fuel carbon dioxide requires knowledge of biogeochemical and physical processes and the fluxes of carbon and nutrients among and between the atmosphere and land and ocean surfaces.

Numerous ongoing and new research programs contribute to these areas. *In situ* studies of the processes responsible for controlling the concentration, distribution, and cycling of oceanic carbon (NSF, NOAA, and DOE), complemented by remote sensing measurements of ocean productivity, sea surface temperatures, and winds (NASA) contribute towards the Joint Global Ocean Flux Study (JGOFS). *In situ* studies of the sequestering of carbon dioxide and the storage and cycling of carbon and other key nutrients within natural and disturbed terrestrial ecosystems (DOI, NSF, EPA, DOE, and USDA)

will be complemented by estimates of standing biomass and the biological productivity of terrestrial ecosystems using satellite imagery (NASA EOS).

(2) What are the major sources responsible for the current increases in atmospheric nitrous oxide and methane?

The well-documented increases in the atmospheric concentrations of methane and nitrous oxide are predicted to contribute to global warming, affect stratospheric ozone, and, in the case of methane, to increase tropospheric ozone. The natural and anthropogenic sources of these gases have been qualitatively explained, but not adequately quantified. Hence, effective emission control strategies cannot be formulated.

Understanding current and future trends in the atmospheric concentrations of methane and nitrous oxide requires knowledge of their emissions from industrial and ecological sources; the processes that control their fluxes between the atmosphere, biosphere, and land and ocean surfaces; the impact of changing environmental conditions upon their fluxes; and their atmospheric distribution and transformations.

Many ongoing and new research programs will contribute to these areas including: studies of the fluxes of methane and nitrous oxide, the processes controlling them, and their response to environmental changes from one or more of the key sources, including natural ecosystems, agricultural systems, managed forests, cattle, biomass burning, and gas hydrates (NASA, NOAA, NSF, EPA, DOI, DOE, and USDA); quantification of the areal extent and environmental and ecological conditions conducive to methane and nitrous oxide emissions from terrestrial ecosystems (NASA EOS); atmospheric distributions and trends of methane and nitrous oxide (NASA and NOAA); and the atmospheric distribution and transformations of species (such as tropospheric ozone, hydroxyl radicals, oxides of nitrogen, carbon monoxide, and non-methane hydrocarbons) that control the distribution and lifetime of methane (NSF, NASA, NOAA, DOE, and EPA).

(3) What are the implications for stratospheric ozone, globally and in polar regions, of increased concentrations of chlorine and bromine?

Current scientific understanding indicates that the antarctic ozone hole will seasonally reoccur until the stratospheric chlorine levels decrease by 30 percent from today's level. However, it is not yet possible to quantify, under conditions of enhanced chlorine and bromine concentrations, the impact of the antarctic ozone hole on ozone levels at mid-latitudes in the southern hemisphere or the probability of significant ozone depletion over the Arctic. An improved quantitative understanding of the processes controlling stratospheric ozone, particularly in the polar regions, would allow improved environmental impact assessments to be conducted and improve policy formulation concerning chlorine and bromine containing chemicals, including proposed substitutes.

To understand the response of stratospheric ozone to changes in chlorine and bromine requires knowledge of their fluxes into the stratosphere; the chemical composition and physical structure of the stratosphere; and the coupling between chemical, dynamical, and radiative processes in the stratosphere.

Ongoing and new research programs that will contribute to these areas include: monitoring the atmospheric distribution of the source gases (NOAA and NASA); monitoring the chemical composition and dynamical structure of the stratosphere using a ground-based network of remote sensing, aircraft and balloons, and satellite observations (NASA, NOAA, and NSF); and studying the atmospheric cycling and transformations of compounds that influence the chemistry of the stratosphere (NASA, NOAA, NSF, and EPA).

Ecological Systems and Dynamics

Table 1 shows that the FY 1991 request for this element is \$178.6 million, a \$88.4 million or 98 percent increase over the FY 1990 level.

Ecological systems are important in global change research for two principal reasons. First, changes in climate, atmospheric composition, and solar radiation can affect the productivity, diversity, and habitat associated with both natural and managed ecosystems. Indeed, much of the policy concern over global change is explicitly linked to such possible ecosystem impacts. Second, photosynthesis, deforestation, and other biospheric processes can affect the chemical composition of the atmosphere, hence contributing to global change. Human influences on ecosystem changes are increasingly a part of current policy debates.

Thus, ecological systems are intrinsically linked to global change through interwoven roles in biogeochemical dynamics, physical climate and the hydrologic cycle, and the actions of humans. However, the scientific uncertainties associated with the composition, distribution, and processes of ecosystems currently slow the formulation of sound, science-based policy options.

The current key questions in these research areas, their relevance to the evolution of public policy of global change, and the associated research of the FY 1991 U.S. Global Change Research Program include the following:

(1) What ecological systems are most sensitive to global change, and how can natural change in ecological systems be distinguished from change caused by other factors?

The diverse climates of the Earth support an equally diverse array of species and ecosystems. Separating the intrinsic natural dynamic changes of ecosystems from those changes

induced by human activities is a challenge that has plagued the ecological sciences and the public policy arena for some time.

The highest priority for determining the sensitivity, types, and causes of possible changes in ecosystems is the documentation of past, current, and future variation in ecosystem properties. Several ongoing monitoring programs and proposed research initiatives will address this need with regard to sensitive ecosystems (e.g., boreal forests, grasslands, and arid and high-elevation areas): DOE's research parks, USDA's forests and experiment stations, DOI's parks, wildernesses and other public lands, and NSF's Long-Term Ecological Research Sites. NASA's EOS satellite-based instruments will extend global observations of ecosystem type, state, and spatial extent. Furthermore, EPA, USDA, NSF, DOI, NOAA, and DOE will examine the ecosystem responses (e.g., alpine treeline change in the western U.S., shrub encroachment into rangeland, ecological succession, small-animal ranges and habitats, and marine ecosystems) to carbon dioxide increases, climatic stresses, and other disturbances.

(2) What are the likely rates of change in ecological systems due to global change, and will natural and managed systems be able to adapt?

Ecosystem change is controlled by the physiological processes of the individual species, as well as by the environments in which they exist. The photosynthetic response of plants to increased carbon dioxide concentrations is relatively fast and often accompanied by higher biological productivity and drought and salinity resistance. However, the full responses of complex ecosystems, such as forests and rangelands, to changes in the climate system and in the chemical composition of the atmosphere may take decades or longer.

Understanding the ecological response to rates of change and how well ecological systems can adapt to change is clearly linked to quantifying impacts for the formulation of policy options. This will require (i) knowledge of ecological responses to specific forcing agents (e.g., temperature stress, soil

moisture, chemical exposure, ocean circulation, and ultraviolet radiation), (ii) research on the interactions between biotic and abiotic processes, and (iii) modeling of interactions, feedbacks, and ecological responses.

The proposed and ongoing research of several agencies will contribute to closing these knowledge gaps. EPA and DOI will develop correlations and models to investigate rates of change in forested and semi-arid ecosystems. USDA, DOE, NSF, and DOI will acquire data on physiological and ecosystem responses in seedling productivity; variation of plant growth due to carbon dioxide, temperature, and ultraviolet exposure; ecosystem changes in high-desert rangeland and coastal regions; successional change of vegetation across climate gradients; and response of managed forests to drought stress. Furthermore, DOE, DOI, USDA, NOAA, and NSF will investigate the responses of particularly sensitive species (e.g., arctic marine mammals, reef corals, commercial fish stock, grasses, grains, and endangered or limited-habitat species) to climatic and other stresses.

(3) How do ecological systems themselves contribute to processes of global change?

The biogeochemical and physical feedbacks from living systems strongly influence the fluxes and amounts of methane, nitrous oxide, carbon dioxide, and the reactive trace gases in the atmosphere, as well as albedo and water fluxes. Decisions regarding land-use policies require that these causative interactions be understood and that their feedbacks be represented correctly in global system models.

DOE, EPA, USDA, NSF, and DOI ongoing and new programs will address these needs through projects that determine the influence of soil biology, total biomass, land-cover type, and transpiration on biogenic gas fluxes and evapotranspiration in different vegetation types, and that characterize the interactions between climate, vegetation, and soils in diverse ecosystems.

Earth System History

Table 1 shows that the FY 1991 request for this element is \$19.1 million, a \$11.4 million or 148 percent increase over the FY 1990 level.

Geological and historical records document the natural variability of the physical environment, climate, and ecosystems from interannual to millennia time scales. These data reveal periods that were significantly colder and warmer than today, as well as past abrupt climate changes and subsequent environmental responses. Understanding this past behavior of the natural system is essential for detecting predicted human-caused perturbations against the background of normal variability and for providing data sets to test climate models. Confidence in model predictions of future change will be increased if the models can reproduce these past climates.

Uncertainties in the predictions of climate models is already a key factor in policy debates, as is whether a greenhouse "signal" can be found in the record of recent decades. In addition, past evidence of the impact of climate changes on ecosystems demonstrates the vulnerability or resilience of these systems to change.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What are the natural ranges and rates of change in the climate and environmental systems?

The paleoclimatic record can provide insight into the cause and effect of global changes. The history of atmospheric carbon dioxide and methane along with records of past climates can be reconstructed from ice core samples. Similarly, the temporal covariations in the terrestrial biosphere, the carbon cycle, and climate need to be reconstructed from fossils, ocean sediments, and the geological record.

To address these opportunities and needs, DOI and NSF will focus on developing new paleoclimate methods, reconstruct past abrupt climate transitions and past warm intervals on Earth, and emphasize studies in the sensitive arid (DOI) and polar (NSF and DOI) regions.

(2) How rapidly have ecosystems adapted to past abrupt transitions in climate?

The long-term geologic record contains evidence for a number of minor- to large-scale, rapid changes that have had profound effects on Earth systems and hence offers the opportunity to observe the environmental effects (e.g., extinction and replacement of biota) of a large sudden perturbation.

While the general characteristics and timing of major abrupt changes throughout the geological record are known, the existing studies are generally incomplete and limited in scale and scope. Better understanding of their effects on Earth systems will require the integrating of records on regional to global scales for selected events.

The programs of USDA, DOI, and NSF will contribute studies that emphasize the effects on the biosphere. The ongoing paleoclimate programs of USDA focus on the impacts of fire severity and frequency on the life histories and distributions of biota. New initiatives will study the effects of climate change on arid regions (DOI), and the impact of abrupt climate changes on ecosystems (NSF).

(3) Do past warm intervals in Earth history provide appropriate scenarios to test model predictions of future global warming?

The assessment of the regional predictions of general circulation models will benefit from a comparison to data showing how representative regions responded during past warm periods. Intervals of past warm climates are known, but

most of the environmental reconstructions of those times are qualitative and the scope of the variables is not comprehensive, which is a limitation in assessing the reliability of the models.

The Program will focus on determining if regional responses to global warming are similar regardless of local conditions or causes of the warming. This goal will be addressed by existing paleoclimatic research projects, such as the Climate of the Holocene Mapping Project (COHMAP) (NSF and DOE) and the Pliocene Project (DOI), as well as by augmenting existing and supporting new interdisciplinary programs. NOAA will augment its study of integrated paleoclimate investigations and global model assessment for these warm-Earth scenarios.

Human Interactions

Table 1 shows that the FY 1991 request for this element is \$15.0 million, a \$10.2 million or 212 percent increase over the FY 1990 level.

A comprehensive picture of global change must include the relationship between biological, atmospheric, hydrologic, and terrestrial changes and the human activities that stimulate or mediate them. These relationships include both the cumulative effects of individual or group actions over long periods of time and the less-concentrated, but equally influential, effects of the actions of social and economic institutions. For example, greenhouse gas emissions are due to several social and economic factors, including growth of human population, energy consumption, agricultural and industrial practices, and regulations.

Without an understanding of human behavior and its consequences for the environment, models will be inadequate to explain, or to develop policies to deal with, global change phenomena. The following research efforts reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) *What kinds of empirical data are needed to measure and understand human interactions in global change?*

The study of human interactions is dependent on having time-series data on a wide variety of human activities and related phenomena, ranging from energy demands to food consumption patterns. The necessary first step is to establish baseline data on environmentally significant human activities that reflect the differing technological, economic, and cultural forces in various societies.

NSF is supporting the collection of baseline data in environmentally critical areas and will establish Long-Term Regional Research Sites. These will support research on methodological problems in creating data bases which span the range of human activities in various regions and societies and will also encompass historical data. DOI will develop data sets for research that addresses the human factors which influence supply and demand of water and land resources. USDA will organize the data necessary for studying the role of human behavior in natural and managed ecosystems, and in the extent and severity of fires. DOE will continue its data collection on fossil fuel utilization and carbon dioxide emissions.

(2) *How and why do human beings and human systems influence physical and biological systems?*

The development of an accurate predictive understanding of human influences on global change (and hence appropriate public policy responses) is dependent upon the availability of data bases that span time and space, characterizing the fundamental processes of change in human systems, and the interactions of these systems with the physical and biological processes. Therefore, a critical early step in understanding human interactions in global change is the support of process studies.

NSF will expand its Human Dimensions of Global Environmental Change Program to put additional emphasis on social processes such as the economic influences in deforestation and the effectiveness of legal and regulatory controls over water resources. NSF's Long-Term Regional Research Sites will be the focus of research on long-term patterns and processes of social, economic, and ecological change. DOI will support the development of methods to estimate: (i) tradeoffs among competing social, environmental, and economic goals, and (ii) the role of human choices on water supplies and in coastal erosion and inundation. USDA's research program will include the effect of fires on rural population distributions.

Solid Earth Processes

Table 1 shows that the FY 1991 request for this element is \$80.9 million, a \$23.5 million or 41 percent increase over the FY 1990 level.

Many solid Earth processes are directly involved in the life-sustaining elements of the regional and global environment. Melting of glaciers, especially polar ice sheets, would cause sea level to rise; large volcanic eruptions can cause climatic cooling for short periods of time; and methane released from permafrost and gas hydrates in response to climatic warming can change atmospheric composition. An improved understanding of solid Earth processes will allow for more effective long-term planning in those coastal regions most vulnerable to rising sea level and for the protection of human populations most apt to be endangered by volcanic eruptions and other catastrophic solid earth processes.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) *How do different coastal regions respond geologically and ecologically to higher sea level, and how can the contributions from changes in climate (e.g., glacier melting and ocean warming) be differentiated from those due to tectonic processes?*

Sea level is predicted to rise as a consequence of global warming, but the absolute magnitude, rate, and timing of the sea level rise are uncertain. Elevated sea level could have serious consequences for coastal environments and human populations, and an improved predictive capability for sea level rise is required for the effective formulation of adaptation or mitigation strategies.

Understanding sea level changes and their consequences requires measurements of the absolute magnitude and rate of sea level rise; differentiation between the contributions of climatic change from those due to movements of the Earth's crust; and prediction of the geological and ecological response of different coastal environments.

Ongoing and new research programs that contribute to these areas include: studies of glaciation and deglaciation during periods of climatic change (NSF and DOI); *in situ* global sea level network (NOAA); satellite ocean altimetry (TOPEX: NASA); the NOAA, NSF, and NASA programs to use the space-based Global Positioning System (GPS), Satellite Laser Ranging (SLR), and Very Long Baseline Interferometry (VLBI) to measure sea level changes; studies of coastal erosion and inundation on the East Coast of the United States (DOI and NASA); Coastal Wetlands Change and Dynamics Program (DOI); and the application of new isotopic methods for dating of landforms, soils, and sediments (NSF).

(2) What are the magnitude, geographic location, and frequency of volcanic eruptions and their effect on climate?

Large volcanic eruptions emit gases, ash, and aerosols into the atmosphere that can cause significant short-term perturbations to the Earth's climate by changing the radiative budget. It is essential to quantify climate change induced both by volcanic eruptions and by increased abundances of greenhouse gases.

Understanding the impact of volcanic eruptions on the Earth's climate requires an improved understanding of the magnitude, frequency, and geographic location of subaerial and submarine volcanic events and the nature and amount of emitted material. Hydrothermal venting from the ocean floor is a major source of heat from the Earth's interior, and it influences the global carbon cycle.

Several ongoing and new programs contribute to this research effort including: studies of gas and ash emissions and degassing processes from U.S. volcanoes (DOI); satellite measurements of atmospheric volcanic aerosols and sulfur gases (Total Ozone Mapping Spectrometer, Earth Probes, and EOS: NASA); and studies of the fluxes of energy, gases, fluids, and particulates from submarine eruptions on the mid-ocean ridges (Ridge Interdisciplinary Global Experiment [RIDGE]: NSF, NOAA and DOI).

(3) How do permafrost regions of the Northern Hemisphere respond to climate warming?

An accelerated release of methane trapped in arctic permafrost and gas hydrates due to a climatic warming would alter the chemical composition of the atmosphere and further enhance the greenhouse effect. Ongoing and new research will contribute to this area through projects that study the dynamics of permafrost change (NSF) and by assessing whether there is a current climatic warming on a local, regional, or hemispheric scale by monitoring subsurface temperatures in arctic permafrost (DOI).

Solar Influences

Table 1 shows that the FY 1991 request for this element is \$13.2 million, a \$4.4 million or 50 percent increase over the FY 1990 level.

The sun influences two of the most important current policy-related phenomena: the depletion of ozone by chlorofluorocarbons and climate warming due to greenhouse gases. In both areas, the main scientific problem is one of separating the effects that are due to human influences from changes induced by natural forcing agents, such as the sun.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What aspects of solar variability are influencing the stratospheric ozone layer?

Since ozone is generated by the breakup of oxygen by solar UV radiation, observed ozone changes will depend, in part, on solar activity. Thus, the detection of human-caused ozone depletions requires that the solar component of ozone change be properly accounted for. This understanding requires long-term UV observations of adequate precision ($\pm 1\%$) over the solar cycle. The required observations will be provided by instruments on NASA's Upper Atmosphere Research Satellite (UARS) and EOS.

(2) What impact do other inputs, e.g., particles, have on the upper atmosphere and how are they coupled to other atmospheric regions?

The physical properties of the upper atmosphere (e.g., temperature, composition, and density) are sensitive to human-influenced gases, such as carbon dioxide and methane, and to solar particles. Changes induced by these agents could be quite substantial and hence could affect satellite orbits and provide

insight into potential sun-atmosphere couplings. NSF's Coupled Energetics and Dynamics of Atmospheric Regions (CEDAR) and Geospace Environment Modeling (GEM) programs will begin the establishment of data bases on solar inputs relevant to the global circulation and couplings.

(3) How does the sun's output vary and what is the impact on terrestrial climate?

A key factor in establishing the Earth's radiation budget is the total solar radiation reaching the planet. This requires continuous measurements of the total solar radiation with very high long-term stability (0.1%). These observations will be provided by Active Cavity Radiometer Irradiance Monitors (ACRIM) on NASA's UARS and EOS.

Data Management

Table 1 shows that the FY 1991 request for data management is a \$129.4 million, a \$64.2 million or 98 percent increase over the FY 1990 level.

Data and information management will provide a bridge between global change observations and scientific understanding, and will be a key factor in the success of programs carried out within all seven interdisciplinary science elements. The traditional concepts and present practices of data management are inadequate for global change studies. The interdisciplinary, interagency, and international aspects of these studies, coupled with a long-term view, pose unprecedented challenges to the data management and research communities alike. Consequently, cooperation in seeking new approaches to archiving and management of data is essential.

Data management includes the means and mechanisms to describe, gather, transmit, validate, process, archive, and disseminate data. The initial thrust will be on data base development in the highest priority science elements and

strengthening the infrastructure required to process, manage, and improve access to the great variety of ground- and space-based observations.

The key data management questions with policy implications include:

(1) How can the data handling and access capabilities be best organized and strengthened?

Data management systems for global change must be able to accept and archive dissimilar types of data collected from different data collection systems, i.e., both ground- and space-based data by different organizations in different formats and on different media.

Interactions among CES agencies through the Interagency Working Group on Data Management for Global Change and with the science community have begun to facilitate improved access to data and data handling capabilities. A major problem facing scientists attempting to use global change data sets is that it is extremely difficult to find out who has what data and how good the data are. Using existing facilities, NASA, NOAA, NSF, DOE, and DOI will continue to develop and expand a Master Directory for Global Change Data by linking with a common architecture, directories, catalogs, and inventories of data in all global change science elements. Hundreds of global change data sets already have been documented and entered.

Studies have been initiated to develop archives with improved quality control, documentation, and ease of access to satellite data, including formation of the EOS Data and Information System (NASA, NOAA and DOI), and procedures are being developed for better distribution of digital data bases. Access to and assimilation of the DOD environmental data bases are being addressed. Bilateral agreements have been signed between NASA and NOAA and between NASA and

USGS for the development of data systems to manage satellite data. The exchange of satellite information between NASA, NOAA, European Space Agency (ESA), Canada, and Japan has been instituted. NASA and NOAA are gathering relevant foreign data to combine with U.S. data.

(2) How can the agencies build the data sets needed to facilitate early results from the Program?

Long-term global measurements must routinely be supported by documentation regarding instrument calibrations, coverage, sampling, data editing, data reduction algorithms, including ancillary data, algorithm validation, assimilation or analysis procedures, and correlative measurements.

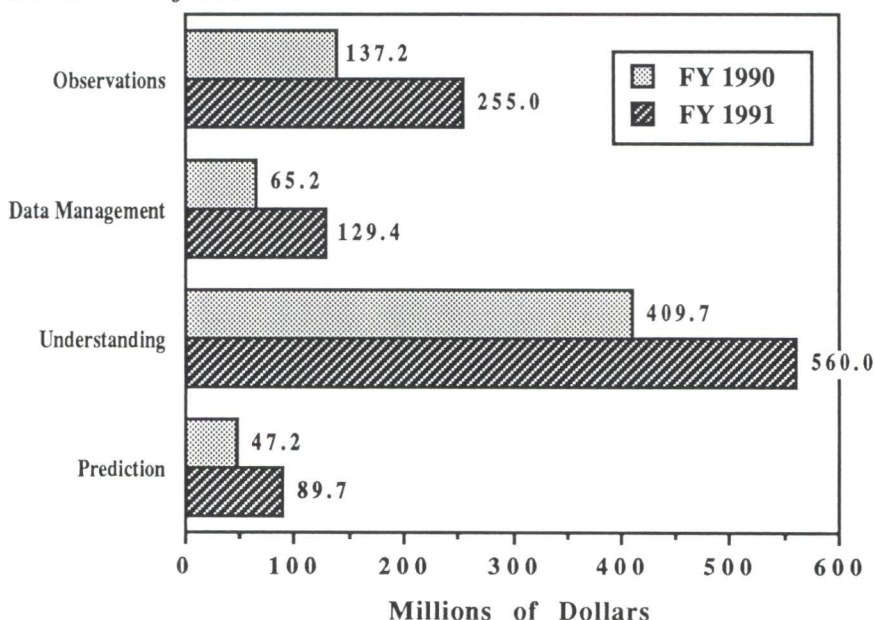
Many ongoing and new research programs contribute to the task of developing integrated global-scale satellite and *in situ* data sets that will support model development including the development of data bases in support of: biological responses to climate, abrupt climate change, anthropogenic forces in global change, long-term ecological research, studies of ecosystem stress, land-surface data, fire severity and occurrence, sea surface temperature fields, and regional ecosystem variables that are sensitive to global change. (All CES agencies are involved in one or more of these activities.) DOE will support a critical review of data for climate modeling, and NSF will support a geosystems data base activity that includes the development and quality control of model-generated data sets. On a priority basis, data sets are being extended into the past, both to document global change and to test and validate diagnostic and predictive models. NOAA and NSF data management elements provide resources for the development of historical and paleo data bases. DOE and DOI have similarly focused programs.

Budget by Scientific Objective

Figure 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by scientific objective: observations, data management, understanding, and prediction. These budgets reflect a balance between each of the scientific objectives, with a strong commitment to data management.

Figure 3
U.S. Global Change Research Program Budget
by Scientific Objective

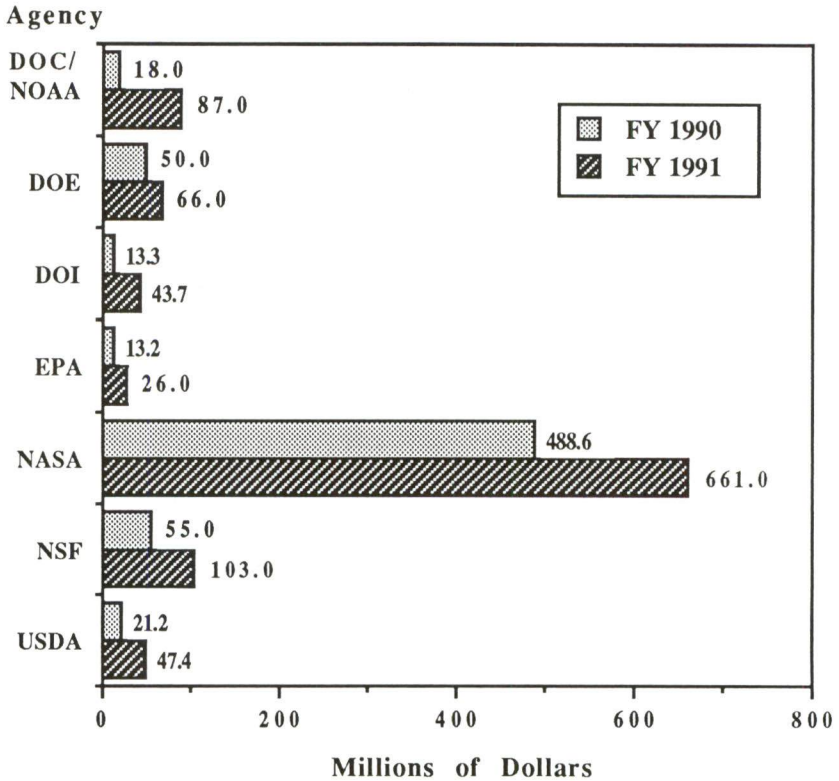
Scientific Objective



Budget by Agency

Figure 4 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by agency. The individual agency efforts build upon their respective scientific and technical strengths.

Figure 4
U.S. Global Change Research Program Budget
by Agency



National Oceanic and Atmospheric Administration (NOAA).

In FY 1991, NOAA has proposed an \$87 million Climate and Global Change Program in support of the U.S. Global Change Research Program. This represents a \$69 million or 383 percent increase above the FY 1990 level. The FY 1991 NOAA contribution involves enhancements to ongoing efforts in: operational *in situ* and satellite observation programs with an emphasis on oceanic and atmospheric dynamics (including sea level), circulation, and chemistry; focused research on ocean-atmosphere interactions, the global hydrological cycle, the role of oceanic circulation and biogeochemical dynamics in climate change, atmospheric trace gas/climate interactions, and the response of marine resources to climate change and related stresses; and programs to improve climate modeling, prediction, and information management capabilities.

Department of Energy (DOE). In FY 1991, DOE has proposed a \$66 million budget for global change research, a \$16 million or 32 percent increase above the FY 1990 level. The DOE maintains a research program directed at the impact of energy production and use on the global Earth system by focusing primarily on climate, atmosphere, ocean, and ecosystem responses. DOE will augment research on climate modeling; studies of carbon dioxide sources in the atmosphere, oceans, and land; impacts on vegetation and ecosystems; and research efforts to quantitatively describe the radiative balance and the cloud-climate feedback in the atmosphere. New initiatives focus on critical data needs for global change research and the climatic variables that may serve as indicators of global change; and on funding to provide education and training to the next generation of scientists.

Department of the Interior (DOI). In FY 1991, DOI has proposed a \$43.7 million budget for global change research, a \$30.4 million or 229 percent increase above the FY 1990 level. DOI efforts include studies of: paleoclimates; interaction and sensitivity of hydrologic, ecological, and landscape systems with climate; arid, polar, and coastal regions and systems; volcano-atmosphere interactions; methane hydrates; changing

land surface characteristics; ocean heat fluxes; social, environmental, and economic consequences of global change including human activities, water resources, biological species variation, and land management; and carbon cycle variation studies; as well as archiving and distributing space- and land-based Earth science data.

Environmental Protection Agency (EPA). In FY 1991, EPA has proposed \$26 million for global change research, an increase of \$12.8 million or 97 percent above the FY 1990 level. EPA's research efforts are focused on evaluating the processes and quantifying the relative contributions of anthropogenic and biological sources of trace gases, quantifying and modeling the consequences of climate change on ecosystems and their subsequent feedback to the atmosphere, and the interaction of trace gases in the atmosphere. Special emphasis will be given to climate sensitive regions, e.g., tundra, wetlands and forests. EPA's research will help provide the process-level understanding and modeling capabilities to predict global change.

National Aeronautics and Space Administration (NASA). In FY 1991, NASA has proposed \$661 million for global change research, an increase of \$172.4 million or 35 percent above the FY 1990 level. NASA research efforts are primarily focused on space-based studies of the Earth as an integrated system. These activities include ongoing research and satellite programs (e.g., the Upper Atmosphere Research Satellite, Ocean Topography Experiment, etc.) that are important precursors to the FY 1991 initiatives: Earth Probes (a series of satellite measurements prior to EOS to monitor atmospheric ozone, ocean color, precipitation in the tropics, and ocean surface winds) and the Earth Observing System (EOS). EOS will provide an integrated, comprehensive monitoring and data management program of simultaneous measurements of key global change variables.

National Science Foundation (NSF). In FY 1991, NSF has proposed \$103 million for global change research, an increase of \$48 million or 87 percent above the FY 1990 level. NSF proposes to augment and initiate programs coordinated internationally to observe, understand, and model atmospheric, oceanic, terrestrial, and social processes and their coupled interactions. Studies include ocean circulation, ocean-atmosphere interactions, cloud-radiation interactions, global atmospheric chemistry, biogeochemical processes, land-sea interactions, past climate change, crustal and related processes impacting global change, ecosystems, solar processes, human dimensions of global change, data base research and development, and a multi-agency education initiative for global change.

United States Department of Agriculture (USDA). In FY 1991, USDA has proposed \$47.4 million for global change research, an increase of \$26.2 million or 124 percent above the FY 1990 level. USDA research efforts are focused on ground-based research programs studying agricultural, forest and range ecosystems as influenced by factors such as water balance, atmospheric deposition, plant responses to changes in atmospheric constituents, UV-B radiation and other global change variables. Some representative studies that will focus on agricultural effects on environmental variables will include mechanisms of methane generation and nitrous oxide release; soil properties including moisture, erosion, organic matter dynamics, nutrient fluxes, and microbes; relationship of global change to forest and range fires, insects, and plant pathogens; and agricultural management systems.

Budget by Federal Budget Function

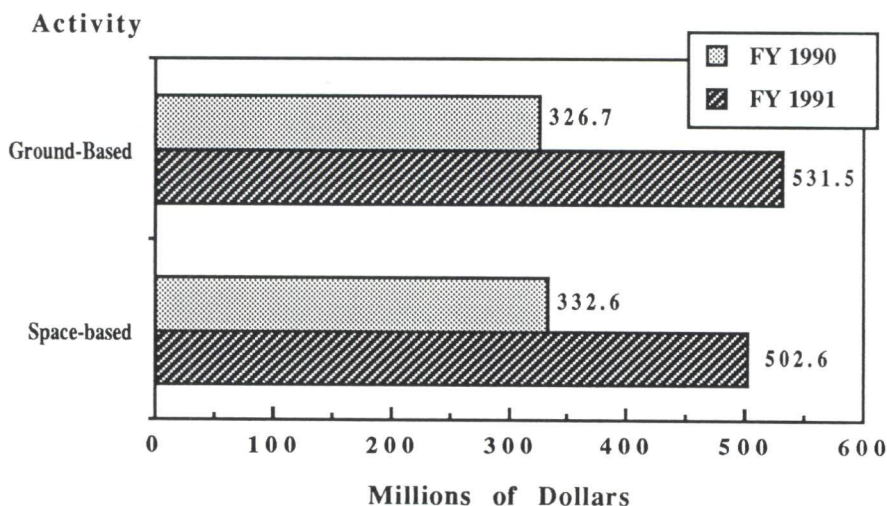
Scientific, environmental, energy, and agricultural resources are vital to the health of our Nation. Table 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by Federal Budget Function. In FY 1991, significant increases above FY 1990 levels are proposed for each budget function. The U.S. Global Change Research Program must be viewed as a single integrated research effort with its success dependent upon cooperation and contributions from each of the individual agency programs.

Table 3 FY 1990 - 1991 U.S. Global Change Research Program by Budget Function (Dollars in Millions)				
Budget Function	Budget Function Number	1990	1991	
TOTAL		659.3	1034.1	
General Science, Space and Technology	250	543.6	764.0	
NASA		488.6	661.0	
NSF		55.0	103.0	
Energy (DOE)	270	50.0	66.0	
Natural Resources and Environment	300	44.5	156.7	
DOI		13.3	43.7	
EPA		13.2	26.0	
DOC / NOAA		18.0	87.0	
Agriculture (USDA)	350	21.2	47.4	

Budget by Ground- and Space-Based Research

Figure 5 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by space- and ground-based research activities. Maintaining an appropriate balance between ground- and space-based research programs is essential for a successful U.S. Global Change Research Program. *In situ* and theoretical studies of physical, chemical, biological, and geological processes must be complemented by a comprehensive space-based program to provide the global observations of key environmental variables. The combination of ground- and space-based measurements is required given the temporal and spatial variability of the systems being studied, and the need to scale the processes occurring at the local level to the regional and global levels. The ground-based program is essential to interpret some of the global satellite observations (e.g., long-term trends), as well as to obtain scientific information not attainable from space (e.g., trace gas fluxes). Both types of program need to be strongly supported, and the FY 1991 budget reflects a reasonable balance.

Figure 5
U.S. Global Change Research Program Budget
by Ground- and Space-Based Programs



Ground-based: The FY 1991 request for the ground-based program is \$531.5 million, a \$204.8 million or 63 percent increase over the FY 1990 level. The budgets of NOAA, DOE, DOI, EPA, NASA, NSF, and USDA include support for a broad range of ground-based and modeling research activities. The activities range from small individual investigator research programs to participation in complex international scientific projects. The budgets would initiate multi-agency research thrusts in several critical areas including: the role of the oceans and terrestrial biosphere in trace gas fluxes; the exchange of energy between the oceans and atmosphere; the cycling of water throughout the Earth system; and expanded monitoring of responses to global change, such as sea level.

Space-based: The FY 1991 request for space-based programs is \$502.6 million, a \$170.0 million or 51 percent increase over the FY 1990 level. The NASA budget includes continued support for TOPEX and UARS, as well as the Earth Probes and EOS initiatives. The TOPEX, UARS, and Earth Probes missions will provide key global measurements, prior to the EOS era that starts in late 1997, including stratospheric composition; surface topography of the global oceans and sea surface wind velocity in order to advance the understanding of ocean circulation; rainfall in the tropics in order to determine the role of tropical precipitation in climate; and ocean color to improve the understanding of ocean productivity. EOS will provide an integrated, comprehensive monitoring program of simultaneous measurements of key global change variables, coupled with a comprehensive data and information system.

U.S. scientific agencies are playing a key role in a number of interdisciplinary international scientific programs involving the land, oceans, and atmosphere, and interactions between them, that require a combination of ground- and space-based measurements for successful implementation. These programs include: World Ocean Circulation Experiment; Tropical Ocean - Global Atmosphere; Global Ocean Flux Studies; Global Ocean Ecosystems Dynamics; Global Energy and Water Cycle Experiment; Global Tropospheric Chemistry Program; International Satellite Cloud Climatology Program; and International Satellite Land Surface Climatology Program.

The Carbon Cycle: An Example of Interdisciplinary Research

Modification of the global carbon cycle by human activities spans both science and policy concerns. This section of the report presents a case study of how the U.S. Global Change Research Program approaches a complex multidisciplinary research area like the carbon cycle.

Policy Needs

Emission of carbon dioxide from the combustion of fossil fuels and changes in land-use practices, and of methane from cattle, rice paddies, permafrost, natural wetlands, gas hydrates, and natural gas production are partly responsible for perturbation of the carbon cycle. Changes in the carbon cycle may affect regional and global climate, the chemistry of the atmosphere, the hydrologic cycle, and the productivity and functioning of ecosystems. Consequently, prudent environmental policy formulation will require a solid scientific understanding of how the carbon cycle varies naturally, how human activities change it, and how it might respond to future changes in environmental conditions.

Scientific Background

Atmospheric carbon dioxide is a radiatively active trace gas with concentrations 25 percent greater now than in the pre-industrial era (prior to 1850) and increasing at about 0.4 percent annually because of human activities. Annual anthropogenic emissions of carbon dioxide are currently about 5.5 billion metric tons from fossil fuel combustion, plus an additional 0.8 to 3.0 billion metric tons from tropical deforestation. Over the past century, fossil fuel use and cement manufacturing released about 200 billion metric tons of carbon into the atmosphere. In the same time period, land-use changes (primarily deforestation) may have released as much as an additional 115 billion metric tons of carbon. However, only 130

billion metric tons of these combined releases remain in the atmosphere. A critical question concerning the global carbon balance is, "What has happened to the remaining carbon dioxide and what will happen to it in the future?"

The natural fluxes of carbon dioxide into and out of the atmosphere from the oceans and terrestrial biosphere are an order of magnitude greater than the anthropogenic fluxes. The oceans, which contain about 50 times more carbon than does the atmosphere, are known to be an important long-term sink for carbon from the atmosphere. In addition, while terrestrial vegetation has always assimilated atmospheric carbon dioxide by photosynthesis, it recently has been suggested that vegetation and soils at northern mid-latitudes may be becoming more effective in sequestering carbon from the atmosphere because of either changes in land management (e.g., reforestation) or because the increasing atmospheric carbon dioxide concentrations may be stimulating plant productivity. These oceanic, terrestrial, biogeochemical, and ecological processes ultimately determine the fate of carbon dioxide from human activities. However, uncertainties in the knowledge of the magnitude of the oceanic and terrestrial sinks limit the accuracy of forecasts of the future fraction of "anthropogenic" carbon dioxide that will remain in the atmosphere.

Atmospheric methane is a radiatively and chemically active trace gas whose concentration is now a factor of two greater than it was in the pre-industrial era and is increasing at about 1 percent annually, presumably because of human activities. The atmospheric abundance of methane is controlled by emissions from oxygen-deficient sources such as natural wetlands, permafrost and gas hydrates, rice cultivation, biomass burning, cattle, natural gas venting, and removal by atmospheric chemical reactions.

Uncertainties in the knowledge of the magnitude of the individual sources and sinks of carbon dioxide and methane severely limit the accuracy of forecasts of their future atmospheric concentrations.

Required Understanding

Biological and physical processes control the uptake and release of carbon by the oceans, and ecosystem dynamics are equally important on land. Economic and human factors dictate the magnitude of fossil fuel emission and the intensity of land disturbance. The task of predicting future abundances of atmospheric carbon dioxide, methane, and other carbon-containing gases requires scientific information, spanning numerous scientific disciplines, including: the exchange of carbon dioxide between the oceans and the atmosphere; the exchange of carbon dioxide and total carbon between the shelves and open oceans, and between the surface waters, deep ocean and sediments; the exchange of gases between terrestrial ecosystems and the atmosphere; the storage and cycling of carbon within terrestrial ecosystems; the extent and ecological state of terrestrial and aquatic ecosystems; atmospheric distributions and transformations of gases; paleocarbon budgets; and the influence of human choices on the carbon cycle.

U. S. Global Change Research Program Approach

After evaluating the policy needs, scientific background, and required understanding, a responsive, multidisciplinary research effort was developed. The box on page 54 gives examples of specific U.S. Global Change Research Program activities related to the carbon cycle. Synthesis and integration of results obtained by investigators working within their numerous disciplines is a critical challenge guiding the U.S. Global Change Research Program. This diversity of research, data collection, and modeling activities is typical of global change research.

Examples of Carbon Cycle Research Activities in the FY 1991 U.S. Global Change Research Program

Climate and Hydrologic Systems

- *General Circulation Models (GCM)*. Conduct carbon dioxide scenario experiments in GCMs using coupled atmosphere-ocean models. (DOE, NASA, NSF, and NOAA)

Biogeochemical Dynamics

- *Earth Probes: Satellite Ocean Color Imager and Scatterometer*. Determine ocean productivity and the wind stress at the ocean surface, which will help characterize the carbon dioxide flux across the air/sea interface. (NASA)
- *Ocean Carbon Studies*. Initiate a program of high-precision measurements of carbon dioxide and total carbon, investigate the cycling of carbon in the world's oceans, and determine the air-sea flux of carbon dioxide. (NSF, NOAA, and DOE)
- *Global Carbon Dioxide and Methane Trends*. Monitor the changing abundance of the radiatively active trace species at globally distributed sites. (NOAA, NSF, NASA, and DOE)
- *Terrestrial/Atmospheric Carbon Cycling*. Determine the fluxes of methane and non-methane hydrocarbons from terrestrial ecosystems and the atmospheric processes that establish their lifetime. (NASA, NSF, NOAA, DOE, EPA, and DOI)

Ecological Systems and Dynamics

- *Carbon Cycling in Ecosystems.* Study carbon cycling in terrestrial ecosystems and the processes controlling carbon dioxide fluxes from photosynthesis, respiration, and land-use changes. (DOE, EPA, DOI, USDA, and NSF)
- *Land-Surface Characterization.* Develop data bases for improved vegetation characterization, such as vegetation/land-cover maps, and vegetation greenness indices. (DOI, NOAA, and NASA)

Earth System History

- *Paleo-Atmospheric Carbon Dioxide Abundances.* Carry out ice core studies of carbon dioxide concentrations and other associated variables. (DOE and NSF)
- *Geological History of the Carbon Cycle.* Reconstruct changes in the distribution of carbon isotopes in the Earth's systems. (NSF and DOI)
- *Modeling the Past Carbon Cycle.* Develop models of the long-term partitioning of carbon between the atmosphere, ocean, and terrestrial reservoirs. (DOI)

Human Interactions

- *Carbon Dioxide Emissions.* Develop second-generation carbon dioxide emission models. (DOE)
- *Carbon Dioxide and Standard of Living.* Examine the national differences in fossil fuel consumption and its relation to the standard of living. (NSF)

Solid Earth Processes

- *Volcanic Carbon Dioxide.* Assess long-term volcanic contributions of carbon dioxide to the oceans and atmosphere. (DOI, NSF, and NOAA)
- *Methane Emissions from Permafrost and Methane Hydrates.* Assess the volume and potential release of methane from permafrost and methane hydrates. (DOI and NSF)

Special Issues

The CES has addressed several issues that are important to the success of the U.S. Global Change Research Program. The sections below describe those issues and the approach that CES has taken.

Education

The science of global change is complex and inherently multidisciplinary. While unraveling answers to scientific questions undoubtedly will require new approaches and technology, another important concern is the development of the human resources and scientific talent to conduct multidisciplinary global change research.

To address this need NSF and DOE will initiate human resources programs in FY 1991 that will annually support several hundred postdoctoral appointments, graduate students, and undergraduate students as research participants, as well as several summer institutes on interdisciplinary global change research problems. The NSF program will be managed by representatives from each of the CES agencies. Training opportunities, both in the U.S. and abroad, will include: (i) support at the individual project level, (ii) training centered at major research centers or technology centers, and (iii) opportunities for students to pursue training at institutions of their choice. The DOE program will encourage basic training at universities offering interdisciplinary programs and operational experience in team research at national laboratories and other science and technology centers. In addition, one component of the NASA EOS program is for educational scholarships.

Emerging Disciplines

The U.S. Global Change Research Program presented here should not be viewed as a full exposition of the details of the program in the outyears. The program will evolve as new projects are developed in response to scientific developments

and policy needs. Each of the U.S. scientific agencies has programs at various stages of planning, and furthermore, there are major scientific planning activities related to global change within U.S. (Committee on Global Change of the National Academy of Sciences) and international (e.g., the International Geosphere-Biosphere Programme [IGBP] of the International Council of Scientific Unions [ICSU], and the World Climate Research Programme [WCRP] of the World Meteorological Organization [WMO]) scientific communities that have not reached the point of submission to agencies for any formal consideration. Examples include work on paleontology, hydrology, experimental ecology, and human interactions.

International Dimension

The U.S. Global Change Research Program is founded on the premise that international cooperation and coordination are fundamental to the scientific planning and the implementation of the entire Program. Research programs like the IGBP and the WCRP are truly international in scope and in design. The complex scientific agenda and the infrastructure needed to address the programs outlined here require a careful assessment and integration of the Program's components with programs of other governments; intergovernmental bodies (e.g., U.N. bodies such as the IPCC); and international non-governmental science coordinating and facilitating mechanisms (e.g., ICSU).

There is no "international" budget item included in the U.S. Global Change Research Program because it is integral to each project element. A major CES coordinating effort has been initiated with ICSU and the international scientific community, the intergovernmental organizations, and CES-like bodies in other countries. During 1990, it is expected that an integrating infrastructure will begin to evolve; will be endorsed by the various participating agencies, organizations, and institutions; and will involve to some extent the private and industrial sector. Bilateral and multilateral research agreements and programs between the U.S. and other countries are an essential part of this international framework.

Appendix

FY1990-1991 Global Change Research Program by Project

Agency		Project	Program Status
DOC	NOAA	TOGA-Tropical Ocean-Global Atmosphere,, incl. COARE-Coupled Ocean Atmos. Response Expt. Ocean Dynamics&Circulation: Atlantic Variability	Enhanced
DOC	NOAA	WOCE-World Ocean Circulation Experiment	
DCO	NOAA	Chemical Tracers & WOCE Hydrography	
DOC	NOAA	Global Hydrological Cycle/GEWEX	
DOC	NOAA	Upper Ocean/Marine Surface Observations	
DOC	NOAA	Stratospheric Monitoring	
DOC	NOAA	Global Sea Level	
DOC	NOAA	Ocean Carbon	
DOC	NOAA	Climate Data Assimilation System	
DOC	NOAA	Long-Term Data Mgmt Planning & Infrastructure	
DOC	NOAA	Climate Modeling & Analytical Centers	
DOC	NOAA	Climate Diagnostics & Database Development	
DOC	NOAA	Paleoclimate Diagnostic Studies	
DOC	NOAA	Marine Sulfur Emissions/Cloud Feedbacks	
DOC	NOAA	Trace Gases/Radiatively Important Trace Species	
DOC	NOAA	Operational Ocean Modeling	New
DOC	NOAA	Long-Term Observing System Planning	
DOC	NOAA	Measurement Technique Development & Testing	
DOC	NOAA	GESDM-Global Environ. Sciences Data Mgmt	
DOC	NOAA	Near-Term Forecasting Improvement	
DOC	NOAA	Marine Ecosystem Response	
DOC	NOAA	Model-Based Fluxes	Existing
DOE	OHER	Core CO ₂ Research	
DOE	OHER	Effects	
DOE	OHER	Information/Coordination	
DOE	OHER	Human Interactions	
DOE	OHER	Oceans	
DOE	OHER	Quantitative Links	Enhanced
DOE	OHER	ARM-Atmospheric Radiation Measurements	
DOE	OHER	Data for Climate Modeling/Detection	New
DOE	OHER	Education	
DOI	USGS	Coastal Erosion & Inundation	Existing
DOI	USGS	Permafrost	Enhanced
DOI	USGS	Interaction of Climate & Hydrologic Systems	
DOI	USGS	Land Surface Data System	
DOI	USGS	Paleoclimates Research	
DOI	USGS	Climate Arid Regions	
DOI	USGS	Biogeochemistry of Greenhouse Gases	New
DOI	FWS	Coastal Wetland Change & Dynamics	
DOI	FWS	Monitoring Fish & Wildlife Impacts	
DOI	MMS	Ecosystem Stress	
DOI	MMS	Physical Oceanography	
DOI	NPS	Integrated Studies NPS Ecosystems	

DOI	NPS	Dynamics of Coastal Systems	New
DOI	PBA	MESEEC- Methodologies to Estimate Social, Economic, and Environmental Consequences	
DOI	PBA	TOCSEEG-Tradeoffs between Competing Social, Environmental & Economic Goals	
DOI	BLM	Ecological Change in Environmentally Stressed Ecosystems of the Western & Northern U.S.	
DOI	USGS	Biogeochemical Research	
DOI	USGS	Sensitivity Hydrologic Systems	
DOI	USGS	Land Characterization	
DOI	USGS	Volcano Emissions	
DOI	WBR	Regional Studies	
DOI	WBR	Sensitivity Hydrologic Systems	
EPA	ORD	Emissions Research	Existing
EPA	ORD	Stratospheric Ozone	Enhanced
EPA	ORD	Ecological effects	
EPA	ORD	Regional Climate	
EPA	ORD	Biofeedbacks	
EPA	ORD	Tropospheric Chemistry	
NASA	OSSA	Space- Based	Existing
NASA	OSSA	UARS-Upper Atmosphere Research Satellite	
NASA	OSSA	TOPEX-Ocean Topography Experiment	
NASA	OSSA	Payload & Instrument Development	
NASA	OSSA	Scatterometer	Enhanced
NASA	OSSA	Operations & Data Analysis	
NASA	OSSA	Earth Observing System (EOS) Platform	
NASA	OSSA	EOS-Earth Observing System	New
NASA	OSSA	Earth Probes	
NASA	OSSA	Ground-based	Existing
NASA	OSSA	Solid Earth Science	
NASA	OSSA	Interdisciplinary Research & Analysis	Enhanced
NASA	OSSA	Suborbital Research Observations	
NASA	OSSA	Model & Data Hydrology/Circ./Physical Climate	
NASA	OSSA	Model & Data Solid Earth/Ecological Systems/ Biogeochemical Dynamics	
NASA	OSSA	Hydrologic/Circulation/Physical Climate Processes	
NASA	OSSA	Upper Atmosphere Research Program	
NASA	OSSA	Laser Network	
NASA	OSSA	Ecosystem Dynamics & Biogeochemical Processes	
NSF	GEO	Stratospheric Ozone	Existing
NSF	GEO	Antarctic Ecosystems	Enhanced
NSF	GEO	TOGA-Tropical Oceans-Global Atmosphere	
NSF	GEO	GTCP-Global Tropospheric Chemistry Program	
NSF	BBS	HDGEC-Human Dimensions of Global Environmental Change	
NSF	GEO/BBS	LMER-Land-Margin Ecosystems Research	
NSF	GEO	RIDGE-Ridge Interdisciplinary Global Experiment	
NSF	GEO	Geodynamics	
NSF	GEO	ARCSS-Arctic Systems Science	
NSF	GEO	Geologic Record	
NSF	GEO	CEDAR-Coupling, Energetics, & Dynamics of Atmospheric Regions	

NSF	GEO	GOFS-Global Ocean Flux Study	Enhanced
NSF	GEO	WOCE-World Ocean Circulation Experiment	
NSF	BBS	Bioresponse to Climate	
NSF	GEO	GEWEX-Global Energy & Water Cycle Experiment	
NSF	GEO	GEM-Geospace Environment Modeling	New
NSF	CES/NSF	Education & Training Program	
NSF	GEO	Abrupt Climate Change	
NSF	GEO	GLOBEC-Global Ocean Ecosystems Dynamics	
NSF	GEO/BBS	Geosystems Databases	
NSF	GEO	CHP-Continental Hydrologic Processes	
USDA	ARS	Biological Response to UV-B	Existing
USDA	CSRS	Atmospheric Deposition	
USDA	CSRS	Stratospheric Ozone Depletion	Enhanced
USDA	FS	Water Yield, Erosion & Sedimentation	
USDA	FS	Wildlife/Domestic Species Interactions	
USDA	FS	Aquatic Ecosystems & Fisheries Habitat	
USDA	FS	Fire Severity	
USDA	FS	Energy, Water, Carbon & Nutrient Cycles	
USDA	FS	Microbes, Plant Pathogens & Insects	
USDA	FS	Species Life History	
USDA	ARS	Ecosystem Modeling	New
USDA	ARS	Biogeochemical Fluxes	
USDA	ARS	Ozone Effects	
USDA	CSRS	Methane & Trace Gases	
USDA	SCS	Pedosphere-Paleoecology	
USDA	SCS	Pedosphere-Processes	

Key to Program Status



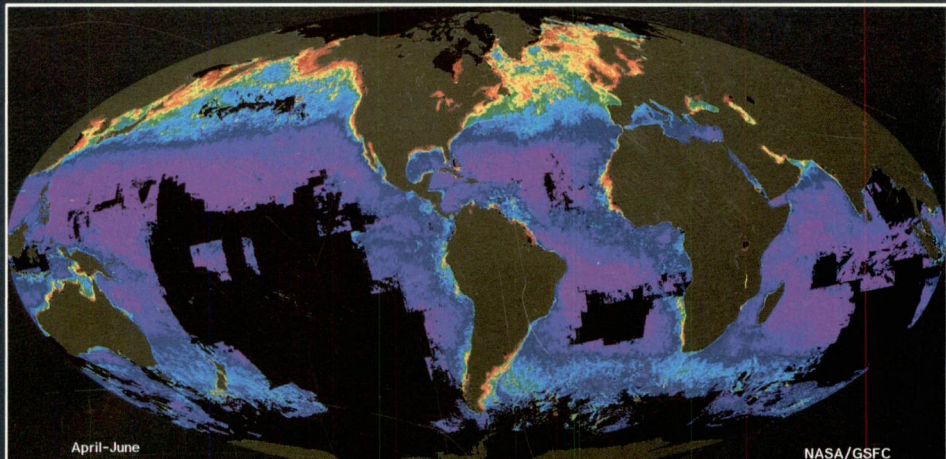
Existing Program
Enhancement of Existing Program
New Initiative

Agency Acronyms

DOE	OHER	Office of Health & Environmental Research
DOI	FWS	Fish & Wildlife Service
	MMS	Minerals Management Service
	NPS	National Park Service
	PBA	Policy & Budget Administration
	WBR	Bureau of Reclamation
	USGS	U.S. Geological Survey
EPA	ORD	Office of Research & Development
NASA	OSSA	Office of Space Science & Applications
NSF	GEO	Geosciences Directorate
	BBS	Biological, Behavioral & Social Sciences Directorate
USDA	ARS	Agriculture Research Service
	CSRS	Cooperative State Research Service
	FS	Forest Service
	SCS	Soil Conservation Service

Global phytoplankton concentrations change seasonally. This three-month composite of phytoplankton concentrations for April—June in 1979 and 1980 shows the “blooming” of phytoplankton over the entire North Atlantic with the advent of northern hemisphere spring. Phytoplankton pigment concentrations range from red (most concentrated) to purple (least concentrated). These measurements were made by the Coastal Zone Color Scanner (CZCS), a radiometer that operated on NASA's Nimbus 7 satellite from 1978 to 1986.

*The U.S. Global Change
Research Program*



April-June

NASA/GSFC