

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.

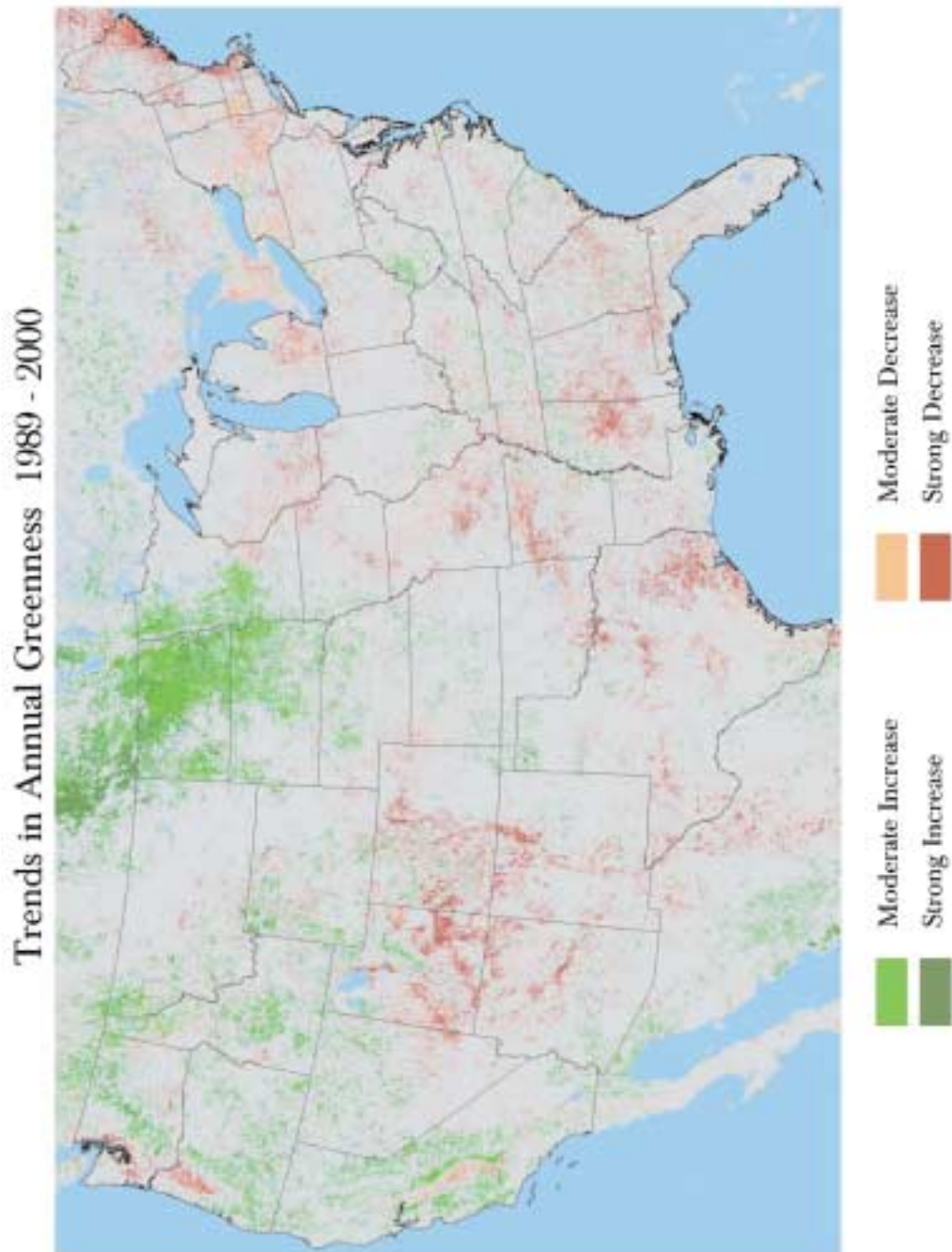


Figure 6. Trends in Annual Greenness 1989 - 2000

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,

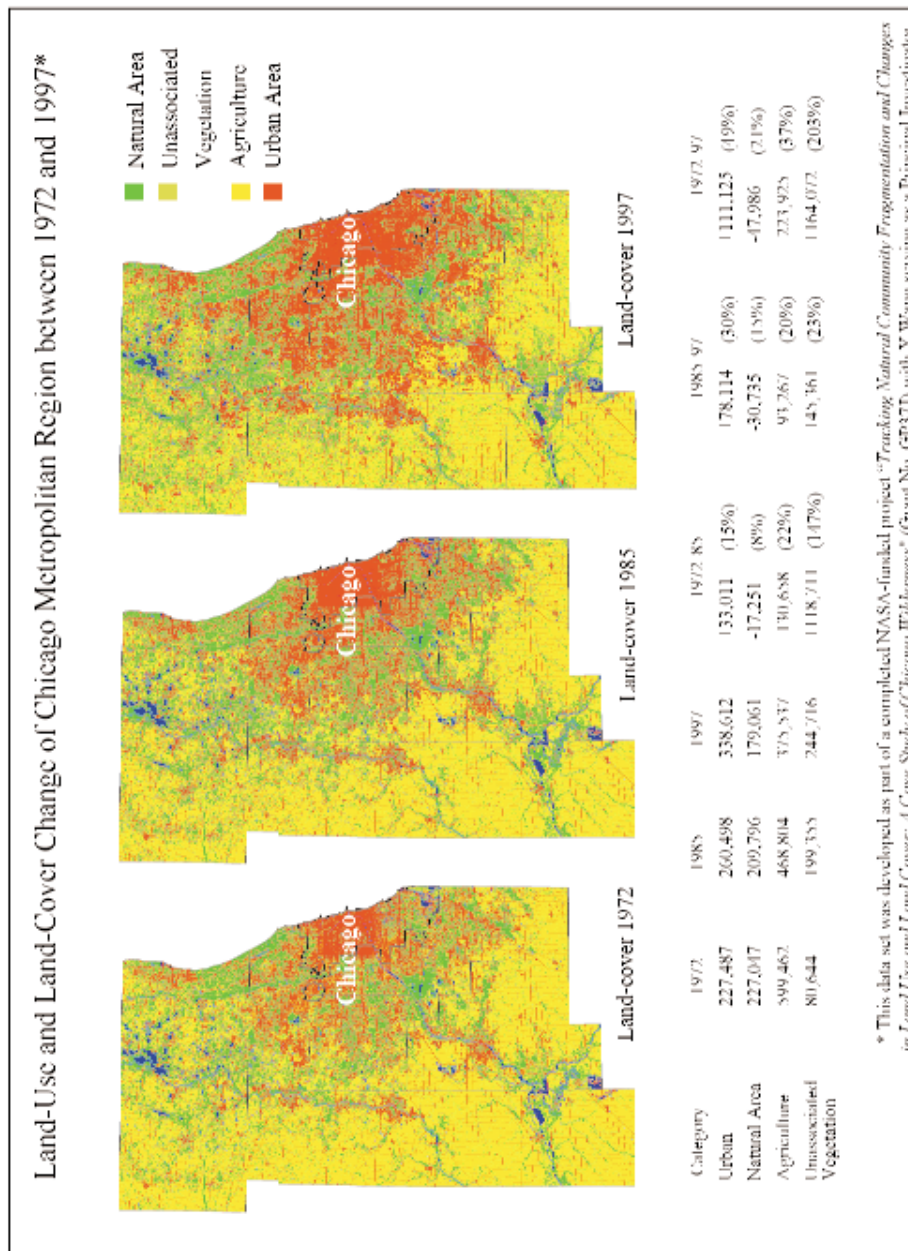


Figure 7. Land-Use and Land-Cover Change in the Chicago Metropolitan Region, 1972-1997

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.