wetlands into the near-shore bay environments through support of integrated research projects on coastal ecosystems—focusing on three new land-coastal margin Long-Term Ecological Research sites added to the network in FY 2000. These long-term collaborative research projects will integrate research on hydrology, biogeochemistry, and ecology.
- Improving the capability to predict changes in the hydrological cycle and water resources on seasonal timescales through initiation of the America Prediction Project as part of the Global Energy and Water Cycle Experiment (GEWEX). This project will place greater emphasis on prediction than has been the case with earlier diagnostics-oriented research. It will cover all of the United States, with a special emphasis on land-atmosphere interactions in the West—including the role of land in monsoonal circulations and the role of mountains in the hydrologic cycle.

The Global Carbon Cycle

The USGCRPbudget includes $229 million in FY 2001 to continue the Carbon Cycle Science Initiative that began in FY 2000 (see Table 6). This ongoing effort will provide critical scientific information on the fate of carbon dioxide emitted to the atmosphere, sources and sinks of carbon on continental and regional scales, and how sinks might change naturally over time or be modified by agricultural or forestry practices. USDA, DOE, DOI/USGS, NASA, NSF, DOC/NOAA, and the Smithsonian Institution will all play important roles in this effort, guided by a science plan that has been drafted with participation by many of the leading scientists in this field.

The Carbon Cycle Science Initiative will employ a wide variety of research activities in a comprehensive examination of the integrated global carbon cycle, with an initial emphasis on North America. Comparison of North America with other regions also will be important for understanding the relative importance of our region in the global context. Atmospheric and oceanographic field sampling campaigns over the continent and adjacent ocean basins will be combined with atmospheric transport models to develop more robust estimates of the continental distribution and subcontinental-scale magnitude of North American carbon sinks. Local-scale experiments conducted in various regions will contribute to the understanding of mechanisms involved in the operation of carbon sinks on land and in the ocean, the quantities of carbon assimilated by ecosystems, and how these quantities might change in the future.

The initiative also will include evaluation of information from past and current land-use changes—from remotely sensed and historical records—to assess how human activity has affected carbon storage on land. Potential management strategies for maximizing carbon storage will be studied, including evaluation of the variability, sustainability, lifetime, and related uncertainties of different managed sequestration approaches. Finally, enhanced long-term monitoring of the atmosphere, ocean, forests, agricultural lands, and rangelands, using improved inventory techniques and new remote-sensing capabilities, will be initiated to determine long-term changes in carbon stocks. Integration of new observations and understanding of carbon cycle processes into regional and global carbon system models will enable us to project more accurately future atmospheric concentrations of carbon dioxide and other greenhouse gases. The ultimate goal of the carbon cycle science program is to answer the following fundamental questions:
- What has happened to carbon that has already been emitted by human activities?
- What will be the future atmospheric carbon dioxide concentration resulting from past and future emissions?
- How do land management, land use, and other factors affect carbon sources and sinks over time?
- How will future environmental changes and human actions affect atmospheric concentrations of carbon-containing greenhouse gases?

Recent Accomplishments

- Net carbon uptake by terrestrial ecosystems was determined from the AmeriFlux Network, which produces unique measurements of the net annual exchange of CO_2 between the atmosphere and terrestrial ecosystems. Data from 12 locations show that net carbon uptake is greater in warmer zones along the north-to-south climatic gradient from Canada to the southeastern United States. These observations are at variance with the conventional wisdom that more carbon accumulates at higher latitudes under colder temperatures. Scientists consider these carbon gains by the terrestrial biosphere significant.
- Three ecosystem models simulating the impact of increasing CO_2 and climate on net carbon storage in U.S. terrestrial ecosystems—and agreeing within 25 percent—have yielded estimates of a land carbon sink that corresponds to about one-third of the estimated total carbon sink, based on inventory data. These model results suggest that other processes, such as regrowth on abandoned agricultural land or harvested forest lands, have larger effects on carbon storage and highlight the need for data on land-use history and more integrated modeling approaches. The model results also show evidence of significant year-to-year variability in carbon storage; variations of 100 percent from year to year are attributable to climate variability.
- USGCRPagencies successfully implemented projects in Iowa and Montana to encourage changes in land management that should lead to increased carbon storage.
- Long-term field experiments in which CO_2, water, and nutrients have been manipulated are producing unique data on ecosystem response to these global change variables. Results include increased vegetation growth, changes in water use, and increased carbon gain by several woody and herbaceous ecosystems. The observed decline in nitrogen content in plant tissues has implications for the quality of forage for animals that might graze in these systems, however.
- A comprehensive synthesis effort is providing an inventory of carbon storage in the world's oceans that is based on observations. Previous estimates of the ocean sink had relied solely on model simulations. For example, the synthesis has revealed that more than 20 billion metric tons of excess atmospheric CO_2 are stored in the Indian Ocean. This effort represents an order of magnitude increase in the quantity and quality of carbon data obtained for the ocean as a result of improved analytical techniques and standards.

Table 6

The Global Carbon Cycle

FY 2001 Budget by Agency
(discretionary budget authority in $millions)

USDA		37.2
DOC/NOAA	Scientific Research	4.6
DOC/NOAA	Surface-Based Observations	5.3
DOE		15.6
DOI/USGS		3.5
NASA	Scientific Research	45.0
NASA	Space-Based Observations	104.6
NSF		13.1
Smithsonian Institution		0.3
TOTAL		**229.2**

FY 2001 Plans

The highest priorities for FY2001 will continue to be understanding and quantifying North American carbon sources and sinks and filling critical gaps in our understanding of the causes of carbon sinks on land as well as processes controlling the uptake and storage of carbon in the ocean. Research advances on these issues will provide information needed as a basis for sound policymaking, as well as valuable information about potential management strategies to land and forest managers in the public and private sectors. Goals include:

- Achieving more comprehensive CO_2-exchange data from key biotic and climatic zones across the United States by adding measurements at new and existing sites in the AmeriFlux research network. Selection of additional sites will be based on competitively reviewed recommendations from the scientific community.
- Reducing uncertainty about carbon gains and losses by the terrestrial biosphere by obtaining additional data on ecosystem processes that control the exchange of CO_2 with the atmosphere. This will include simultaneous measurements of atmospheric CO_2 changes, use of isotopic methods, and other approaches. These studies will be an important component of investigations of the North American terrestrial carbon sink.

The USGCRPalso will improve observational capabilities and develop new techniques to measure carbon stored in forests, soils, and agricultural lands. New satellites will obtain systematic global coverage of the pattern of aboveground vegetation and its photosynthetic carbon uptake. Goals include:

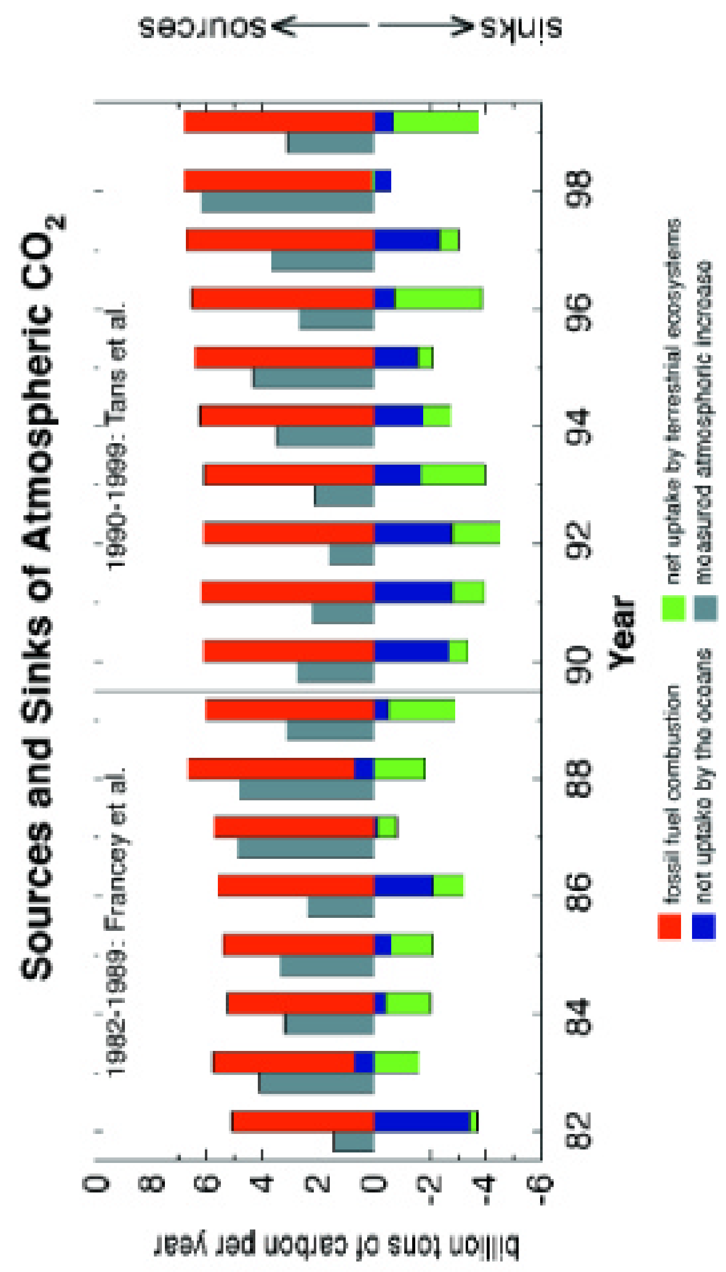

Figure 4. Partitioning of Fossil-Fuel-Derived Carbon

(See page 40 for additional information)

- Generating the first quantitative, geo-referenced, spatially comprehensive estimates of global terrestrial net primary productivity using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's EOS-Terra satellite.
- Producing a quantitative assessment of which approaches for measuring carbon work best for a given scale. The USGCRP will acquire, compare, and integrate measurements at local, regional, and global scales, and reconcile differences among measurements and modeling approaches.
- Reducing the uncertainty of estimates of exchange of CO_2 between the ocean and the atmosphere in the North Atlantic and Pacific to less than a factor of two. This improved understanding of the role of the ocean in the carbon cycle will help to constrain estimates of the Northern Hemisphere terrestrial sink.

Understanding Changes in Ecosystems

The USGCRPbudget includes $224 million in FY 2001 for the study of changes in managed and unmanaged ecosystems (see Table 7). The biosphere consists of diverse ecosystems that vary widely in complexity and productivity, in the extent to which they are managed, and in their economic value to society. Ecosystems directly provide forage, timber, fish, food, and fiber, as well as other services such as water cycling, climate regulation, recreational opportunities, and wildlife habitat. Ecosystems respond to and contribute to global change.

On one hand, changes in temperature and precipitation may alter the ranges of plant and animal species. The rates of change projected over the next century are faster than any that have occurred in the past 10,000 years; therefore, the character and diversity of ecosystems could undergo substantial change if their constituent species cannot adapt. Ecosystems also contribute to global change, however, by playing a role in modifying the atmosphere—and hence the climate system. Terrestrial and marine ecosystems play a role in carbon storage and the release of carbon to the atmosphere; they also are sources and sinks of other greenhouse gases, including methane and nitrous oxide. In addition, vegetation and soils influence climate by affecting the amount of radiation reflected or absorbed, the evapotranspiration of water, and other feedbacks to temperature, precipitation, and weather systems.

Management of ecosystems and natural resources will be an important aspect of society's response to global change. Ecosystems have the capacity to respond to stress; when that capacity is exceeded, however, natural resources and services are altered and begin to decline. Our ability to achieve a sustainable future depends on the protection of public lands and other lands, sustainable use of terrestrial and aquatic renewable resources, and more efficient use of nonrenewable resources. Better scientific understanding of the processes that regulate ecosystems and the capability to predict ecosystem changes and evaluate the potential consequences of management strategies will improve our ability to manage for sustainability.

Recent Accomplishments

- Research has documented significant changes in the growth and development of Ponderosa and Jeffrey pine in response to elevated ozone exposure and elevated nitrogen deposition. Above-ground biomass increases, while root biomass decreases with exposure to ozone and nitrogen, raising important questions about predisposing trees to drought-induced mortality and other stressors. The interaction of ozone and nitrogen pollution has significant implications for the storage of carbon in soils, forest-floor litter, and woody biomass.
- A new assessment of fire risk from climate change uses results from Mapped Atmospheric-Plant-Soil System (MAPSS) vegetation distribution model simulations for seven future climate scenarios. The dynamic simulations indicate that climate change could lead to increased fire frequency over much of the western United States and, under scenarios that project the greatest warming, over many eastern U.S. forests.
- Research results suggest that increasing atmospheric CO_2 levels could stimulate the growth of rangeland plant species because of the direct CO_2 fertilization effect and indirectly by reducing water stress by virtue of increased water-use efficiency of plants at elevated CO_2 levels. In rangelands where undesirable species such as mesquite occur or are introduced, however, elevated CO_2 also could cause a deleterious effect on rangeland plant species composition by increasing the growth and establishment of such species.

Table 7
Understanding Changes in Ecosystems

FY 2001 Budget by Agency
(discretionary budget authority in $millions)

USDA		29.2
DOE		10.8
DOI/USGS		13.9
EPA		3.0
NASA	Scientific Research	32.0
NASA	Space-Based Observations	101.9
NSF		29.0
Smithsonian Institution		3.8
TOTAL		**223.6**