

OUR CHANGING PLANET

THE FY 2002
U.S. GLOBAL CHANGE RESEARCH PROGRAM



A Report by the Subcommittee on Global Change Research,
Committee on Environment and Natural Resources
of the National Science and Technology Council

A Supplement to the President's Fiscal Year 2002 Budget

On the Front Cover: True-color Earth image

MODIS Views Earth as a System. The Moderate Resolution Imaging Spectroradiometer (MODIS) can see the Earth in the same colors our eyes see (i.e., red, green, and blue), as well as in 33 other spectral bands. This radiative information can be used to derive information about an unprecedented number of parameters related to global change, including ocean plant life, land vegetation cover, cloud properties, atmospheric particulates (aerosols), and surface temperature. This image shows the Earth in true color as it appears to the MODIS instrument on the Terra spacecraft.

Terra, the flagship of the Earth Observing System (EOS) satellite series, was launched in December 1999. Other instruments on Terra are providing information about clouds, aerosols, trace gases, additional land surface and ocean properties, and the Earth's radiation budget. Data from Terra will make important contributions to USGCRP-supported investigations of climate change, atmospheric composition, the global water cycle, the global carbon cycle, and changes in ecosystems.

Source: NASA MODIS instrument team

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US Global Change Research Program



September 2001

Members of Congress:

I am pleased to transmit to you a copy of *Our Changing Planet: The FY 2002 U. S. Global Change Research Program*. This document, which is produced annually, describes the activities and plans of the U.S. Global Change Research Program (USGCRP), which was established in 1989 and authorized by Congress in the Global Change Research Act of 1990. Strong bipartisan support for this interagency program has resulted in more than a decade's worth of scientific accomplishment.

As we look ahead to next year and beyond, a number of developments are taking place that will bring about changes in the USGCRP. On June 6th, the National Academy of Sciences released *Climate Change Science: An Analysis of Some Key Questions*, which identified a number of major outstanding uncertainties in our current understanding of human-induced climate change. The report states:

“Because there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward). Reducing the wide range of uncertainty inherent in current model predictions of global climate change will require major advances in understanding and modeling of both (1) the factors that determine atmospheric concentrations of greenhouse gases and aerosols, and (2) the so-called 'feedbacks' that determine the sensitivity of the climate system to a prescribed increase in greenhouse gases. There is also a pressing need for a global system designed for monitoring climate.”

“Climate projections will always be far from perfect. Confidence limits and probabilistic information, with their basis, should always be considered as an integral part of the information that climate scientists provide to policy- and decision-makers. Without them, the IPCC SPM [Summary for Policymakers] could give the impression that the science of global warming is 'settled,' even though many uncertainties still remain. The emission scenarios used by the IPCC provide a good example. Human dimensions will almost certainly alter emissions over the next century. Because we cannot predict either the course of human populations, technology, or societal transitions with any clarity, the actual greenhouse gas emissions could either be greater or less than the IPCC scenarios.

Without an understanding of the sources and degree of uncertainty, decision-makers could fail to define the best ways to deal with the serious issue of global warming.”

On June 11, the President announced that the U.S will undertake a new Climate Change Research Initiative focused on reducing key areas of uncertainty in climate change science. The USGCRP agencies are taking part in the development of this initiative, and we expect this process to result in significant changes to some aspects of our climate modeling, observation, and research efforts over the next year, including enhanced international cooperation in each area. The National Academy’s findings will strongly influence the federal research priorities that are established.

The USGCRP is already collaborating with the science community to refine the USGCRP long-term plan. Following the successful example established by the USGCRP carbon cycle initiative, we are also developing more detailed science strategies for each of the program’s major research areas. These strategies will be updated regularly to assure that the program meets the information needs of public and private sector decision-makers and takes full advantage of evolving capabilities, including NASA’s Earth Observing System satellites, more advanced atmospheric chemistry and ecosystem models, and improvements in information and communications technologies.

This is an exciting time for global change research. I believe the USGCRP is poised to greatly enhance our understanding of climate change and its potential ecological and socio-economic impacts, and contribute to the development of effective coping strategies for the US and other nations.

A handwritten signature in black ink that reads "Margaret Leinen". The signature is written in a cursive, flowing style.

Margaret Leinen
Chair, Subcommittee on Global Change Research

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THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

The United States Global Change Research Program (USGCRP) supports research on the interactions of natural and human-induced changes in the global environment and their implications for society. The USGCRP began as a Presidential initiative in 1989 and was codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606). The statute directs the implementation of a program aimed at “understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment.”

On June 11, 2001, President Bush announced the establishment of the U.S. Climate Change Research Initiative to study areas of uncertainty and identify priority areas for investment in climate change science. The definition of this new initiative is underway, and is expected to lead to changes in USGCRP climate research activities in FY 2003 and beyond. These changes will be highlighted in the next annual report of the USGCRP.

What is “Global Change?”

The Global Change Research Act defines global change as “changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life.” This perspective recognizes the profound socioeconomic and ecological implications of global environmental change. The USGCRP focuses on four sets of interacting changes in the coupled human-environment system, a system that is undergoing change at a pace unprecedented in human history:

- **Changes in the natural and human-induced forces affecting the Earth system**, such as solar variability, volcanic eruptions, water vapor and clouds, atmospheric composition (such as carbon dioxide, other greenhouse gases, and aerosols), socioeconomic characteristics and activities (such as population growth, consumption patterns, and technological choices), and changes in land use and land cover;
- **Changes and variability in Earth system attributes that directly affect natural and human activities**, including temperature, precipitation, oscillations and modes of climate (e.g., El Niño-Southern Oscillation and the less well-understood North Atlantic Oscillation and Pacific Decadal Oscillation), sea level, extreme weather events, air quality, water availability and quality, and many others;
- **Changes in ecosystems**, from the relatively pristine to the intensively managed, including potential effects on the productivity of agriculture, forestry, fisheries, and the ability of natural systems to absorb or adapt to new conditions; and
- **Changes in human communities, organizations, societies, and economies** triggered by the above changes, as well as by our responses.

These changes are occurring on many time and spatial scales. Many feedbacks and interdependencies link them. The existence of many different types of forces complicate efforts to understand the interactions of human and natural systems and how these may affect the capacity of the Earth to sustain life over the long-term. Indeed, the interactions between changes in external (solar) forcing, human activities, and the intrinsic variability of the Earth's atmosphere, hydrosphere, and biosphere make understanding and projecting atmospheric and oceanic circulation, global energy and water cycles, and biogeochemical cycling among the most demanding scientific challenges.

Why a USGCRP?

The USGCRP was established as a multiagency effort to:

- Develop and coordinate a comprehensive and integrated program, in order to increase the overall effectiveness and usefulness of global change research supported by the U.S. Government;
- Address key scientific uncertainties about changes in the Earth system, both natural and human-induced;
- Observe, understand, predict, evaluate, and communicate the implications of global change for society and the environment; and
- Provide a sound scientific basis for policymaking and resource management decisionmaking on issues related to global change.

The basic questions of how human activities and natural variability may affect the capacity of the Earth to sustain life and provide environmental resources for society call for an integrated scientific approach, yet the issues are so complex and wide-ranging that they extend beyond the mission, resources, and expertise of any single agency. Through collaboration, the USGCRP agencies are able to support scientific research more effectively. Today the USGCRP combines and coordinates the research of ten Federal departments and agencies having active global change research programs and provides liaison with the Executive Office of the President. Since its inception, the USGCRP has strengthened research on key scientific issues and fostered much-improved insight into the processes and interactions of the Earth system.

The USGCRP sets priorities and carries out its activities in close association with, and in support of, coordinated science priorities of the national and international research community, particularly those advanced by the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), and the International Human Dimensions Programme (IHDP). The USGCRP has benefited from a longstanding and ongoing interaction with several boards, committees, and panels of the National Research Council of the National Academy of Sciences. The Academy is responsible for evaluating periodically the scientific merit of USGCRP research priorities and activities. The National Research Council has issued more than 30 reports during the past decade that have advised the USGCRP on global change research.

During its first decade, the USGCRP pursued a wide-ranging research effort to investigate the issues raised by evidence of climatic and other changes in the Earth system. The USGCRP research strategy focused on improving understanding of broad, global-scale Earth system processes, characteristics, and change, with a focus on problems such as the depletion of the stratospheric ozone layer resulting from human activities, the timing and magnitude of greenhouse warming, the degree of predictability in El Niño events, and the relationships linking the health of ecosystems, changes in land cover, and climate change.

Research supported by the USGCRP has demonstrated that the observed changes in global environmental conditions during the 20th century exceeded the range of natural fluctuations during the past 1,000 years. USGCRP-supported research also has demonstrated that human activities worldwide are clearly responsible for changes in atmospheric composition, global climate, the global water cycle, land use and land cover, and systems of living organisms that contribute to the web of life. Collectively, humankind has become an agent of change that must be considered in efforts to understand and project the future of global environmental change.

Scientific Insights from Global Change Research

Among the body of scientific insights that has resulted from the study of the Earth system, global change researchers have:

- Observed and explained the growth in atmospheric concentrations of substances that deplete the stratospheric ozone layer, which protects living organisms from exposure to higher levels of ultraviolet radiation. Ongoing research and observations have shown that emission controls implemented under the Montreal Protocol have begun to decrease the concentrations of several ozone-depleting gases.
- Quantified the atmospheric residence time—from months to millennia—of ozone-depleting and greenhouse gases. Long residence times imply a quasi-irreversible commitment to the associated global change—an example is the unavoidable multidecadal time lag in the recovery of the ozone layer, despite curtailed emissions.
- Found that cooling of the stratosphere caused by the increase in the atmospheric concentrations of greenhouse gases is likely to enhance ozone depletion, potentially delaying the recovery of the stratospheric ozone layer.
- Predicted successfully the onset of the 1997-1998 El Niño and the subsequent La Niña, as well as some of the resulting climate anomalies around the world. Improvements in the accuracy and lead times of forecasts, as well as increased access to and familiarity with climate forecast information, have enhanced their usefulness in supporting decisions about resource planning and disaster mitigation.
- Recognized that several large-scale patterns of natural variability, including the El Niño/Southern Oscillation, the Pacific Decadal Oscillation, and the North Atlantic Oscillation/Arctic Oscillation may alter the frequency and intensity of occurrence of extreme weather and climate events over North America, Europe, and the adjacent ocean basins.
- Concluded that the observed increase in global average surface temperature during the past century is consistent with a significant contribution from human-induced forcing. The Intergovernmental Panel on Climate Change projects a global average temperature increase of 1.4° to 5.8° C by 2100 if emissions are not reduced.
- Determined from paleoclimatic reconstructions of pre-instrumental temperatures that the 1990s appear to have been the warmest decade (and 1998 the warmest year) in the past 1,000 years, and that the observed 20th century warming exceeds what would be expected from natural variability typical of the past 1,000 years.
- Demonstrated the cooling effect of atmospheric sulfate aerosol particles on climate, particularly in the Northern Hemisphere. This finding has made possible climate model simulations that better match observed global tem-

perature trends, and hence aid in providing more-credible simulations of future climate change.

- Identified declines in the extent and thickness of Arctic sea ice during the past several decades, and demonstrated that decreases in Northern Hemisphere sea ice extent exceed what would be expected from natural variability alone.
- Found in the paleoclimatic record of late glacial conditions that rapid climate change events and rapid transitions in climate apparently occurred within decades or less, and then lasted for centuries or longer.
- Documented that regional air pollution can be transported over long distances and affect atmospheric composition on transcontinental scales. Plumes of polluted air from industrializing areas of Asia, mineral dust from the Sahara Desert, and smoke and ash from Mexican and Canadian forest fires have been shown to reach the United States.
- Found firmer evidence that North American terrestrial ecosystems are sequestering a significant amount of carbon, thereby offsetting a portion of the increase in atmospheric CO₂ concentrations from fossil fuel emissions.
- Concluded that land use change (including regrowth of forests cleared for agriculture in the 19th and 20th centuries) and land management (such as fire suppression), along with CO₂ fertilization, nitrogen deposition, and climate change, all appear to play important roles in determining the magnitude of the North America terrestrial carbon sink.
- Estimated the global ocean carbon sink for the 1990s, identified major sources of uncertainty in this estimate, and discovered that iron is a limiting nutrient for photosynthesis in major regions.
- Documented and quantified, using satellite observations, large-scale changes in land cover and land use, such as the loss of tropical forest in Brazil, Southeast Asia, and Africa. These changes, driven largely by human activities, are contributing to the loss of biodiversity, changes in atmospheric composition, and climate change.
- Identified critical regions of rapid land-use change from the perspective of carbon storage, biodiversity, food supply, and human health.
- Detected, and attributed to 20th century climate change, alterations in ecosystems including shifting of animal geographic ranges, increases in growing-season leaf duration, earlier plant flowering seasons, changes in annual tree growth and reproduction, and die-off of tropical corals. Revealed the significant vulnerability of many ecosystems to global change.
- Identified and characterized, from long-term studies of watersheds, the processes that control water, energy, and chemical fluxes over a broad range of spatial and temporal scales.
- Obtained a multi-year record of observations of tropical rainfall from space and identified significant differences in the distribution of deep convective clouds, the occurrence of lightning, and precipitation patterns between continental and oceanic regions.

Table 1
U.S. Global Change Research Program
 FY 2000 – FY 2002 Budget by Agency
 (Discretionary budget authority in \$millions)

Agency	FY 2000	FY 2001	FY 2002 Request
Scientific Research			
Department of Agriculture (USDA)	56	56	56
Department of Commerce / National Oceanic and Atmospheric Administration (DOC/NOAA)	67	80	93
Department of Energy (DOE)	113	119	121
Department of Health and Human Services / National Institutes of Health (HHS/NIH)	48	52	57
Department of the Interior / U.S. Geological Survey (DOI/USGS)	27	27	22
Environmental Protection Agency (EPA)	21	23	22
National Aeronautics and Space Administration (NASA)	232	254	253
National Science Foundation (NSF)	187	187	187
Smithsonian Institution (SI)	7	7	7
Scientific Research Subtotal	758	805	818
Observations and Data Systems			
National Aeronautics and Space Administration (NASA)	929	908	819
U.S. Global Change Research Program Total	1,687	1,713	1,637

Because Department of Defense (DoD) research activities are conducted for defense-related missions, they are not included in this USGCRP budget crosscut. Related DoD research does contribute to achieving USGCRP goals, however.

Operational space-based and in situ observing systems and programs are not included in the USGCRP budget crosscut, but contribute to achieving USGCRP goals.

RESEARCH PROGRAM: NEAR-TERM PLANS

Table 2
U.S. Global Change Research Program

FY 2001 – FY 2002 Budget by Research Program Element
(Discretionary budget authority in \$millions)

Program Element	FY 2001	FY 2002 Request
Climate Variability and Change	533.0	486.4
Atmospheric Composition	345.6	309.8
Global Carbon Cycle	214.2	221.1
Global Water Cycle	312.6	309.4
Changes in Ecosystems	204.9	199.2
Human Dimensions of Global Change	99.5	107.4
U.S. Global Change Research Program Total¹	1,713	1,637

¹USGCRP FY 2001 and FY 2002 totals include \$3.1 million for DOE Small Business Innovative Research/Technology Transfer (SBIR/STTR) program.

Because DoD research activities are conducted for defense-related missions, they are not included in this USGCRP budget crosscut. Related DoD research does contribute to USGCRP goals, however.

Operational space-based and in situ observing systems and programs are not included in the USGCRP budget crosscut, but contribute to achieving USGCRP goals.

Climate Variability and Change

The USGCRP budget includes \$486 million in FY 2002 for research and observations related to understanding climate variability and change. The Earth's prevailing climate is a fundamental element in the well-being of societies and natural systems. Climate strongly affects the viability of agriculture, the distribution and productivity of forests and rangelands, the diversity of flora and fauna, the availability of water, the spread of insects and rodents that carry human disease organisms, the intensity and frequency of floods and severe weather events, and much more. The essential scientific questions about climate system behavior range across all timescales, from seasons and years to decades, centuries, and millennia.

USGCRP-supported research has played a leading role in major scientific advances, which have provided valuable new climate information to the public and decisionmakers. While progress in climate science has been impressive, there remain many unresolved questions about key aspects of the climate system, particularly with respect to certain issues that have major societal implications. For example, improving understanding about the causes of climate change and reducing uncertainty about current and projected future changes is essential to providing a sound scientific underpinning for climate impacts assessments and future policy decisions. We are just now beginning to understand how climate variability and change influence the occurrence and severity of extreme events such as hurricanes, droughts, and floods. We have identified several important patterns of climate variability other than El Niño events, but do not yet know to what extent they are predictable. Our predictive capabilities at local and regional scales show promise in some regions and for some phenomena, but are still inadequate in many instances. We have yet to obtain confident estimates of the likelihood of abrupt global and regional climate transitions, although such events have occurred often in the past and, in some climate model simulations, have been projected to occur during the 21st century. And, perhaps most fundamentally, we do not yet have a clear understanding of how climate variability may be modified in the future by human-induced climate changes, particularly on regional and local scales, and how such changes in climate may alter the vulnerability and sustainability of both human and natural systems.

Recent Accomplishments

- Applied climate models to simulate the observed global warming over the past century, in which the warming occurred primarily in two distinct 20-year periods, from 1925 to 1944 and from 1978 to the present. The results showed that while the latter warming is primarily attributable to increases in greenhouse gas (radiative) forcing, the warming of the early 20th century could have resulted from a combination of human-induced radiative forcing and an unusually high variability of the coupled ocean-atmosphere system.
- Documented that the heat content of the upper 3000 meters of the Earth's oceans has been increasing since the 1950s. In addition to this warming trend, there is a decadal signature to the variability in many of the oceans that requires improved physical understanding.
- Showed in two studies, each using a different sophisticated climate model, that the ocean warming that has been measured over the last half-century is virtually the same as what would be expected from the observed increase in greenhouse gases and aerosols in the atmosphere.
- Identified an enhanced rate of heating of the Northern Hemisphere tropical oceans. This rapid warming has contributed to unprecedented coral bleaching over the past decade.
- Began deployment of the Argo array of profiling floats in the global oceans. This observational system will increase our capabilities to observe long-term trends in ocean temperatures, currents, and salinity, as well to improve predictions of the influence of events such as El Niño and La Niña on seasonal climate.

- Carried out the first detailed comparisons of cloud-resolving model simulations and single column model results with observational data, based on three years of continuous observations in the Atmospheric Radiation Measurement Program’s Southern Great Plains site. These comparisons give the first detailed look at how cloud parameterizations in climate models actually perform in real atmospheric situations.
- Made accurate, systematic satellite measurements of solar variability, now completed through a full 22-year solar cycle, using the ongoing collection and analysis of data from ACRIMSAT, which was launched in December 1999.
- Deployed the Global Lake Drilling System (GLAD 800) to Lake Titicaca in Bolivia/Peru in an international collaborative research effort to retrieve a 500,000-year record of atmospheric dynamics and climate in this tropical region.
- Recovered an unprecedented record of changing temperature variability from a Himalayan glacier at an altitude of 23,500 feet, showing the last 50 years were warmer than any other equivalent period in the last 1,000 years.
- Submitted to Congress an assessment of climate change titled *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, which was produced by a team of authors operating under the auspices of the Federal Advisory Committee Act. The assessment includes an overview of about 150 pages and a foundation volume that is about 600 pages long.

Table 3 Climate Variability and Change

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOC/NOAA	44.8
DOE	70.8
DOI/USGS	4.5
NASA	61.9
NSF	92.4
Smithsonian Institution	2.0
Scientific Research Subtotal	276.4
NASA Space-Based Observations	193.7
NOAA Surface-Based Observations	16.3
Observations Subtotal	210.0
Climate Variability and Change Total	486.4

Improving the Effectiveness of U.S. Climate Modeling

The USGCRP commissioned the National Research Council (NRC) to prepare two reports to provide guidance on how to further develop U.S. modeling efforts. *Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities*, was published in 1998. In March 2001 the NRC released *Improving the Effectiveness of U.S. Climate Modeling* as a follow-up. Also, an Ad Hoc Working Group on Climate Modeling, established by the Subcommittee on Global Change Research, released its report, *High-End Climate Science: Development of Modeling and Related Computing Capabilities*, in December 2000. These reports provide valuable guidance on how to improve U.S. climate modeling efforts. They emphasize several findings: 1) the acknowledged U.S. leadership in basic climate science research that feeds both domestic and international modeling programs; 2) current conditions within the U.S. high-end climate modeling structure that impede integrating the basic knowledge into a world-leading climate modeling capability; and 3) the challenges of moving to quasi-operational high-end climate modeling, including software, hardware, human resource, and management issues, and most importantly, the need to establish a dedicated capability for high-end modeling activities.

The USGCRP's immediate challenge is to correct the problems identified in (2) above and develop a strategy and implementation plan for enhancing high-end modeling. Over the longer term, the USGCRP will develop criteria to determine when the national high-end modeling effort has reached a point where it can routinely produce high-quality standard products on demand as was identified in (3) above. Further, the USGCRP must ensure that a productive partnership is maintained between product-driven climate modeling activities and the high-end modeling research program that will ensure its future success.

A number of significant steps have been taken toward addressing the immediate challenge:

- The capability and capacity of computing facilities at several major U.S. modeling centers have been upgraded or are scheduled for upgrade.
- Common modeling frameworks are being developed to help ensure that software advances can be more readily shared among centers and laboratories.
- Investigation of the suitability of distributed memory, high-end computers for climate modeling is underway.

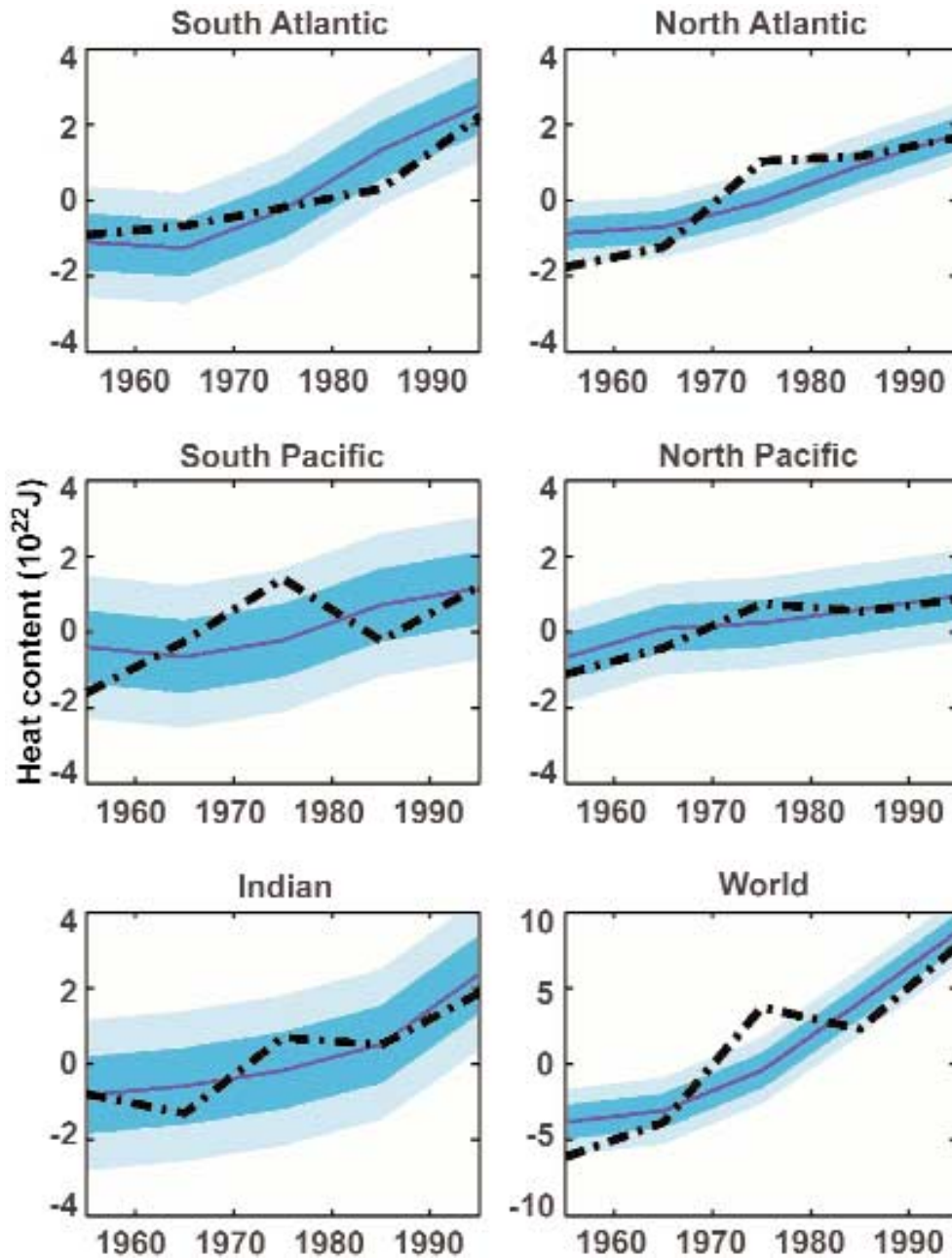


Figure 1. Ocean Warming Since the 1950s

Decadal values of anomalous heat content (10^{22} J) in various ocean basins. The heavy dashed line is from observations, and the solid line is the average from five realizations of the state-of-the-art Parallel Climate Model forced by observed and estimated anthropogenic forcing. Both curves show significant warming in all basins since the 1950s.

Source: Barnett, et al. *Science*, 13 April 2001. See Appendix B for additional information.

FY 2002 Plans

The USGCRP will continue to enhance observational and modeling capabilities for improved understanding, prediction, and assessment of climate variability and change on all timescales. Key research goals for FY 2002 include:

- Enable more realistic climate simulations and more confident climate projections by making the next generation of the Community Climate System Model (CCSM-2) available to scientists for research and assessment applications. The model will have improved ocean, atmosphere, sea ice, and land surface components. Major software engineering improvements to the CCSM-2 system will enable significantly more rapid scientific development and testing because the model (and model components) will be easier to use and computationally more efficient.
- Improve the radiative flux calculations and associated heating rates in climate models with measurement and modeling efforts using data collected at the Atmospheric Radiation Measurement Program (ARM) Cloud and Radiation Testbed sites.
- Expand, from 150 to 280 floats per year, the U.S. contribution to the international array of profiling floats that measure upper-ocean temperatures and salinity. This is a step in developing the global observing system necessary to support climate research and prediction, and for climate change detection and attribution. The United States has made a commitment to supply and maintain a total of 1,000 floats within the designed global array of 3,000 floats. In addition, surface-drifting buoys will be deployed in undersampled regions to complete the Global Drifter Array. The composite global ocean observing system that is being developed is crucial for more accurate assessment of the ocean's role in climate variability and change.
- Document the effects of tropical ocean temperature and rainfall patterns on changes in the frequency, location, and intensity of extreme weather events over the United States, as well as air-sea interactions in both tropical systems and midlatitude oceanic and landfalling storms, through expanded diagnostic and modeling efforts. This will improve capabilities to calculate the connections between climate and weather, particularly climatic influences on extreme events such as droughts and floods. The derivation of regional-scale forecasts of climate variations from global model forecasts will be enhanced using higher-resolution regional models.
- Improve near-term climate forecasts using enhanced climate monitoring capabilities, advances in coupled ocean-atmosphere modeling, and insights about climate variability. New products to be developed include biweekly to multi-season forecasts of droughts, hurricane activity in the Atlantic and Pacific oceans, and changes in seasonal risks of temperature extremes and wildfires. The benefits of using satellite altimeter observations on improving 12-month El Niño forecasts with a state-of-the-art coupled ocean-atmosphere model will be quantified.
- Assimilate near-decade-long satellite time-series data on sea-surface topography into a high-resolution Pacific Ocean model to improve understanding of the mechanisms contributing to the Pacific Decadal Oscillation and its role in seasonal to decadal climate variations.
- Analyze cores recovered from Lake Titicaca in Bolivia/Peru by the Global Lake Drilling System (GLAD 800) to strengthen our knowledge of natural climate vari-

ability over geologic time in this tropical region. Outfitting the GLAD 800 system with the capability to maintain drilling stability in rough waters will enable cost-effective drilling in large lakes, which are a currently untapped and potentially important storehouse of paleoclimate information.

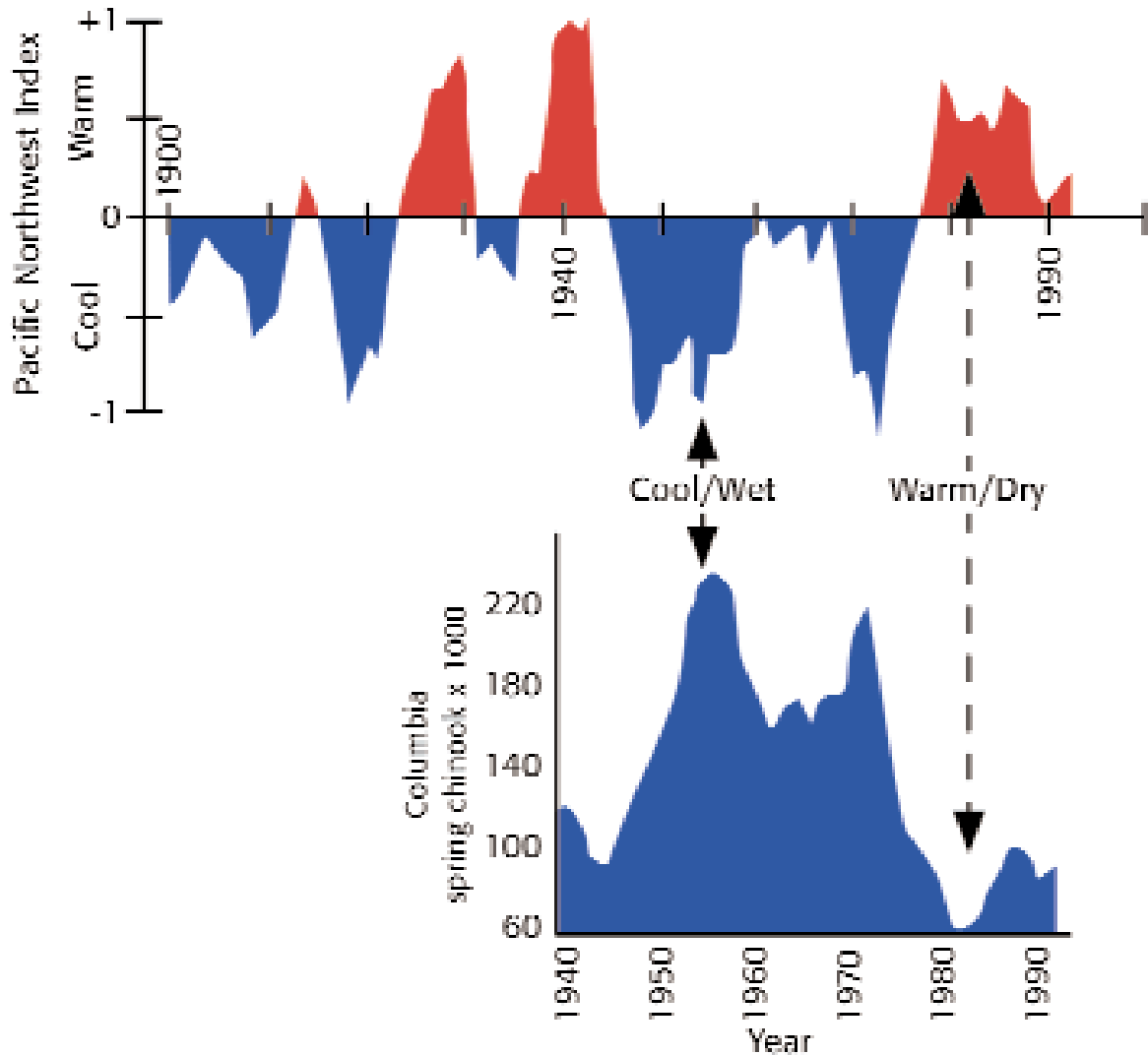


Figure 2. Observed Effects of Climate Variability on Salmon

Abundances of many salmon stocks closely track interdecadal climate variation. Since 1940, Upper Columbia bright spring Chinook are abundant when the Pacific Northwest Index (one measure of decadal climate variation) is negative. Both are 5-year moving averages.

Source: National Assessment Overview report, p.70. See Appendix B for additional information.

Atmospheric Composition

The USGCRP budget includes \$310 million in FY 2002 for research and observations related to improving understanding of ongoing changes in atmospheric composition. The atmosphere links the other components of the Earth system—including the oceans, land, terrestrial and marine biosphere, and the frozen regions. Because of these linkages, the atmosphere is a conduit of change. For example, natural events and human activities can change atmospheric composition in ways that alter the Earth's radiative (energy) balance. Associated responses involving the climate system and the stratospheric ozone layer influence the well-being of human and natural systems.

Because the atmosphere is the “fast mixer” in the Earth system, changes in the composition and chemistry of the atmosphere spread over very large areas very quickly. As a result, observations of changes in the atmosphere are among the very earliest harbingers of changes in the global environment. The very long atmospheric residence times of some chemical species cause changes in their concentrations to be virtually irreversible for decades, centuries, and millennia—thereby affecting all countries and populations, not just the emitters. The improving capability for modeling the composition of the global atmosphere as a whole is enabling quantification of the linkages between continental air quality and climate change, which were once considered separately and independently.

Future research will build upon recent scientific accomplishments. In one of the extraordinary success stories of global change research, scientific understanding has led to measures that have reversed the decades-long growth in atmospheric concentrations of the substances responsible for depleting the stratospheric ozone layer. The steps agreed to in the 1987 Montreal Protocol on the ozone layer (and subsequent amendments) are beginning to produce the intended results. For example, the tropospheric concentration of chlorine peaked in 1994—thereby building public confidence in science-based governmental and industrial decisionmaking.

Recent Accomplishments

- Observations from the Upper Atmosphere Research Satellite (UARS) show a decline in the total abundance of chlorine compounds in the stratosphere. This result adds credence to the model calculations used to project future changes in atmospheric chemistry and validates the basic strategy that was embarked on with the Montreal Protocol. This evidence of a stratospheric peaking of chlorine compounds follows a similar pattern observed five years ago in the troposphere, demonstrating consistency in our understanding of the transport of chemicals between the troposphere and the stratosphere and of atmospheric chlorine chemistry.
- Recent data from the Total Ozone Mapping Spectrometer (TOMS) demonstrate how short-term variability in global climate can combine with fires originating in connection with forest-clearing activity to produce massive air pollution over a wide area. These results describe a buildup of pollution in Southeast Asia during the last El Niño event, in September 1997. Ozone column measurements document an intensely polluted air mass covering densely populated areas around Singapore and Indonesia. These high pollution levels resulted from an unprecedented incidence of fires occur-

ring on the island of Borneo (Kalimantan). This analysis built on a decade of research that has led to an increasingly precise description of tropospheric ozone.

- A synthesis of results from meteorological data and satellite measurements shows a strong historical relationship between late-wintertime minimum temperatures and stratospheric ozone depletion in the Arctic region—colder temperatures are associated with greater ozone depletion.
- Recent measurements add support to the hypothesis that the Arctic springtime will show individual years of substantial depletion of the ozone layer, even as the trend of increasing atmospheric concentrations of chlorine is reversed. Concentrations of reactive nitrogen and chlorine during the coldest Arctic winters of the 1990s are similar to the levels observed in the Antarctic. This finding illustrates the importance of the linkage between atmospheric chemistry and temperature, and suggests that the future health of the ozone layer in the Northern hemisphere will be linked to future changes in stratospheric temperature caused by rising concentrations of greenhouse gases.
- With multiagency support, the Aerosol Characterization Experiment-Asia (ACE-Asia) was completed successfully in spring 2001. Newly developed instrumentation, including improved airborne sampling techniques, was used to characterize the distribution of aerosols in the region of outflow of air masses in Northeast Asia. NSF, Navy, and NOAA aircraft-based observing instruments were complemented by ground-based and satellite observations to measure a complex mixture of pollution-derived and natural aerosols, including mineral dust.
- Improved atmospheric transport and chemistry models have been developed that assimilate satellite observations in real time and include descriptions of atmospheric aerosols and their transport. Information on distributions and chemical nature of aerosols is needed in order to determine their radiative impact. Aerosol models with predictive capabilities have been developed and used successfully in several field campaigns to guide the deployment of research aircraft.
- The relative importance of seasonally and geographically varying processes that affect the production and fate of oxidants has been evaluated quantitatively for several metropolitan areas in the United States, providing vital information on the likely success of various possible control strategies for tropospheric ozone.

Table 4 Atmospheric Composition

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOC/NOAA	7.8
DOE	12.6
NASA	54.1
NSF	16.9
Smithsonian	0.3
USDA	18.0
Scientific Research Subtotal	109.7
NASA Space-Based Observations	199.1
NOAA Surface-Based Observations	1.0
Observations Subtotal	200.1
Atmospheric Composition Total	309.8

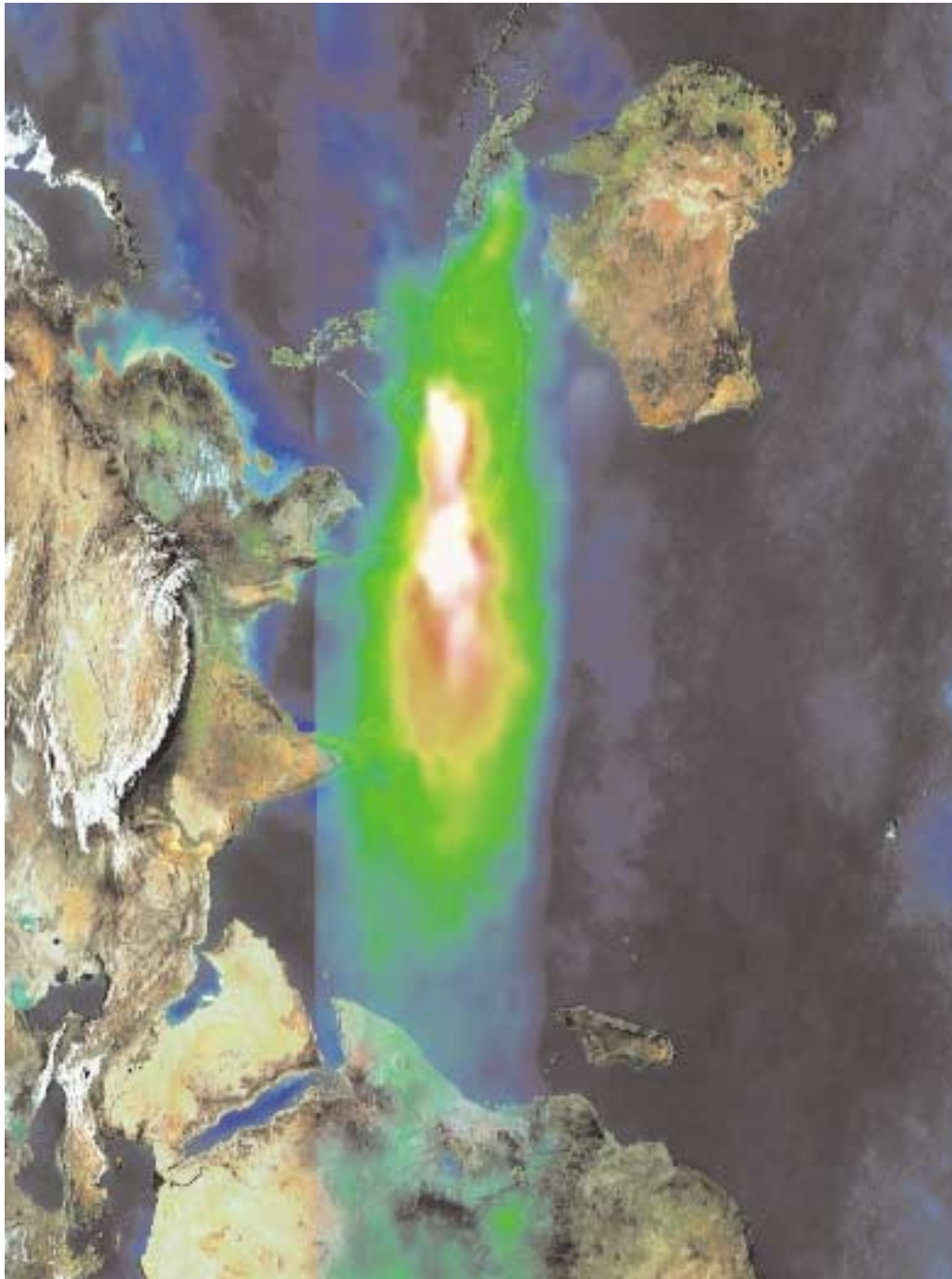


Figure 3. Large-Scale Atmospheric Pollution in Southeast Asia During the Last El Niño Event

The Total Ozone Mapping Spectrometer (TOMS) shows a heavily polluted air mass covering much of Southeast Asia during the last El Niño event (October 1997), an illustration of how short-term variations in global climate and land-use practices can lead to unhealthy levels of large-scale pollution.

Source: NASA. See Appendix B for additional information.

FY 2002 Plans

The USGCRP will continue to gather and analyze information through measurement, modeling, and assessment studies to enhance understanding of atmospheric composition and of the processes affecting stratospheric and tropospheric chemistry. Key research goals for FY 2002 include:

- Quantify interannual variations in global emissions of carbon monoxide and methane using measurements obtained from the EOS Terra satellite and data on forest fires taken over North America using airborne instruments, in association with simulations using atmospheric chemical transport models. The results will enable a more accurate evaluation of the contribution of fires and fossil-fuel combustion to global concentrations of these gases, and of the sources of methane and its potential to change atmospheric composition and climate.
- Initiate a study to characterize the magnitude and chemistry of the atmospheric plume from East Asia and assess its contribution to regional and global atmospheric chemical composition. The study will use data gathered by the Transport of Chemical Evolution over the Pacific (TRACE-P) airborne mission, satellite data, and atmospheric models. During FY 2002, in the first of the Intercontinental Transport and Chemical Transformation experiments, airborne and shipborne measurements will be taken of gases and aerosol chemical composition that are key to the photochemistry of the eastern Pacific Ocean, and results will be analyzed. This research will enable a better quantification of the relationship between changes in regional air quality and changes in global atmospheric composition, processes, and radiation balance, as well as an indication of the impact of air pollution from Asia on North America.
- Improve radiative transfer and chemical transport models using the comprehensive data set obtained by the Aerosol Characterization Experiment-Asia (ACE-Asia). This experiment was designed to increase understanding of how atmospheric aerosol particles affect the Earth's climate system. Detailed analysis of the data on chemical, physical, and optical properties of the aerosols, as well as radiation measurements, will be used to determine the radiative impact of aerosols in the region of outflow of air masses in Northeast Asia.
- Launch the SAGE III satellite to continue the long-term (multidecade) record of the evolution and interannual variability of high-latitude ozone, aerosol, and polar stratospheric cloud profiles. Data obtained by SAGE III will be combined with data obtained from previous instruments as a step toward improving estimates of the contribution of ozone changes to climate change. In addition, these analyses will improve understanding of the response of ozone, aerosol, and polar stratospheric cloud concentrations to climate variation.
- USGCRP-supported scientists play a major role in leading and preparing an updated international scientific assessment of stratospheric ozone depletion—the next in a series that has provided the scientific underpinning for decisions made under the Montreal Protocol on protection of the ozone layer. Particular attention will be devoted to interpreting the observed downward trends in ozone-depleting gases in terms of the reported emissions; characterizing the impacts on the ozone layer of new, very-short-lived chemicals; examining the latest information on trends in stratospheric ozone; and evaluating the role of climate change in the recovery of the ozone layer.

- Conduct field, laboratory, and modeling studies to improve understanding of the fundamental atmospheric processes associated with energy-related emissions and their effects on air quality and climate, and of the fundamental processes that control transport of energy-related pollutants out of the near-surface and transition boundary layers up to levels where they can be dispersed globally.

Global Carbon Cycle

The USGCRP budget includes \$221 million in FY 2002 for research and observations related to understanding the global carbon cycle. Carbon is important as the basis for the food and fiber that sustain human populations, as the primary energy source that fuels human economies, and as a major contributor to the planetary greenhouse effect and the potential for climate change. Carbon dioxide (CO₂) and methane (CH₄) concentrations have been increasing in the atmosphere, primarily as a result of human use of fossil fuels and land clearing, and are now higher than they have been for at least 400,000 years.

Of the CO₂ emitted to the atmosphere, about half is currently taken up as part of the natural cycling of carbon into the ocean, and into land plants and soils. These reservoirs of carbon are known as carbon “sinks.” Changes in land management practices and the addition of CO₂ and nutrients are known to have the potential to enhance significantly the uptake of carbon, particularly by forests and croplands. Options for enhancing carbon sequestration in the oceans are also being considered. Uncertainties remain, however, about how much additional carbon storage can be achieved through improved management of ecosystems and other approaches, for how long the enhanced storage could be sustained, and just how vulnerable or resilient the natural carbon cycle is to manipulation of sources and sinks.

Successful carbon management strategies will need to be based on solid scientific information on the basic processes affecting the global carbon cycle, an understanding of long-term interactions of carbon dynamics with other aspects of the Earth system (such as climate variability and change and the global water cycle) and other environmental changes (such as nitrogen deposition), assessment of how management for maximizing carbon storage affects other uses of ecosystems, and the vulnerability of stored carbon to disturbance. In addition, knowledge of the carbon cycle, especially biological productivity, is essential for effective natural resource management and for maintaining the long-term sustainability of ecological goods and services.

The research community has developed a plan for enhancing understanding of the global carbon balance. Research progress is being stimulated by breakthroughs in the development of techniques for observing and modeling the atmospheric, terrestrial, and oceanic components of the carbon cycle. A concerted research effort is planned to identify, characterize, quantify, and project the major regional sources and sinks of CO₂. Key research topics will include the Northern Hemisphere terrestrial carbon sink; the oceanic carbon sink; the global distribution of carbon sources and sinks and their temporal dynamics; the effects of land use and land management on carbon sources and sinks; projecting future atmospheric CO₂ and related greenhouse gas concentrations; and scientific issues of carbon management.

Recent Accomplishments

- In 2001, the SeaWiFS satellite instrument marked its third anniversary of uninterrupted remote-sensing data set on ocean color. An instrument aboard the EOS Terra satellite also began producing a wide array of data products on marine ecosystems. Ocean color measurements can be converted into estimates of phytoplankton (or “plant”) biomass in the ocean surface layer, and can indicate the presence of certain species. Phytoplankton are important to measure because they process carbon in the upper ocean, transforming carbon from dissolved form to particulate, and are therefore essential components of the ocean carbon cycle. Without phytoplankton living in the ocean’s surface layer, atmospheric carbon dioxide levels would be many times higher than they are today.
- Uptake of carbon in North America and European ecosystems was demonstrated across a wide range of latitude locations. The rates of carbon storage range from near zero at high latitudes to 7.5 tonnes of carbon gain per hectare at southern latitudes in North America. Differences in the data between North American and European sites suggest that, at a given latitude, higher temperatures promote greater carbon uptake.
- Preliminary results from the ongoing Large-Scale Biosphere-Atmosphere Experiment in Amazonia have led to new insights into the complexity of carbon cycling in Amazonia, with significant implications for quantifying the global carbon budget and for how processes known to affect the cycling of carbon are represented in biogeochemical cycling models.

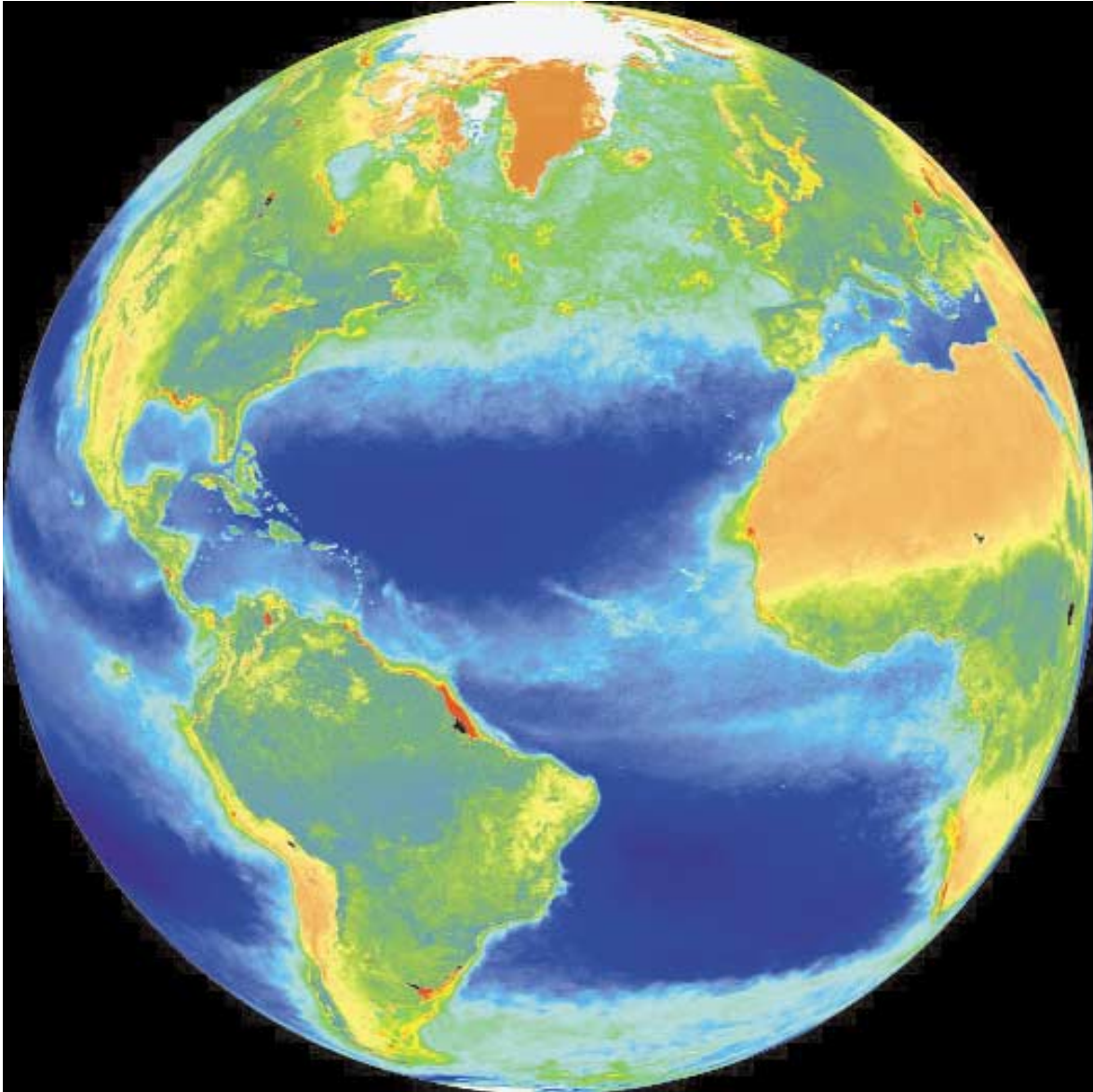


Figure 4. Plant Life on Earth as Observed From Space

False-color image of plant life on Earth as observed from space with the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). On land, greens indicate abundant vegetation, and tans show relatively sparse plant cover. In the oceans, blue areas are the least biologically productive, whereas green, yellow, and red areas represent progressively greater productivity.

Source: SeaWiFS Project, NASA Goddard Space Flight Center and ORBIMAGE. See Appendix B for additional information.

Table 5 Global Carbon Cycle

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOC/NOAA	4.8
DOE	13.7
DOI/USGS	3.0
NASA	47.2
NSF	21.5
Smithsonian	0.3
USDA	14.8
Scientific Research Subtotal	105.3
NASA Space-Based Observations	111.6
NOAA Surface-Based Observations	4.2
Observations Subtotal	115.8
Global Carbon Cycle Total	221.1

FY 2002 Plans

The USGCRP will continue to focus on understanding and quantifying carbon sources and sinks, particularly in North America, and on filling critical gaps in understanding of the causes of carbon sinks on land as well as processes controlling the uptake and storage of carbon in the ocean. Key research goals for FY 2002 include:

- Quantify the amounts and changes in carbon storage in crop land and grazing land soils, as affected by management practices such as tillage, crop rotation, irrigation, and animal feeding, by expanding studies to agricultural systems used throughout the United States, as part of a five-year research effort. Because the values from individual practices are not simply additive, agricultural “systems” will be studied, in controlled experiments and on farms and ranches. The studies will lead to the development of decision-support tools and models that can enable land managers to project the amounts and changes in carbon storage in crop and grazing lands under different management practices, at spatial scales ranging from individual fields to large regions.
- Improve quantification of terrestrial biosphere carbon exchanges with the atmosphere and of global and regional carbon budgets, using ongoing acquisition of near-daily global measurements of the terrestrial biosphere from instruments on EOS

Terra (enhanced by new data from EOS Aqua after launch). The unprecedented calibration of EOS sensors and new, refined and validated algorithms will make improved quantification of productivity possible. These same data will make possible new, quantitative analyses of agricultural and forest productivity and enable early warning of regional food shortages and certain disease and pest outbreaks. Provision of timely data to U.S. and U.N. operational famine early warning programs focused on Africa and Latin America will yield more accurate forecasts of food shortages and disease/pest outbreaks. Early in FY 2002, “science quality” data will be released and end users, such as the U.N. Food and Agriculture Organization, will be able for the first time to integrate high-quality data from the MODIS instrument into their operational analyses.

- Complete an intercomparison of atmospheric transport models used to estimate carbon sources and sinks on a global scale. Transport models are a large source of uncertainty in locating and quantifying sources and sinks. Improvements in these models also will enable more accurate forecasts of weather and climate variability.
- Initiate a major ocean experiment and observations in the Southern Ocean around the Antarctic Polar Front Zone. This experiment will involve scientists from across the country in investigating: (1) the role of iron in the biological pump of carbon in silicate-rich versus silicate-poor High-Nutrient-Low Chlorophyll (HNLC) waters; (2) the ways in which iron mediates the differential drawdown of major nutrients; (3) iron limitation of carbon fixation and export from surface waters; (4) the biophysical response of primary producers to added iron; and (5) the potential effect of iron-induced carbon export on mid-water remineralization and denitrification processes. This effort will begin to provide a stronger scientific basis for discussions of the efficacy and efficiency of using the oceans to draw down atmospheric CO₂.
- Complete the field analysis phase of a unique collaborative study of gas exchange in the equatorial Pacific—the ocean’s largest natural source region of CO₂. Preliminary results suggest that CO₂ fluxes across the sea-air interface are highly dependent upon the near-surface winds and local mixing processes in the top few meters of the water column. This study is contributing to our understanding of processes that control gas exchange at the surface of the ocean and will ultimately lead to an improved ability to parameterize gas exchange using remote sensing. Understanding gas exchange is essential for being able to estimate the amount of CO₂ that the ocean absorbs from or releases to the atmosphere.

Global Water Cycle

The USGCRP budget includes \$309 million in FY 2002 for research and observations related to understanding the global water cycle. Providing adequate supplies of clean water and coping with extreme hydrologic events, such as floods and droughts, pose major obstacles to achieving social and economic goals, to sustaining essential ecosystems, and to managing natural resources effectively. During the 20th century, water systems and infrastructure were developed to reduce floods and store water for future distribution. Nonetheless, floods and water shortages still cause significant property damage, public health risks, loss of life, and impairment of agricultural, commercial, indus-

trial, and recreational activities.

Complex scientific questions arise in efforts to understand the relationships between climate processes and the water cycle, as do questions about how societies and water management systems should respond to the impacts of natural climate variability and human-induced change. Reliable seasonal forecasts and longer-range projections of precipitation, evaporation, and water flow and quality are needed to optimize the use of water over seasonal, and annual to decadal planning cycles.

Study of the water cycle requires systematic, high-resolution observations of atmospheric, hydrologic, land surface/vegetation and other climate system variables using existing (operational) and new satellite and in-situ systems. In addition, models are required for data assimilation as well as for simulation and predictability studies. Research activities are directed toward enhancing capabilities to quantify and predict, on seasonal and longer timescales, trends in the global water cycle and the regional availability of fresh water resources. Emphasis is being placed on the interaction between the water cycle and the carbon, nitrogen, and nutrient cycles, as well as the effort to achieve a better understanding of the role of water management institutions and other human activities in the distribution and quality of available water resources. Each year, a combination of observational programs and modeling, analysis, and process studies addressing a range of spatial and temporal scales, contribute to improving the quantification and prediction of changes in the water cycle at global and regional scales, and of the impacts of these changes.

The Global Water Cycle Study Panel, established by the USGCRP and made up of leading representatives of the research community, completed development of a Global Water Cycle Science Plan, which was published in May 2001. Using this plan as a framework, the USGCRP Interagency Working Group on the Global Water Cycle developed a long-term strategy for implementation.

Recent Accomplishments

- Completed almost four years of rainfall measurements by the Tropical Rainfall Measuring Mission (TRMM), which, combined with other satellite and surface-based observations, has provided a greatly improved global tropical rainfall climatology. TRMM also has provided the data for preparation of accurate maps of the diurnal cycle of precipitation, contributing to a new benchmark for documenting tropical precipitation. In parallel, TRMM data provide a more accurate basis for verifying global precipitation weather forecasts, a goal of the U.S. Weather Research Program.
- Completed the first year of analysis of global measurements of the radiative properties of clouds and aerosols taken by EOS Terra. These observations, together with those of EOS Aqua (launch scheduled for late 2001/early 2002) will reduce uncertainty in the determination of cloud/aerosol radiative forcing and feedback processes involved in the heating and cooling of the Earth's surface and atmosphere.
- Developed improved representations for modeling of the land surface, including topographic variability, soil physics, and snowpack physics. These improvements will contribute to more accurate seasonal predictions of changes in weather patterns associated with El Niño cycles, and resulting changes in land surface hydrology.
- Completed the second precisely controlled mapping of most of Antarctica in a mode

that will enable the calculation of surface flow rates. High-resolution data from LANDSAT-7 and EOS Terra showed the early beginnings of a crack in an Antarctic ice flow. The crack, found to be 25 km long and 400-500 meters wide in January 2001, was growing at about 13 meters a day. This is the first observation of the beginning of the formation of massive icebergs.

- Provided the means for accurate, continuous measurements of water vapor vertical profiles from field campaigns at one of the Atmospheric Radiation Measurement (ARM) program sites. These new measurements provide an improved understanding of the variability of atmospheric water vapor at all altitudes of interest to climate and weather-prediction modelers.
- Differentiated the chemical characteristics in spring snow melt between cool morning periods and warmer periods later in the day. Increased understanding of these processes will improve estimates of the impacts of global change on water quality in streams and rivers carrying snowmelt water.
- Analyses of data acquired with commercial aircraft have demonstrated the ubiquity, globally and throughout the year, of air that circulates widely in relatively thin layers in the troposphere (present in layers averaging about 1 km thick at altitudes from 2 to 12 km). The existence of these layers, which can be characterized by their water vapor and ozone content, has important implications for understanding the large-scale atmospheric circulation when the radiative properties of these layers are taken into account.

Table 6 Global Water Cycle

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOC/NOAA	5.7
NASA	56.6
NSF	12.7
USDA	2.8
Scientific Research Subtotal	77.8
NASA Space-Based Observations	231.6
Global Water Cycle Total	309.4

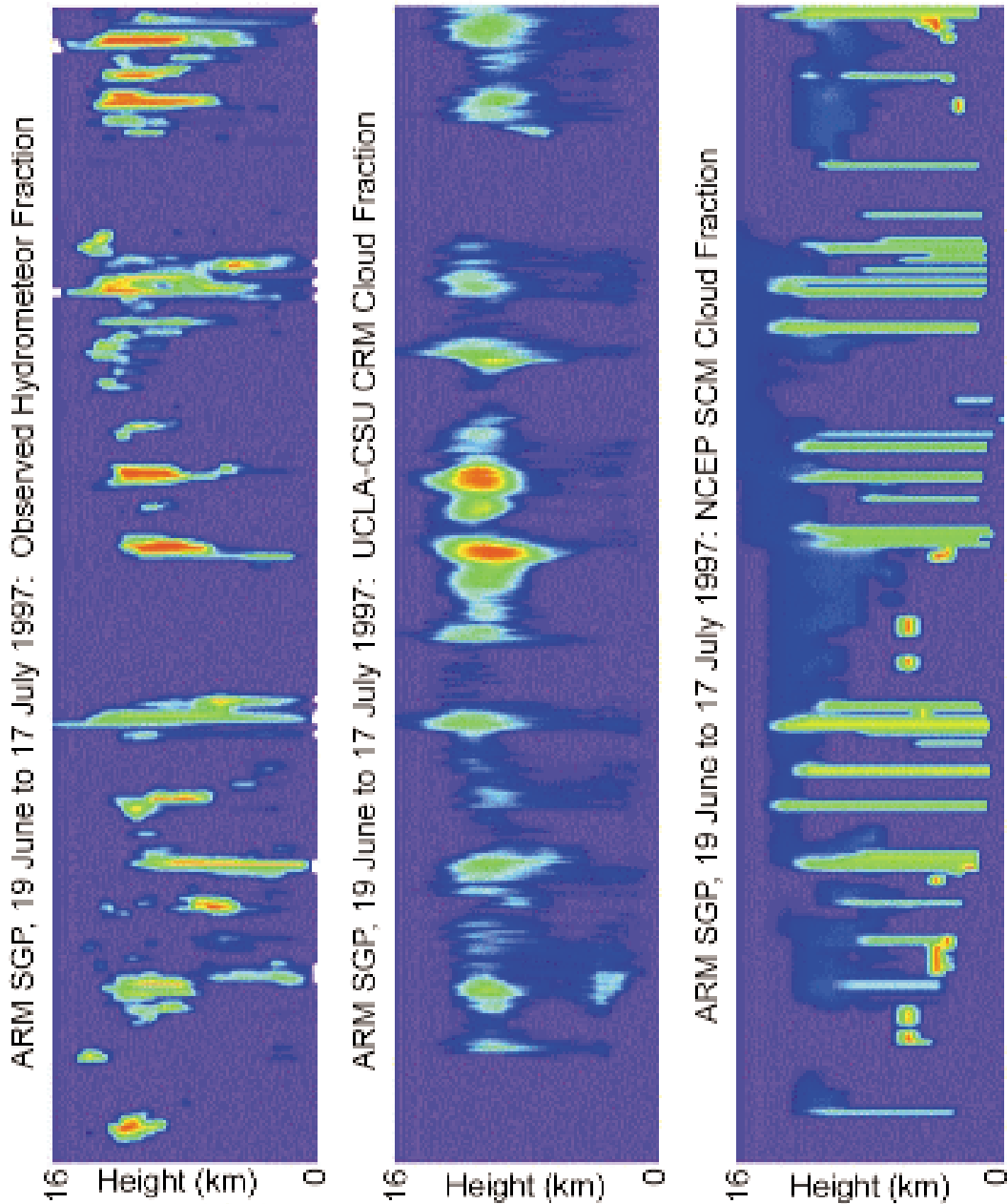


Figure 5. Modeling Clouds

Predicted vs. observed time-height cloud fraction at the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains site from 19 June to 17 July 1997. Left panel: Cloud fraction observed by cloud radar. Center and right panels: Cloud fraction predicted by models. Color indicates cloud fraction, which ranges from 0 (violet) to 1 (red). Developing the capability to account for cloud water distribution will lead to improved climate simulation models and will support efforts to predict precipitation.

Source: DOE ARM Program. See Appendix B for additional information.

FY 2002 Plans

The USGCRP will continue to improve the capabilities for measuring important aspects of the global water cycle and will conduct a number of important research and analysis projects. Key research goals for FY 2002 include:

- Analyze data from the first year of the EOS-Aqua satellite, which is scheduled for launch in late 2001/early 2002. These results should complement measurements from EOS-Terra of clouds, aerosols, radiation budget parameters, land surface characteristics, vegetation cover, snow cover, sea surface temperature, sea ice, atmospheric temperature and water vapor, and other critical parameters. Together, these data sets will enable a more accurate quantification of the water cycle at global and regional scales.
- Launch the EOS/ Earth System Science Pathfinder Gravity Recovery and Climate Experiment (GRACE) (November 2001) to improve measurement of the mass balance of ice sheets, and changes in storage of water/snow on continents. Launch ICESat (December 2001), the first mission to use precision altimetry to measure changes in the topography and mass balance of polar ice sheets. Conduct elevation-change surveys of areas in Greenland that show the most dramatic thinning of the ice sheet, to determine if the thinning is constant, accelerating, or decelerating. Produce high-resolution (10 m) maps for parts of Antarctica, to provide a basis for detecting changes in ice sheets.
- Reduce uncertainty (by 3-7 percent in monthly mean) in the current International Satellite Cloud Climatology Project dataset of globally observed cloud characteristics, particularly in the polar regions, by comparing it with new satellite datasets (that include new constraints on the derived quantities), and with in situ ground-based and airborne measurements.
- Demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture from airborne platforms.
- Demonstrate the impact of assimilating rainfall data from the Tropical Rainfall Measuring Mission on forecasting the track and intensity of tropical storms.
- Improve quantification of land-surface hydrology and the ability of models to simulate climate at regional (large watershed) scales, through the development and demonstration of improved methods to quantify components of the water budget. In an experiment in the Walnut River watershed, winter and summer storm events will be studied in conjunction with ongoing ARM carbon flux and meteorological measurements. A prototype water isotope measurement and modeling program will be implemented.
- Investigate the exchanges of water, energy, and carbon nutrients at selected experimental basins. The processes that control these exchanges are critical to understanding snowpack chemistry, surface hydrology, and climate response.

Changes in Ecosystems

The USGCRP budget includes \$199 million in FY 2002 for research and observations related to understanding changes in managed and unmanaged ecosystems. Human well-being and environmental quality are dependent on the continued healthy functioning of ecosystems. The Earth's diverse ecosystems vary widely in their complexity and productivity, in their intensity of management, and in their utilitarian and intrinsic value to society. USGCRP-supported ecosystem research and assessment efforts contribute to effective ecosystem management and conservation. These contributions include improving understanding of effects of natural processes, human impacts, and environmental variability and change on ecosystem structure (composition, arrangement), functioning (e.g., growth, cycling of nutrients), and production of resources such as clean air and water, food, fiber, energy, wildlife, and recreational spaces.

Ecosystem structure and function, and the production of ecosystem goods and services, are vulnerable to changes in climate, atmospheric composition, and other environmental factors, including the direct influence of humans through the use of land and resources. Such changes can alter ecosystems at multiple scales. Species populations may decrease or increase, and they may become endangered or invasive. Areas covered by some types of vegetation may shrink or expand in size. Landscape-level changes can affect the productivity and health of terrestrial, wetland, and aquatic ecosystems, as well as the sustainability and quality of ecosystem goods and services. The occurrence of direct and indirect interactions among changing environmental forces, and even among interacting ecosystems, each at different scales of time and space, pose scientific research challenges and management issues of unparalleled complexity.

Management to enhance the adaptability and sustainability of ecosystems and natural resources will be an important aspect of society's attempts to reduce the unwanted impacts of global change. It may be possible to enhance the resilience of ecosystems to environmental change through careful resource management practices. Also it may be possible to design and adopt management practices that reduce ecosystem vulnerability to changing occurrences of fire, drought, invasive species, and other disturbances. Increasing the amount of carbon stored in natural and managed ecosystems can offset a portion of the atmospheric carbon emissions from fossil fuels. However, achieving such goals requires increased knowledge of the interactions of management practices with other disturbances; their potential impacts on ecosystem health and on production of ecosystem goods and services; and the role of societal preferences and values in environmental decisionmaking. Improved scientific knowledge of the basic processes that regulate ecosystems is a fundamental requirement for improving the capability to project future climate, ecosystem responses to environmental changes, the value of various management options, and the sustainability of ecosystem goods and services.

Recent Accomplishments

- Field studies with controlled, elevated CO₂ levels indicated that growth stimulation of a few invasive plant species in the arid U.S. Southwest was stronger than growth stimulation in native species. In a separate controlled-environment experiment, increased atmospheric CO₂ improved seedling survival of five species of woody plants during drought, with the beneficial effects greatest and most consistent for the two species considered the most drought-tolerant. These findings indicate that responses to rising atmospheric CO₂ are species-specific, which could result in shifts in the species composition of plant communities.
- In an ozone (O₃) sensitive wheat variety grown in the absence of ozone stress, elevated CO₂ did not enhance yield compared to yield at ambient CO₂. On the other hand, yield was enhanced by elevated CO₂, compared to yield at ambient CO₂, when the wheat was grown at elevated ozone concentrations. The latter occurred because elevated CO₂ prevented the suppression of yield by O₃, and the yield was effectively the same as if there was no O₃ stress. In another experiment, stimulation of tree growth resulting from elevated CO₂ was fully negated by elevated ozone. These findings highlight the uncertainties in projecting crop and forest productivity as CO₂ and climate change, because energy production from fossil fuel combustion causes an increase in both tropospheric CO₂ and ozone, and at comparable relative rates.
- After eight years of experimental manipulation of precipitation received by a forest, growth of existing large trees was mostly unaffected by annual and summer precipitation increases, or by decreases of as much as 30 percent. However, seedling and sapling mortality and nutrient cycling were affected. The discovery that large trees were relatively insensitive to chronic changes in precipitation may require revisions of many models used to predict effects of climatic change on forests.
- Synthesis of results from the Boreal Ecosystem-Atmosphere Study (BOREAS) and other research programs in North American boreal and Arctic ecosystems have demonstrated that high-latitude ecosystems play a major role in the climate system. Average temperature and precipitation in these regions have increased, but changes in soil moisture remain uncertain.

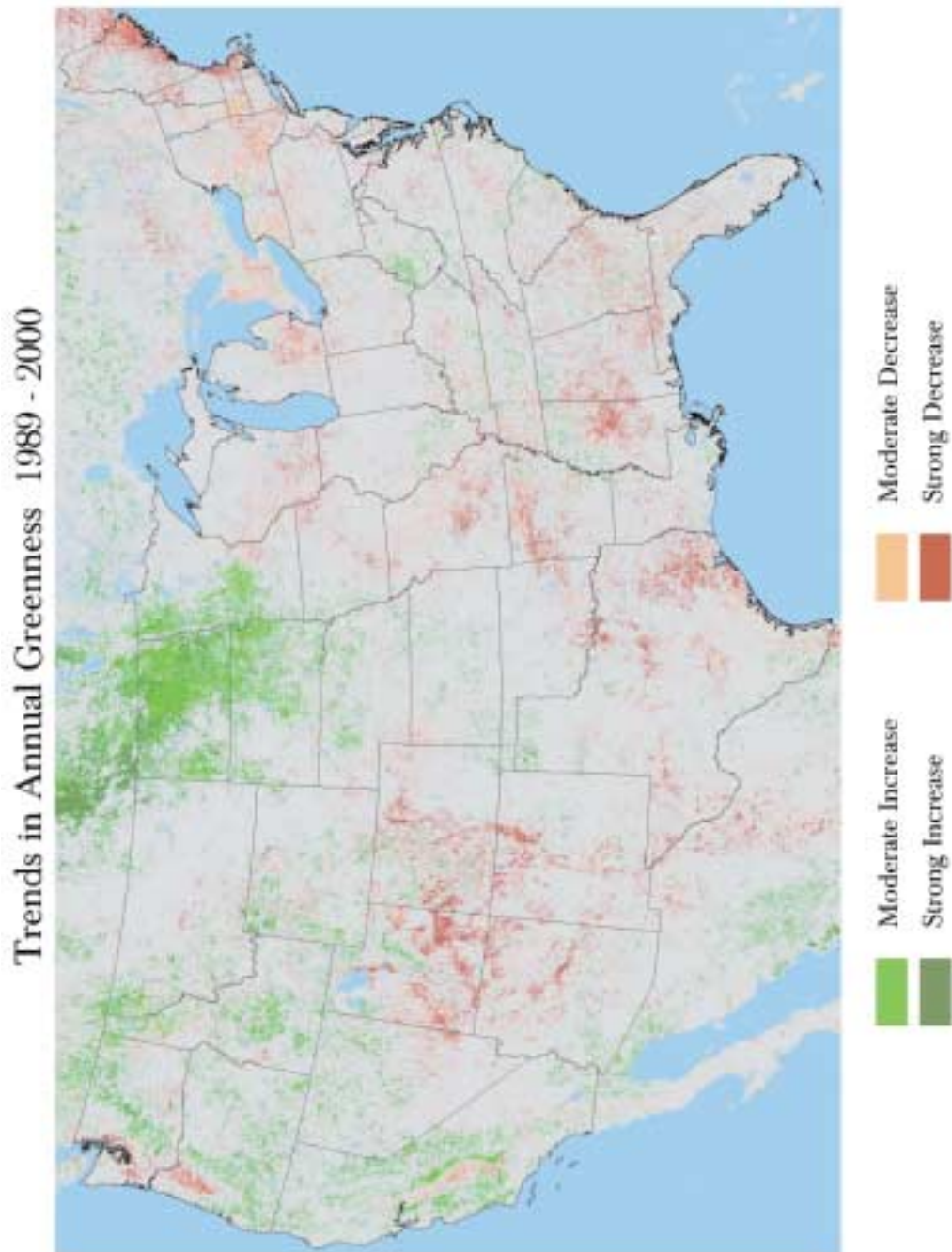


Figure 6. Trends in Annual Greenness 1989 - 2000

Changes in annual greenness during the period 1989-2000 as measured by the normalized difference vegetation index (NDVI) derived from the advanced very high resolution radiometer (AVHRR) satellite sensor. The north-central Plains show a well-defined region of increasing greenness, while the Southwest, southeastern Texas, and the Southeast all show trends of decreasing greenness during the period of record. Research is underway to identify the causes of these trends.

Table 7 Changes in Ecosystems

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOE	12.4
DOI/USGS	14.5
EPA	2.0
NASA	33.2
NSF	30.1
Smithsonian	3.8
USDA	20.6
Scientific Research Subtotal	116.6
NASA Space-Based Observations	82.6
Changes in Ecosystems Total	199.2

FY2002 Plans

The USGCRP will emphasize ecological process research to improve the capabilities for projecting future climate, identify current and future ecosystem vulnerabilities (including risks to the quantity and quality of goods and services), and develop options to enhance ecosystem resilience and reduce vulnerabilities. Key research goals for FY 2002 include:

- Identify impacts of management practices for croplands, rangelands, and forested lands on ecosystem productivity and storage of carbon removed from the atmosphere.
- Test the performance of models using measured responses of a hardwood forest ecosystem to eight years of experimentally imposed increases and decreases in precipitation.
- Identify and quantify linkages among the land, the atmosphere, and disturbance processes in the tropics, including trace gas and aerosol emissions from fire, land-use change, vegetation recovery, biogeochemical processes, and other processes in tropical savannas (Africa) and forests (Amazonia).
- Improve the abilities of ocean ecosystem models to project the productivity of ocean resources and chemical movement and storage, by incorporating new satellite-derived ocean color data sets and coupling the data to models of ecosystem dynamics, biogeochemistry, and ocean circulation.

- Project the impact of sea-level rise on coastal vegetation; quantify effects of natural processes and current wetland management and restoration practices on wetland vulnerability to submergence.
- Develop a method to identify the aquatic resources and services most at risk from disturbance, climate variability, and environmental change.

Human Dimensions of Global Change

The USGCRP budget includes \$107 million in FY 2002 for the study of the human dimensions of global change. Human activities are changing the natural environment at local, regional, and even global scale and play an important part in virtually all “natural” systems. For example, human activities have altered the vegetation on as much as half of the Earth’s land surface and have increased atmospheric concentrations of carbon dioxide by about 30 percent since the start of the industrial revolution, which in turn will cause changes in ecosystems and climate. In addition to such environmental changes, social, economic, and cultural systems are changing and developing in a world that is increasingly crowded, urban, and interconnected. The extent and pace of these changes increase the resilience of some groups while increasing the vulnerability of others to environmental change. Vital resources for human populations — agricultural and forest products, clean air, clean water, and affordable energy — are vulnerable to a variety of global changes. Humans respond to the effects of global change through adaptations that enhance — and through maladaptations that harm — the resilience and productive capacity of managed and natural systems. Developing a more integrated understanding of the complex interactions of human and Earth-system processes is essential for identifying vulnerable systems and pursuing options to enhance resilience.

In an effort to identify strategies to enhance the resilience of human systems to global environmental change, the USGCRP will continue to support research both on human activities that influence environmental change from local and regional to global scales and on how human systems prepare for and respond to environmental changes. About half of the human dimensions budget is devoted to improving understanding of the health effects of exposure to UV radiation, which is particularly important because this exposure can be increased by stratospheric ozone depletion. A relatively small but expanding research area will focus on analyses of the regional impacts of climate on human systems and how improved information about changes in global climate, water, and land surface can help decisionmakers in the public and private sectors.

Recent Accomplishments

- EPA and NOAA have established ongoing regional research and assessment projects in six regions across the United States to study the effects of climate variability and change on natural and human systems. These projects have been highly successful in analyzing the regional context of global change impacts, fostering relationships between scientists and stakeholders in the regions, and determining how research can meet stakeholder needs for water-resource planning, fisheries management,

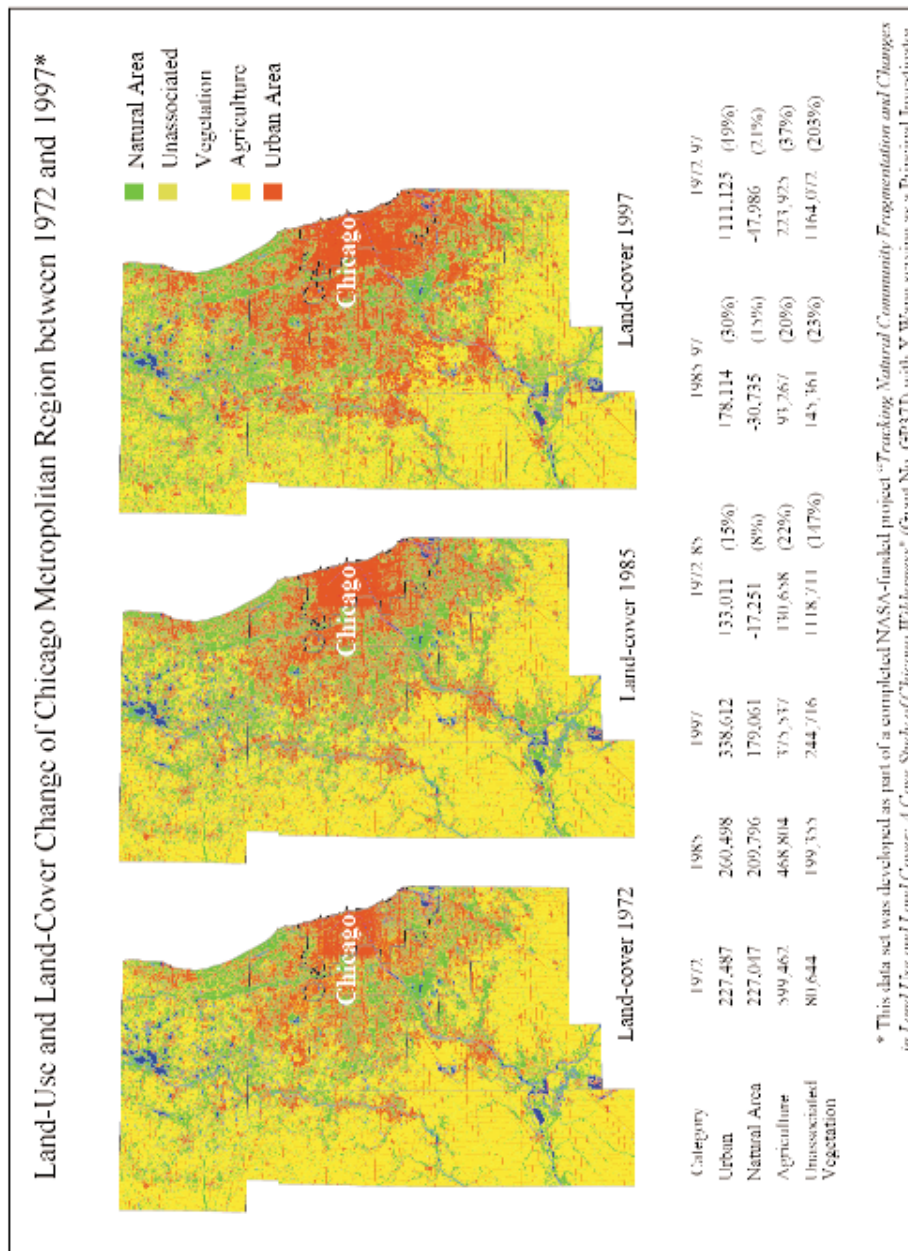


Figure 7. Land-Use and Land-Cover Change in the Chicago Metropolitan Region, 1972-1997

Land cover maps of the Chicago Metropolitan Region document changes in several categories of land cover and land use using LANDSAT imagery from 1972, 1985, and 1997. A 49 percent increase in urban and suburban land area dominates the land-cover changes in the past 25 years. Most of this expansion came at the expense of agricultural lands (a 37 percent decrease), and of natural area, including forest, woodland, prairie, and wetland (a 21 percent decrease).

Source: NASA and Y.Q. Wang, University of Rhode Island. See Appendix B for

ranching, and other climate-sensitive resource management issues.

- Analyses are showing that significant reductions in the projected cost of mitigating greenhouse gas emissions can be achieved by reducing emissions of greenhouse gases other than carbon dioxide. Just as integrated assessment analyses have shown potential reduction in costs by allowing the optimization of where and when carbon dioxide reductions can take place, new analyses project reductions in cost through the trade-off of other greenhouse gases for carbon dioxide. Although much work remains to be done, cost curves for emissions of other gases in various sectors, such as U.S. agriculture, are being developed and incorporated into the integrated assessment analyses.

Table 8 Human Dimensions of Global Change

FY 2002 Budget by Agency
(Discretionary budget authority in \$millions)

Scientific Research	
DOC/NOAA	5.6
DOE	8.0
HHS/NIH	57.0
EPA	20.0
NSF	13.7
Smithsonian	0.6
Scientific Research Subtotal	104.9
NOAA Surface-Based Observations	2.5
Human Dimensions Total	107.4

FY 2002 Plans

The USGCRP will continue to support fundamental research and assessments of the effects of human activities on the global environment and the potential societal consequences of global change. Key research goals for FY 2002 include:

- Award a second set of competitive multiyear grants as part of the interagency program on Climate Variability and Health, for research to improve understanding of the human health consequences related to climate variability, and to enhance the integration of useful climate information into public health policy and decisionmaking. EPA, NOAA, NASA, NSF, and the Electric Power Research Institute jointly support research by multidisciplinary teams ranging from studies of vector-borne and water-borne infectious diseases to asthma and respiratory infections.
- Continue multiyear regionally based research and assessments of the implications of climate variability and change for natural and managed systems in eight U.S. regions. In FY 2002, results are expected from five regional integrated sciences and assessment projects at different stages of development in the Pacific Northwest, California, the Southwest, the Intermountain West, and the Southeast. Each of these projects focuses on key research and decision-support issues for the particular region; for example, the Pacific Northwest project focuses on climate and weather-related linkages to marine ecosystems (chiefly Pacific salmon), hydrology and water resources including hydropower, and forest and coastal resources. Important components of ongoing projects in the Mid-Atlantic, Great Lakes, and Gulf Coast regions include public-private partnerships, analyses of stakeholders' needs, methods for improved communication of global change information, and projections of future impacts of environmental change coupled with changing social and economic forces in the regions under study.
- Increase emphasis in FY 2002 and beyond on the representation of land-use change in integrated assessment analyses. The carbon budget component of integrated assessment models is sensitive to the portrayal of natural terrestrial and oceanic carbon sinks, which have feedbacks to other sectors, such as agriculture and unmanaged ecosystems. Terrestrial carbon sequestration scenarios will rely on projections of land availability, and the integrated assessment analyses will be able to represent more accurately the competing needs for land resources, such as farming, biomass, sequestration, and ecosystem conservation.

INTERNATIONAL CONNECTIONS

International Research Cooperation

The USGCRP contributes to and benefits from international research efforts to improve understanding of global change on both the regional and global scales. USGCRP-supported scientists coordinate many of their programs with those of their counterparts in other countries, thus providing essential inputs to the increasingly complex models that enable scientists to improve analysis and prediction of global change. Some examples of recent, ongoing, and planned global change research and related activities in which USGCRP-supported scientists are heavily involved and for which international cooperation, participation, and support are especially important are highlighted below.

U.S.-Japan Cooperation in Global Change Research

U.S. scientists involved in global change research work closely with their counterparts in many other countries on a bilateral basis. In particular, during the past year the United States and Japan have co-sponsored a series of scientific workshops to identify important global change research problems of mutual interest and to recommend ways in which scientists from the two countries might usefully address these problems.

The USGCRP hosted the 8th U.S.-Japan Workshop on Global Change in November 2000 at the National Institutes of Health. The Workshop developed major recommendations regarding research to study health impacts of global change, in particular the impacts of greater and more long-lasting exposures to higher temperatures interacting with different air pollutants, and the impacts of depletion of stratospheric ozone, which results in greater exposures to UV radiation. A workshop on monsoon systems identified a number of cooperative bilateral and multilateral activities for the two sides to undertake. In October 2001, Japan will host the ninth workshop in this series, on Carbon Cycle Management in Terrestrial Ecosystems.

Climate and Societal Interactions

NOAA's Climate and Societal Interactions Program supports Regional Climate Outlook Fora, pilot application projects, workshops, training sessions, capacity building, and technical assistance for better understanding of climate variability and extreme events, and for improving prediction and forecasting capability and data management, in Africa, Latin America and the Caribbean, Southeast Asia, and the Pacific.

The Climate Information Project (CIP) is developing a new program—Radio and Internet for the Communication of Hydro-Meteorological and Climate Information (RANET)—to provide training to meteorological services worldwide on the use and production of radio and multimedia content in conjunction with digital satellite communication. This effort is being led by NOAA and involves a number of international partners, including the U.S. Agency for International Development, the World Bank, the World Meteorological Organization (WMO), the Inter-American Institute for Global Change Research (IAI), the System for Analysis, Research, and Training (START), and the Asia-Pacific Network for Global Change Research (APN).

The East Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC)

Scientists from universities and national meteorological services in the United States, Mexico, Chile, and Peru are cooperating in EPIC, which is entering its major field phase in 2001. The scientific objectives of EPIC are to observe and understand: (1) ocean-atmosphere processes in the equatorial and northeastern Pacific portions of the Inter-Tropical Convergence Zone (ITCZ); and (2) the properties of cloud decks in the tradewind and cross-equatorial flow regime and their interactions with the ocean below. Achieving the EPIC objectives is expected to resolve certain difficulties in the performance of coupled atmosphere-ocean models. The observational strategy is to coordinate a series of research aircraft missions with research vessels operating in the ITCZ, supported by enhanced monitoring by moored buoys, satellite remote sensing, and other observational platforms.

Studies of Global Ocean Ecosystems Dynamics (GLOBEC)

Scientists and research vessels from Germany, the United Kingdom, and the United States are conducting a closely coordinated major GLOBEC Southern Ocean field study on krill, a key component of marine ecosystems. The field study will be carried out this year and next near the West Antarctic Peninsula. Krill is an essential component of the southern ocean food web and a commercially important species. Predators of krill—including sea birds, seals, and whales—depend critically on this food resource. Sea ice plays an essential role as a habitat both for krill (which feed beneath the ice) and their predators. Since evidence suggests that interannual variation in the extent of sea ice affects the abundance of krill, improving understanding of the role of climate factors affecting sea ice will comprise a critical component of the Southern Ocean GLOBEC program.

The IGBP Open Science Conference

The International Geosphere-Biosphere Programme (IGBP) convened an open science conference in July 2001 in Amsterdam. This Conference presented the latest results of global change research at a series of levels: research conducted through the individual IGBP core projects and research integrated across these projects; research that has been integrated between the IGBP and the World Climate Research Program (WCRP), the International Human Dimensions Program (IHDP), Diversitas, and the Global Change System for Analysis, Research and Training (START) and other regional programs; and individual research projects on which these integrated efforts are based. The Conference also identified new approaches to study of the complex planetary system in which human activities are closely linked with natural processes.

The International Group of Funding Agencies for Global Change Research (IGFA)

IGFA facilitates international global change research in the natural, economic, and social sciences by bringing the perspective of national funding agencies to strategic

research planning and implementation. At its October 2000 meeting, most IGFA member nations reported increases in funding for global change research, initiation and deployment of new national programs, and establishment of some new research centers. Among the issues that IGFA will consider at its next meeting in October 2001 will be the planning now underway to strengthen the international infrastructure for biodiversity research through *Diversitas*.

Diversitas

Diversitas is intended to promote, facilitate, and catalyze scientific research on biodiversity. The specific objectives are to provide accurate scientific information and predictive models of the status of biodiversity and sustainability of the use of the Earth's biotic resources, and to build scientific capacity in biodiversity research. A planning meeting in September 2001 is intended to advance research on systematics, inventorying, and taxonomy; research on global invasive species; and international observations in support of biodiversity research.

International Paleoclimate Research

An international team of researchers from the United States, Germany, and Russia is investigating El'gygytgyn Lake in northeastern Siberia just north of the Arctic Circle. This impact crater was formed 3.6 million years ago by a meteorite impact and its sediments hold the promise of revealing the evolution of Arctic climate a full one million years before the first major glaciation of the Northern Hemisphere.

Through an international consortium of researchers, the Nyanza Project team, involving scientists from the United States, Europe, and four countries in Africa, is studying climate variability, as well as environmental and ecological change, through the entire episode of human evolution. As part of this project, a unique 2,000-year-old annually resolved record of atmospheric circulation and dynamics, revealing El Niño-Southern Oscillation (ENSO) and solar cycles, has been recovered from sediments in Lake Tanganyika—the second deepest lake on the planet.

The IPCC Third Assessment Report

The Intergovernmental Panel on Climate Change (IPCC) was set up jointly by the World Meteorological Organization and the United Nations Environment Programme to provide an authoritative international statement of scientific opinion on climate change. The IPCC's periodic assessments of the causes, impacts, and possible response strategies to climate change are the most comprehensive and up-to-date reports on the subject available, and form the standard reference for all concerned with climate change in academia, government, and industry worldwide. In the IPCC's new Third Assessment Report, hundreds of international experts have assessed climate change in reports of three Working Groups, with a Synthesis Report also to be published.

The "Summary for Policymakers" and "Technical Summary" for each of the IPCC Working Groups is available on the IPCC Web site at <http://www.ipcc.ch/>. IPCC reports may also be accessed via links on the USGCRP Web site at <http://www.usgcrp.gov>. The IPCC Third Assessment Reports have been published by Cambridge University Press:

- IPCC, *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I. [J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, D. Xiaosu, and K. Maskell (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881 pp., 2001.
- IPCC, *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II. [J. McCarthy, O. Canziani, N. Leary, D. Dokken, and K. White (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1032 pp., 2001.
- IPCC, *Climate Change 2001: Mitigation*. Contribution of Working Group III. [B. Metz, O. Davidson, R. Swart and J. Pan (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 752 pp., 2001.
- IPCC, *Climate Change 2001: Synthesis Report: Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, forthcoming late 2001.

Ordering information for the published reports is available at <http://www.cup.org/> or at <http://uk.cambridge.org/earthsciences/climatechange/>, or, in the United States, by telephone at 1-800-872-7423 or fax at 914-937-4712.

USGCRP WEB SITE



To meet the need for accurate and useful information on global change, the USGCRP maintains a Web site that helps connect scientists, government officials, and the private sector to information they are seeking.

Regular updates to the site's "What's New" page provide many links to new material on the USGCRP site and also from a wide range of other sources on the Web. Links are selected from hundreds of monitored sites – including those maintained by the government agencies that participate in the USGCRP. Site visitors can link to material ranging from the National Assessment of the Potential Consequences of Climate Variability and Change to short press releases announcing recent scientific advances, and audio segments.

For those seeking background information on the USGCRP itself, the site provides concise online documents. Users who wish to focus on any of the USGCRP agencies will find many postings conveniently organized by agency. Visitors looking for information by topic will find many links organized by research program element, ranging from Understanding the Climate System to Carbon Cycle Science to the Human Dimensions of Global Change. The site also contains links specifically collected and organized for teachers in elementary and secondary schools.

Other useful links on the site provide access to key Web sites and other current and archived material, including:

- Editions of *Our Changing Planet*, the USGCRP annual report
- The USGCRP Global Change Data and Information System
- USGCRP-related international scientific research programs
- The Intergovernmental Panel on Climate Change
- The Global Change Research Information Office
- Lists of upcoming events
- Research opportunities, including calls for proposals
- Archived material dating back to 1990, including background papers for USGCRP-sponsored events.

Each page on the site contains an e-mail link to the USGCRP Office, for additional inquiries.

GCRIO was established pursuant to the Global Change Research Act of 1990. The GCRIO Web site at <http://www.gcrio.org/> also serves as a gateway to a wide range of global change information for the general public in the United States and internationally.

APPENDIX A: THE USGCRP BUDGET AND PROGRAM BY AGENCY

The first table in this Appendix presents the FY 2001-FY 2002 USGCRP budget by Research Program Element, showing each department or agency's budgetary contribution to each element. The budget pages for individual participating agencies that follow include a listing of programs designated for inclusion in the USGCRP, as well as a general description of each agency's "Areas of Global Change Research." For each agency, a "FY 2002 Program Highlights" section outlines briefly some of the key USGCRP-related activities proposed for the coming year. In addition, the agencies conduct a broad range of "Related Research," as indicated, funding for which is not included as part of the USGCRP budget because the research is conducted primarily for other purposes.

The resources allocated to specific programs within agencies as reflected in these tables for FY 2001 appropriated funds and the FY 2002 budget request are estimates only, and are subject to adjustments based on decisions on scientific and programmatic priorities among USGCRP agencies and their advisory bodies and on the input of the national and international scientific communities.

Each agency budget also includes a "Mapping of Budget Request to Appropriations Legislation." The entry for each agency points to the location (or locations) in the various Appropriations bills (and, in some cases, Appropriations Committee reports) of funding for USGCRP activities. Note that it is common for global change research to be funded within Appropriations accounts that also include funding for other activities, so that Appropriations bills and committee reports do not necessarily designate funding specifically for global change research. Thus, the actual funding level for global change research activities must be determined, in part, by decisions within agencies about how to allocate appropriated funds. It should also be noted that global change research activities are funded by seven separate Appropriations bills. Thus, the relationship between the USGCRP budget crosscut and the Appropriations process is complex.

Table 9 U.S. Global Change Research Program

FY 2001 – FY 2002 Budget by Research Program Element by Agency
(Discretionary budget authority in \$millions)

	NOAA Science	NOAA Obs	DOE	DOI	EPA	NIH	NASA Science	NASA Obs	NSF	SI	USDA	Total
Climate Variability and Change												
FY01	44.6	9.0	70.3	6.0	0.0	0.0	61.9	238.8	100.4	2.0	0.0	533.0
FY02	44.8	16.3	70.8	4.5	0.0	0.0	61.9	193.7	92.4	2.0	0.0	486.4
Atmospheric Composition												
FY01	7.8	1.0	12.6	0.0	0.0	0.0	55.9	233.1	16.8	0.3	18.1	345.6
FY02	7.8	1.0	12.6	0.0	0.0	0.0	54.1	199.1	16.9	0.3	18.0	309.8
Global Water Cycle												
FY01	5.7	0.0	0.0	0.0	0.0	0.0	56.3	237.5	10.3	0.0	2.8	312.6
FY02	5.7	0.0	0.0	0.0	0.0	0.0	56.6	231.6	12.7	0.0	2.8	309.4
Global Carbon Cycle												
FY01	4.8	1.0	12.7	4.0	0.0	0.0	46.7	113.9	16.0	0.3	14.8	214.2
FY02	4.8	4.2	13.7	3.0	0.0	0.0	47.2	111.6	21.5	0.3	14.8	221.1
Changes in Ecosystems												
FY01	0.0	0.0	12.4	17.0	3.0	0.0	32.8	85.0	30.1	3.8	20.8	204.9
FY02	0.0	0.0	12.4	14.5	2.0	0.0	33.2	82.6	30.1	3.8	20.6	199.2
Human Dimensions of Global Change												
FY01	5.6	0.0	8.0	0.0	20.0	51.6	0.0	0.0	13.7	0.6	0.0	99.5
FY02	5.6	2.5	8.0	0.0	20.0	57.0	0.0	0.0	13.7	0.6	0.0	107.4
USGCRP Total												
FY01	68.5	11.0	119.1*	27.0	23.0	51.6	253.6	908.3	187.3	7.0	56.5	1713
FY02	68.7	24.0	120.6*	22.0	22.0	57.0	252.9	818.6	187.3	7.0	56.2	1637

*DOE totals include \$3.1 million for Small Business Innovative Research/Technology Transfer (SBIR/STTR)



Department of Agriculture

USDA	Program Title	FY00	FY01	FY02 Request
ARS	Agriculture and Rangeland Global Change	13.0	12.6	12.4
ARS	Methyl Bromide Research	14.9	16.7	16.6
CSREES	Improved Response Models	7.7	6.9	6.9
CSREES	UV-B Monitoring Network	1.0	1.4	1.4
ERS	Economics of Global Change and Agriculture	0.8	0.8	0.8
FS	Forest Global Change Research	16.9	16.9	16.9
NRCS	Soil Carbon Studies, Soil Surveys and Inventories	1.2	1.2	1.2
USDA Total		55.5	56.5	
President's Request				56.2

- ARS: Agricultural Research Service
 CSREES: Cooperative State Research, Education, and Extension Service
 ERS: Economic Research Service
 NRCS: Natural Resources Conservation Service
 FS: Forest Service

Areas of Global Change Research. USDA-sponsored research focuses on understanding terrestrial systems and the effects of global change (including water balance, atmospheric deposition, vegetative quality, and UV-B radiation) on food, fiber, and forestry production in agricultural, forest, and range ecosystems, examining the role of managed and unmanaged terrestrial systems in the global carbon cycle, and assessing how agricultural and forestry activities can contribute to a reduction in greenhouse gas concentrations.

FY 2002 Program Highlights. As part of the collaborative interagency Carbon Cycle Science Program, in FY 2002 USDA will conduct research on how land management practices affect the net carbon balance and develop methods to assist farmers, ranchers, and forest landowners in increasing carbon sequestration and better managing other greenhouse gas emissions. USDA will continue to quantify carbon sources and sinks from land management activities, including fluxes for all U.S. forest and agricultural lands and other land uses. The implications of changes in water quality and availability on agricultural and forest land productivity will be assessed. USDA research will examine the economic implications of alternative greenhouse gas offset strategies. In addition, USDA will continue to assess how resilient managed agricultural, rangeland, and forest ecosystems are to climate change and what adaptation strategies will be needed to adjust to a changing climate.

ARS will focus on four broad research areas: 1) studies of the carbon cycle and

carbon storage, emphasizing identification and quantification of the current and potential roles of agriculture in the global carbon cycle with sufficient accuracy to inform policy and aid producers in making decisions that are both economically and environmentally sound; 2) managing non-carbon dioxide trace gases, such as methane and nitrous oxide, which are produced by certain processes in some crop and animal production systems; 3) determining the impacts of increased atmospheric carbon dioxide, rising temperatures, and altered water availability on crops and their interactions with other biological components of agricultural ecosystems; and 4) characterizing and measuring changes in weather and the water cycles at local and regional scales, and determining how to manage agricultural production systems facing such changes.

CSREES will continue to support the USDA UV-B Monitoring Network. Information from this research network is combined with satellite-based measurements to provide an accurate climatological UV-B irradiance database. This database documents long-term trends and supports research and assessment of the potential for damage to ecosystems. Global change research in CSREES's National Research Initiative (NRI) Competitive Grants Program and formula-funded programs aims to increase understanding of the possible impacts of global environmental change on the sustainability of agriculture and forestry.

ERS will continue to focus on two broad research areas: 1) the long-run impacts of the accumulation of greenhouse gases on agriculture, including effects resulting from changes in temperature and precipitation, and from carbon dioxide fertilization; and 2) the economic implications of alternative net greenhouse gas emission reduction and carbon sequestration options for U.S. agriculture.

FS global change research program has established a national plan of forest sustainability to continue providing water, recreation, timber, wildlife, and clean air in a changing environment. Focus for FY 2002 will be to: 1) improve understanding of changes in forest carbon storage resulting from management, 2) improve strategies for sustaining forest health under multiple environmental stresses; and 3) develop projections of future forest water quality and yield in light of potential changes in climate.

NRCS will continue to collect data necessary to estimate soil carbon inventories, develop new technologies and methods to cost-effectively measure soil carbon, and work with collaborators to assess the impacts of policies and programs on soil carbon stocks.

Related Research. In addition to focused USGCRP research, the USDA sponsors research contributing to the assessment of global change effects on the agricultural food and fiber production systems and the forest and grassland ecosystems of the United States and worldwide. Programs include long-term studies addressing the structure, function, and management of forest and grassland ecosystems; research in applied sciences, including soils, climate, food and fiber crops, pest management, forest fish and wildlife, and social sciences; implementation of ecosystem management on the national forests and grasslands; and human interaction with natural resources.

CSREES will support global change research by funding a new consortium of ten Land Grant University partners to study the mitigation of greenhouse gases through agricultural production practices. The overall goal of the consortium is to provide the tools and information needed to implement soil carbon sequestration programs success-

fully so that the accumulation of greenhouse gases in the atmosphere can be lowered, while providing income and incentives to farmers, as well as improving the soil.

Mapping of Budget Request to Appropriations Legislation. In the Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations Bill, USGCRP activities are funded under Title I-Agricultural Programs, within the ARS, CSREES Research and Education Activities, and ERS; and under Title II-Conservation Programs, within the NRCS Conservation Operations account. In the Interior and Related Agencies Appropriations Bill, USDA USGCRP activities are funded in the USDA FS section under Title II-Related Agencies, within the FS Forest Research account.



Department of Commerce / National Oceanic and Atmospheric Administration

DOC	Program Title	FY00	FY01	FY02 Request
NOAA	Aerosols	1.1	1.1	1.1
NOAA	Applications of Regional Forecasts	3.6	3.7	3.7
NOAA	Atmospheric Chemistry	6.6	6.7	6.7
NOAA	Carbon Cycle Science	4.7	4.8	4.8
NOAA	Climate Change Data and Detection	4.4	6.7	6.8
NOAA	Climate Dynamics and Experimental Prediction	17.3	17.7	17.7
NOAA	Climate Variability and Predictability (CLIVAR)	19.3	20.2	20.3
NOAA	Global Energy and Water Cycle Experiment (GEWEX)	4.8	5.7	5.7
NOAA	Human Dimensions of Global Change Research	1.9	1.9	1.9
NOAA	Paleoclimatology*	2.2	0.0	0.0
NOAA	Health of the Atmosphere**	0.8	0.0	0.0
NOAA	Climate Observations and Services		11.0	24.0
DOC Total***		66.7	79.5	
President's Request				92.7

* The Paleoclimatology Program is included in the Climate Change Data and Detection Project beginning in FY01.

** Contribution to NOAA Health of the Atmosphere Program ends in FY00.

*** FY00 total reflects appropriation less rescission of \$400K.

NOAA National Oceanic and Atmospheric Administration

Areas of Global Change Research. NOAA's global change efforts are designed to provide a predictive understanding of the climate system and its modes of variability, and to advance the application of this information in climate-sensitive sectors through a suite of process research, observations and modeling, and application and assessment activities. Specifically, NOAA's research program includes ongoing efforts in operational in situ and satellite observations with an emphasis on oceanic and atmospheric dynamics, circulation, and chemistry; understanding and predicting ocean-land-atmosphere interactions, the global water cycle, and the role of global transfers of carbon dioxide among the atmosphere, ocean and terrestrial biosphere in climate change; improvements in climate modeling, prediction, and information management capabilities; the projection and assessment of variability across multiple timescales; the study of the relationship between the natural climate system and society and the development of methodologies for applying climate information to problems of social and economic consequences; and archiving, management, and dissemination of data and information useful for global change research.

FY 2002 Program Highlights: NOAA research will continue to advance understanding of the whole-system dynamics and modes of climate variability, and the application of information generated by this research to decisionmaking processes in climate-sensitive regions and sectors. For FY 2002, NOAA requests new resources for Climate Observations and Services. The new funding will support: 1) regional assessments, education, and outreach; 2) contributions to climate change assessments; 3) observational and modeling efforts to improve forecasting of weather-climate connections at subseasonal time scales; 4) atmospheric carbon sampling over North America and analysis studies; and 5) enhancements to the global ocean observing system for climate. FY 2002 program highlights in support of the USGCRP research elements include:

Atmospheric Composition:

- Characterizing the “ozone-friendliness” of substitutes for ozone-depleting gases, developing methods for the detection of the recovery of the ozone layer, and characterizing the regional variance of tropospheric ozone and its role in the heat budget.
- Quantifying the trends and sources/sinks of long-lived greenhouse gases, and characterizing the fundamental processes that control the shorter-lived radiative species.
- Advancing efforts to reduce uncertainties in the understanding of direct radiative forcing by tropospheric aerosols through an integrated program focused on targeted in situ measurements of aerosols integrated with model analyses.

Climate Variability and Change:

- Increasing understanding of the role in climate variability, and the predictability, of the El Niño-Southern Oscillation, the North Atlantic (or Arctic) Oscillation, Tropical Atlantic Variability, the Pacific Decadal Oscillation, and the Pan-American monsoons.
- Continuing the advancement of the sustained global ocean observing system to support Climate Variability and Predictability (CLIVAR) research, operational and experimental climate forecasting, and the major scientific assessments.
- Advancing the improvement of models and modeling systems for climate prediction at all timescales and the ability to provide regional-scale forecasts and predicted probabilities of extreme weather events.
- Advancing detailed studies of past climate variability on seasonal to centennial time scales using century to millennia-long paleoenvironmental proxy records in order to improve the current understanding of seasonal to decadal variability.
- Developing and applying advanced statistical techniques to detect climate change signals and attribute these to specific causes.

Global Carbon Cycle:

- Advancing efforts to produce more accurate projections of future atmospheric CO₂ concentrations by better parameterization of transfers of CO₂ between ocean, atmosphere, and terrestrial biosphere, and development of dynamic, coupled carbon cycle models.
- Initiating observations and modeling necessary to quantify the magnitude and variability of the Northern Hemisphere terrestrial sink, with an initial focus on large scale observations over the North American continent and adjacent ocean basins.

- Continuing to document the inventory of carbon in the ocean as it accumulates, and characterize how that inventory might be affected by changes in ocean circulation in the future.

Global Water Cycle:

- Investigating the role of land surfaces on the predictability of warm season precipitation over North America, with emphasis on seasonal and interannual variability.
- Completing studies in the Missouri River Basin showing how the land surface effects on the atmosphere are modulated by large-scale atmospheric circulation.
- Completing the characterization of regional water and energy budgets over the Mississippi River Basin.
- Implementing observational activities and data assimilation products needed to support the GEWEX Coordinated Enhanced Observing Period, and developing the data sets and parameterizations necessary to extend the Land Data Assimilation System (LDAS) developed for the United States to the entire globe.

Human Dimensions of Global Change:

- Advancing understanding of societal vulnerability and current coping mechanisms related to climate variability on seasonal up to decadal time scales (including climate extremes and surprises), and the potential use of climate information for economic, management, and policy planning purposes.
- Advancing efforts to foster the application of forecast information in climate-sensitive regions and sectors such as agriculture, water resources, energy, marketing, human health, and transportation infrastructure.

Related Research. In addition to focused USGCRP research, related activities include advance short-term weather forecasting and warning services; marine ecosystem research; prediction and observation systems in support of weather and seasonal to interannual climate forecasts; and facilitating the dissemination of global change information.

Mapping of Budget Request to Appropriations Legislation: In the Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriations Bill, NOAA activities are funded under Title II—Department of Commerce and Related Agencies, within the NOAA Operations, Research, and Facilities account. In Appropriations Committee reports, funding for NOAA’s USGCRP activities is the Climate and Global Change line-item within Oceanic and Atmospheric Research.



Department of Defense

Areas of Global Change Research. The Department of Defense does not support dedicated Global Change Research, but continues a history of participation in the USGCRP through sponsored research that concurrently satisfies National Security requirements and stated Goals of the USGCRP. A non-inclusive summary of unique Defense research and infrastructure associated with the USGCRP is described below. Because these efforts are not part of the OMB Global Change Research Program construct, a budget table is not included. All data and research results are routinely made available to the civil science community.

FY 2002 Program Highlights. This summary of contributing Defense research and infrastructure is framed in terms of the USGCRP Program Elements.

Atmospheric Composition. The Naval Research Laboratory's Special Sensor Ultraviolet Limb Imager, scheduled for launch late 2001, will provide long-term baseline data for investigations of global change in the upper atmosphere. Analysis and prediction of world-wide aerosol concentrations, including desert dust, biomass smoke, marine and anthropogenic aerosols, and a radiative transfer algorithm yielding atmospheric transmission coefficients is generated by the Navy Aerosol Analysis and Prediction System [NAAPS].

Climate Variability and Change. Several DoD funded projects under the aegis of the National Oceanographic Partnership Program [NOPP] contribute directly to USGCRP goals. The Ocean Acoustic Observatory Federation involves government and private research organizations to exploit data from active and retired Navy Sound Surveillance System [SOSUS] stations for ocean acoustic tomography and thermometry measurements in the Eastern Pacific. This effort capitalizes on previous work done under the Acoustic Thermometry of Ocean Climate [ATOC] project. Another NOPP research effort, Estimating the Circulation and Climate of the Ocean [ECCO] is underway now to describe ocean transport and transport fluctuations of heat, volume, and freshwater and their relationship to air-sea fluxes. The DoD High Performance Computing [HPC] Challenge is sponsoring two relevant projects: a high resolution coupled atmosphere-ocean-ice model, the Coupled Environmental Model Prediction [CEMP] system, and a 1/32-degree global ocean nowcast/forecast model.

The Distributed Ocean Data System [DODS] is another NOPP-sponsored effort to facilitate data access by providing a transparent interface to recognize and process data in various formats. The DODS plug-and-play feature simplifies access via the internet. DODS software is free; details are available at <http://www.unidata.ucar.edu/packages/dods/>.

Navy continues to support the International Arctic Buoy Programme [IAGP]. These data are available at <http://iabp.apl.washington.edu>. Data and model output fields are available from the GODAE World Wide Web server at <http://www.usgodae.fnmoc.navy.mil>. The Defense Modeling and Simulation Office [DMSO] World Wide Web site <http://mel.dmsomil> provides access to a variety of environmental and geospatial data and

models. The multiagency MEDEA group will continue to bridge the national security and civil community for access to classified environmental data.

Global Water Cycle. Three space-based remote-sensing projects are on track to provide high resolution atmospheric and oceanographic data to the military and civil communities. First, WindSat is scheduled for launch late in 2001 with a polarimetric microwave radiometer sensor to measure vector winds over the ocean. Planning for the Naval EarthMap Observer [NEMO] mission is underway to provide hyperspectral data to characterize the global littoral. And Navy and NASA are jointly developing a mission to demonstrate geosynchronous imaging spectrometer technology. This project will launch in 2004 and carry the Navy Indian Ocean Meteorology and Oceanographic Imager [IOMI] and NASA's Geosynchronous Imaging Fourier Transform Spectrometer [GIFTS] sensor packages.

Terrestrial and Marine Ecosystems. Several research efforts coordinated under the NOPP umbrella comprise the Ocean Biological Information System [OBIS]. The OBIS is a public-private partnership and a new component of the UN Global Biodiversity Information Facility [GBIF]. Navy is directly investing in the development of new, in-water instruments capable of measuring biological and chemical properties of the sea associated with the fine structure of biological and chemical dynamics via the Thin Layers (Critical Scales) Program. The Strategic Environmental Research and Development Program [SERDP] is supporting related research to develop long-lived miniaturized sensors to measure terrestrial and marine ecosystem parameters.

Related Research and Infrastructure. Other DOD-sponsored research and supporting infrastructure, not described above, also contribute to observing, understanding and predicting environmental processes related to global change. Associated research programs include theoretical studies and observations of solar phenomena, monitoring and modeling of unique features in the middle and upper atmosphere, terrestrial and marine environmental quality research, and energy conservation measures.

DOD's continued investment in environmental infrastructure such as the Oceanographic Research Vessel Fleet, the Cold Regions Research and Engineering Laboratory, and the various services' operational oceanographic and meteorological computational centers will continue to provide data and services useful to the USGCRP.

Mapping of Budget Request to Appropriations Legislation. In the Department of Defense Appropriations Bill, research associated with the USGCRP is funded under Title IV – Research, Development, Test and Evaluation. In Appropriations Committee reports, nearly all funding is included within the budget for Defense Research Sciences.



Department of Energy

DOE	Program Title	FY00	FY01	FY02 Request
BER	Climate & Hydrology	67	70	71
BER	Atmospheric Chemistry & Carbon Cycle	26	26	27
BER	Ecological Processes	12	12	12
BER	Human Interactions	8	8	8
BER	Small Business Innovative Research/ Technology Transfer (SBIR/STTR)	0	3	3
DOE Total		113	119	
President's Request				121

BER Biological and Environmental Research Program

Areas of Global Change Research. Research supported by DOE's Office of Biological and Environmental Research (BER) addresses the effects of energy production and use on the global Earth system, primarily through studies of climate response. It includes research in climate modeling, atmospheric chemistry and transport, atmospheric properties and processes affecting the Earth's radiation balance, and sources and sinks of energy-related greenhouse gases (primarily CO₂). It also includes research on the consequences of atmospheric and climatic changes on ecological systems and resources, critical data needs for the detection and attribution of climate change, and tools and methods needed to conduct scientific assessments of climate change, and education and training of scientists and researchers in global change.

FY 2002 Program Highlights. DOE supports global change research at its National Laboratories and other public and private research institutions, including universities. In FY 2002, DOE, along with the other USGCRP agencies, will continue to integrate the frontiers of climate and computational science to accelerate progress in climate simulation model development, testing, and application. In support of the USGCRP, highlights of the BER global change program include activities in the following four key areas:

Climate and Hydrology. DOE will continue the development of advanced diagnostics and an on-line diagnostic library to evaluate the ability of climate models to simulate and predict climate variability and change. To better connect observational and modeling research programs, DOE will implement a parameterization testbed that will facilitate the development and implementation of improved physics modules into climate models. Additionally, extensive effort will be directed toward advancing the computational, numerical, and software engineering aspect of climate models as part of the

Scientific Discovery through Advanced Computing Program in DOE's Office of Science.

Using data collected at the Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed sites, DOE's ARM Program will continue measurement and modeling efforts to improve the radiative flux calculations and associated heating rates in climate models.

DOE will conduct an experiment in the Walnut River watershed to advance land-surface hydrology and climate models at regional (large watershed) scales. The focus will be on developing and demonstrating improved methods to evaluate components of the water budget. Winter and summer storm events will be studied in conjunction with ongoing water and carbon flux and meteorological measurements, and a prototype water isotope measurement and modeling effort will be implemented. DOE will also develop capability in Single Column Model and test General Circulation Models to assess their ability to account for cloud water distribution determined from ARM site observational data streams. This effort will lead directly to improved cloud parameterization schemes in climate models and to supporting precipitation prediction efforts being evolved under the USGCRP.

Atmospheric Chemistry and Carbon Cycle. DOE will continue the support of field, laboratory, and modeling studies to improve our understanding of the atmospheric processes associated with transport, transformation, and dispersion of energy-related emissions and their effects on air quality and climate, including studies of oxidants, aerosols, and the heterogeneous chemistry of these materials. It will also include studies of the dispersion of energy-related materials through the lower troposphere to help understand the fundamental processes that control vertical transport for stable and transition boundary layers and how pollutants move through these layers in the lower atmosphere.

Research in both terrestrial and marine environments will be continued to improve understanding of the global carbon cycle. DOE will continue field CO₂ enrichment experiments (FACE), observations of net CO₂ exchange between the atmosphere and biosphere (AmeriFlux), and dynamic modeling of the carbon cycle and its relationship to climate influences. This research will focus on biophysical controls, biogeochemical mechanisms and climate-related feedbacks of terrestrial carbon cycling. Data from experiments and tested carbon cycle models will be used for predictions of future atmospheric CO₂ change and for estimating quantity and longevity of carbon sequestration by terrestrial ecosystems. Support for experiments and AmeriFlux measurements continues to be a high priority. DOE also will continue to fund the development and application of new molecular biological probes to carbon and nitrogen cycles in nearshore marine environments. A field experiment combining a range of new probes with biogeochemical rate measurements and satellite imagery will be planned for a well-characterized nearshore site.

Ecological Processes. A continuing weak link in understanding effects of environmental change on ecosystem structure and functioning is a lack of ecosystem-scale experiments available to both parameterize and test ecosystem models. The DOE global change program will continue to support large-scale and long-term experimental field manipulations of environmental factors in several terrestrial ecosystems throughout the United States. Key studies include: (a) the Throughfall Displacement Experiment

(TDE), started in 1993 in a deciduous forest in eastern Tennessee; and (b) several Free-Air CO₂ Enrichment (FACE) experiments initiated since 1995. The TDE will be continued to document further the effects of chronic changes in precipitation on forest processes and structure, and will be used to test several ecosystem models in the coming year. DOE-supported FACE experiments include those in both deciduous and evergreen forest plantations, a desert ecosystem, and artificial plant communities constructed to test hypotheses about the role of biodiversity in regulating plant-community responses to elevated CO₂. The combination of elevated CO₂ with elevated O₃ is being studied in one FACE experiment (initiated in 1998), providing unique data on forest responses to multiple changes in the troposphere. These large-scale experiments (TDE and FACE) are needed to develop confidence in—and improve scientific understanding represented by—ecological models, which form the basis of most assessments of ecological responses to environmental change. Thus, DOE will support model development and evaluation parallel to the experimental programs, and will also support laboratory research needed to explain results in the ecosystem-scale field experiments.

Human Dimensions. The DOE human dimensions program will continue its support of fundamental research to develop and improve data, models, and methods that can be used by others to analyze and assess the implications of various policy options and questions relevant to climate change. The FY 2002 focus areas will include: developing data and methods for use in assessing the benefits and costs of enhancing terrestrial carbon sinks, estimating the costs of non-CO₂ greenhouse gas mitigation, and assessing the influence of invention and diffusion of new technologies on greenhouse gas emissions. DOE also will continue support of the Carbon Dioxide Information and Analysis Center (CDIAC), to enable it to respond to data and information requests from users from all over the world who are concerned with the greenhouse effect and global climate change. The CDIAC will pay special attention in FY 2002 to data needs associated with carbon flux, regional air pollution, and ocean data.

Related Research: DOE plays a major role in carbon sequestration research to slow the increase in atmospheric concentrations of energy-related greenhouse gases, especially carbon dioxide, and their emissions to the atmosphere. The research builds on but is not part of the USGCRP. It focuses on developing the understanding needed both to enhance the net carbon sequestration of excess CO₂ from the atmosphere in terrestrial and ocean systems and to assess the potential environmental consequences and ancillary benefits. DOE (in collaboration with NSF) will support an iron-fertilization experiment in the Southern Ocean, the largest high nutrient-low chlorophyll region in the world's oceans, focusing on quantifying the amount of carbon that is exported to the deep ocean—a prerequisite for carbon sequestration.

Mapping of Budget Request to Appropriations Legislation: In the Energy and Water Development Appropriations Bill, DOE USGCRP activities are funded under Title III, Department of Energy, within the Energy Supply, Research, and Development Activities account. In Appropriations Committee reports, funding for DOE's USGCRP programs is included within the Biological and Environmental Research account.



Department of Health and Human Services / National Institutes of Health

HHS/NIH	Program Title	FY00 Actual	FY01 Estimate	FY02 Request
NIEHS	Human Health Effects of Exposure to UV Radiation and CFC Replacement Chemicals	5.2	5.7	6.2
NEI	Health Effects of UV Radiation	14.0	15.8	17.7
NCI	Health Effects of UV Radiation	28.2	29.8	32.8
NIAMS	Health Effects of UV Radiation	0.3	0.3	0.3
HHS/NIH Total		47.7	51.6	
President's Request				57.0

- NIEHS National Institute of Environmental Health Sciences
- NEI National Eye Institute
- NCI National Cancer Institute
- NIAMS National Institute of Arthritis and Musculoskeletal and Skin Diseases

Areas of Global Change Research. Three NIH institutes support research on the health effects of UV and near-UV radiation. Their principal objectives include an increased understanding of the effects of UV and near-UV radiation exposure on target organs (e.g., eyes, skin, immune system) and of the molecular changes that lead to these effects, and the development of strategies to prevent the initiation or promotion of disease before it is clinically defined. In addition, NIEHS supports research on the health effects of CFC replacement chemicals, including studies on the metabolism and toxicity of HCFCs and halogenated hydrocarbons.

FY 2002 Program Highlights. The NIEHS program supports grants and intramural projects that investigate the effects of UV exposure on the immune system, aging process, sensitive tissues such as the retina and skin, and methods to reduce these harmful effects. Other projects involve the comparison of mutagenic potential in bacteria of UV and near-UV radiation at levels found in natural sunlight and at levels anticipated with a 15 percent depletion of stratospheric ozone. Several projects supported by NIEHS are investigating molecular changes in DNA that lead to aberrations and mutations in human tissue, rodents, fruit flies, and bacteria, and the variety of ways these organisms repair damage to DNA resulting from UV exposure.

The NEI supports studies on the impacts of UV radiation on the eye (retinal damage as well as corneal capacity). A major initiative is underway to determine how and why eye cataract develops and to search for ways to prevent or slow the progression of cataract, an age-related eye disease that affects 17-20 million people globally. This project is investigating the role of UVB radiation, which has been implicated as a specific risk factor in cataract development. Another important area of research is the under-

standing of certain detoxification systems in the eye and how they combat damage from UVB radiation. The goal of this effort is to identify drugs that might have therapeutic or preventative applications.

The NCI is supporting a wide range of studies to characterize the etiology, biology, immunology, and pathology of a variety of changes in the skin (morphological effects that might precede skin cancer), including photoaging, non-melanoma skin cancers, and melanoma caused by exposure to UV radiation. Other research is exploring UV-induced immunosuppression, which is critical to the development of UV-induced skin tumors, and the cellular and molecular basis for the genetic predisposition to UVB-induced skin cancer in people with Basal Cell Nevus Syndrome.

The NIAMS supports basic and clinical research on the effect of UVA and UVB radiation on skin.

Related Research. In addition to research areas that are designated as part of the USGCRP budget, NIEHS conducts research related to other impacts of global change on human health, including the effects of environmental and occupational exposures to air pollution, agricultural chemicals, and materials used in technologies to mitigate or adapt to climate change. Exposures of special concern include those that contribute to the greatly increased incidence of childhood asthma and that disrupt the normal functioning of the endocrine system. Renewed concern about emerging and reemerging infectious diseases has prompted increased attention to a variety of diseases whose incidence would be affected by environmental change. Other HHS agencies provide significant resources for research on the prevention of and treatment for water-, food- and vector-borne diseases, such as cholera, salmonella, encephalitis, malaria, dengue, and Lyme disease.

Mapping of Budget Request to Appropriations Legislation. In the Departments of Labor, Health and Human Services, and Education and Related Agencies Appropriations Bill, USGCRP activities are funded under the NIH section of Title II—Department of Health and Human Services.

streams and wetlands; carbon cycling and sequestration in soils and sediments; land cover trends; and climate-vegetation change history and modeling, all with a focus on DOI lands. Biogeochemical cycling research is developing an understanding of the interactive influence of climate and ecosystems on carbon cycling by understanding the exchanges of water, energy, and nutrients between the atmosphere and land surface. The processes that control the cycling and fate of carbon and other nutrients in soils, rivers, lakes, reservoirs, and estuarine systems are critical to understanding carbon fluxes. Understanding of the role of land-use change and associated erosion and sedimentation processes on carbon storage in soil and sediments is key to determining human influences on carbon cycling. Research in Alaska is developing an understanding of boreal soil carbon dynamics and the historic and modern interactions among climate, surface temperature and moisture, fire, and carbon sequestration. Land cover trends research is developing an understanding of rates, patterns, and impacts of landscape changes in North America and their consequences for carbon stocks. Vegetation change research is developing a detailed history of vegetation change and models of possible future changes in North America to better understand future carbon stocks.

Changes in Ecosystems. USGS ecosystems research focuses on impacts on terrestrial and coastal ecosystems and fish and wildlife by determining the exposure, sensitivity, and adaptive capacity of natural systems and ecological processes to multiple environmental factors, including climate and other natural and anthropogenic influences at the local, landscape, regional, and continental scale. Research provides the scientific knowledge and technologies for conservation, rehabilitation, and management of ecosystems needed by public land management agencies. Land surface characterization includes research and development of techniques to monitor, analyze, describe, and predict land use, land cover, and other surface characteristics data. These data sets are used to characterize and map the Earth's surface, model land surface processes, detect changes over time, project the response of the land surface to changes in climate and other environmental influences, and investigate the impact of land-cover changes on the environment. Research to understand the causes and consequences of land-cover change is also conducted, in part, to improve model development and application.

Satellite Data Management and Dissemination. The USGS also operates and continually enhances the capabilities of the EROS Data Center to serve as the National Satellite Land Remote Sensing Data Archive, by maintaining existing datasets, adding new ones, and converting older data sets from deteriorating media to modern, stable media. This archive supports all research components that investigate the land surface and the ecosystems it supports.

Related Research. DOI also sponsors contributing research programs addressing the collection, maintenance, analysis, and interpretation of short- and long-term land, water, biological, and other geological and biological processes and resources through dispersed observing networks; research in land use and land cover, including creation of maps and digital data products; and inventorying and monitoring of biological habitats, resources, and diversity.

Mapping of Budget Request to Appropriations Legislation. In the Interior and Related Agencies Appropriations Bill, DOI USGCRP activities are funded under Title I-Department of the Interior. Funding for U.S. Geological Survey USGCRP programs is included within the USGS Survey, Investigations, and Research account.



Environmental Protection Agency

EPA	Program Title	FY00	FY01	FY02 Request
ORD	Assessment of Consequences of Climate Variability and Change	18.0	20.0	20.0
ORD	Changes in Ecosystems	3.0	3.0	2.0
EPA Total		21.0	23.0	
President's Request				22.0

ORD Office of Research and Development

Areas of Global Change Research. EPA's Global Change Research Program is an assessment-oriented program with primary emphasis on understanding the potential consequences of climate variability and change on human health, ecosystems, and socioeconomic systems in the United States. This entails: (1) improving the scientific basis for evaluating effects of global change in the context of other stressors and human dimensions (as humans are catalysts of and respond to global change); (2) conducting assessments of the risks and opportunities presented by global change; and (3) assessing adaptation options to improve society's ability to respond effectively to the risks and opportunities presented by global change as they emerge.

FY 2002 Program Highlights. The program has made a major commitment to the National Assessment activities organized through the USGCRP. The Global Change Research Act of 1990 mandates that the USGCRP conduct periodic assessments of the potential consequences of global change, to be conducted not less than every four years. As part of the first U.S. National Assessment of the Potential Consequences of Climate Variability and Change, EPA helped to successfully produce the Mid-Atlantic and Great Lakes Regional Assessments and Human Health Assessment. The Gulf Coast Regional Assessment is ongoing. All of the EPA-sponsored assessments fed into the Overview and Foundation documents for the first U.S. National Assessment. EPA will continue to make significant contributions to the ongoing U.S. National Assessment process. EPA will continue to sponsor these regional and sectoral assessments through cooperative agreements with universities. The EPA-sponsored assessments will continue to be conducted through public-private partnerships that actively engage researchers from the academic community, decisionmakers, resource managers, and other affected stakeholders in the assessment process.

EPA's intramural assessment program has four areas of emphasis: (1) human health; (2) air quality; (3) water quality; and (4) ecosystem health. These four focus areas are consistent with EPA's mission and the strengths of EPA's research program:

Human Health. Since health is affected by a variety of social, economic, political,

environmental, and technological factors, assessing the health impacts of global change is a complex challenge. As a result, health assessments in EPA's Global Program go beyond basic epidemiological research to develop integrated health assessment frameworks that consider the effects of multiple stresses, their interactions, and human adaptive responses. Along with health sector assessments conducted in conjunction with the USGCRP National Assessment process, there are research and assessment activities focused on the consequences of global change on weather-related morbidity and vector- and water-borne diseases. In addition, the results from the Global Program's air quality assessments will be used to evaluate health consequences.

Ecosystems. The EPA's mission is not only to protect human health but also to safeguard the natural environment. EPA has pledged to provide environmental protection that "contributes to making communities and ecosystems diverse, sustainable, and economically productive." Consistent with this goal, EPA's Global Program has planned three research and assessment activities that evaluate the effects of global change on 1) aquatic ecosystems (which may include lakes, rivers, and streams; wetlands; and estuaries and coastal ecosystems); 2) invasive non-indigenous species; and 3) ecosystem services. EPA's assessments of the effects of global change on aquatic ecosystems will use as input the research being done by other USGCRP agencies on marine and terrestrial ecosystems. Thus, EPA's ability to complete its assessments successfully depends crucially upon the ability of other USGCRP agencies to complete their related research and assessment activities.

Air Quality. Few studies have investigated the effect of global change on air quality. Given EPA's legal mandates with respect to air pollution and substantial capability and expertise in modeling air quality and evaluating integrated response actions, examining the effects of global change on air quality is a logical focus of the Global Program. Assessments are planned that will examine the potential consequences of global change on tropospheric ozone and particulate matter. The air quality assessments will provide input to related human health assessments.

Water Quality. Water quality is affected by changes in runoff following changes in precipitation and evapotranspiration and/or changes in land use. The program plans assessments of the possible impacts of global change (climate and land-use change) on water quality. The water quality assessments will either contribute to or benefit from Human Health and Ecosystems assessments.

Intramural and extramural research contribute to assessments. To capitalize on expertise in the academic community, a significant portion of the program's resources are dedicated to extramural research grants administered through the STAR (Science to Achieve Results) grants program. The STAR program focuses on two principal areas related to global change research—science to support assessments of consequences of global change and human dimensions research. EPA will continue to coordinate closely with other USGCRP agencies that support human dimensions research to identify the specific topics that should be emphasized within the STAR program.

Related Research. In addition to the focused USGCRP activities, EPA conducts research that contributes to the characterization and understanding of risks to ecosystems and to human health. The ecosystem-based research is designed to understand and predict ecosystem exposure, responses, and vulnerabilities to high-risk chemicals and non-chemical stressors (e.g., invasive species, genetically altered organisms) at multiple

scales of biological organization and geographic scales. The research in human health is oriented toward assessing the cumulative health risks to humans (e.g., cancer, reproductive, cardiovascular), including high-risk subpopulations (e.g., children), from chemical stressors emanating from multiple sources. Both of these major research areas will be impacted by and are inextricably interrelated with climate change.

Mapping of Budget Request to Appropriations Legislation. In the Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, EPA USGCRP activities are funded under the EPA section of Title III – Independent Agencies, within the Science and Technology account. Appropriations Committee report language may specify more directly the funding for global change research.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA	Program Title	FY 2000 Enacted	FY 2001 Planned	FY 2002 Request
	Ecological Processes (Terrestrial Ecology)	16.9	16.9	16.9
	Land Cover and Use Change (Ecology and Atmospheric Chemistry)	6.3	6.2	6.3
	Stratospheric Chemistry	18.3	16.9	16.7
	Atmospheric Chemical Modeling	7.1	7.2	7
	Tropospheric Chemistry	8.7	9.4	9
	Radiation Science Program	9.6	10.9	7.9
	Land Surface Hydrology/Water cycle (Water Cycle Processes)	6.3	6.3	6.3
	Atmospheric Dynamics & Remote Sensing	4.9	5.8	5.1
	Physical Oceanography & Ocean Modeling	8.1	8.6	8.5
	Biological Oceanography (Ocean Biogeochemistry)	4.7	4.7	4.7
	Polar Programs	6.3	6.6	5.5
	Global Modeling and Analysis Program (Global Atmos Model & Analysis)	7.2	7.6	7.3
	Global Data Integration & Validation (Global Change Data Analysis)	4	4.1	3.7
	Interdisciplinary Research and Analysis	15.6	18.1	25
	Global Water Cycle	0	5	8
	Global Carbon Cycle	0	5	5
	Global Ocean Research (includes NOPP)	1	3	4
	Aircraft Emissions	0	4	4
	EOS Science	55	48.4	54.3
	GLOBE	5	5	5
	Mission Analysis Program	40.8	47.2	40.6
	Ocean Color Data Purchase/Sea WIFS	2.5	2.7	2.2
	Pathfinder Science Studies	3.7	4.2	0.0
NASA	Global Change Science Program	231.8	253.6	252.9
	Earth System Science Pathfinder	90	111.5	84
	EOS Data and Information Systems (EOS DIS)	278.9	281.4	252.7
	EOS Flight Development (less Tech Inf.)	348.9	335.2	357.9
	EOS Special Spacecraft	121.1	111.2	56.4
	Information Systems	7.6	9.7	13.6
	LANDSAT		10.3	1.4
	1.7			
	Mission Operations	47.6	57.8	52.3
	Total Ozone Mapping Spectrometer (TOMS)	24.5	0.1	0.0
NASA	Global Change Hardware Development	928.9	908.3	818.6
NASA Total	President's Request	1160.7	1161.9	1071.5

Areas of Global Change Research. The mission of NASA's Earth Science Enterprise (ESE) is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. NASA provides the research and technology employed by NOAA and others who provide these predictive services to the Nation. NASA has mapped out a new Research Strategy for the next decade to address the questions:

How is the Earth changing, and what are the consequences for life on Earth?

- How is the global Earth system changing?
- What are the primary causes of change in the Earth system?
- How does the Earth system respond to natural and human-induced changes?
- What are the consequences of change in the Earth system for human civilization?
- How well can we predict future changes in the Earth system?

The five component questions follow a logical scientific progression of variability, forcings, responses, consequences, to prediction. Under each of the five are a set of detailed questions, 23 in all, that reflect thematic research areas that are well-aligned with the USGCRP program elements, as described below. While in the past, NASA's Earth science programs were observation-driven, the Research Strategy is question-driven, and NASA is rebalancing its investment portfolio across observations, research, analysis & modeling, applications demonstration, and advanced technology development in order to answer the selected science questions. NASA will address the USGCRP research program elements, such as Climate Variability and Change, the Global Water Cycle, and the Global Carbon Cycle, in terms of the above questions.

Recent Accomplishments: The past two years have been the most productive in the history of NASA's Earth Science Enterprise, as measured by its contribution of top science discoveries internationally. Major accomplishments include:

- Demonstrated ability for 2-day storm formation prediction with QuikSCAT;
- Observed influence of Arctic polar stratospheric clouds on ozone in SOLVE aircraft campaign;
- Tested a coupled ocean-atmosphere model using observations of the 1997-99 El Niño/La Niña, and began use in prediction experiments;
- Completed a model of Pacific Ocean circulation employing temperature, salinity and velocity data;
- Successfully launched Terra, ACRIMSAT, SRTM, NOAA-L, GOES-L, and EO-1;
- Conducted 3 major international scientific field campaigns (SOLVE, SAFARI, PACRIM)

FY 2002 Program Highlights. Through the end of FY 2002, ESE plans to launch QuikTOMS, Aqua, Jason-1, SAGE III (on Russia's Meteor-3M), GRACE, ICESat, SORCE and SeaWinds (on Japan's ADEOS-2). In addition, NASA will continue implementation of its Research Strategy, consonant with the USGCRP's Long-term Plan. The following describes expected progress by question.

How is the global Earth system changing?

- Combine analysis of global water vapor, precipitation, and wind data sets to decipher variations (and possible trends) in the cycling of water through the atmosphere and their relation to sea surface temperature changes.
- Establish a quantitative relationship between vegetative indices time series derived from the AVHRR and MODIS instruments to ensure long-term continuity and comparability of time series.

What are the primary causes of change in the Earth system?

- Provide the first comprehensive multi-instrument, multi-angle integrated data set for the study of sources and sinks and distribution of tropospheric aerosols over land.
- Characterize the role of land-cover changes associated with natural fires in determining the carbon balance of ecosystems in two major boreal forest areas.

How does the Earth system respond to natural and human-induced changes?

- Near decade-long sea surface topography time series will be assimilated into a high resolution Pacific Ocean model to elucidate the mechanisms of the Pacific Decadal Oscillation and its impact on seasonal to decadal climate variations.
- Map the surface velocities at their outlets of at least 10 major outlet glaciers draining West Antarctica and at least 10 draining East Antarctica.

What are the consequences of change in the Earth system for human civilization?

- Demonstrate impact of assimilation of TRMM rainfall data on forecasting track and intensity of tropical storms by showing improvement in near real-time hurricane and typhoon forecasts in a variety of cases and conditions.
- Increase the coverage of space-based maps of coral reef distribution by 25 percent beyond current estimates by using remote-sensing imagery.

How well can we predict future changes in the Earth system?

- Document in peer-reviewed literature the quantified impact of satellite altimeter observations on improving 12-month El Niño forecasts with a state-of-the-art coupled ocean-atmosphere model.

Scientific Research: The priorities embodied in NASA's ESE Research Strategy for 2000-2010 reflect the national priorities identified by the National Research Council in several recent reports, including Global Environmental Change: Research Pathways for the Next Decade and Atmospheric Science in the 21st Century. ESE manages its research along thematic areas that map readily to USGCRP research program elements as follows.

USGCRP Program Element

Climate Variability and Change
Atmospheric Composition
Global Water Cycle
Changes in Ecosystems / Global
Carbon Cycle

ESE Research Theme

Oceans and Ice in the Earth System
Atmospheric Chemistry, Aerosols, and Solar Radiation
Global Water and Energy Cycle
Biology and Biogeochemistry of Ecosystems and the
Global Carbon Cycle

NASA's Earth Science Enterprise has rebalanced its portfolio of investment among research, observing and information systems, and other areas to increase the percentage of investment in sponsored research from 17 percent in 1998 to a target of 25 percent. This change reflects two recent developments. First is the movement from a "data poor" to a "data rich" environment with the deployment of EOS. Second is a strategic shift from being principally a supplier of observations to an emphasis on answering the science questions posed in the Research Strategy.

Space and Suborbital Observations & Information: NASA remains the principal supplier of global to regional-scale observations for global change research, both through research satellites and the operational weather satellites built and launched by NASA for NOAA. Deployment of the Earth Observing System is well underway, with LANDSAT 7, QuikSCAT, Terra, and ACRIMsat already in orbit and providing science data. Terra, Aqua (late 2001/early 2002) and Aura (2003) are the larger, multi-instrument EOS missions, and are accompanied by a series of smaller missions such as ICESat (ice sheet topography), Jason (ocean topography), and SORCE (solar irradiance). Complementing EOS' long-term monitoring for the study of variability and trends are a series of small, focused Earth Explorer missions to study forcings and responses in the Earth system. These include the Earth System Science Pathfinder missions such as VCL (vegetation canopy), GRACE (Earth's geoid), PICASSO (3-D aerosol profiles) and Cloudsat (3-D cloud profiles). Satellite data are compared with data from a variety of aircraft and balloon-borne instruments for both remote sensing and in situ measurements. Major scientific field campaigns using these suborbital platforms study Arctic ozone depletion, regional and cross-regional aerosol transport, and hurricane formation. The EOS Data and Information System (EOSDIS) is 90 percent complete and is processing and distributing data products from the current EOS satellites. In FY 2000, EOSDIS provided more than 8 million data products in response to 1.5 million user requests. EOSDIS processes more data from Terra in a single day than the Hubble Space Telescope generates in a year. NASA has begun planning for the evolution of data and information system services to support Earth science over the next decade.

Related Research: Outside the scope of the USGCRP, NASA's Earth Science Enterprise also conducts research and observing missions to study the solid Earth and related natural hazards. ESE also manages an applications demonstration program in partnership with State and local governments, academia, and industry to test new uses of remote-sensing data to solve practical societal problems in food and fiber production, infrastructure planning, flood hazard assessment, and other areas.

Mapping of Budget Request to Appropriations Legislation. In the Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, National Aeronautics and Space Administration USGCRP activities are funded under the NASA section of Title III-Independent Agencies, as part of the Science, Aeronautics, and Technology account. Within this account, Appropriations Committee reports specify funding for the Earth Science program.

ties necessary for fundamental research on global change, and promote the enhancement of models designed to improve our understanding of Earth system processes and interactions and to develop advanced analytic methods to facilitate basic research. NSF also supports fundamental research on the general processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of varying environmental conditions.

FY 2002 Program Highlights. During FY2002, NSF will support research and related activities addressing all six of the USGCRP program elements and the interdisciplinary science aspects that link them. As in preceding years, NSF will continue to invest in collaborative international programs such as the World Climate Research Programme, the International Geosphere-Biosphere Programme, and the International Human Dimensions Programme.

A major focus on atmospheric composition and chemistry will continue through programs in tropospheric chemistry. Studies of atmospheric transport of aerosols will provide insights into how aerosols affect the radiative and cloud nucleating properties of the atmosphere, and ultimately the climate.

In concert with its agency partners, NSF will continue its emphasis on climate variability and change. This is a major activity for the Agency and consists of support for observational campaigns and numerous analytical and modeling activities, as well as paleoclimate studies. A number of ocean and atmospheric science projects will address topics identified in the CLIVAR implementation plans. Ocean science studies will address superannual changes in ocean structure, ocean circulation and ocean-atmosphere coupling to improve the present, relatively poor, understanding of the role of the ocean in climate, and should lead to the development of better climate models. In addition, improved coupled atmosphere/ocean models will incorporate parameterizations of land-surface processes and biogeochemistry. Continued support of the second generation community climate model will provide opportunities for U.S. climate scientists to understand better the climate and its variability.

NSF is increasing its support for studies of the carbon cycle. In FY 2002 NSF will take the first steps to implement a globally integrated carbon cycle research portfolio to encourage cooperative research among atmospheric, marine, geological, and ecological scientists to understand the key processes underlying carbon cycling. As an element of the effort, ocean sciences will support the JGOFS Synthesis and Modeling Project and SOFEX, a complex mesoscale fertilization experiment in the Southern Ocean, and continue several CO₂ observational time-series activities (Hawaii and Bermuda ocean stations, and atmospheric CO₂ and O₂ observational programs).

Water pervades nearly all environmental issues and clearly requires a comprehensive approach. NSF is one of the several agencies supporting global water cycle research and will focus on key aspects with its available resources. NSF programs will emphasize the development of hydrologic and atmospheric models to simulate the water cycle and to understand the processes that control it.

Several programs will address aspects of land-use and land-cover change as important aspects of global change. Ecological rates of change and related species diversity, Arctic systems and their temporal variability, water and energy influences on vegetative systems, and diverse human influences exemplify program components related to land

use and land cover.

Several NSF programs will focus on terrestrial and marine ecosystems through observational and laboratory studies. NSF will continue to support the collection of terrestrial and marine ecosystem data through its Long-Term Ecological Research programs. In addition, studies will continue in terrestrial ecosystem functions and landscape ecology. The Global Ocean Ecosystem Dynamics program will continue to study the impact of the global ocean environment on marine ecosystems. In FY 2002 experimental research will focus on the Northwest Atlantic, Northwest Pacific, and Southern Ocean.

Related Research. In addition to the research focused on global change, NSF will continue to support research on broader topics that are closely related to global change. These include, *inter alia*, studies of the atmosphere, ocean, land surface, ecosystems, and human dimensions that add substantively to the specific programs supporting USGCRP objectives. Thus, much NSF research support may be considered “contributing research.”

Mapping of Budget Request to Appropriations Legislation. In the Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, NSF USGCRP activities are funded under the NSF section of Title III – Independent Agencies within the NSF Research and Related Expenses account.



Smithsonian Institution

SI	Program Title	FY00	FY01	FY02 Request
NMNH/STRI	Long-Term Environmental Change	1.6	1.6	1.6
SAO/NASM/SERC	Monitoring Natural Environmental Change	1.2	1.2	1.2
NZP/NMNH/SERC	Biological Responses	4.2	4.2	4.2
Smithsonian Total		7.0	7.0	
President's Request				7.0

- 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

Areas of Global Change Research. Within the Smithsonian Institution, global change research is conducted at the Smithsonian Astrophysical Observatory, the National Air and Space Museum, the Smithsonian Environmental Research Center, National Museum of Natural History, Smithsonian Tropical Research Institute and National Zoological Park. Research is organized around themes of atmospheric processes, ecosystem dynamics, observing natural and anthropogenic environmental change on daily to decadal time scales, and defining longer-term climate proxies present in the historical artifacts and records of the museums as well as in the geologic record at field sites. The Smithsonian Institution program strives to improve knowledge of the natural processes involved in global climate change, provide a long-term repository of climate-relevant research materials for present and future studies, and to bring this knowledge to various audiences, ranging from scholarly to lay public. The unique contribution of the Smithsonian Institution is a long-term perspective, e.g., undertaking investigations that may require extended study before producing useful results and conducting observations on sufficiently long (e.g., decadal) timescales to resolve human-caused modification of natural variability.

FY 2002 Program Highlights.

Atmospheric Composition: Researchers at SAO will study stratospheric trace species that play an important role in ozone photochemical cycles using balloons, airplanes, and satellites. Solar activity and irradiance are being studied to understand better the climatic effects of solar variability. At SERC, measurements will be made of spectral UV-B in Maryland (>25-year record), Florida, Arizona, and other sites in the United States. These data will be disseminated electronically to meet the needs for assessing

the biological and chemical impact of varying UV exposure.

Climate Variability and Change: Ongoing global sea-level change is being estimated by SAO using space geodetic measurements. Research at NASM emphasizes the use of remote-sensing data to improve theories of drought, sand mobility, soil stability, and climate change in the eastern Sahara. Studies at NMNH and STRI focus on the paleoecology of climate change.

Changes in Ecosystems: Several SI programs will examine biological responses to global change. At SERC, research will be conducted on the responses of global ecosystems to increasing CO₂ (also a contribution to the **Global Carbon Cycle** program), exotic species introductions, and solar UV. At STRI, research will be conducted on the effects of climate change (including CO₂ increase) on tropical ecosystems. Biodiversity education and research will be performed at STRI, NMNH and NZP. Tropical biodiversity research programs monitor global change effects through repeated sampling of flora and fauna in tropical forests, and identifying the physical and biological processes of growth and decline of species. Other studies on ecosystem response to increasing habitat fragmentation will be conducted at NZP.

Human Dimensions of Global Change: The general public and research community will be informed of global change research conducted by the Smithsonian and other USGCRP agencies via exhibits, such as the planned “Forces of Change: Global Links” display at NMNH, educational programs, and a global change information Web page.

Related Research. Many global change research projects at the Smithsonian are supported by other private and public sources. These projects are nonetheless organized around the USGCRP program elements and thus amplify the scope and impact of research supported by direct Federal appropriation. Other contributing activities include research conducted by several units within the Smithsonian in a variety of habitats concerning natural and human-induced variations in species, populations-communities, and ecosystems. These studies help clarify the relative importance of global change effects as one of several agents of ecological change. Studies of environmental change over long time periods are aided by the Institution’s collections. Utilized by researchers around the world, these materials provide raw data for evaluating changes in the physical and biological environment that occurred before human influences.

Mapping of Budget Request to Appropriations Legislation. In the Interior and Related Agencies Appropriations Bill, Smithsonian Institution USGCRP activities are funded in the SI section of Title II—Related Agencies, within the Salaries and Expenses account. Appropriations Committee reports specify funding for a Sciences line item component of this account, which includes USGCRP programs.

APPENDIX B: ADDITIONAL INFORMATION ON FIGURES

Figure 1. Ocean Warming Since the 1950s

Decadal values of anomalous heat content (10^{22} J) in various ocean basins. The heavy dashed line is from observations, and the solid line is the average from five realizations of the Parallel Climate Model (PCM) forced by observed and estimated anthropogenic forcing. (The PCM was developed primarily by the National Center for Atmospheric Research, with the ocean and sea-ice components contributed by the DOE Los Alamos National Laboratory.) Both curves show significant warming in all basins since the 1950s. The shaded bands denote one (heavy shading) and two (light shading) standard deviations about the model mean signal estimated from the standard deviation in the scatter of the five-member ensemble. The heat content is computed over the upper 3000 m of the water column. The space/time sampling was identical for both model and observations. Basin averages for the northern oceans are defined between 60°N and the equator. The southern ocean averages are between the equator and 77°S.

Large-scale increases in the heat content of the world's oceans have been observed to occur over the last 45 years. The horizontal and temporal character of these changes has been closely replicated by the state-of-the-art PCM forced by observed and estimated anthropogenic greenhouse gases and aerosols. Application of optimal detection methodology shows that the model-produced signals are indistinguishable from the observations at the 0.05 confidence level. Further, the chances of either the anthropogenic or observed signals being produced by the PCM as a result of natural, internal forcing alone are less than 5%. This suggests that the observed ocean heat-content changes are consistent with those expected from anthropogenic forcing, which broadens the basis for claims that an anthropogenic signal has been detected in the global climate system. Additionally, the requirement that modeled ocean heat uptakes match observations puts a strong, new constraint on anthropogenically forced climate models. It is unknown if the current generation of climate models, other than the PCM, meet this constraint.

Tim P. Barnett*, David W. Pierce, Reiner Schnur, "Detection of Anthropogenic Climate Change in the World's Oceans," *Science*, 292 (5515): 270, 13 April 2001.

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Figure 2. Observed Effects of Climate Variability on Salmon

Abundances of many salmon stocks have closely tracked interdecadal climate variation since 1940. Upper Columbia bright spring Chinook are abundant when the Pacific Northwest Index (one measure of decadal climate variation) is negative. Both curves are 5-year moving averages.

Northwest salmon stocks have been highly stressed for decades by intense fishing pressure and threats to their stream habitats. Salmon are sensitive to various climate-related conditions, both inshore and offshore, at various times of their life cycle. Although the relative contributions of and interactions between climate and non-climate factors, and inshore and offshore conditions, are highly uncertain, salmon stocks throughout the North Pacific show a strong association with the Pacific Decadal Oscillation. Salmon in the Northwest are more abundant in the cool PDO phase, while Alaska salmon show the opposite pattern. The mechanisms for this observed climate effect on stocks are poorly known, and probably include some effects of both freshwater and marine changes.

National Assessment Synthesis Team, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, Overview report, p. 70, and Foundation report, pp. 262-263.

Figure 3. Large-Scale Atmospheric Pollution in Southeast Asia During the Last El Niño Event

The Total Ozone Mapping Spectrometer (TOMS) shows a heavily polluted air mass covering much of Southeast Asia during the last El Niño event (October 1997), an illustration of how short-term

variations in climate and changes in land-use practices can lead to unhealthy levels of large-scale pollution. The color scale represents the integrated column abundance of ozone in the lower-most region of the atmosphere (the troposphere) in Dobson units. The scale runs from blue, representing about 20 Dobson units or less, to red, representing about 70 Dobson units. Column abundances of 30 Dobson units and greater indicate polluted regions, with ozone concentrations in some layers of the atmosphere as high as 100 parts per billion. The grey scale represents the aerosol index, a relative scale of aerosol abundance that indicates the location of high levels of smoke from the fires. The data show that the smoke and ozone, both products of the biomass burning, moved in different ways through the atmosphere. The fires and smoke were doused by rainfall at the end of 1997, but higher than normal ozone lasted another seven months.

This research, sponsored by NASA's Earth Science Enterprise, may soon help scientists do a better job of tracking pollution plumes around the world and help provide more advance warning of unhealthy air. Since 1996, with the launch of the TOMS Earth Probe satellite, scientists have been able to measure tropical smoke aerosols and tropospheric ozone, major components of air pollution and hazardous to health, on a daily basis. During the 1997 El Niño event, when Indonesian fires caused unhealthy air throughout the Southeast Asia region, TOMS was able to observe pollution spreading out from Kalimantan in southern Borneo (Indonesia). This image clearly demonstrates that air pollution is more than a local problem. Pollution from both biomass burning and industrial activity can travel great distances and affect regions far from the source.

TOMS was designed to monitor the health of the stratospheric ozone layer, which protects life on Earth from exposure to higher levels of ultraviolet radiation. The ability of TOMS to measure tropospheric ozone, a source of pollution, is an outgrowth of the increased precision of TOMS observations over time, coupled with increased knowledge of atmospheric composition and its variability.

For a more detailed account of this research, See A.M. Thompson, et al., "Tropical Tropospheric Ozone and Biomass Burning," *Science*, 16 March 2001, p. 2128.

Source: NASA

Figure 4. Plant Life on Earth as Observed From Space

False-color image of plant life on Earth as observed from space with the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). On land, greens indicate abundant vegetation, and tans show relatively sparse plant cover. In the oceans, blue areas are the least biologically productive, whereas green, yellow, and red areas represent progressively greater productivity. Since September 1997, SeaWiFS has measured light absorption by land plants and phytoplankton chlorophyll biomass in the oceans, providing a basis for quantifying biospheric photosynthesis.

Phytoplankton process carbon in the upper ocean, transforming it from dissolved form to particulate, and are therefore essential components of the ocean carbon cycle. Without phytoplankton living in the ocean's surface layer, atmospheric carbon dioxide levels would be many times higher than they are today.

SeaWiFS image from the cover of *Science*, 30 March 2001. *Science OnLine* subscribers see: <http://www.sciencemag.org/content/vol291/issue5513/cover.shtml>.

Source: SeaWiFS Project, NASA Goddard Space Flight Center, and ORBIMAGE

Figure 5. Modeling Clouds

Predicted vs. observed time-height (surface to 16 km above the surface) cloud fraction at the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains site from 19 June to 17 July 1997. Top panel: Shows the cloud fraction observed by cloud radar (3-hour averages). Center panel: cloud fraction predicted by UCLA-CSU cloud resolving model (1-hour averages). Bottom panel: cloud fraction predicted by National Centers for Environmental Prediction (NCEP) single column model (3-hour averages). Color indicates cloud fraction, which ranges from 0 (violet) to 1 (red).

ARM focuses on acquiring the data for understanding the role of clouds in climate and on seeing this understanding reflected in the improvement of the appropriate components of General Circulation Models (GCMs). The ARM data provide the testbed data sets for the process models representing the cloud-climate feedbacks in the currently available GCMs as well as in the future

climate-change-prediction models of regional-scale resolution. Developing the capability to account for cloud water distribution determined from observations at ARM sites will lead to improved cloud parameterization in climate simulation models and will support efforts to predict precipitation.

Source: DOE Atmospheric Radiation Measurement Program

Figure 6. Trends in Annual Greenness 1989 – 2000

Changes in annual greenness during the period 1989-2000 as measured by the normalized difference vegetation index (NDVI) derived from the advanced very high resolution radiometer (AVHRR) satellite sensor. NDVI values for each year are integrated over the growing season to produce the seasonal integrated NDVI (annual greenness). The number of runs statistical test is then run for each pixel to identify those areas that show an increasing or decreasing trend that is stronger than would be expected by random chance.

Source: U.S. Geological Survey

Figure 7. Land Use and Land Cover Change in the Chicago Metropolitan Region between 1972 and 1997.

Land cover maps of the Chicago Metropolitan Region document changes in several categories of land cover and land use during a 25-year period using LANDSAT imagery from 1972, 1985, and 1997. This data set was developed as part of a NASA-funded project entitled “Tracking Natural Community Fragmentation and Changes in Land Use and Land Cover: A Case Study of *Chicago Wilderness* with Dr. Yeqiao Wang and Dr. Debra Moskovits serving as the Principal Investigators. Chicago Wilderness is an alliance of more than 90 organizations, including local, state, and Federal agencies, research and nongovernmental institutions, and landowners in the Greater Chicago area. It is also a regional nature reserve of 81,000 hectares extending in a crescent around Lake Michigan, from southeastern Wisconsin, through Illinois, into northwestern Indiana. Its goal is to maintain existing natural areas and restore others in a network of protected lands and waters connected by greenways and wildlife corridors.

This study reveals that dramatic increases in urban land dominate the land-cover changes in the past twenty-five years. Between 1972 and 1985, urban land increased by 14.5 percent. The rate of urban and suburban expansion accelerated to increase by nearly 30 percent between 1985 and 1997. Between 1972 and 1997, the total area of developed land increased by 49 percent. Most of the suburban land expansion came at the expense of agricultural lands, with a total decrease of 37 percent over the 25 years. In addition, more than one-fifth of natural area (21 percent), including forest, woodland, prairie, and wetland, was converted to urban use during that period. Urban sprawl results not only in wholesale loss of natural lands, but also in extreme fragmentation and isolation of the remaining natural areas within the suburban matrix. Another significant change in land cover is the increase in unassociated vegetation over time. Unassociated vegetation includes a mixture of shrubs, trees, and abandoned agricultural fields. This increase reflects the degradation of natural lands in the absence of appropriate management and ecological restoration.

Through a series of pilot projects demonstrating the utility of NASA imagery for conservation biology, NASA has supported efforts by Chicago Wilderness to use remote sensing, particularly with imagery from the LANDSAT spacecraft, to complete a current vegetation map of the area in the reserve and examine changes in land use and land cover. This figure depicts changes in land cover during that time period. The information is a vital tool for use by those developing a Biodiversity Recovery Plan for the region.

Source: NASA and Y.Q. Wang, University of Rhode Island. The data set was developed as part of a NASA-funded project, *Tracking Natural Community Fragmentation and Changes in Land Use and Land Cover; A Case Study of Chicago Wilderness*, with Dr. Wang serving as a Principal Investigator.

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Abstract

Our Changing Planet: The FY 2002 Global Change Research Program is a report to Congress supplementing the President's FY 2002 budget, pursuant to the Global Change Research Act of 1990. The report describes the U.S. Global Change Research Program (USGCRP); summarizes scientific insights from global change research, discusses the six Research Program Elements and FY 2002 plans in each of these research areas; and includes an appendix that details the FY 2002 budget, including program components and program highlights for each of the departments and agencies that comprise the USGCRP. Achieving the goals of this program will require continued strong support for the scientific research needed to improve understanding of how human activities are affecting the global environment, and of how natural and human-induced global change is affecting society and ecosystems.

Back Cover: Greenland Ice Sheet: High-Elevation Balance and Peripheral Thinning

See image located at: <http://visibleearth.nasa.gov/cgi-bin/viewrecord?2172>

Aircraft laser-altimeter surveys over northern Greenland in 1994 and 1999 have been coupled with previously reported data from southern Greenland to analyze the recent mass-balance of the Greenland Ice Sheet. Above 2,000 meters elevation, the ice sheet is in balance on average but has some regions of local thickening or thinning. Thinning predominates at lower elevations, with rates exceeding one meter per year close to the coast. Analysis of the data indicates a net loss of about 51 cubic kilometers of ice per year from the entire ice sheet, sufficient to raise sea level by 0.13 millimeter per year—approximately 7 percent of the observed rise.

This amount of sea level rise does not threaten coastal regions, but these results provide evidence that the margins of the ice sheet are in a process of change. The thinning cannot be accounted for by increased melting alone. It appears that a change in ice dynamics is the most likely cause. Increased creep rates in the lower reaches of the glaciers, and therefore increased discharge velocities, would cause the ice to thin. There is no direct evidence for such changes in dynamics, nor is it understood why they would apply to many glaciers in different parts of Greenland.

Source: W. Krabill*, et al., "Greenland Ice Sheet: High-Elevation Balance and Peripheral Thinning," *Science*, 289 (5478): 428, 21 July 2000. *Laboratory for Hydrospheric Processes, NASA Goddard Space Flight Center

For further information on the Greenland mapping project, including the technology behind the science, visit the Airborne Topographic Mapper (<http://aol.wff.nasa.gov/aoltm.html>) site.

Image credit: NASA Goddard Space Flight Center Scientific Visualization Studio

The U.S. Global Change Research Program

