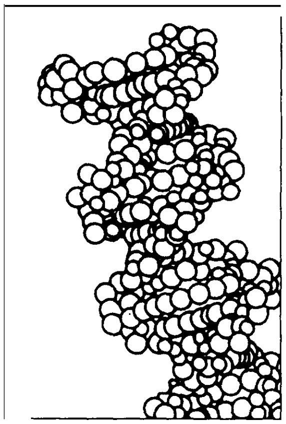
# Global Change Research in the Federal Government

# 3

On October 13, 1992, the United States ratified the United Nations Framework Convention on Climate Change. The convention was one of the key accomplishments of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Its declared goal is ‘‘stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system, ’ and it calls for parties to return “individually or jointly to their 1990 levels of these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol” (46). Most of the 166 countries that signed the convention have pledged to do so by 2000 (on April 21, 1993, President Clinton made a commitment to reduce U.S. greenhouse gas emissions to 1990 levels by that year). The convention also requires all participating countries to prepare action plans detailing their strategy to mitigate climate change. The Biodiversity Convention, signed by most developing and industrialized countries at UNCED, calls for the development of strategies for global biodiversity conservation, and Agenda 21, the comprehensive action agenda to promote sustainable development adopted at UNCED, also calls for policies to minimize environmental degradation.

All these concerns about climate change, biodiversity, and sustainable development reflect a policy agenda that is inextricably linked to scientific research. “The relationships between scientific and technological advancement and government support are complex, and the stakes in these decisions are high, not just for scientists and engineers, but for society as a whole. Consequently, a better understanding of the process of articulating goals, both within and outside science, is vital” (3).



The Federal Government launched a multi-agency research effort in 1989 in response to the uncertainties and potential risks of climate change. Its purpose is to observe, understand, and predict global change (9) When the U.S. Global Change Research Program (USGCRP) was created as a Presidential Initiative in 1989, it did not have an explicit plan to link research to policy. Before codifying the program, Congress directed it to provide information useful to policy makers; however, Congress did not identify or mandate any mechanism to ensure this. When the program was first implemented, key questions of the scientists and policy makers were: Are humans significantly changing the climate, and can climate change be predicted? The program was intended to replace a crisis-driven, one-problem-at-a-time approach to environmental problems with a more systemic, proactive approach that recognizes that different environmental problems are linked by the very nature of the Earth system.[1] Although the program is scientifically well--grounded, it has become overwhelmingly a physical science program focused on basic Earth system processes that largely ignores the behavioral, economic, and ecological aspects of environmental problems. For example, understanding the role clouds play in climate change and the role of the ocean-kind-atmosphere interface is now its highest priority.

Understanding the size and scope of USGCRP can be difficult, and the coordination challenges of such a large interagency program are formidable. Agency personnel committed to the program have made a commendable effort to ensure that the program functions smoothly. However, USGCRP is not a managed entity with one budget, nor does it have an authoritative body making decisions on projects. It is, rather, a loosely coordinated collection of several programs and budgets. Even this level of coordination is undermined at the legislative level, where the program, collected into a compilation of budgets by the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), is splintered into several parts and never considered as a whole during the authorization, appropriation, and oversight processes.

The primary questions of policy makers have changed since 1989 in the wake of the world climate treaty and the publication of several key reports: the Intergovernmental Panel on Climate Change (IPCC) reports, the Environmental Protection Agency (EPA) reports on the potential effects of climate change and policy options, and the Committee on Science, Engineering and Public Policy (COSEPUP) report.[2] It is now generally accepted that unequivocal detection of the greenhouse effect requires another decade of measurements, and that rates of climate change and regional details about climate changes will not be available for at least that long (see ch. 2). Thus, questions being asked today have moved beyond the basic science issues of "observing, understanding and predicting' climate change to a second set of concerns: What can be done to mitigate or adapt to climate change? What are the climate effects of most concern? How can we manage natural and human systems wisely given an uncertain climate? Consequently, USGCRP'S mission statement and priorities are now too narrow to address questions such as how to minimum negative impacts of climate change.

The congressional committees requesting this study recognized that decisionmaking must continue in the face of uncertainty. They expressed the following concerns to the Office of Technology Assessment (OTA):

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[1] The *Earth* system is the sum of all interactions among living organisms and their biotic and abiotic environments.

[2] IPCC's *Scientific Assessment (28), Impacts Assessment (26), Response Strategies (27),* and *Supplementary Report to the IPCC Scientific Assessment* (29); EPA's *Policy Options for Stabilizing Global Climate* (52) and *The Potential Effects of Global Climate Change on the United States (51);* and COSEPUP's Panel on Policy Implications of Greenhouse Warming, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base (10).*

- "We think it is prudent to begin--today—investigating how our research and development programs should incorporate concerns about climatic uncertainty. "[3]
- ''Do current U.S. R&D Programs focus on the right questions to provide information about effects on different systems, potential strategies for making systems more resilient in the face of climate change and adapting to such changes that may occur?'
- "What information can more research provide over various time frames to guide decisions about reducing greenhouse gas emissions, ameliorating effects of global climate change, and building resiliency into systems?'

Conducting research to answer some of these questions has been a low priority. Although the results of the program, as currently structured, will provide valuable information for predicting climate change, they will not necessarily contribute to the information needed by public and private decisionmakers to respond to global change. Three areas are particularly lacking: ecosystem-scale research, adaptation research (ecological, human, and economic), and integrated assessments (evaluation of all focused and contributing research results and their implication for public policy). Research can begin now on topics more closely related to policy decisions despite incomplete answers from the physical sciences. More research is needed on the impacts of climate change on natural and managed ecosystems and the resulting implications for land and water resource management, on how people adapt, and on why people resist change. Key projects for a USGCRP committed to policy-relevant research should also include gathering information about the relative importance of population size and expectations of quality-of-life improvements, the demand for goods and services (including clean water, agriculture and forestry products, and access to natural areas), and economic and institutional barrriers to the dissemination and adoption of technological innovation. Some of the research in these areas will take decades and, if started now, may leave us much better prepared to respond to global change in the future.

Implicit in the current structure of USGCRP is that the initiation of a comprehensive adaptation research program must wait until predictions of climate change are reliable. However, there are several important reasons not to wait to initiate adaptation research. First, according to IPCC estimates, few reliable predictions of climate change on a regional scale will be available before the next 15 to 20 years. Although such regional information might help focus research on managed and natural systems in areas expected to experience the most change, research on ecosystems is a multidecade task (see vol. 2, chs. 4-6) and should begin now. Second, even though the effects of climate change on a regional level cannot currently be modeled accurately, general effects can be predicted, such as sea level rise. Adaptation research that addresses sea level rise and other effects of climate change need not wait for reliable predictions. Third, much adaptation research makes sense regardless of climate change. For example, restoration of wetlands addresses adaptation to climate change, but it also addresses the current depletion of wetlands due to other causes. Adaptation research can use historical records of societal, economic, and environmental impacts of environmental change combined with reasonable hypothetical scenarios for future environmental change (31).

Because policy makers and scientists have different educational and professiona1 backgrounds, scientific research findings need to be translated

[3] House Committee on Science, Space, and Technology, letter to OTA, Sept. 27, 1991.

[4] Senate Committee on Environment and Public Works, letter to OTA, Oct. 4, 1991,

[5] Senate Committee on Commerce, Science, and Transportation, letter to OTA, Oct. 8, 1991,

into terms relevant to policy making and decisionmaking. Regardless of the "completeness" of climate research, policy makers are making decisions now that affect global change and whether the Nation will mitigate and/or adapt to it. They also decide where to allocate scarce resources for research.

A recent National Research Council report, *Research to Protect, Restore, and Manage the Environment (37),* stated: "No matter how good the science, environmental problems cannot be solved without integrating the science with environmental policy. To accomplish that, integrative study is needed to bridge the multidisciplinary gaps and deal with the conflicting goals held by varied constituencies. Research is necessary but not sufficient to solve problems. ' One way to improve the relevance of research results for policy makers is through the use of integrated assessments. Integrated assessments are a mechanism for synthesizing all the research relevant to an identified problem and for presenting research results in policy-relevant language. Such assessments, if conducted by multidisciplinary teams on a regular basis, could help bring together and evaluate research results produced by USGCRP, which is now composed largely of isolated programs and projects.

Although assessments were not included in the original USGCRP program, they are included in a rudimentary form in the FY 1994 budget (8). However, there has been no fundamental change in the mission of USGCRP, which remains predominately focused on understanding climate change. As a result, different people draw different conclusions about what changes in research focus to expect from USGCRP. In addition, the quality of assessments is determined solely by the information fed into them and the backgrounds of those constructing the assessment framework. If ecological, economic, and sociological research continues to be neglected, the planned assessments will not be useful to policy makers (24). John Gibbons, assistant to the President for science and technology, testified recently that USGCRP needs to expand the scope of its research to include the impacts of climate change on natural and human environments and strategies for mitigating and adapting to climate change. He also recognized the need to improve the integration of research with policy making (20).

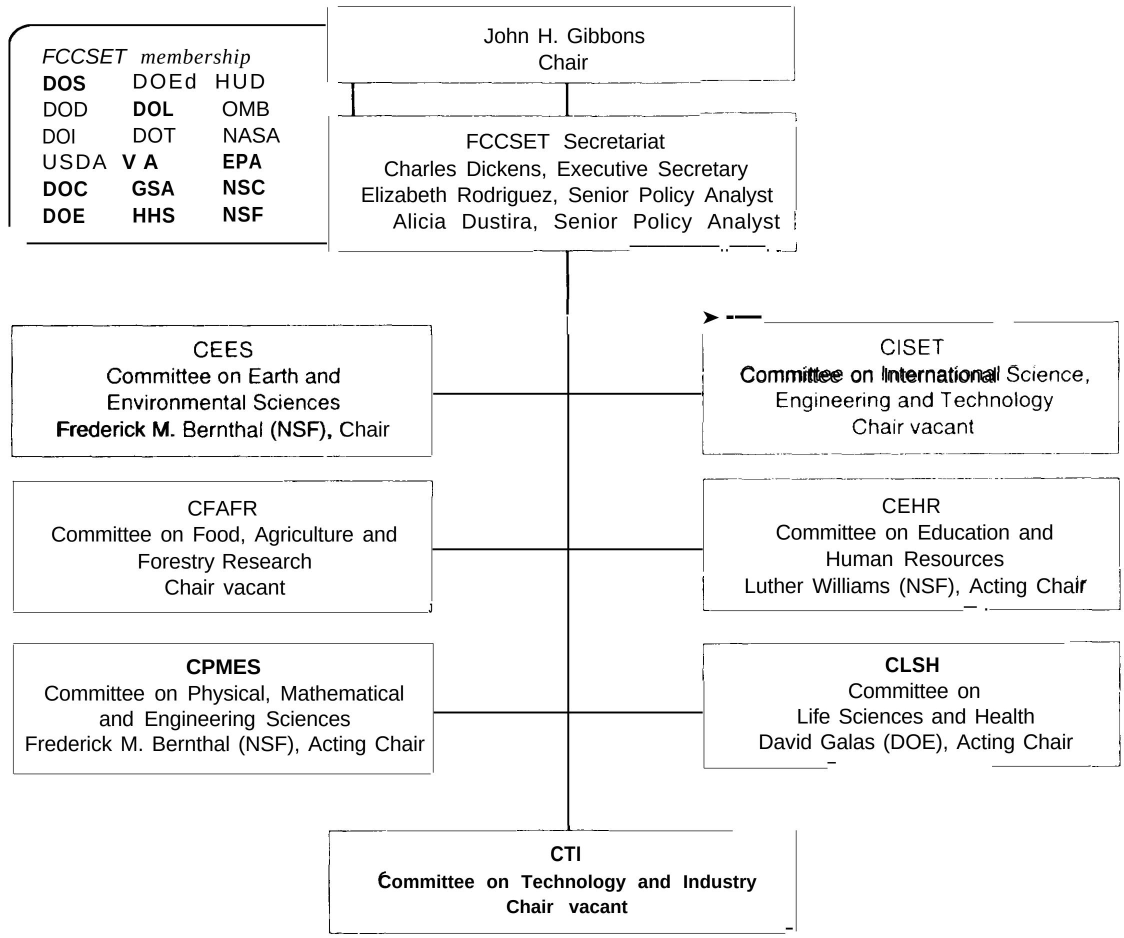
This chapter will examine the broad issues surrounding the Federal research effort to understand climate change-particularly within the context of the natural and managed systems discussed in chapters 4 through 6 of volumes 1 and 2. The options presented here, if implemented, could help commit the Federal Government to addressing areas of imbalance in USGCRP, the need for adaptation research, and the issues surrounding a national research program with an explicit science-policy interface. These program changes could benefit policy makers and decisionmakers by ensuring that USGCRP and other federally funded global change research supply the integrated information they need to make choices in the face of uncertainty about global change and its impacts.

## THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

### Inception and Structure

Recognition that human activity could significantly alter the global environment grew during the 1970s and 1980s. Concerns focused particularly on the threat of climate change from increased emissions of greenhouse gases and the depletion of the ozone layer by chlorofluorocarbons (CFCS). In response to the potential risks of climate change and the uncertainties surrounding the science, the Federal Government launched a massive, multiagency research effort in 1989 "to observe, understand, and, ultimately, predict global changes and to determine the mechanisms influencing these changes" (9). In 1989, USGCRP was developed by the Committee on Earth Sciences (now the Committee on Earth and

**Figure 3-l A-Organizational Chart for the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET)**




NOTE: For definition of terms, see figure 3-1 B, next page.

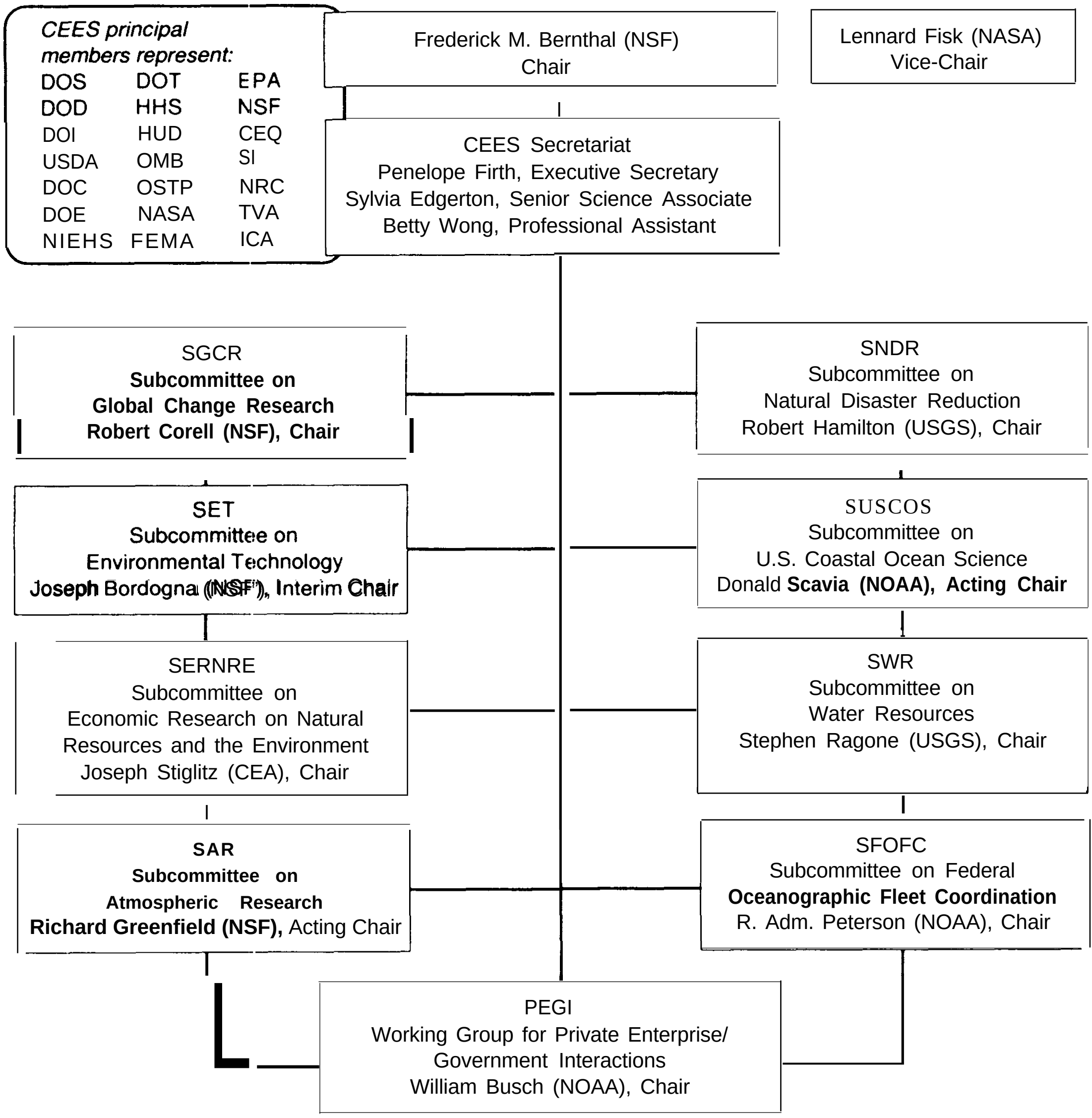
*(Continued)*

Environmental Sciences, CEES), an interagency group under FCCSET in the President's Office of Science and Technology Policy (OSTP) (see fig. 3-l). USGCRP became the first Presidential Initiative[6] indicating that it was to be a high-priority program with strong administrative backing. In 1990, Congress passed the U.S. Global Change Research Act (P.L. 101-606), which codified USGCRP. In 1992, USGCRP became a National Research Program.[7] Between FY 1989 and FY 1993, the Government spent $3.7 billion on this effort. A new administration that asserts its commitment to taking action on climate change issues and a Congress with a large number of new members coincide with this 5-year benchmark and could change the direction and scope of the

6 Presidential Initiatives are programs of particular importance to the national interest. Aside from USGCRP, four other Presidential Initiatives exist: high-performance computing and communication, advanced materials and processing, biotechnology research, and mathematics and science education. The Administration uses FCCSET to coordinate interagency research in these areas.

7 FCCSET developed this category for continuing Presidential Initiatives that have reached maturity.

**Figure 3-1 B-Organizational Chart for the Committee on Earth and Environmental Sciences (CEES)**




NOTE: DOS=Department of State; DOD=Department of Defense; DOI=Department of the Interior; USDA=U.S. Department of Agriculture; DOC=Department of Commerce; DOE=Department of Energy; DOEd=Department of Education; DOL=Department of Labor; DOT=Department of Transportation; VA= Department of Veterans Affairs; GSA=General Services Administration; HHS=Department of Health and Human Services; HUD=Department of Housing and Urban Development; OMB=Office of Management and Budget; NASA=National Aeronautics and Space Administration; EPA=Environmental Protection Agency; NSC=National Security Council; NSF=National Science Foundation; NIEHS=National Institute of Environmental and Health Sciences; OSTP=Office of Science Technology Policy; FEMA=Federal Emergency Management Agency; CEQ=Council on Environmental Quality; SI=Smithsonian Institution; NRC=National Research Council; TVA=Tennessee Valley Authority; ICA=Intelligence Community Affairs; CEA=Council of Economic Advisors; USGS=U.S. Geological Survey; NOAA=National Oceanic and Atmospheric Administration.

SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1994 U.S. Global Change Research Program* (Washington, DC: CEES, 1993).

program for FY 1994. There is no official termination date for the program; however, program plans indicate that it will last at least 40 years (11).

Three "activity streams," or program elements, defined the USGCRP mission between its inception and FY 1994:

- Documentation and analysis of Earth system changes, which include observation—using both ground- and space-based observation systems—and data management;
- Process Research to enhance the understanding of the physical, geological, chemical, biological, and social processes that influence Earth system behavior; and
- Integrated Modeling and Prediction of Earth system processes.

Each of these priorities is represented by a working group under the Subcommittee on Global Change Research under CEES. The chair of the subcommittee along with the chair of each of the working groups make up the principal body responsible for the planning, development, coordination, and review of USGCRP (7). In FY 1994, a new activity stream, Assessment, was added.

USGCRP was originally envisioned as a complete *global change* research program, covering research on natural climate change, human-induced climate change, impacts of climate and land-use change on the Earth system, and impacts of human activity on ecosystem health. The program has evolved in parallel with the Intergovernmental Panel on Climate Change (IPCC) and has drawn heavily from the panel's work.[8] Consequently, the main focus of **global change** research under USGCRP has become climate change. Important global changes other than human-induced climate change, such as loss of biodiversity, changes in land use, and increases in industrial pollution, were determined to be beyond the scope of USGCRP and are addressed only to the extent that they interact with the climate system. This is reflected in the research priorities of the program's science elements.

To guide research, CEES identified and prioritized seven scientific research elements, or science elements.[9] In order of priority, the science elements are Climate and Hydrologic Systems, Biogeochemical Dynamics, Ecological Systems and Dynamics, Earth System History, Human Interactions, Solid Earth Processes, and Solar Influences (7). More-specific areas of research are prioritized under each of these seven research elements (see fig. 3-2). Several criteria, although not applied systematically, are used to evaluate projects under each research element, including: relevance and contribution to the overall goal of the program, scientific merit, ease or readiness of implementation, links to other agencies and international partners, cost, and agency approval.

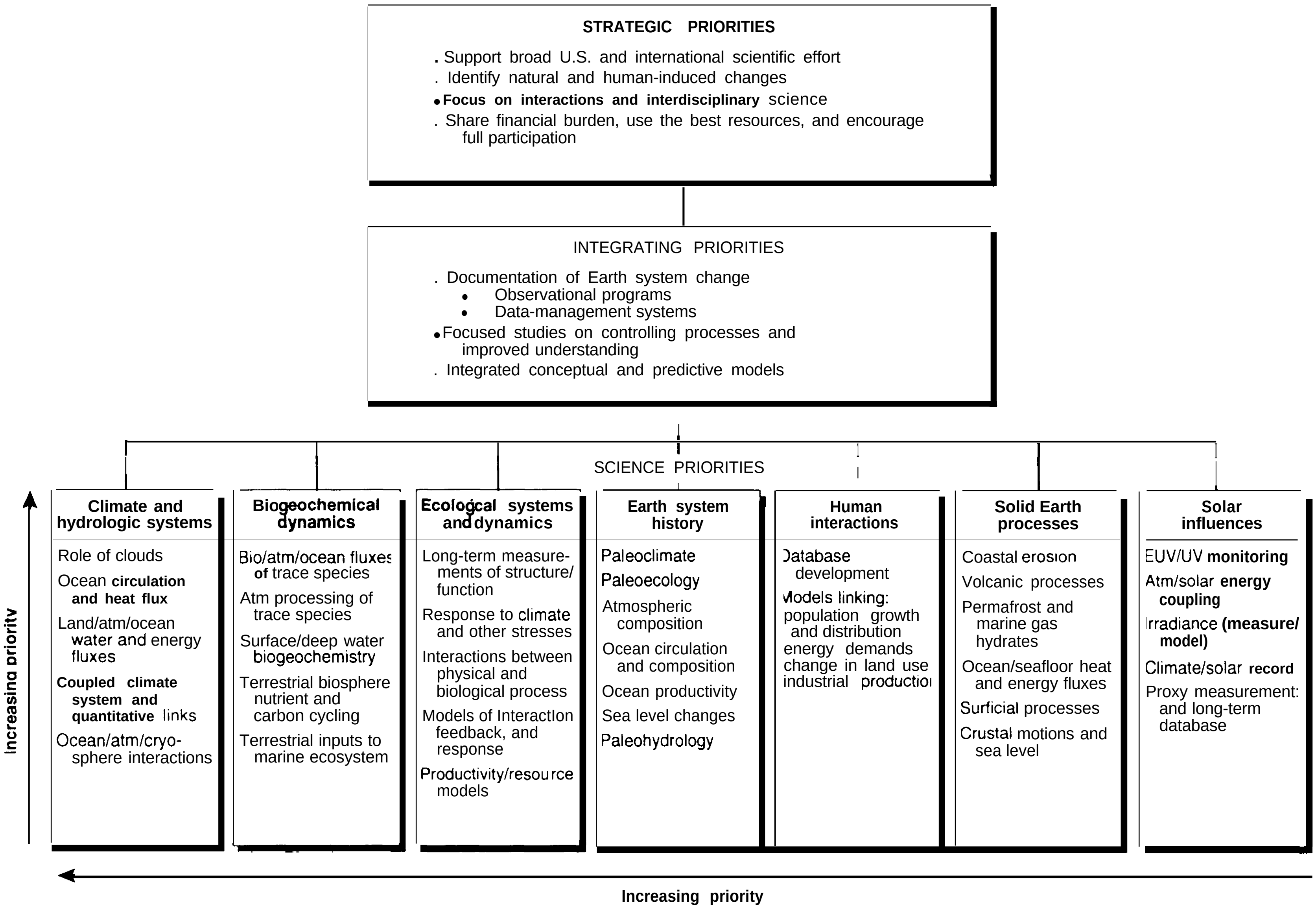
## New Developments

In 1992, CEES began developing a management plan for the program that would include the addition of Assessment as a fourth activity stream along with Documentation, Process Research, and Integrated Modeling and Prediction (see fig. 3-3). The primary function of the Assessment working group is to ''. . document the state of scientific knowledge and address the implications of the science of global change for national and international policy-making activities over abroad spectrum of global and regional environmental issues" (8). The group will also help coordinate the scientific assessments of global change with

[8] IPCC is an intergovernmental body sponsored jointly by the World Meteorological Organization and the United Nation's Environmental Programme. The group was set up in 1988 to assess the scientific undemanding of natural and human-induced climate change, its impacts, and potential response strategies. IPCC is scheduled to produce another full assessment in 1995,

[9] CEES (formerly CES) works closely with and has drawn heavily on the ongoing activities of the National Academy of Sciences (NAS), the World Climate Research Program (WCRP) of the World Meteorological Organization, the International Council of Scientific Unions (ICSU), the International Geosphere-Biosphere Program (IGBP), and IPCC in designing the structure of USGCRP and in identifying the program's key scientific issues and research priorities.

**Figure 3-2—Priority Framework for USGCRP**




NOTE: aim-atmosphere; EUV/UV–extreme ultraviolet/ultraviolet.

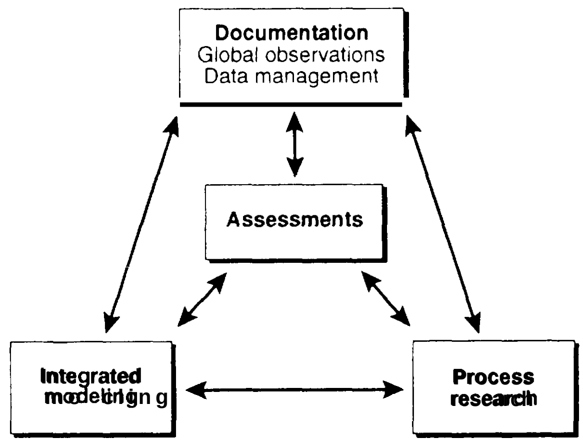
SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1993 U.S. Global Change Research Program* (Washington, DC: CEES, 1992).

related assessments on environmental impacts, technologies for adaptation and mitigation, risk assessment, and policy-response strategies (12). Although the FY 1994 budget proposal reflects these changes, it is unclear how much money agencies will allocate for assessment and how the assessments will be structured. The FY 1994 budget does not show Assessment separately but, rather, embeds it within the other three activity streams. Comprehensive assessments cannot be carried out without expanding the ecological and socioeconomic aspects of the program and incorporating impacts research into it. The FY 1994 budget does not reflect any significant expansion in these areas.

Nonetheless, the Administration has expressed interest in significantly broadening the program to include studies of environmental and socioeconomic impacts and of mitigation and adaptation strategies. "The development of a successful assessment activity in the USGCRP will, I believe, go far toward demonstrating the Clinton-Gore administration's commitment not only to research but to effective action to manage this Nation's national and international environmental policy' (19). If this research materializes, it could then be integrated with research on Earth system processes to conduct integrated assessments. The expanded program should be reflected in the FY 1995 USGCRP budget.

To ensure progress in each of the activity streams, timetables and milestones have been included in each agency's USGCRP research program, although they have not appeared in any published document. These milestones, specified for both the near term (5 to 10 years) and the long term (10 to 30 years), "will guide program and budget development and serve as a critical element in evaluating program accomplishments and progress' (11). The Office of Management and Budget (OMB) could hold research programs to these targets only if the milestones are clearly stated and easily measured and, therefore, enforceable. Representative George Brown, chairman of the Committee on Science, Space, and Technology, has suggested building performance guidelines into authorizing legislation as well as mandates that would redirect or terminate programs that do not make sufficient progress toward stated goals (2).

**Figure 3-3-Functional Architecture of USGCRP**




SOURCE: Committee on Earth and Environmental sciences (CEES), *Our Changing Planet: The FY 1993 U.S. Global Change Research Program* (Washington, DC: CEES, 1992).

## ■ The Interface Between Policy and Science

Research programs intended to be relevant to management and policy making often fail because of fundamental tensions among researchers, resource managers, and decisionmakers. These tensions are created because of conflicts in the time horizons of each group, differences between priority- or goal-setting processes, and differences in the agendas of extramural research organizations (e.g., universities, industries, and independent laboratories), mission-oriented agencies, and Congress.

The timetable for governmental decisions is driven primarily by the annual budget cycle and an election cycle that ranges between 2 and 6 years. Not surprisingly, policy makers funding global change research often have a shorter time horizon for "answers" than do researchers. This disparity leads to tension between Government officials, who are required to formulate annual budgets and make immediate decisions, and the scientific community, whose long-term research is dependent on continuous and reliable funding. When the questions of policy makers are not answered in one or even a few years, it may become more difficult to sell a program as relevant to policy needs. Mission-oriented agencies are repeatedly deflected by the 'crisis-of-the-month' syndrome, which siphons resources away from long-term programs (37). The result may be annual budget fluctuations and/or rapidly shifting priorities-both of which are detrimental to the development of a sound scientific program. A balance between continuity in priorities and funding and flexibility in project direction is essential (3).

Tension arises between extramural research organizations and the Federal Government because of different research agendas. Universities and independent laboratories judge their scientists to a large extent on their ability to raise funds for research. Adherence to management- and policy-relevant goals is not seen as important unless it leads to more Federal funding.

Many scientists believe that the science must be "complete" before policy conclusions can be made safely. Policy makers, on the other hand, cannot afford the luxury of complete information. Decisions about reauthorizing environmental legislation and natural resource planning and management will continue to be made based on the best available information. "[I]f policy is to be effectual, then we must make policy while we continue to investigate the physical and societal effects of global warming. But this means that policy will also enter the feedback loop, influencing societal responses and physical effects' (30). Science need not proceed in a sequential fashion. Research on the climate system need not be "complete" before research on the ecological effects of climate change is undertaken nor does research on the ecological effects of climate change need to be ''complete' before research on the societal impacts of and potential responses to climate change is initiated (45). If USGCRP is to address policy-relevant questions, a parallel approach to climate effects and response research is necessary.

In a narrow sense, USGCRP is policy-relevant if the most important policy concern is to gain a better understanding of Earth system processes in order to predict climate change. However, the major international assessments conducted by IPCC demonstrate that the key questions policy makers need to address move far beyond the narrow definition of ''observe, document, and predict" global change, into the realm of issues related to adaptation and mitigation. As a result of focusing research funds on climate prediction, USGCRP is not addressing other key science issues or broad policy questions for the near term. For example, what plants and animals are sensitive to climate changes? How might biota and vegetation respond to changes in climate? What are the implications for forestry, agriculture, and natural areas? What mitigation strategies would slow climate change the most? How much would they cost? To whom? How might society respond to changes in climate and global ecosystems? What technologies should be developed? How will the effects of climate change interact with other global environmental changes? How important is climate change in the scheme of long-term environmental threats? How can natural resources be managed to minimize economic and ecological loss? These issues were largely excluded from USGCRP to keep it primarily driven by the earth sciences. Even if accurate regional climate predictions could be given today, land managers, planners, decisionmakers, and policy makers would not have all the information they need to guide their response (33). As originally envisioned in 1990, these issues were to be addressed under the CEES Working Group on Mitigation and Adaptation Research Strategies (MARS), which was abolished in 1992.

If USGCRP begins to address this broader set of questions, it will be moving closer to policy-relevant research. Some fear that a program driven by policy concerns will undermine or

**Table 3-l—List of Departments and Agencies or Bureaus Involved in USGCRP Research**

| | | |
|---|---|---|
| DOC | Department of Commerce | |
| | NOAA | National Oceanic and Atmospheric Administration |
| DOD | Department of Defense | |
| | CRREL | Cold Regions Research and Engineering Laboratory |
| | ONR | Office of Naval Research |
| DOE | Department of Energy | |
| | OHER | Office of Health and Environmental Research |
| DOI | Department of Interior | |
| | BIA | Bureau of Indian Affairs |
| | BLM | Bureau of Land Management |
| | BOM | Bureau of Mines |
| | BOR | Bureau of Reclamation |
| | FWS | Fish and Wildlife Service |
| | NPS | National Park Service |
| | 0 s | Office of the Secretary |
| | USGS | U.S. Geological Survey |
| EPA | Environmental Protection Agency | |
| | ORD | Office of Research and Development |
| HHS | Department of Health and Human Services | |
| | NIEHS | National Institute of Environmental Health Services |
| NASA | National Aeronautics and Space Administration | |
| | OSSA | Office of Space Science and Applications |
| NSF | National Science Foundation | |
| | BIO | Directorate for Biological Sciences |
| | GEO | Directorate for Geosciences |
| | SBE | Directorate for Social, Behavioral, and Economic Sciences |
| SI | Smithsonian Institution | |
| | IC | International Center |
| | NASM | National Air and Space Museum |
| | NMNH | National Museum of Natural History |
| | NZP | National Zoological Park |
| | SAO | Smithsonian Astrophysical Observatory |
| | SERC | Smithsonian Environmental Research Center |
| | STRI | Smithsonian Tropical Research Institute |
| TVA | Tennessee Valley Authority | |
| | RBO | River Basin Operations |
| USDA | Department of Agriculture | |
| | ARS | Agricultural Research Service |
| | CSRS | Cooperative State Research Service |
| | ERS | Economic Research Service |
| | FS | Forest Service |
| | Scs | Soil Conservation Service |

SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1993 U.S. Global Change Research Program* (Washington, DC: CEES, 1992).

change the direction of science. Others maintain that the second set of policy-relatd questions can be addressed adequately by research driven by the earth sciences. Maintaining the long-term policy relevance of scientific research under USGCRP will require a formal and iterative assessment link that simultaneously transfers scientific research results in policy-relevant language to decisionmakers and policy concerns to the research community.

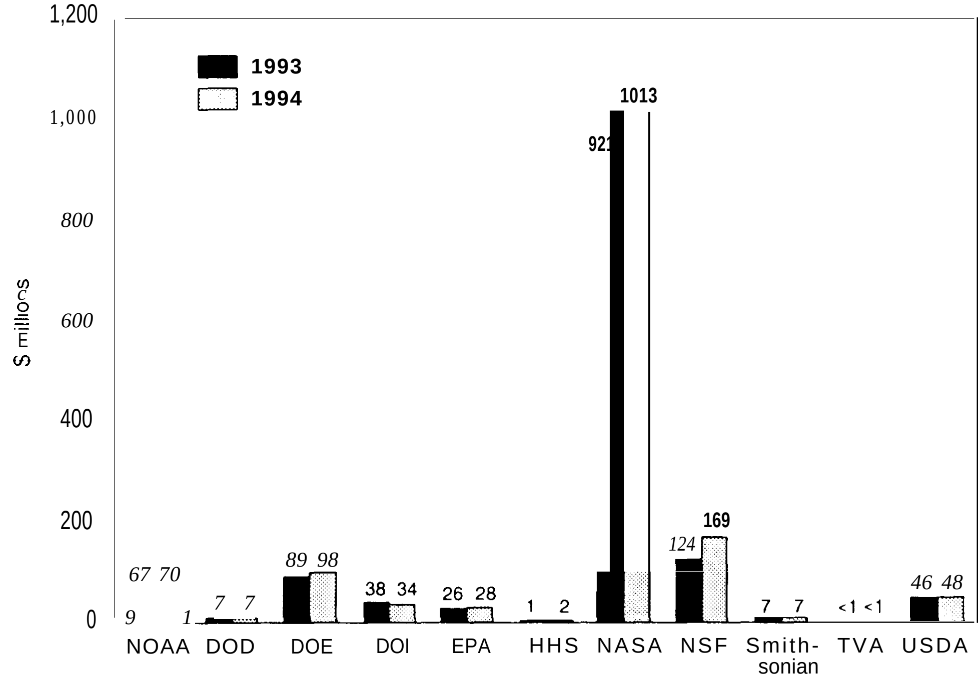
## PRIORITIES AND BALANCE IN USGCRP

### Budget

CEES designed USGCRP as a cohesive, integrated research program that would encompass the unique attributes of 11 Federal agencies, including 31 bureaus, but it did not assign a central management body (see table 3-l). The priority scheme set up by the three activity streams and the seven science elements is intended to guide budget decisions, and, to date, finding levels have followed these priority areas.

Since the program formally began in FY 1990, the USGCRP budget has grown from $660 million in its first year to $1.33 billion in FY 1993 (7, 9). The proposed budget for FY 1994 is $1.47 billion (8). The budget can be analyzed in terms of distribution across agencies, activity streams, and science elements (see figs. 3-4, 3-5, and 3-6). In FY 1993, projects funded by the National Aeronautics and Space Administration (NASA) comprised 69 percent of the program's budget ($921 million) while projects funded by the Department of the Interior (DOI), which contains most of the land-management agencies, comprised 3 percent of the program's budget ($38 million). For FY 1994, the requested budget for DOI's global

**Figure 3-4—U.S. Global Change Research Program Budget by Agency**




NOTE: For definition of terms, see table 3-1. FY 1994 values are the requested, not the appropriated, amounts.

SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1994 U.S. Global Change Research Program* (Washington, DC: CEES, 1993).

change research program decreased to 2.3 percent of the total.

Of the activity streams, Documentation, including observation and data management, received 45 percent of the budget ($595 million) in FY 1993. Earth Process Research for understanding climate change received 46 percent of the budget ($610 million), and Integrated Modeling and Prediction received 9 percent of the budget ($121 million).[10]

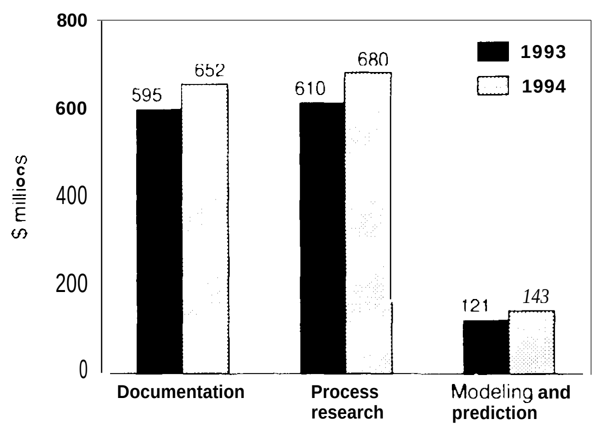
Although USGCRP programs include projects on almost every aspect of climate change, the bulk of the funds is focused on answering scientific questions related to understanding the physics and chemistry underlying climate systems. Research on Climate and Hydrologic Systems and Biogeochemical Dynamics constituted about 71 percent of the program's FY 1993 budget ($937 million). Ecological Systems and Dynamics received 17 percent of the budget ($224 million). The remaining 12 percent of the budget ($165 million) was divided among the remaining four research elements: Earth System History, Human Interactions, Solid Earth Processes, and Solar Influences (8).

Projects are categorized as *focused--directly* relating to global change--or *contributing*—justified on a basis other than global change but having the potential to contribute to the global change knowledge base (see fig. 3-7).[11] Even when both focused and contributing research are considered, 70 percent of all funds is targeted for

10 Most of the funds for modeling and prediction go toward nonmodeling process research. The major modeling groups have received only a small portion of these funds.

11 Unless specifically no@ budget figures refer to the focused budget.

Figure **3-5—USGCRP** Focused Budget **by** Activity Stream




**NOTE: Total budget does not Include one-time appropriation of $5 million for the State Department in FY 1993 because the distribution of funding among proposed projects is still being determined. The budget for the FY 1994 Assessment activity stream is embedded in the otherthree activity streams. FY 1994 values are the requested, not the appropriated, amounts.**

**SOURCE: Committee on Earth and Environmental Sciences (CEES),** *Our Changing Planet: The FY 1994 U.S. Global Change Research Program* **(Washington, DC: CEES, 1993).**

projects in the first two priority research areas. There are no standardized criteria for classifying contributing research, and each agency uses its own system. Consequently, it is difficult to know precisely the extent of contributing research or to get a comprehensive picture of relevant research. Both focused and contributing programs are considered in a procedure called the ''budget crosscut. " USGCRP is one of only a few Federal programs that uses a budget crosscut as a coordinating mechanism. This approach has been reasonably successful in facilitating cooperation and securing new funding for global change research. The USGCRP budget-crosscut process works as follows.

Each program within an agency submits new projects to the appropriate subworking group of CEES. This subworking group determines whether to recommend to the agency that the project be included in USGCRP (projects can be added later in the budget process, but this is the most likely step at which new projects are added).

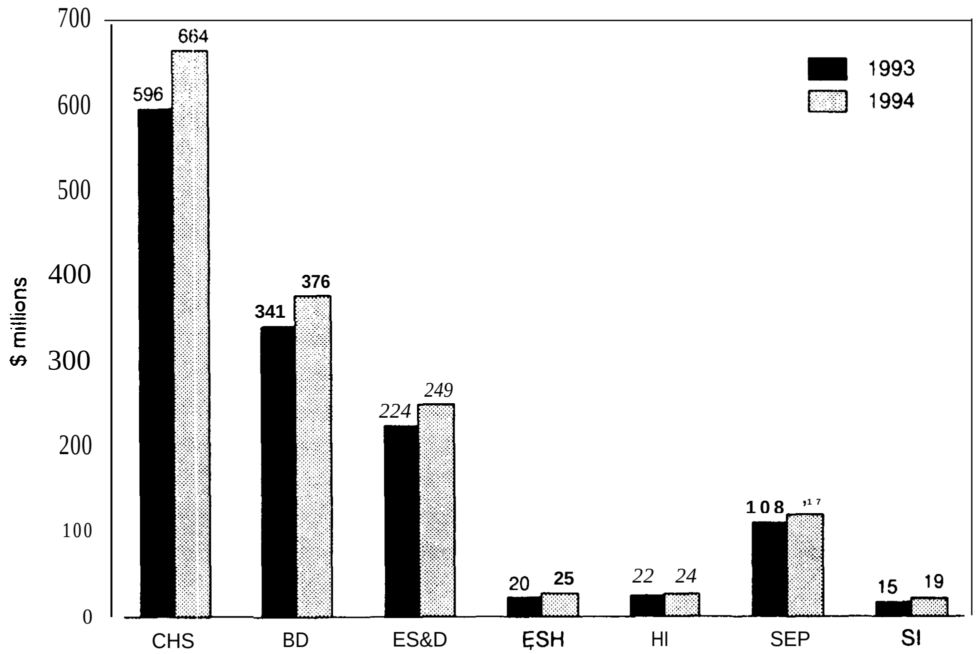
Each agency that participates in USGCRP then develops its own GCRP budget, with some coordination between agencies for joint projects. These budgets are then submitted to CEES, which may continue to negotiate with the agencies. CEES submits one budget proposal incorporating programs from all participating agencies to the Office of Management and Budget (OMB). When the proposal reaches OMB, it is initially reviewed at one meeting by all of the budget examiners for the various agencies involved in USGCRP. Although one examiner takes the lead for USGCRP, the participation of the other examiners is critical because each must understand the purpose of the USGCRP projects that fall within his or her agency's budget. The USGCRP budget is returned to each agency when that agency's whole budget is returned. At that point, deliberations between OMB and the agencies proceed as normal. As agencies work to meet OMB-established budget targets, they look at modifying all projects-they can accept or reject OMB'S recommendations and reprogram their global change budgets.[12] The final USGCRP budget is presented to Congress along with the annual Presidential Budget Request.[13] When the program first started, approximately 70 percent of the proposed budget consisted of research funds from already existing projects.

The USGCRP budget falls within the jurisdiction of several congressional authorization and appropriations committees and subcommittees (see table 3-2). With all of these committees reviewing components of the USGCRP budget, it

12 During the first few years of the program, USGCRP required agencies to ''fence off,'' or commit, their global change research budget requests to the program. They could not reprogram this money later *if* OMB *cut* overall agency funding further down the line.

13 The first two budget requests were long, detailed documents accompanied by executive summaries, but since FY 1992, only the summaries have been published. USGCRP staff determined that the information in the detailed budgets changes slowly and, therefore, needs to be published only every 5 years.

**Figure 3-6—USGCRP Budget by Science Element**




NOTE: CHS-Climate and Hydrologic Systems; BD-Biogeochemical Dynamics; ES&D-Ecological Systems and Dynamics; ESH-Earth System History; H-Human interactions; SEP-Solid Earth Processes; SI-Solar Influences. FY 1994 values are the requested, not the appropriated, amounts.

SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1994 U.S. Global Change Research Program* (Washington, DC: CEES, 1993).

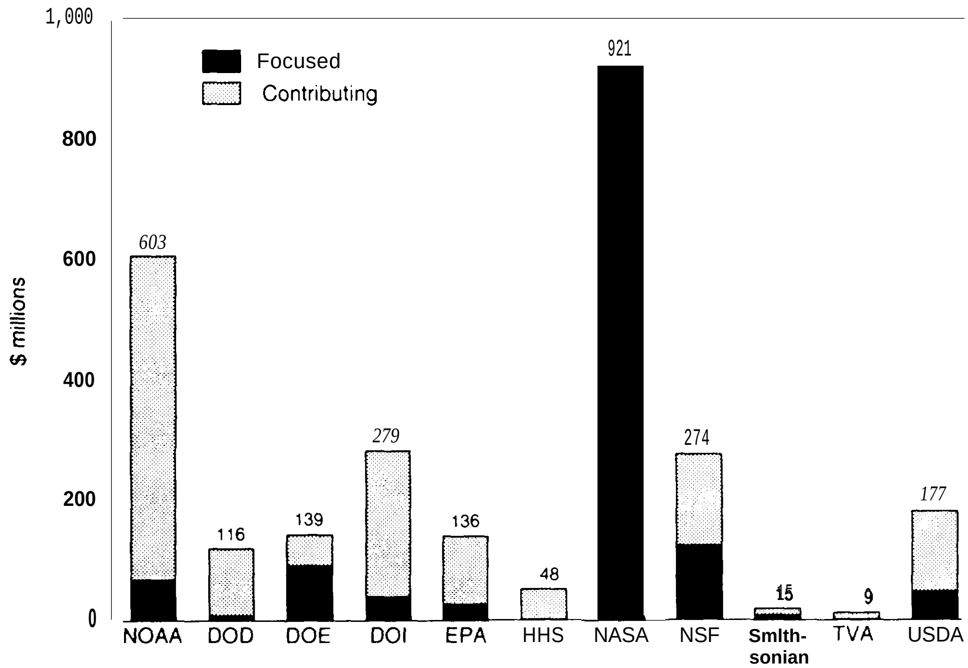
is much more difficult for Congress to consider the USGCRP budget as a whole than it is for the executive branch to do so. Several members of Congress have complained about the fragmentation of congressional attention to the USGCRP budget, but no alternatives have been proposed. It might be useful for Congress to consider using an ad hoc appropriations subcommittee consisting of members from the committees with primary jurisdiction over elements of USGCRP to review the program's budget as a comprehensive unit. If two or three agencies are cooperating on a single project, but one agency does not receive funding for it, the entire project could beat risk.[14] Large, interagency programs such as USGCRP will require innovative methods of funding if they are to succeed.

## Satellite vs. Nonsatellite Measurements

NASA's Mission to Planet Earth (MTPE) program accounts for over 60 percent of USGCRP focused funding (crossing several of the priority research areas). The core of the MTPE program is the development and maintenance of the Earth Observing System (EOS), an ambitious satellite program originally designed to provide

14 For example, at OTA's *workshop* "EOS and USGCRP: Are We Asking and Answering the Right Questions?" (Feb. 25-26, 1993), participants cited program such as the World Ocean Circulation Experiment (WOCE), Tropical Oceans Global Atmosphere (TOGA), and the Joint Global Ocean Flux Study (JGOFS)(50). All three are interagency research programs where the success of the entire program depends on contributions from NASA, the National Oceanic and Atmospheric Administration, and the National Science Foundation. However, in a recent budget cycle, NASA received more than it asked for these programs while NOAA and NSF received no money. Rather than kt the programs die, NASA filled the financial gap left by inadequate funding for NOAA and NSF.

**Figure 3-7—FY 1993 USGCRP Budget of Focused and Contributing Programs by Agency**

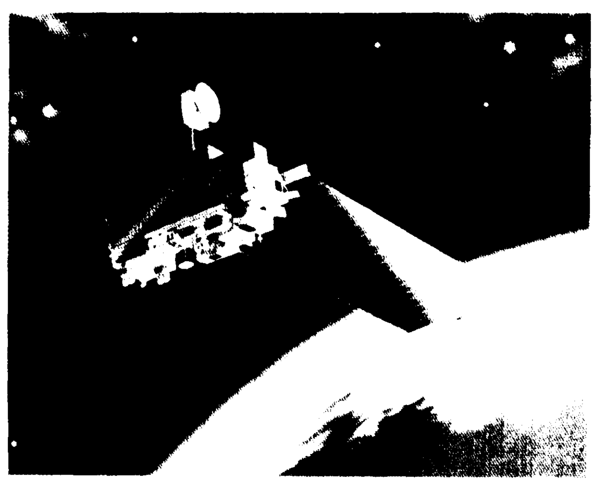



NOTE: For definition of terms, see table 3-1.

SOURCES: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1993 U.S. Global Change Research Program* (Washington, DC: CEES, 1992); Office of Technology Assessment 1993.

data over a 15-year period related to the study of precipitation; ocean circulation; sources and sinks of greenhouse gases; changes in land use, land cover, hydrology, and ecology; changes in glaciers and ice sheets; ozone; and volcanic activity. Because of EOS'S central role in NASA's USGCRP effort and the great expense of putting satellites in space, the USGCRP budget as a whole is heavily weighted toward satellite-based measurements.[15]

EOS has suffered extensive restructuring over the past few years, which may jeopardize the quality of information gained from remaining EOS instruments. Some instruments that were supposed to have improved the understanding and observation of possible climate change impacts



MARTIN MARIETTA ASTRO SPACE

*Artist's conception of NASA's Earth Observing System (EOS). EOS (AM-1 Platform) is scheduled to be launched in 1998.*

[15] Although about 50 percent of NASA's USGCRP budget is classified as nonsatellite programs, most of these support data maintenance and operation of the satellite programs.

**Table 3-2--Congressional Authorization Committees and Appropriations Subcommittees with Significant Legislative Authority over Agencies with a USGCRP Component**

| House and Senate Authorization Committees | Jurisdiction [a] |
|---|---|
| **House** | |
| Agriculture | USDA |
| Armed Services | DOD, DOE |
| Energy and Commerce | DOE, HHS |
| Natural Resources | DOE, USDA/FS, SI |
| Sciences, Space, and Technology | NASA, NSF, DOE, EPA, NOAA, SI |
| Public Works and Transportation | NOAA, SI |
| Merchant Marine and Fisheries | USDA, NOAA, SI |
| **Senate** | |
| Agriculture, Nutrition, and Forestry | USDA |
| Armed Services | DOD, DOE |
| Commerce, Science, and Transportation | NSF, NASA, NOAA |
| Energy and Natural Resources | DOE, DOI |
| Labor and Human Resources | DOE, DOI, HHS |
| Environmental and Public Works | EPA, SI |
| Rules and Administration | SI |
| **House and Senate Appropriations Subcommittees** | |
| Labor, Health and Human Services, and Education | HHS |
| Housing and Urban Development and independent Agencies | NASA, NSF, EPA |
| Energy and Water Development | DOE |
| Interior and Related Agencies | DOE, USDA, DOI, SI |
| Agriculture and Rural Development[b] | USDA |
| Commerce, Justice, State, and Judiciary | NOAA |
| Defense | DOD |

[a] For definition of terms, see table 3-1.
[b] The corresponding subcommittees of the Senate and House Committees on Appropriations have the same name with one exception: the Senate Subcommittee on Agriculture, Rural Development, and Related Agencies and the House Subcommittee on Rural Development, Agriculture, and Related Agencies,

SOURCES: U.S. Congress, Office of Technology Assessment (OTA), *Federally Funded Research; Decisions for a Decade,* OTA-SET-490 (Washington, DC: Government Printing Office, May 1991); Office of Technology Assessment, 1993,

have been dropped or postponed. For example, the High Resolution Imaging Spectrometer (HIRIS), an instrument potentially capable of resolving some of the more subtle aspects of ecological change that cannot be detected by satellites today, was originally scheduled to be part of EOS, but was dropped during program restructuring (54). EOS began as a $30 billion program, but was scaled back to an $8 billion program (see box 3-A).[16]

Most participants at OTA's workshop "EOS and GCRP: Are We Asking and Answering the Right Questions?" agreed that had EOS been designed initially to be an $8 billion program, it likely would be different from the program we have today. All acknowledged that much good data will be collected and good science will be done through EOS, but that it will provide neither the continuous, multidecade data set necessary for ecosystem studies nor a true global monitoring

16 For more discussion of EOS, see references 49 and 50.

## Box 3-A-Remote Sensing as a Tool for Coping with Climate Change

Remote sensing is the observation of the Earth from a distance. The ability to view and monitor large areas of the Earth has become valuable in understanding regional and global-scale phenomena such as weather systems, deforestation rates, and, most recently, climate change. Remote sensing can help reduce the uncertainties associated with climate change in two ways: 1) by improving climate predictions through better understanding of atmospheric and climate processes and 2) by improving scientists' ability to detect and predict the effects of climate change on the biosphere. Both uses of remote sensing would be important for coping with climate change. However, most biosphere-related climate research to date has focused on the former, whereas relatively little has focused on the latter. This box examines the uses and limitations of remote-sensing technologies for observing, detecting, and understanding changes in the biosphere resulting from climate change, land-use change, or other factors.

### Development of remote-sensing technology

Airborne sensors-The oldest form of remote sensing-invented about 100 years ago--consists of photographs taken from balloons. The development of the airplane made aerial photography the primary way to monitor and study the Earth's surface from a distance. Scientists also discovered t hat images created from other parts of the electromagnetic spectrum (i.e., the infra red region) could provide additional information about surface characteristics, such as mineral composition, soil moisture, and crop condition.

The U.S. Forest Service has been using aerial photography since the 1930s to measure the area of forests, monitor forest health, and plan timber harvests. Aerial photography is also an important tool in the U.S. Fish and Wildlife Service's National Wetland Inventory Program The technique is best suited for observing relatively small areas and for studies requiring a high level of spatial detail. Riparian wetlands and wetlands less than 5 acres (2 hectares)[1] in area, for example, cannot be accurately characterized by satellite-based observations (18). Therefore, aerial photography is an essential tool for comprehensive wetland monitoring.

However, using aerial photography to get consistent coverage overlarge areas for regional analysis is very difficult and costly. The aerial photography technology used frequently by the National Aeronautics and Space Administration (NASA) for ecological studies can cost about $10,000 per flight. Difficulties also lie in determining exactly where the plane is in space so that the area being photographed can be precisely identified. Also, taking photographs at different times from exactly the same vantage point is difficult. Although aerial photography may be preferable for ecological applications requiring high levels of detail (e.g., wetland inventory and forest monitoring), it is not practical for routine, regular measurements or for studies of large-scale ecological phenomena.

Remote sensing from satellites--By the late 1960s, advances in technology made transmitting electronic images to Earth from satellite-based instruments practical. Polar-orbiting satellites (orbits pass over both the North and South Poles) allow imaging of the entire globe. These Earth observation satellites are equipped with various sensors that detect natural radiance (electromagnetic waves emitted by surface features) and reflectance (those reflected from Earth's surface).[2] The intensity and wavelength of the signal detected become a type of signature for certain surface features. By combining these signals, various vegetation types and other characteristics can be identified.

1 To convert acres to hectares, multiply by 0.405.

2 Sunlight is absorbed by Earth's atmosphere, scattered and reflected off Earth's surface, or absorbed by its surface. Surface features that absorb some waves can re-emit electromagnetic signals-often at longer wavelengths. In general, reflected (or scattered) signals give information about the structure of the surface features, and radiated signals give information about Its chemical composition.

*(Continued on next page)*

## Box 3-A-Remote Sensing as a Tool for Coping with Climate Change--(Continued)

Satellites include several instruments that monitor Earth with "passive sensors" designed to detect a narrow range, or window, of various parts of the electromagnetic spectrum. These windows are called ***spectral bands.*** By detecting different parts of the spectrum, a variety of signatures is obtained. Being able to detect narrower bands improves the ability to categorize detected signatures by wavelength. More narrow bands over a wider range of the spectrum enables detection of more signatures, which improves the ability to discern closely spaced objects and identify surface features. Identification of a wetland, for example, generally requires analysis of three or more infrared spectral bands (18): one discriminates amounts of vegetation, water, and soil moisture; another helps **determine water** quality; and another helps to classify different vegetation types. However, detailed geographic and spectral resolution is more expensive, requires higherdata-collection rates, and limits spatial coverage (49). Passive optical sensors detect only surface features. They cannot be used for Earth observation through clouds, accurate measurement of soil moisture through dense vegetation cover, or detection of submerged vegetation. Radar instruments have "active" sensors that provide their own illumination via microwave pulses and then measure the reflected energy. Unlike optical sensors, radar data can be acquired through clouds and at night. Radar signals are especially sensitive to water and may improve the way soil and vegetation moisture are measured (53, 54). In addition, radar can probe to greater depths and may provide better information about surface roughness, canopy height, and, perhaps, vegetation beneath a dense canopy than can optical sensors (53,54).

Several countries besides the United States, including France, Japan, India and Russia, have launched satellites for environmental studies and Earth observation. Discussed below are satellites whose data are most widely used by US. scientists for detecting change in the biosphere and for large-scale ecosystem studies.

Advanced Very High Resolution Radiometer (AVHRR)--This scanning radiometer, aboard NOAA's Polar Orbiting Environmental Satellite (POES), uses five detectors to create surface images in five spectral bands (49). AVHRR data allow multispectral analysis of vegetation, clouds, lakes, coasts, snow, and ice and have been used to monitor crop conditions, classifyglobal vegetation, and demonstrate the scale of deforestation in the tropics (44). AVHRR provides daily coverage of the Earth, allowing frequent monitoring of a large region and the creation of virtually cloud-free images at a fraction of the cost and computing time required for aerial photography or other satellite technologies (43).[3] Although AVHRR data have much lower spatial resolution than do data from aerial photography--about 0.7 miles (1.1 kilometers)[4] per pixel, or data point--O.6-mile to 16-mile resolutions are adequate for "assessing many global or regional trends in land cover, vegetation damage, deforestation, and other environmental conditions" (44).

Landsat--In 1972, NASA launched the first of a series of Landsat satellites for civilian Earth observation and monitoring. Now, a 20-year continuous data set has been acquired for some selected areas (primarily in the United States and the former Soviet Union), making Landsat data the primary source of data for detecting long-term ecological trends. This long-term record is just now beginning to provide valuable information about trends and changes In wetland area, vegetation types, forest growth, deforestation rates, and urban expansion.

Consistency in measurement is very important for maintaining accurate and useful long-term records. Landsat missions have been designed so that data from different missions can be compared while allowing moderate advances In technology. Sustaining Landsat missions and maintaining a continuous data set over 20 years has not been easy. Over this time, operation of Landsat has changed from public to private and back to public

3 The EROS Data Center makes global data sets that are almost aloud-free by imaging over approximately 10 days.

4 To connvert miles to kilometers, multiply by 1.609.

hands.[5] These changes have threatened to limit the availability of data to users, have increased the costs of data to users, and have limited the number of scenes imaged. Landsats 4 and 5 have already surpassed their expected life spans by several years. The recently launched Landsat 6 (October 1993) never reached orbit, and the long-term Landsat record is now threatened.

The main advantage of Landsat and similar satellites is that they can distinguish surface features with higher spatial and spectral resolution and broader spectral coverage than do AVHRR data.[6] Landsat data have been used to identify and monitor crops, classify forest stands with finer classification scales, and assess damages from natural disasters. However, Landsat provides less frequent coverage of an area (every 16 days) and requires more computing time and power than do AVHRR data sets. For these reasons, AVHRR is more widely used than Landsat for global data analyses. Landsat data sets are also significantly more expensive than are AVHRR data sets. According to one scientist, "The 10-times greater expense and 1,000-times-greater data volume [of Thematic Mapper of Landsat (TM) data as opposed to AVHRR data preclude] use of multiple annual [Landsat] data sets for global studies" (43). (The cost of each 120-by 110-mile scene is about $5,000 (18)).

New technologies[7]—instruments considered for Landsat 7 will improve surface resolution and allow the creation of topographic images (by having the ability to point to the side), thereby increasing Landsat's revisit frequencies from once every 16 days to once every 3 days (49). Until recently, a High Resolution Imaging Spectrometer (HIRIS) was under consideration for development as part of NASA's Earth Observing System (EOS) program. In principle, HIRIS data could be used to detect specific species of trees or other ground cover, track pollutants in water, and identify natural vegetation that is under stress. A Synthetic Aperture Radar (SAR) proposed for EOS--but recently canceled--would have been capable of multiangle, multifrequency, and multipolarizartion measurements (49). SAR could have measured soil moisture under vegetated land, determined the vertical structure of vegetation canopies, and measured canopy moisture (53). However, both HIRIS and SAR were dropped from consideration because of high costs and launch requirements (54).

Uses of remote sensing under climate change[8]

Many questions about climate change impacts and how to respond to them remain unanswered. For example, which plant and animal communities are likely to change first? How will they change? How fast will changes occur? Which species are already declining? Why? Where? Which are flourishing? Satellite data are already being used to answer many questions related to large-scale ecological change, but limitations in both satellite technology and in ecological understanding prevent some of the most compelling questions about global ecological change from being addressed with satellite data. The table in this box (next page) lists some potential uses of remote-sensing data.

Remote sensing for scientific study-Although an Earth observation satellite has never been launched specifically for ecological studies (41), current operating satellites can help reveal some important aspects of

5 Landsat 4 and 5 are operated and maintained by the Earth Observation Satellite Company (EOSAT, a private company. Landsat 6 will be launched by the U.S. Government but operated by EOSAT (16). The Land Remote Sensing Policy Act of 1992 (P.L. 102-555) transfers all control of future Landsat missions (starting with Landsat 7) to the Department of Defense and NASA (49).

6 Landsat4 and 5 carry the Thematic Mapper (TM) sensor, providing 100-foot (30-m) ground resolution in six spectral bands (one thermal infared band has a 390-foot (120-m) resolution). Landsat 6 is scheduled for launch on September *5,1993,* and will carry an Enhanced Thematic Mapper Imaging Instrument (ETM). ETM will improve the TM by adding a 5-foot resolution panchromatic sensor, making it possible to collect data streams with sharper resolutions and increase vegetation discrimination.

7 See *The Future of Remote Sensing from Space: Civilian Satellite Systems andApplications (49)* for a more complete discussion of the future of remote-sensing technologies.

8 Much of this section was developed from a workshop, "Ecology and Remote Sensing," held September 18, 1992, at the University of Maryland at College Park.

*(Continued on next page)*

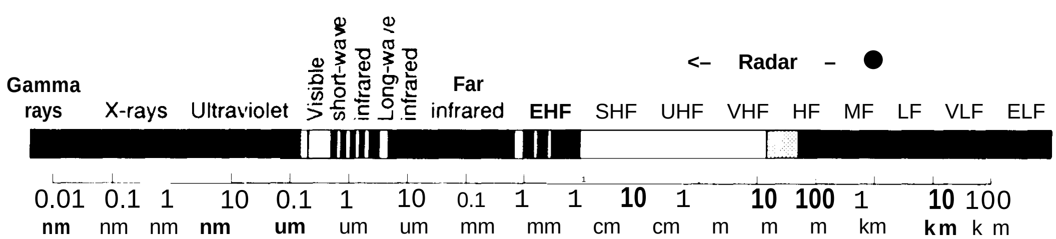
## Box 3-A--Remote Sensing as a Tool for Coping with Climate Change--(Continued)

Potential uses of current remote-sensing data for biosphere study
- Classify land-surface cover
- Detect Vegetation- climate relationships
- Detect frequency and extent of fire
- Detect inundation extent
- Detect surface soil moisture in areas of low vegetation cover
- Detect land and ocean surface temperature
- Calculate ocean color indices
- Calculate vegetation indices
- Estimate global net primary production
- Estimate ranges of evapotranspiration
- Measure horizontal canopy structural characteristics
- Measure canopy biochemical constituents
- Measure vegetation water content

Potential uses of future remote-sensing data.[a]
- Classify vegetation cover by community types or species assemblages
- Detect and monitor margins of ecosystems
- Detect successional stages in forests
- Characterize vegetation stress (in natural communities as well as in crops)
- Estimate contaminant concentrations in water and snow
- Estimate biochemical composition of vegetation canopies in more detail
- Estimate canopy structural characteristics with independent methods
- Estimate biomass
- Estimate extent of deforestation
- Measure soil moisture in vegetated areas
- Measure vertical canopy structural characteristics
- Measure canopy biochemical constituents in more detail
- Measure canopy moisture content
- Measure canopy height

a Some uses may require further research in order to be proven.

SOURCES: U.S. Congress, Office of Technology Assessment (OTA), Ecology and Remote Sensing Workshop, Center for Global Change, University of Maryland at College Park, Sept. 18, 1992; U.S. Congress, Office of Technology Assessment (OTA) workshop, 'EOS and USGCRP: Are We Asking and Answering the Right Questions?" Washington, DC, Feb. 25-26, 1393; S.L. Ustin et al., "Opportunities for Using the EOS Imaging Spectrometers and Synthetic Aperture Radar in Ecological Models," Ecology, vol. *72, No. 6,1991,* pp. 1934-45; D.E. Wickland, "Mission to Planet Earth: The Ecological Perspective," Ecology, vol. 72, No. 6,1991, pp. 1923-33.




Most of the energy that is reflected, absorbed, or scattered by the Earth's atmosphere is visible or shortwave infrared energy (from 0.4 to 4 microns). in the thermal infrared, most attenuation is by absorption. Short-wavelength radiation is reflected by clouds, water vapor, aerosols, and air; scattered by air molecules smaller than radiation wavelengths; and absorbed by ozone in shorter wavelengths (<0.3 micron) and by water vapor at the longer visible wavelengths (>1.0 micron).

SOURCE: A.M. Carleton, Satellite Remote Sensing in Climatology(Boca Raton, FL: CRC Press, 1991).

changing ecosystems and the consequences of various impacts on the biosphere. Most importantly, satellite data have allowed the biosphere to be studied from a new perspective and at much larger scales than ever before, opening up a whole new area of ecological study. The most direct application of satellite data is the detection and study of land-use change. Because satellite data can be used to discern broad classes of vegetation (e.g., grasslands, crops, evergreen forests, and deciduous forests), it has been an important tool in studying the extent of deforestation in the tropics and the extent of desertification in Africa.

Leaf area, which can be calculated from remote-sensing data, has been used for identifying more specific types of vegetation cover of large vegetated areas. A Leaf Area Index (LAI) is being used to identify the extent of specific crops (such as wheat) and their stress levels throughout the growing season. It is also being used to monitor the condition of rangelands, pastures, and other mostly homogeneous land cover. This technique is less useful for natural vegetation where suboptimal growing conditions and a mix of species make t he links among LAI, vegetation type, and health weak.

Remote sensing has also been used to monitor soil-moisture conditions in areas where--and during seasons when--vegetation cover is sparse, but it cannot measure ground soil moisture in heavily vegetated areas. Thus, satellite images ***miss*** most forested wetlands. Coastal erosion and some processes of large, shallow, open wetlands (such as those in the Mississippi River Delta) can easily be studied and monitored over time with remote-sensing data. For adequate delineation of wetlands, many wetland scientists believe that color infrared data at a 16-foot (5-meter)[9] resolution viewed in stereo is required (18). Landsat 7 may be able to get this kind of resolution for wetland delineation, but wetland scientists studying the larger-scale processes of coastal wetlands would rather have a coastal contour map at l-foot contour intervals than improved satellite remote-sensing technology (50).

Remote-sensing data have been used for tipping forest evapotranspiration and photosynthesis-key processes that control the exchange of energy and mass in terrestrial vegetation. Climate change will likely perturb patterns of evapotranspiration and photosynthesis. Regional maps of these processes will help researchers detect and understand such change.

Remote sensing for land-management and planning-Remote-sensing data are being used in conjunction with data from other sources as a tool for land management and planning. For example, the Fish and Wildlife Service launched the Gap Analysis Project (GAP) in 1991 to identify areas of potentially high biodiversity and their protection status to guide future land acquisitions and habitat-protection efforts. Remote sensing (mostly Landsat data) is the primary tool used to identify vegetation types (see vol. 2, box 5J),

In addition, Geographic Information Systems (GISs) have been developed and used throughout Government agencies for regional analyses and planning. Vegetation and land-cover information from remotely sensed data is combined with digitized geologic, geographic, hydrologic, and topographic data in one computer system, so that one overlay containing all this information can be studied and used to test potential land-use decisions (such as altering the hydrology). Such analyses can lead to a better understanding of the Earth's surface and subsurface processes and more sound regional land-use planning near environmentally sensitive areas (see vol. 2, box 5-J).

Ducks Unlimited uses remotely sensed data from satellites in combination with aerial photography from the Fish and Wildlife Service's National Wetlands Inventory project for wetland monitoring. For their purposes, combining National wetlands Inventory digital data with satellite data for evaluating wetland functions is more valuable than using either product alone (18).

Current satellite data are useful for studying ecological processes on a very large scale, but are relatively inadequate for detecting more subtle ecological changes, such as those at ecotones, at the edges of ecosystems, or within an individual plant community. "Satellite data cannot match the extent, classification detail, or reliability" of data from aerial photography and other manual techniques used in the National Wetlands Inventory Project (18).

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9 To convert feet to meters, multiply by 0.305.

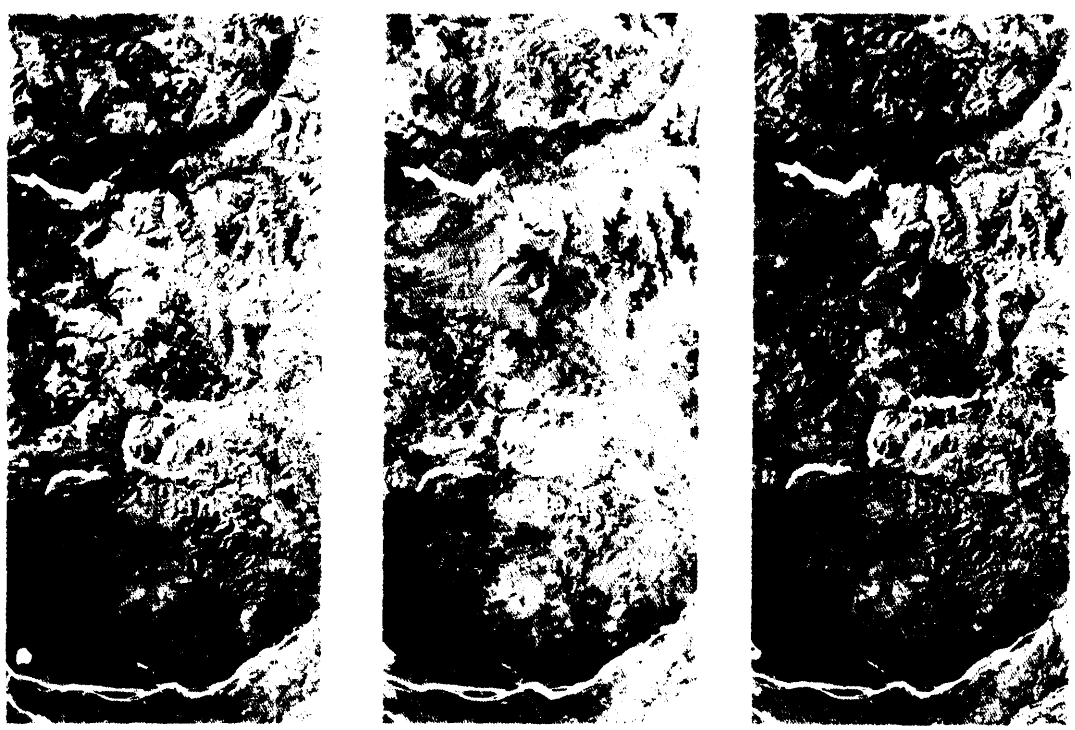
***(Continued on next page)***

## Box 3-A-Remote Sensing as a Tool for Coping with Climate Change--(Continued)

### Limitations to broader applications of remote sensing

The principal drawbacks of satellite data for detecting impacts of climate change are their limited spatial and spectral resolution. Remote sensing can be used to determine broad classes of vegetation, but it cannot identify species or communities. With satellite-based information, it is nearly impossible to study the more subtle aspects of regional ecological change. These include vegetation health in natural areas and mixed forests, ecological change at ecosystem boundaries, migration of a single species or even a species community, drought conditions and soil-moisture trends in heavily vegetated areas, and exact rates of wetland loss. Furthermore, few ecologists are skilled at studying ecosystems at large, coarse-resolution scales.

Technology is available to expand applications of satellite remote sensing for studying impacts of climate change, but high costs, launching requirements, and scientific priorities have delayed its development Even current satellite data have not been used to their full potential for studying potential impacts of climate change. For example, large-scale studies of the biosphere are limited by the availability of data sets. The only global vegetation data set available is the Global Vegetation index (GVI), generated from AVHRR data. Even a



**Landsat MSS Image September 15, 1973** | **Landsat MSS Image May 22, 1983** | **Landsat MSS Image August 31, 1988**

LANDSAT/U.S. GEOLOGICAL SURVEY

***Landsat data have been used to identify and monitor crops, classify forest stands, and assess damages from natural disasters. These Landsat images of Mount St. Helens show the area in 1973 before the volcano erupted and in 1983 and 1988, after the volcano erupted.***

consistent, calibrated, single-source map of U.S. land cover and land use does not exist. More detailed coverage of large areas on the global or continental scale is limited by high costs and data volume. In fact, many university researchers have started to study AVHRR data despite its limited resolution and spectral information because of the high costs of Landsat data.

Another factor that limits wider use of remotely sensed data stems from differences among scientific disciplines. Many ecologists, for example, are not trained to use satellite data (41), and those who use remote-sensing technologies are typically not mainstream ecologists. There has never been a remote-sensing instrument designed specifically for ecological studies (41). Furthermore, few remote-sensing scientists have backgrounds in ecology or biology (41). Ecologists must essentially take what they can get from remote-sensing data that may not be optimal for their field. Opportunities for interdisciplinary studies at universities and the relatively recent surge of interest in ecosystem research (spurred by climate change, deforestation, and global pollution) may help to bridge the gap.

SOURCE: Office of Technology Assessment 1993.

network. Both these shortcomings are important to consider in future discussions about the science base of USGCRP. Many correlative measurements made with airborne platforms or ground-based instruments (that would verify and calibrate the satellite measurements and provide continuous coverage when satellites are not operating) were originally planned to be part of USGCRP but were not funded. Costs for such efforts could be a small percentage of the USGCRP budget—in the tens of millions of dollars each year.[17]

The Landsat satellite monitoring program is of significant ecological interest because it is the primary source of data for detecting long-term ecological trends (18).[18] Landsat satellites contain instruments that analyze multispectral data to obtain images of the Earth (see box 3-A). New technologies have allowed resolution to improve from about 100 feet (30 meters)[19] to a few feet. Landsat data allow changes to be detected in vegetation type and cover, hydrologic patterns, extent of wetlands, land use, and soil moisture. It is the only satellite monitoring program that has a 20-year data set, despite several changes in ownership and new technology over the years that nearly resulted in its termination. The data are just now becoming relevant for ecological studies of changes in vegetation cover due to natural processes. Multidecade data sets are vital to global change research; however, consistency is extremely difficult because the average life of a satellite is only 5 years. A central element of an extended set of missions must be ensuring the compatibility of future satellite data with current data while accommodating new technologies. In addition, subsequent satellites must survive fiscal fluctuations.

## ■ Balance Among NASA and Other USGCRP Agencies

The question of balance between satellite and nonsatellite measurements is directly connected to the question of balance among participating USGCRP agencies. Currently, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Energy (DOE)

17 OTA'S workshop "EOS and USGCRP: *Are we Asking* and Answering the Right Questions?' Washington, DC, Feb. 25-26, 1993.

18 Landsat receives approximately 25 percent of its budget from NASA and 75 percent from DOD. It is a part of NASA's Mission to Planet Earth, but it is separate from EOS.

19 To convert feet to meters, multiply by 0.305.

LANDSAT/U.S. GEOLOGICAL SURVEY

*This Landsat photo of Yellowstone National Park demonstrates the different land-use patterns in the vicinity of the park. A clear line, formed by different land-use patterns, delineate the park boundary. The area spans three States and is managed by Federal, State, private, and tribal landowners. The Federal portion of the area comprises two National Parks, nine National Forests, and land owned by the Fish and Wildlife Service and the Bureau of Land Management. (See vol. 2, ch. 5, box 5-F.)*

control 80 percent of the focused research budget for USGCRP. Even when contributing programs are considered (e.g., those that are ongoing for other reasons), NASA, DOE, and NOAA control 60 percent of the USGCRP budget (see figs. 3-4 to 3-7). The lack of participation by agencies other than NASA has led to gaps in the overall program. For example, DOI, which manages approximately 500 million acres (200 million hectares)[20] of public land that could be affected by climate change, requested a decrease in USGCRP funding for both FY 1993 and FY 1994. This can be attributed partly to management agencies focusing their resources on what they perceive as more immediate management concerns.

Another dimension of the imbalance in agency participation is the historical attraction that Congress and the executive branch have had for space-based research. Federal agencies may correctly perceive that it is easier to get financial support for large, space-based projects than for lower-profile research such as monitoring (36, 55).

NASA's contribution dwarfs contributions from other agencies, but it is unclear how to bring more balance to the program to help fill the gaps and make the necessary links to other global change issues. Because USGCRP does not have a program budget, it would be difficult to redistribute funds across agencies; however, there might be opportunities to modify projects within agencies to help meet the needs of global change research.

## ADAPTATION RESEARCH IN THE FEDERAL GOVERNMENT

The Mitigation and Adaptation Research Strategies program was created about the same time as USGCRP and operated as an independent working group under CEES. MARS was conceived to develop 'a coordinated Federal research strategy for mitigation of, and adaptation to, global change and with assessment of economic, social and environmental effects of the proposed responses. The program addressed four functions: mitigation, adaptation, economics, and social dynamics (5). MARS objectives under its adaptation program were to:

1. determine the sensitivity and adaptive capacity of human and other natural systems to global change, and the social, cultural, economic, and other constraints or impediments to implementation of adaptive measures and methods to reduce those constraints;
2. determine the mechanisms and timing required for current evaluation procedures and practices to be modified to meet soci-

[20] To convert acres to hectares, multiply by 0.405.

ety's needs to accommodate global change, given the uncertainties about the timing and magnitude of global change and its effects; and

3. identify, develop, demonstrate, and evaluate technologies and strategies to adapt to global change.

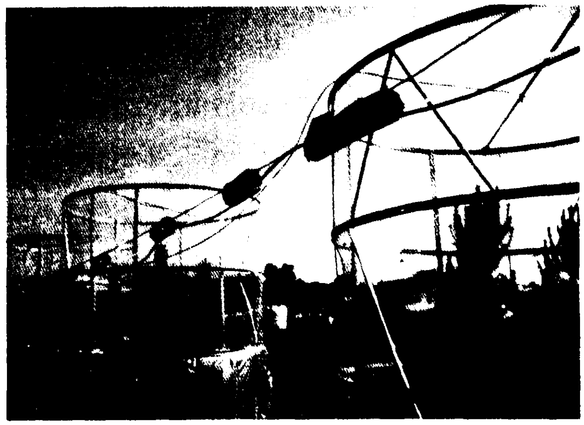
These objectives were to be directed toward water resources; natural systems; food, forestry, and fiber; and human systems. In a sense, MARS was charged with conducting all the research components missing from USGCRP.

However, MARS did not receive the administrative backing that USGCRP did and never developed an interagency research program on mitigation and adaptation research. By 1992, MARS, as a formal entity, ceased to exist. Under the CEES Subcommittee on Global Change, an informal, and later formal, Subcommittee on the Environment and Technology formed in 1992, which continues to address mitigation and adaptation issues, but in a much broader context. Although this subcommittee has no budgetary power, it is holding the door open for agencies with more interest in applied climate change research than in basic research, such as the Environmental Protection Agency, the Department of Housing and Urban Development (HUD), the Tennessee Valley Authority, the U.S. Department of Agriculture (USDA), and the Department of the Interior, to redirect their funds to this end.

Although MARS provided a forum for agencies to discuss global change programs of mutual interest, it was unable to exercise any influence over project selection and funding. Consequently, MARS served primarily to identify existing agency programs and projects that addressed mitigation, adaptation, social dynamics, and economic issues either as a main focus or as a contributing element.

## Research "Focused" on Adaptation

MARS classified only a handful of projects as focused on adaptation research, and funding for these projects totaled $8.18 million in N 1992 (5) (see table 3-3A). These projects are not included in USGCRP per se because they do not conform to the USGCRP mission of ''observe, understand, and predict. "




*Three-level, open-top chambers, such as these at Finley Farm, North Carolina, can be used to study the effects of increased carbon d-oxide, ozone, and drought stress on trees and plants.*

Of the $8.18 million considered focused on adaptation research, NOAA spent $4.1 million, or close to 50 percent, the National Science Foundation (NSF) and EPA each spent $1.2 million, or 15 percent, each, and USDA spent $0.35 million, or 4 percent, of the total spent on adaptation research. DOI, the department that houses land-management agencies responsible for 500 million acres of public land, was conspicuously absent from the MARS list of agencies undertaking focused adaptation research.

Examples of focused adaptation research include: a $200,000 NSF program on the effects of climate change on coastal zones; a $1.1 million USDA program that seeks to simulate the effects of changing climate and management practices on organic matter, crop yields, and rangeland productivity; a $20,000 TVA program on regional climate scenarios; a $30,000 TVA program addressing the sensitivity of the TVA reservoir and power supply systems to extreme meteorology; a $250,000 Department of Defense (DOD) program that assesses the impacts of potential climate

**Table 3-3A—FY 1991 and 1992 Focused Research by Agency and Function ($ millions)**

| | Totals | | Mitigation | | Adaptation | | Economics | |
|---|---|---|---|---|---|---|---|---|
| Agency[a] | 1991 | 1992 | 1991 | 1992 | 1991 | 1992 | 1991 | 1992 |
| DOC | 3.3 | 5.1 | 0.1 | 1.0 | 3.2 | 4.1 | | |
| DOD | | 1.1 | | | | 1.1 | | |
| DOE | 1.7 | 2.2 | 1.7 | 2.2 | | | | |
| DOS | <0.1 | 0.1 | | | <0.1 | 0.1 | | |
| DOT | | 0.2 | | | | 0.2 | | |
| NSF | 1.2 | 1.2 | | | 1.2 | 1.2 | | |
| USDA | | 3.5 | | 2.1 | | 0.4 | | 1.0 |
| EPA | 3.3 | 3.3 | 2.4 | 2,1 | 1.0 | 1.2 | | |
| Totals | 9.5 | 16.5 | 4.1 | 7.3 | 5.4 | 8.2 | | 1.0 |

[a] **DOS= Department of State; DOT= Department of Transportation. For definition of other terms, see table 3-1.**

**SOURCE:** Committee on Earth and Environmental Sciences (CEES), Mitigation and Adaptation Research **Strategies Working Group,** *MARS Working Paper 1: Description of Proposed Cooordinated Program* **(Washington, DC: CEES, 1992).**

**Table 3-3 B--FY 1991 and 1992 Focused Adaptation Research by Agency and Element ($ millions)**

| | Totals | | Natural Systems | | Human Systems | | Food, Forestry, and Fiber | | Water Systems | |
|---|---|---|---|---|---|---|---|---|---|---|
| Agency[a] | 1991 | 1992 | 1991 | 1992 | 1991 | 1992 | 1991 | 1992 | 1991 | 1992 |
| DOC | 3.2 | 4.1 | 0.7 | 1.1 | 0.4 | 1.0 | | | 2.2 | 2.0 |
| DOD | | 1.1 | | | | | | | | 1.1 |
| DOS | <0.1 | 0.1 | <0,1 | 0.1 | | | | | | |
| DOT | | 0.2 | | | | 0.2 | | | | |
| NSF | 1.2 | 1.2 | | | 1.2 | 1.2 | | | | |
| USDA | | 0.4 | | 0.1 | | 0.1 | | 0.1 | | 0.1 |
| EPA | 0.9 | 1.2 | 0.3 | 0.4 | 0.2 | 0.3 | 0.2 | 0.3 | 0,2 | 0.3 |
| Totals | 5.4 | 8.2 | 1.0 | 1.6 | 1.8 | 2.8 | 0.2 | 0.3 | 2.4 | 3.4 |

[a] **DOS= Department of State; 130 T= Department of Transportation. For definition of other terms, see table 3-1.**

**SOURCE:** Committee on Earth and Environmental Sciences **(CEES), Mitigation and Adaptation Research Strategies Working Group,** *MARS Working Paper I: Description of Proposed Coordinated Program* **(Washington, DC: CEES, 1992).**

change on water resource management; and a $50,000 DOE program on regional impacts that seeks to develop a model designed to capture the essential climate-sensitive relationships within and between resource sectors (6).

Research that MARS classified as focused on economics received $1.0 million in FY 1992; no research was classified as focused on social dynamics.

## Research "Contributing" to Adaptation

MARS identified research on the effects of climate change on natural and engineered systems and research on the potential impact on society of these changes as contributing to adaptation research. With the exception of NASA's component, the majority of USGCRP research under the science elements Ecological Systems and Dynamics and Human Interactions can be considered impacts research--that is, how climate change effects plants, animals and people. Ecological Systems and Dynamics research made up $224 million, or 17 percent, of the FY 1993 USGCRP budget, and Human Interactions research made up $22 million, or less than 2 percent of the USGCRP budget. NASA spent 66 percent

**Table 34A-Percent of Total FY 1992 USGCRP Budget for the Third Science Element, Ecological Systems and Dynamics (ESD), Compared with Percent of Each Agency's GCRP Budget for ESD[a]**

| Agency | Percent of USGCRP ESD budget allocated or requested[b] | | Percent of USGCRP ESD budget allocated or requested as percent of each agency's GCRP budget | |
|---|---|---|---|---|
| | FY 1993 | FY 1994 | FY 1993 | FY 1994 |
| DOC/NOAA | 1 | 1 | 5 | 4 |
| DOD | <1 | <1 | 15 | 15 |
| DOE | 2 | 2 | 4 | 4 |
| DOI | 4 | 3 | 21 | 24 |
| EPA | 4 | 4 | 36 | 39 |
| HHS | 0 | 0 | 0 | 0 |
| **NASA[c]** | **66** | **66** | **16** | **16** |
| **NSF** | **10** | **12** | **17** | **18** |
| Smithsonian | 2 | 2 | 62 | 62 |
| TVA | 0 | 0 | 0 | 0 |
| **USDA** | **11** | **10** | **53** | **52** |

[a] **ESD received $224,3 million in FY 1993; for FY 1994, the budget request is for $249.3 million** (approximately 17 percent of the total USGCRP budget).
[b] FY 1993 figures represent appropriated funds; FY 1994 figures represent requested funds.
[c] Part of the reason the NASA figures are so high is that the capital costs of their projects are greater relative to other projects, Although these comparisons are instructive, they do not reflect information on the cost and yield of research.

**Table 3-4 B-Percent of Total FY 1992 USGCRP Budget for the Fifth Science Element, Human Interactions (Hi), Compared with Percent of Each Agency's GCRP Budget for HI[a]**

| Agency | Percent of USGCRP HI budget allocated or requested | | Percent of USGCRP Hi budget allocated or requested as percent of each agency's GCRP budget | |
|---|---|---|---|---|
| | FY 1993 | FY 1994 | FY 1993 | FY 1994 |
| DOC/NOAA | 3 | 3 | 1 | 1 |
| DOD | 0 | 0 | 0 | 0 |
| DOE | 11 | 10 | 3 | 3 |
| DOI | 13 | 6 | 7 | 4 |
| EPA | 15 | 11 | 13 | 10 |
| HHS | 5 | 6 | 100 | 100 |
| NASA | 0 | 0 | 0 | 0 |
| NSF | 42 | 53 | 8 | 8 |
| Smithsonian | 3 | 3 | 10 | 10 |
| TVA | 0 | 0 | 0 | 0 |
| USDA | 8 | 9 | 3 | 4 |

[a] HI received $22.2 million in FY 1993; for FY 1994, the budget request is for $24.4 million (approximately 1.6 percent of the total USGCRP budget).
[b] FY 1993 figures represent appropriated funds; FY 1994 figures represent requested funds.
SOURCE: Office of Technology Assessment, 1993.

of the total USGCRP Ecological Systems and Dynamics budget; however, Ecological Systems and Dynamics research represents only 16 percent of the agency's global change research budget (see table 3-4A). In addition, NASA's research in this area focuses primarily on ecological *functions* and *characterizations,* not *effects* of climate change on ecological systems. In contrast, USDA spends only 11 percent of the USGCRP Ecological Systems and Dynamics budget, which represents 53 percent of their global change research budget. DOI spends 3.5 percent of the USGCRP Ecological Systems and Dynamics budget, which represents 21 percent of their global change research budget (see table 3-4A). The agencies that one would expect to conduct the bulk of research on ecological systems and the effects of climate change on ecosystems—EPA and the land-management agencies of DOI and USDA—play only a minor role. The reasons are varied and complex, but include the higher capital costs of NASA projects and the reluctance of some agencies to actively support and participate in the program. Consequently, these agencies' contributions to USGCRP comprise projects that are in place for reasons other than climate change research, such as characterizing ground- and surface-water flows, maintaining weather data, and monitoring ecosystem change.

Definitions of what encompasses Ecological Systems and Dynamics research become very important in the face of such disparate budget allocations among agencies. If the definition is not consistent across agencies, or if it is too broad, large gaps could potentially exist. For example, it is unclear how much large ecosystem research is being conducted—such as research on the use of corridors for the migration of plants and animals in response to global change or techniques for ecosystem transplantation. Are we clarifying rates at which various species in an ecosystem can migrate? Do we understand how to maintain ecosystems in place? Will pest ranges increase? Will fire hazards increase'? Are our crop and tree varieties genetically diverse enough to cope with the range of potential changes? What agencies are addressing these questions, and is research adequate to find the answers to these questions? What questions under this research category does NASA attempt to answer compared with what questions USDA attempts to answer? NASA's contribution to the understanding of ecological systems comes largely from space-based measurements and observations, whereas the land-management agencies' contribution comes more from field research. Box 3-B highlights weaknesses in environmental research identified by the National Research Council (NRC).

Of the $22 million spent on Human Interactions, NSF spends 42 percent, which represents 7.5 percent of their global change research budget. Except for the Department of Health and Human Services (HI-IS), which spends $5.41 million, or 100 percent, of its USGCRP budget on Human Interactions, the percent of agency USGCRP budgets allocated to Human Interactions ranges from 0 to 10 percent (see tables 3-3B and 3-4B). Although it is difficult to obtain reliable numbers, because social science research has many labels, it is doubtful that any Federal agency devotes as much as 1 percent of its total research budget to environmental social science (37).

Specific projects classified as contributing to adaptation include: a $4.7 million program at DOI's National Park Service (NPS) to improve the scientific basis of adaptive management of the types of ecosystem responses likely to be associated with climate and other global environmental changes; a $1.3 million program at DOI's Bureau of Reclamation (BOR) to study the changes in hydrologic processes under scenarios of global climate change and to determine the potential impacts on snowpack, snowmelt, and runoff in the 17 Western States; a $1.5 million program at DOI's U.S. Geological Survey (USGS) to evaluate the sensitivity of water resources to climate variability and change across the United States; and a $150,000 DOE program to evaluate the existing social science knowledge base concerning energy and the analysis of the role of institutions in making decisions affecting climate change (6).

Very little of the effects research described above could also be considered research on the impacts of global change on human systems. USGCRP'S new Economics Initiative does consider the impact of climate change on the economy, and several agencies support research in this area, including NSF, NOAA, and USDA (in its Economics Research Service). However, the eco-

**Box 3-B-Weaknesses in U.S. Environmental Research Identified by the National Research Council**

- The research establishment is poorly structured to deal with complex, interdisciplinary research on large spatial scales and long-term temporal scales. These traits characterize the primary needs of an effective environmental research program.
- There is no comprehensive national environmental research plan to coordinate the efforts of the more than 20 agencies involved in environmental programs. Moreover, no agency has the mission to develop such a plan, nor is any existing agency able to coordinate and oversee a national environmental research plan if one were developed.
- The lack of unintegrated national research plan weakens the ability of the United States to work creatively with governments of other nations to solve regional and global problems.
- The Nation's environmental efforts have no clear leadership, As suggested by the lack of a cabinet-level environmental agency, the United States has lacked strong commitment to environmental research at the highest levels of government. Environmental matters have been regarded as less important than defense, health, transportation, and other government functions.
- Although individual agencies and associations of agencies analyze data to provide a base for decisions on strategies and actions to address specific environmental problems, no comprehensive "think tank" exists for assessing data to support understanding of the environment as a whole and the modeling of trends whose understanding might help to set priorities for research and action.
- Bridges between policy, management, and science are weak There is no organized system whereby assessments of environmental problems can be communicated to decisionmakers and policy-setters.
- Long-term monitoring and assessment of environmental trends and of the consequences of environmental rules and regulations are seriously inadequate. The United States has a poor understanding of its biological resources and how they are being affected by human activities. Although biological surveys have a long history at the State and Federal level in the United States, it is only very recently that we appear to be approaching a consensus on the need for a comprehensive, national biological survey.
- There is insufficient attention to the collection and management of the vast amount of data being developed by the 20 agencies involved in environmental research. Collection and management of environmental life-science data are less well organized than those of environmental physical-science data.
- Education and training in the Nation's universities are still strongly disciplinary, whereas solution of environmental problems requires broadly trained people and multidisciplinary approaches, Opportunities for broadly based interdisciplinary graduate degrees are few, and faculty are not rewarded as strongly for interdisciplinary activities as they are for disciplinary activities. Thus, there is a risk that environmental scientists appropriately trained to address pressing needs will be lacking.
- Biological-science and social-science components of environmental research are poorly supported, compared with the (still inadequate) support given to the physical sciences.
- Research on engineering solutions to environmental problems is seriously underfunded. That reduces our ability to protect ecosystems and restore damaged ones to productivity and jeopardizes the Nation's ability to achieve major economic benefits that are certain to derive from increasing worldwide use of technologies for these purposes.
- With respect to environmental affairs, government operates in a strongly adversarial relationship with both industry and the general public, to the detriment of integrated planning and maintenance of an atmosphere of mutual trust that is essential for effective government functioning.
- With important exceptions in the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey, most environmental research and development is narrow, supporting either a regulatory or a management function. That appears to be particularity true in the environmental life sciences.

SOURCE: National Research Council, Research to Protect, Restore, and Manage the Environment, Committee on Environmental Research, Commission on Life Sciences (Washington, DC: National Academy Press, 1993).

nomics component of USGCRP is not well-integrated with the rest of the program.[21]

CEES is aware of the absence of research on the impacts of climate change and has slightly expanded Earth Process Research, the second integrating priority, to include research to determine the impacts associated with predicted global changes (12). However, explicit recognition of the need for research on impacts of climate change is not yet reflected in the program structure.

## A New Adaptation Program

For reasons discussed above, it is necessary to pursue research on impacts of global change and potential response and adaptation strategies without waiting for USGCRP to complete climate research. The issues addressed by MARS continue to be discussed because MARS sought to answer near-term policy questions and questions that naturally accompany climate change research: If the climate is changing, how will forests, agriculture, and natural areas be affected and what should we do? MARS may not have had the administrative, congressional, and program support it needed to pursue its mission a few years ago, but now MAIM-related questions are being asked with more persistence, and it might be time to consider reinstating another MARS-type program.[22] The following discussion addresses how such a program might be structured. We suggest some possible ways to incorporate adaptation into USGCRP below and in option 3-5.

A framework for developing research priorities for an adaptation research program (ARP) should be developed through a combination of an interagency committee and an external advisory panel. The interagency committee should consist of members from several scientific disciplines and the policy- and decisionmaking communities. Committee and advisory panel members should be committed to the goal of creating a management- and policy-relevant research program.

The committee and advisory panel could address the following questions:

1. What areas of science are important to pursue in order to support adaptation research? What existing federally supported research, which is not currently classified as global change research, could be augmented to support an adaptation-focused research program?
2. What areas of research would most effectively reduce the physical, biological, social-behavioral, and economic uncertainties faced by decisionmakers in choosing among policy options affecting global change?[23]
3. How can ARP be organized so that it is useful to public and private decisionmakers?

Answers to these questions require cooperation and coordination in the ecological and social sciences communities, coordination among the land-management agencies, and a clear delineation of the role of adaptation research in agency policy and management. As concluded by the Committee on Human Dimensions of Global Change, there is "an almost complete mismatch between the roster of Federal agencies that support research on global change and the roster of agencies with strong capabilities in social science" (35). There is a similar mismatch between the roster of Federal agencies with environmental responsibilities and the roster of agencies with strong capabilities in social science (37).

21 OTA's workshop "EOS and USGCRP: Are We Asking and Answering the Right Questions?" Washington, DC, Feb. 25-26, 1993.

21 OTA's workshop "EOS and USGCRP: Are We Asking and Answering the Right Questions?' Washington, DC, Feb. 2S-26, 1993.

22 Congress specifically asked OTA to address adaptation issues; however, if Congress chooses to instigate an adaptation program, it should also decide whether related mitigation issues should readdressed along with an adaptation program, as a separate program, or within USGCRP.

23 This question was developed in the National Acid Precipitation Assessment Program's @NM'@ 1984 annual report for Task Group I (39). Unfortunately, that task group was disbanded the next year.

The Ecological Society of America's Sustainable Biosphere Initiative (SBI) has made a start in fostering cooperation among the ecological and social sciences. SBI has clearly laid out scientific priorities in the ecological sciences. Coordination among the land-management agencies is also beginning with groups such as the Terrestrial Research Interest Group, an ad hoc coordinating committee of Federal agencies and other organizations conducting terrestrial research (see box 5-J). An adaptation program could continue to encourage such efforts.

### *Budget* Mechanisms *for* ARP

Because the scope of any ARP would reach across agencies, a new agency or executive body, or a new office in an existing agency, could be created to house it or, as with USGCRP, a budget crosscut could be used. Because several agencies have significant expertise and infrastructure to pursue research on adaptation to global change and because of budget constraints, Congress might find it difficult to create a separate body for ARP. If an existing agency housed ARP, it could undermine the ARP mission by creating tension among agencies about interagency authority. Because budget crosscuts have worked well in the past, at least until the point when they are submitted to Congress, the use of a budget crosscut for ARP might be desirable.

FCCSET currently coordinates the budget crosscut of USGCRP and could coordinate the budget crosscut for ARP. However, because FCCSET supports science, engineering, and technology initiatives but does not initiate management- and policy-relevant deliberations within these programs, it may not be the best organization for ARP budget coordination. If an office within the White House coordinated ARP's budget, the program could more easily maintain its emphasis on policy-relevant research; however, it might be more subject to political pressure.

### ARP Within USGCRP

If Congress does not wish to create anew ARP, but chooses instead to augment the existing USGCRP three points should be considered. First, the priorities of USGCRP would need to be changed. In addition to observation, understanding, and prediction, "planning' for climate change and other global changes, including adaptation, would have to be incorporated into the USGCRP goals. The seven scientific elements in the priority structure of USGCRP might need to be rewritten, with the help of advisory panels, agency personnel, and, perhaps, the National Research Council. More funds would need to be allocated to the research topics under the present Ecological Systems and Dynamics and Human Dimensions elements. Adaptation would have to be incorporated into the existing elements, or a new adaptation element would have to be added.

Second, as would be the case with a separate program for adaptation, the land-management agencies must be encouraged to unify their research programs that address ecological and human-system response to and management of global change. Congress must commit more resources to the Ecological Systems and Dynamics and Human Interactions research areas, especially within the land-management agencies. Finally, projects currently supported under USGCRP would need to be reviewed for their usefulness to adaptation research. For example, the Earth Observing System (EOS) currently concentrates on climate monitoring and ecological monitoring, primarily for the sake of determining land-atmosphere interfaces for global climate models. Could EOS be modified to provide information on processes that are important for adaptation?

## EVALUATION MECHANISMS

To date, there has been no formal evaluation of the overall scope, goals, and priorities of USGCRP and of whether its activities collectively are addressing the needs of policy makers.

Several evaluation mechanisms could be used to address the dichotomy between science and policy in USGCRP, including internal and external reviews, integrated assessments, and coordinated congressional oversight. Appropriate communication links among scientific disciplines, Federal agencies, State agencies, policy makers, decisionmakers, and all levels of USGCRP are vital for its success.

## ■ Reviews

Most formal reviews of USGCRP elements have centered on the instruments and methods used in research about specific scientific priorities or have focused on individual projects within the program. For example, teams reviewing the EOS program have addressed specific instruments that EOS should use, and the National Academy of Sciences (NAS) has carried out reviews and midcourse evaluations of specific agency programs and projects.

Reviews should be used as a mechanism for maintaining flexibility in the program and to redirect its activities, if necessary. Reviews should: be timely and efficient; include people who do not have an immediate stake in USGCRP, but do have significant knowledge about its current structure, content, and history; be conducted periodically to reflect the nature of the questions being asked; and identify programs that can be eliminated as well as recommend new ones. Perhaps most importantly, reviews that call for a redirection in the overall program should consider that research on global change issues requires a financial and institutional commitment that transcends political and budgetary cycles. Reviews should not be used to respond to the political crisis of the day or as a mechanism to undermine effective programs with long time horizons.

## ■ Integrated Assessments

Reviews generally look at individual parts of a program or the program as a whole and determine how they are functioning; they do not try to integrate the program's different research results. Integrated assessments are a mechanism for synthesizing all the research relevant to an identified problem and for presenting research results in a policy context to decisionmakers (13, 42).[24] Just as important, integrated assessments help guide research and identify key assumptions, uncertainties, gaps, and areas of agreement. The Federal Government tried to incorporate an assessment process into the National Acid Precipitation Assessment Program (NAPAP) in the 1980s with only limited success (see box 3-C). A challenge for the global change research community will be to devise assessments that minimize disruption of ongoing programs but still allow for redirection of program elements in light of new discoveries, advances in technology, and changing long-term needs of policy makers.

Scientific information is critical, but not sufficient, in determining how the United States should respond to the risks of global change. If USGCRP is to be driven by social relevance as well as by scientific curiosity, its research priorities should include sociocultural factors as well as physical factors (23). Integrated assessments could help determine the importance of the problems presented by global change relative to other policy problems, outline alternative policies to respond to global change, and explain the pros and cons of various responses and implementation strategies.

For example, preliminary results of an integrated assessment computer model to prioritize policy-relevant research, by Carnegie Mellon University, suggest that: economic and ecological impacts are unambiguously the most important

24 Integrated *assessment* (also known as *comprehensive and end-to-end Assessment)* is an evolving concept. An integrated assessment of global change would generally include at least the following activities: assessments of the physical science component of a project; assessments of the potential impacts of change on the environment, human health, and the economy; assessments of the effectiveness and economic impact of possible societal responses to change; and assessments of the political feasibility of possible responses (31).

## Box 3-C--Lessons from NAPAP

In 1980, Congress passed the Acid Precipitation Act (Title Vll of the Energy Security Act, P.L. 98-294) and thereby established an interagency task force to plan and oversee a 10-year National Acid Precipitation Assessment Plan (NAPAP). The National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the Environmental Protection Agency jointly chaired the task force, which included representatives from the Department of the Interior, the Department of Health and Human Services, the Department of Commerce, the Department of Energy, the Department of State, the National Aeronautics and Space Administration, the Council on Environmental Quality, the National Science Foundation, and the Tennessee Valley Authority along with representatives of the Argonne, Brookhaven, Oak Ridge, and Pacific Northwest National Laboratories and four Presidential appointees. The purpose of NAPAP was to increase our understanding of the causes and effects of add precipitation through research, monitoring, and assessment activities that emphasized the timely development of science for use in decisionmaking (39).

NAPAP (with an annual budget that ranged from about $17 million at the beginning of the program to just over $300 million at its end) was one of the most ambitious interagency programs ever focused on a particular problem (47). It was designed to be a major research effort that provided policy-relevant information in a timely manner. It succeeded in its research efforts, but it did not provide policy-relevant information in a timely manner. Because the nature of problems facing the country is increasingly interdisciplinary and global in scope, it is reasonable to assume that the government will mandate more programs that try to bridge the gap between science and public policy. To reap the greatest benefits from these programs, it will be necessary to incorporate the lessons of NAPAP into program structure. This box focuses on the Task Group on Assessments and Policy Analysis and the overall lessons learned from such a large, interagency program.

When founded, NAPAP consisted of 10 task groups, each with a single agency serving as the coordination contact: Natural Sources of Acid Precipitation, Human Sources of Acid Precipitation, Atmospheric Processes, Deposition Monitoring, Aquatic Effects, Terrestrial Effects, Effects on Materials and Cultural Resources, Control Technologies, Assessments and Policy Analysis, and International Activities. In 1985, the assessments and policy analysis task group was disbanded--a decision that undermined the value of the program for decisionmakers.

Congress established NAPAP in large part to determine whether acid rain was a problem. However, in the context of research NAPAP did not approach acid rain as a unified issue. Rather, it examined the subject at multidisciplinary and subdisciplinary levels with little emphasis on synthesizing findings, As stated in one critique *(24):*

> The program reported findings in excruciating disciplinary detail, an approach which was not especially helpful to non-specialist decision makers. The disciplinary pluralism of NAPAP also allowed policy advocates to pick and choose among NAPAP's reported findings, emphasizing facts or uncertainties supporting a particular position and reemphasizing others. NAPAP lacked an extra-disciplinary perspective that would have allowed it to characterize acid rain as a problem, non-problem, or ' something in between,

Assessment and policy analysis research develops and uses quantitative methods to organize and communicate scientific and other information in ways that allow comparison of policy choices. These methods include decision analysis, benefit-cost analysis, risk analysis, and technology assessments. The NAPAP Task Group on Assessments and Policy Analysis attempted to begin early in the program to develop integrated assessment methodologies and to perform multiple assessments throughout the program to ensure policy relevance. A 1985 report was to include an assessment of the current damages attributed to acid deposition, an uncertainty analysis of key scientific areas, and the implications of uncertainty for policy choices. The task group also tried to develop a framework for the methodology for subsequent integrated assessments in 1987 and 1989 (25),

*(Continued on next page]*

## Box W-lessons from NAPAP--(Continued)

However, in 1985, NAPAP's management changed and, consequently, the focus of the program changed. The assessments task group was disbanded, and responsibility for assessments was transferred to NAPAP's director of research. It was uncertain whether NAPAP would produce even one assessment: NAPAP ceased funding integrated assessment modeling because the Interagency Scientific Committee decided to spend their limited funding on other research. The new director repeatedly delayed the 1985 assessment, but it was finally released-with much controversy--in 1987. The 1987 and 1989 integrated assessments were never produced. Finally, during the last few years of the program, NAPAP produce its second integrated assessment; however, the 1990 publication of the report came too late to be of maximum use to policy makers in formulating the amendments to the Clean Air Act (47).

Because NAPAP failed to carry out the full range of assessmentis t originally planned, key components for the 1990 integrated assessment were either not pursued or were underfunded, and the assessment was incomplete (39). For example, although NAPAP was initially supposed to evaluate the economic effects of add deposition on crops, forests, fisheries, and recreational and aesthetic resources and to determine the implications of alternative policies, funds were significantly reduced for research in these areas (47).

The Oversight Review Board (ORB) of NAPAP, in its 1981 report to the Joint Chairs council of the Interagency Task Force on Acidic Deposition, strongly emphasized that an assessment function be given primacy throughout an interagency program (39). ORB's keyrecommendation on lessons learned about the interface between science and policy was to give assessment priority over research (24) because "science and research findings *per se* have little to offer directly to the public policy process, [and] their usefulness depends on assessment, defined as the interpretation of findings relevant to decisions" (39). ORB also outlined eight other suggestions that any program with such a close interface between science and policy should follow:

1. Match institutional remedies to problems.
2. Obtain and maintain political commitment.
3. Take steps to ensure continuity.
4. Configure organization and authority to match responsibility.
5. Give assessment primacy.
6. Provide for independent external programmatic oversight.
7. Understand the role of science and how to use it.
8. Take special care with communication.
9. Prepare early for ending the program.

The insights gained from the experiences of NAPAP were not considered when designing the U.S. Global Change Research Program (USGCRP)-a much larger program on both a temporal and spatial scale than NAPAP. Some argue that USGCRP is following the same path as NAPAP--good research will come from USGCRP, but the results will not be used to inform policy, and decisions concerning global change will be made with little more knowledge than is available today (42). The logical questions to ask are: Why didn't Congress use the experiences of NAPAP in formulating legislation for USGCRP, and how should incorporation of lessons from NAPAP be integrated into USGCRP and future Interagency programs?

**SOURCE: Office of Technology Assessment, 1993.**

**sources** of uncertainty **and** that reducing the uncertainty is more important than resolving the differences among climate models; the priority placed on research in different fields will vary according to the policy objectives chosen and the time horizon; although they must not be ignored, uncertainties about climate variables appear, in many cases, to be less important than certain social, economic, and ecological factors; and models that measure all impacts in monetary terms are unlikely to be able to explore many of the most important aspects of the climate problem (15).

Regardless of the scope of an integrated assessment, its primary functions should be: to identify key questions to be answered, to survey the state of current scientific judgments about what we know and do not know about global change and its impacts, to identify and prioritize what the key uncertainties are in relation to policy needs, to list key assumptions and judgments, to identify where new research is needed to aid the policy process most effectively, including research on key uncertainties in understanding the climate system and fostering mitigation and adaptation research, and to establish the requirements for peer and public review (24, 42).

Assessments need not be conducted sequentially (e.g., results of earth science research or economic research need not be complete before an assessment can begin), but should begin at the beginning of a program and continue throughout the life of the program (l). The ideal assessment would pay particular attention to bridging gaps and maintaining essential links among various research projects and disciplines and would determine the value of new information.

The Massachusetts Institute of Technology, Carnegie Mellon University, the Electric Power Research Institute, and Battelle Pacific Northwest Laboratory have programs for developing computer models for integrated assessments. For example, the Battelle Pacific Northwest Laboratory is developing an Integrated Climate Change Assessment Model (ICCAM)[25] that will incorporate information from models on human activities, atmospheric composition, climate and sea level, and terrestrial ecosystems (17). ICCAM is intended to be an integrated collection of these models in a reduced, or simplified, form, with the goal of giving practical answers to practical questions. The models are limited by the complexity and uncertainty of each system, and some fear that the results from these integrated assessments could be difficult to understand. However, these models can at least help to structure thought, direct inquiries, identify which uncertainties are important and which are not, and suggest courses of action (40).

Assessments could be performed by independent, nongovernment committees, Federal interagency task forces consisting of agency personnel who are participating in the program, a mix of the two groups, or by the National Academy of Sciences (42). Nongovemment committees would offer the fresh perspective of independent evaluators who are less weighed down by political agendas; however, they might have little control over the agencies they are trying to influence. Interagency committees would have the advantage of using Government researchers who are well-informed about the program and who could not easily ignore assessment findings.

To date, integrated assessments have received little administrative support and almost no funding from any ongoing program. Some agency personnel have expressed interest in integrated assessments, but few have committed any resources to it (EPA and DOE have funded some assessment research). The little funding that integrated assessments have received has come largely from NSF and the Electric Power Research Institute. A small percentage of the total USGCRP budget—perhaps 1 to 5 percent--could be set aside for integrated assessment (15, 50). The Carnegie Commission also recommends that a larger percentage of environmental research and development dollars go toward assessment and policy research (4).

[25] Battelle Pacific Northwest Laboratory is working in conjunction with the University Corporation for Atmospheric Research, the Electric Power Research Institute, the U.S. Department of Energy, and the Environmental Protection Agency.

## ■ Congressional Oversight

Congress has held several hearings on global climate change that have focused predominantly on what we know, what we do not know, the accuracy of current data, reconciling the existence of conflicting data, the implication of climate change for natural resources and the economy, and the potential costs of actions designed to mitigate climate change. However, these hearings have not successfully addressed USGCRP as a program. Some hearings have focused on the current research of program participants, which is a first step in determining the necessity of the research, but few have focused on whether USGCRP research was supplying information needed to develop policy responses to global change. The direction of the program and its emphasis on the frost two science elements have not been altered.

In addition, the different committees with jurisdiction over USGCRP have not been equally active in their oversight activities. As a result, certain portions of the program are regularly reviewed while others are never reviewed.

New approaches to traditional authorization and appropriation procedures for large interagency programs such as the USGCRP need to be considered. The current authorization and appropriation process guarantees that USGCRP will be examined by Congress only in pieces (38). An annual, ad hoc appropriation subcommittee might be created to specifically address the USGCRP budget as a whole. This committee should consist of members from appropriation subcommittees with jurisdiction over elements of USGCRP (see table 3-2).

For congressional oversight to be effective in influencing USGCRP, a long-term systematic approach to communication and oversight must be developed. Congressional feedback, expectations, and prospective actions must be communicated quickly to the program. Oversight should be extended to include regular meetings among policy makers who have jurisdiction over USGCRP and USGCRP participants; an interdisciplinary, multiagency group working with USGCRP; and outside reviewers. Results from these meetings should be freely and widely disseminated. Oversight hearings should be coordinated with all committees who have jurisdiction over USGCRP (see table 3-l).

# POLICY OPTIONS: AUGMENTING THE FEDERAL RESEARCH EFFORT ON GLOBAL CHANGE

To policy makers, climate change does not become a problem the moment that the change in the Earth's mean average temperature becomes statistically significant. For them, it becomes a problem when a community feels the pinch of an unwanted event-drought or flood or decline of timberland, for example. Knowing how best to ameliorate or cope with any costs that climate change might induce is important to policy makers. Knowing how mitigation efforts to reduce greenhouse gases will affect our ability to adapt is important. Knowing what information is knowable and unknowable over various time scales is important to policy makers. This kind of information does not automatically emerge from a basic research program. To be useful to the governing bodies of the world, the science facts gained by USGCRP must somehow be translated into potential costs or benefits incurred by climate change and must guide strategies to prepare for or react to change. Currently, there is no formal mechanism in USGCRP for making the link between policy and science.

Given the complicated and long-term nature of climate change, the research needed to understand it, and the shorter-term needs of policy makers, a research program for global change should ideally:

- identify the key science and policy questions for the near term and the long term;
- orchestrate a research program that involves the physical, biological, and social scientists;

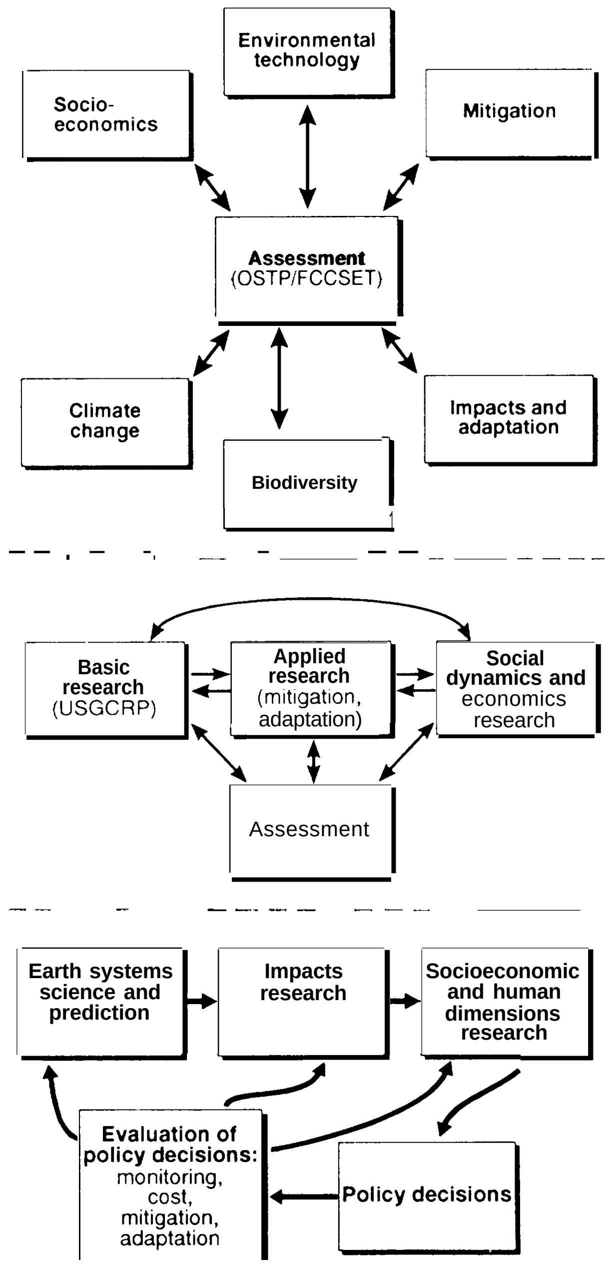
- integrate the research results across disciplines (i.e., assess the state of understanding) periodically; and
- communicate results back to the researchers and policy makers effectively.

Identifying the outcomes that matter to policy makers should be the first step in refining global change research programs, with scientists helping the policy makers to ask pertinent questions (14). Next, scientific priorities should be compared with the policy questions. Where there are serious mismatches between scientific and political priorities, programs should be reevaluated-not to direct a basic science agenda, but to ensure that key information needed for policy decisions from many disciplines is available alongside the fundamental chemistry and modeling. The particular disciplines, research methods, and instruments that would be used to gather and analyze data should flow from these priorities and should be science-driven. Ideally, information needs of decisionmakers will influence questions asked by scientific researchers, and vice-versa. For example, the communication between scientists and policy makers may cause a change in key policy questions, which in turn may redirect the research program; "policy makers need to understand the limitations of what science can determine, and scientists must understand what the policy community really needs" (42). This has proved difficult in past research efforts, such as NAPAP's (See box 3-C).

The following policy options generally fall under three categories:

- Effectively broaden USGCRP by incorporating results of Federal research relevant to but not currently under its purview. USGCRP as currently constructed and implemented cannot do this. It could require congressional or executive branch codification. There are several policy options directed both at broadening USGCRP and at ensuring that USGCRP and other programs relevant to global change are connected (the

**Figure 3-8-Alternative Organizational Schemes for Global Change Research**




SOURCE: Office of Technology Assessment, 1993.

diagrams in fig. **3-8** show some possible organizational schemes for building in some of the missing components). The National

Research Council has recommended the creation of a National Environmental Council in the Executive Office of the President (37), and the National Commission on the Environment (NCE) recommended the development of a National Environmental Strategy (34); either or both of these could complement the options described below.

- Increase funding or redirect funding to areas where research is inadequate. A modest redirection of 1 to 5 percent of current funding ($15 to $70 million) could begin filling in the large gaps between the current climate change program and a policy-relevant global change program (15, 50). Because the bulk of this OTA report focuses on natural-resource-based systems and the Nation's potential to adapt to climate change, we discuss coordinating existing ecosystem research and initiating new efforts that are critical to planning for and/or managing natural resources under climate change. However, building strong socioeconomic components of USGCRP is equally important.
- Make the program more relevant to policy making by incorporating an assessment function. Assessment and regular reevaluation of USGCRP could be instrumental in identifying the current information base on climate change, gaps in knowledge, and short- and long-term policy questions.

## Effectively Broaden USGCRP

As currently structured, USGCRP is a collection of programs from several agencies with no central management. Although research should remain decentralized, coordination should be centralized and top-down. The Subcommittee on Global Change Research under the Committee on Earth and Environmental Sciences is currently responsible for coordinating activities under the Federal Coordinating Council for Science, Engineering, and Technology. FCCSET acts largely as a fulcrum for coordination, but agency participation in FCCSET projects is voluntary, and FCCSET has no authority over how participating agencies spend their funds. A previous OTA report (48) looked broadly at the health of U.S. research and development and concluded:

> In the Executive Branch, Congress should insist, at a minimum, on iterative planning that results in: a) making tradeoffs among research goals; and b) applying (after scientific merit and program relevance) other criteria to research decisionmaking that reflects plarnning for the future. . . OSTP [Office of Science and Technology Policy] could initiate broader priority-setting.

Option 3-1: Amend *the Science Policy Act of 1976 (PL. 94-282), which established the Office of Science and Technology Policy and the Federal Coordinating Council on Science, Engineering, and Technology, to strengthen the ability of these offices to coordinate science and ecosystem management across agencies.* OSTP was established to "define coherent approaches for applying science and technology to critical and emerging national and international problems and for promoting coordination of the scientific and technological responsibilities and programs of the Federal departments and agencies in the resolution of such problems, ' and FCCSET was established to "provide more effective planning and administration of Federal scientific, engineering, and technological programs" (P.L. 94-282). These offices have the authority to develop and implement coherent, Government-wide science policy and have been the mechanism for coordinating several multiagency programs. However, OSTP has not always been an active or influential player in the executive branch, and FCCSET lacks the authority to set priorities, direct policy, and fully participate in the budget process (2, 21). The directions for environmental research must be set—and responsibilities among various Federal agencies must be coordinated-at the executive level because environmental research is of the highest national importance.

About 20 Federal agencies have major responsibilities related to the environment. In all instances (except for EPA), concern for the environment is not the primary role of the agency conducting the environmental research (37). For example, DOE supports much environmental research, but the department's primary responsibility is energy, not the environment.

OSTP could be given budgetary authority, perhaps in conjunction with the Office of Management and Budget, to guide agency programs that contribute to science and technology. This could mean reinstating "fencing," or requiring agencies to commit funds to USGCRP projects (see footnote 12). These funds could not then be redirected to meet OMB targets for other areas within each agency.

A further step would be to create a National Science and Technology Council to replace FCCSET as proposed by Vice President Gore in his National Performance Review (21). Under this plan, agencies would clear their budgets with the science council as well as with OMB.

Option 3-2: *Establish a committee within FCCSET to standardize the criteria for classifying focused and contributing research to USGCRP and to classify all government research accordingly.* Much research that could qualify as ''contributing' to USGCRP may be ongoing under another title (such as ''Environmental Biology;' see option 3-6 below). Likewise, more "focused work" might occur in the agencies if the USGCRP scope is broadened. A defined set of criteria for classifying research would be of great value in identifying Federal research that is truly pertinent to the global change problem and in identifying critical gaps in research.

Option 3-3: *Reassess program priorities. Reassess the* order of priority given to the seven science elements. Although the current structure is producing good science, research results will not be sufficient to provide the information necessary to answer policy questions concerning the impacts of climate change on the Nation's resources. To answer these questions, more emphasis needs to be directed toward the science elements that address the ecological, socio economic, adaptation, mitigation, and human aspects of global change. Some of this can be done easily within the current construct of USGCRP; some may require additional programs outside the USGCRP research structure.

Option 3-4: *Make research on the human dimensions of global change a primary element of the program.* A human-dimensions program would look at the interface between human actions and the natural environment. Humans alter the environment through population growth, economic growth, technological change, political and economic institutions, and attitudes and beliefs. Human response to a changing environment will depend on individual perceptions, markets, sociocultural systems, organized responses at a subnational level, national policies, international cooperation, and global social change (35). These elements of a human-environment interface will directly influence adaptation responses to climate change.

Option 3-5: *Create an adaptation and mitigation research program (ARP) either within USGCRP or separate but parallel to it.* This program should either have the authority to influence project selection throughout USGCRP or feed into a formal assessment process that influences program direction. Congress must decide whether an ARP should function as a program separate from, but parallel, to USGCRP or whether ARP should operate within USGCRP. If ARP is created as a separate program, it should have formal ties to USGCRP. If USGCRP subsumes adaptation, the USGCRP mission would have to change to make adaptation equal in importance to the other three activity streams.

The mission of such a program must explicitly state its management and policy orientation. ARP's mission might be:

> . . .**to** pursue research that will support public and private decisionmaking on issues related to global change if climate change occurs. At a minimum,

research will include studies of the public and private management of natural and managed systems and of how to develop strategies to adapt to the effects of climate change. Annually, the program will assess the state-of-the-science, develop Government policy and management options for responding to the potential for global change (including programs that supply information to private decisionmakers), and incorporate these findings into new research directions. The assessment, policy options, and new directions for research will be reported to Congress in an annual report presented along with the President's Budget Request,

The program must include a formal mechanism for bridging the gap between science and policy; specifically, integrated assessments need to be at the center of any ARP structure. Congress should consider mandating this in any enabling legislation in order to ensure that assessments are given top priority.

Congress should consider several "rules of thumb" in structuring the program:

- Management agencies should act as the lead agencies.
- Goals for research must have problem-oriented task descriptions and milestones that are specific and easily measurable.
- Congress should consider retaining the "power of advice and consent in the appointments of the director and assistant directors of the program.

Other mechanisms for ensuring policy relevance could include requiring the program to make periodic reports to Congress, and giving Congress oversight and investigation authority.

If Congress chose to augment USGCRP, it must recognize that the program has little ability at present to target its programs to help public and private decisionmaking. Given the structure of USGCRP, management- and policy-relevant research would be hard to initiate because the process of setting priorities in USGCRP is dominated by key agency personnel in conjunction with members of the national and international scientific community.

## Incorporate More Ecosystem Research and Natural Resource Planning Into USGCRP

Although an estimated $900 to $943 million is spent on what can be considered research in environmental life sciences (22) or environmental biology,[26] there is currently very little ecological research directed specifically at protecting natural areas under climate change and helping land managers modify management strategies to respond to climate change.[27] Of the $943 million that FCCSET estimates is spent on environmental biology, only 11 percent was also reported as USGCRP program money.[28] A former working group under FCCSET found that in 1992, only $8 million was spent on research focused on adaptation.[29] This number represents less than 0.8 percent of the USGCRP budget and less than 0.9 percent of the amount spent on environmental biology research. A review of ecological experiments from 1980 to 1987 found that 50 percent of all studies were done on very small scales--on plots less than 3 feet in diameter; only 7 percent lasted longer than 5 years. Large-scale and long-term experiments are essential to respond to

26 J. Gosz, Executive Secretary, subcommittee on Environmental Biology, Committee on Life sciences and Health, Federal Coordinating Council for Science, Engineering, and Technology, personal communication, Sept. 14, 1993.

27 FCCSET defines *environmental biology* as all areas of biology dealing with the study of organisms and their interactions with their biotic and abiotic environment (J. Gosz, personal communication, Sept. 14, 1993). Gramp et. al. (22) defiie *environmental life sciences as processes* and interactions of living resources such as environmental biology, including ecology, forestry, biology, and marine biology.

28 Gosz, op. cit., footnote 26.

29 The Working Group on Mitigation and Adaptation Strategies (disbanded in 1992) of the Committee on Earth and Environmental Sciences of FCCSET identified Federal research that focuses on or contributes to adaptation to global change (6).

the challenges of global research (37). Yet, research on large-scale ecosystem management, structure, and function is necessary to protect natural areas in the future, and it is not clear that it is occurring under the auspices of ' ● environmental biology' or USGCRP.

USGCRP as currently designed will not provide either the practical technologies that might allow us to be more prepared for climate change or the ecological information that would be helpful in providing policy guidance and adaptation options for natural systems.

Option 3-6: *Conduct a review of ecological research within USGCRP and across Federal agencies, evaluate how much long-term ecosystem-level research relevant to climate change, biodiversity, and other long-term problems is under way; and identify important gaps in ecological research.* A review of all research on ''natural resources' has not yet been conducted across the Federal agencies. Existing analyses suggest a great deal of money is spent on research relevant to the environment, but how much is useful to understanding long-term ecological problems (such as biodiversity and climate change) is not known. There is currently no mechanism for consolidating results from disparate research efforts into ''general patterns and principles that advance the science and are useful. for environmental decisionmaking. Without such synthesis studies, it will be impossible for ecology to become the predictive science required by current and future environmental problems' (32).

In volume 2, chapter 5, of this report, we highlight key gaps in our understanding of ecosystems, such as: past climate changes and corresponding species responses, restoration and translocation ecology, the effectiveness of corridors and buffer zones, the development of ecological models, and the effect of elevated $CO_2$ on assemblages of plants and animals.

Basic research in these areas is needed now to determine how species might respond to climate change and how best to provide for their protection in the future. Agencies could attempt to redirect existing funds within USGCRP or procure new funds for addressing these basic ecological research needs under the Ecological Systems and Dynamics research area. Alternatively, NSF, whose mission is to support basic scientific research, could take the lead in supporting these research areas outside the auspices of USGCRP. The new National Biological Survey (see ch. 1 and vol. 2, ch. 5) could also be an appropriate vehicle to use in addressing some of the research that directly relates to land-management issues.

An effort to characterize and synthesize ongoing research could help bridge the gap between basic research and natural resource planning. Such a review could be conducted by OSTP, NAS, or an independent commission.

Option 3-7: *Make research on monitoring and managing natural resources a key component of a broadened global change research program. One* of the most prudent approaches to natural area conservation under climate change is more coordinated management on the ecosystem or regional scale. This approach would also help address threats to biodiversity and maximize possibilities for species survival under climate change. The land-management agencies should receive increased funding--or existing funds should be redirected-for research that would directly address concerns of managing natural resources under climate change. In particular, as the National Research Council recommends (37), "environmental research should advance the social goals of *protecting the* environment for present and future generations, *restoring* damaged environments so that they are productive once more, and *managing our* natural, economic, cultural, and human resources in ways that encourage the sustainable use of the environment.

Inventory and monitoring programs are usually the last to get funds and the first to be cut in a budget crisis (36, 55); existing institutions are poorly designed to support and strengthen them (37). Many monitoring programs that have been established in protected natural areas have been discontinued because of personnel changes, policy alterations, or budget cuts (55).[30] Baseline information is needed on the status and trends of vegetation cover, plant distributions, animal distributions, soils, and water resources to detect and monitor climate-induced changes. All Federal agencies conduct some type of inventory as a matter of policy, but these efforts vary widely in completeness and quality, are not consistently implemented and funded, and are not coordinated at the national or even agency level.

A concerted effort to connect, in a timely manner, the information contained in inventories to the resource-management and land-use-planning process is vital. If these connections are not adequately addressed, the gap between research and management could increase, which would be detrimental to DOI's new National Biological Survey.

## Incorporate Assessment and Oversight

**Option 3-8:** *Amend the U.S. Global Change Research Act of 1990 (P.L. 101-606) to require periodic integrated assessment reports to be presented to Congress and specify key participants in the assessment process. If* such a program is incorporated into USGCRP, it should be positioned above the agency level. However, because all of the elements necessary for an integrated assessment are not found in USGCRP, an assessment program would have to incorporate information from outside the program and include research that is not formally contained within USGCRP but that contributes to it. An assessment program should fund external and internal assessment efforts. Because integrated assessments that use computer models to knit together all aspects pertinent to global change are not well-developed, they should be used only as a guide to steer program elements. To ensure policy relevance, an assessment program must be given the authority to influence program priorities and project selection. Assessment teams must be interdisciplinary. Documenting the state of scientific knowledge is listed as the primary function of the newly created Assessment Working Group; however, the results of such a survey are highly dependent on the questions being asked-what is regarded as unknown or uncertain depends on what one wants to know and the perspective and background of the person or team carrying out the assessment (24). To ensure commitment and accountability to the assessment process, the director of an assessment program could be appointed with the advice and consent of Congress.

Option 3-9: *Create innovative congressional involvement in USGCRP.* USGCRP does not function as an individual agency, and Congress cannot expect to interact with the program in the same manner it does with agencies. Congress needs to create a forum where USGCRP can be addressed as a whole before being broken down into individual components that fit neatly into authorization and appropriation jurisdictions. For example, the Environmental and Energy Study Institute could conduct an annual seminar for its congressional members on the USGCRP budget, or Congress could establish an ad hoc appropriation committee consisting of members from each committee and appropriations subcommittee with jurisdiction over USGCRP to consider the program's budget as a whole.

Congress should conduct oversight of the program as a whole. Because USGCRP is an interagency program, it cannot be evaluated effectively by Congress on an agency-by-agency basis or through the activities of individual committees working independently. Committees with jurisdiction over USGCRP should coordinate oversight of the program.

[30] For example, in FY 1993, the Bureau of Land Management (BLM) eliminated 6 of its 16 acid rain stations to release about $30,000 fOr other BLM activities. Several of the six stations had been in operation for 10 years and had been maintaining data seta to monitor the health of forests and the effects of acid rain. Continuation of this long-term record was lost as a result of these cuts.