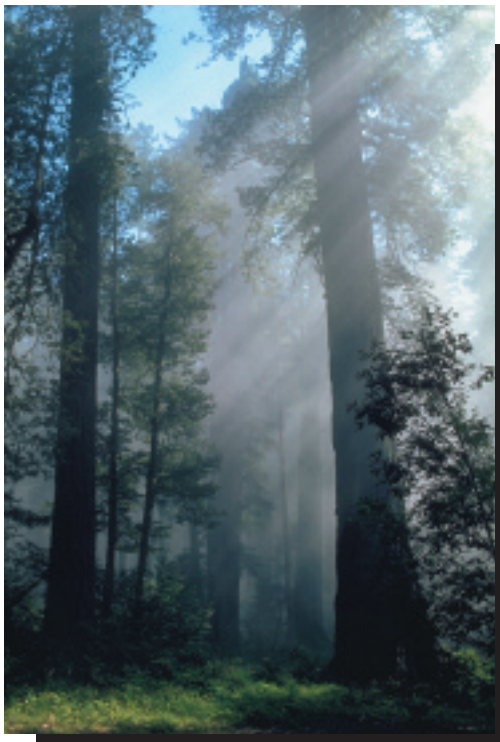
CHAPTER 15

International Research and Cooperation



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Goals for International Cooperation in Climate Science

Climate varies over a wide range of geographic scales that transcend national boundaries. Climate change and its impacts are therefore intrinsically international in scope. To study climate change and variability on appropriate scales thus requires international cooperation—cooperation among scientists and research institutions and governmental agencies. U.S. scientists, institutions, and agencies are at the forefront of such international cooperation, reflecting the leadership role of U.S. climate science. The United States, at the governmental level, similarly leads in efforts to develop and maintain an intergovernmental framework within which climate change science, including research and observational programs, can be planned and implemented.

The overarching goals of U.S. efforts to promote international cooperation in support of the U.S. Climate Change Science Program (CCSP) are therefore to:

- Actively promote and encourage cooperation between U.S. scientists and scientific institutions and agencies and their counterparts around the globe so that they can aggregate the scientific and financial resources necessary to undertake research on change at all relevant scales, including both the regional and global.
- Expand observing systems in order to provide global observational coverage of change in the atmosphere and oceans and on land, especially as needed to underpin the research effort.
- Ensure that the data collected are of the highest quality possible and suitable for both research and forecasting, and that these data are exchanged and archived on a timely and effective basis among all interested scientists and end users.
- Support development of scientific capabilities and the application of results in developing countries in order to promote the fullest possible participation by scientists and scientific institutions in these countries in the above research, observational, and data management efforts.

To achieve these goals, CCSP has assigned high priority to development of international cooperation to support the research elements of the program in the realization of programmatic goals. This includes working closely with U.S. scientists involved in the various CCSP components to ensure effective advocacy of their programmatic needs and interests in the complex international framework that has been established for global change research. CCSP supports U.S.

scientists in interfacing with international organizations and other countries on the many broad issues related to global change and global climate change.

CCSP remains dedicated to supporting and participating in existing cutting-edge international climate change science and technology research and assessments—for example, by assisting scientists in the planning and implementation of international collaborative projects. In doing so, CCSP continues to advocate maintaining the flexible international framework that permits U.S. scientists and agencies to select the approach that best suits their needs from various avenues for international cooperation.

CCSP will continue to support improvement of data sharing across international boundaries, thus contributing to the most effective development of scientific results and knowledge; to seek reductions in administrative and political barriers to international collaborative research and scientific exchange; to support expansion of specific observation systems and associated scientific infrastructure; and to support research in areas such as the mitigation of and adaptation to change—areas essential to economic development and its sustainability. CCSP will also continue to support programs that are building capacity through the training of competent scientists to address global change issues, the education of stakeholders, and the strengthening of institutions.

The International Framework

CCSP is a leader within a global network of active and engaged international research scientists and institutions. This network has developed an extensive framework to address both research and observational requirements for addressing global climate change issues. This framework includes a series of global-scale research programs; non-governmental and intergovernmental international organizations at both the regional and global level; various networks for coordination of observing systems—both *in situ* and remote sensing—and data exchange and management; international assessments; and organizations that focus on education, training, and capacity building.

The International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), the World Climate Research Programme (WCRP), Diversitas, and the Earth System Science Partnership (ESS-P) are among the most important of these organizations. CCSP has and will continue to interact with these organizations directly when appropriate, and by supporting U.S. scientists to participate in and provide dynamic scientific leadership for them through financial support, provision of data products, and scientific input.

National agencies that conduct and fund global change research, satellite remote-sensing systems, agricultural and forest research, and development projects also coordinate their efforts with their counterpart agencies in other countries through a number of organizations and networks. These include the International Group of Funding Agencies for Global Change Research (IGFA), the Committee on Earth Observation Satellites (CEOS), and the Consultative Group on International Agricultural Research (CGIAR). The United States, for example, is one of the largest donors to CGIAR, which sponsors 16 international agricultural research centers devoted to improving food security, alleviating poverty, and improving the management of natural resources in developing nations. These centers are engaged in biological research that is intended to increase production of basic food crops and livestock and to maintain and enhance the natural resource base relating to soil, water, aquatic resources, agroforestry, and forestry.

The United States interacts at the intergovernmental level with partner countries in United Nations organizations that support global change research, both directly and indirectly. Preeminent among these are the World Meteorological Organization (WMO); the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organization (UNESCO); the United Nations Environment Programme (UNEP); the Food and Agriculture Organization (FAO); the United Nations Development Programme (UNDP); and the World Health Organization (WHO). The anticipated re-entry of the United States into UNESCO should provide additional opportunities for U.S. scientists to interact with and participate in the full range of UNESCO science activities. Through its participation in UNEP, UNDP, and the World Bank, the United States also participates actively in and supports the Global Environment Facility (GEF), the primary international institution for the exchange of energy and carbon sequestration technologies with the developing world.

International Assessments and Applications

As a leader in climate change science, the United States assumes responsibility to participate in and provide data to international assessments such as those concerning ozone, biodiversity, ecosystems, and climate. In addition to the role that the United States plays in assessments, the federal government also provides support for and data to a number of programs that apply climate change information to provide critical decision support resources such as the U.S. Agency for International Development's (USAID) Famine Early Warning System (FEWS NET).

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer stands as one of the best examples of effective international cooperation on an environmental issue. In response to growing evidence of stratospheric ozone depletion, the nations of the world were able to develop the Montreal Protocol. Through global cooperation and compliance and the development of new non-depleting technologies, the increase in atmospheric concentrations of ozone-depleting gases has slowed and in some cases started to decline. International assessment has been a critical part of this process from the very beginning, providing the scientific underpinnings for decisionmaking on this issue. The series of Scientific Assessments of Ozone Depletion has provided decision support resources in the form of scientific information about the global state of ozone-depleting compounds.

The Millennium Ecosystem Assessment (MA) is building a new framework to link ecosystem services (e.g. food, fuel, clean water)

with human well-being. MA takes an integrated and multi-scale (local, regional, to global) approach and focuses on ecosystem services, the consequences of changes in ecosystems for human well-being, and the consequences of changes in ecosystems for other life on Earth. It addresses questions like: "What are the potential impacts, both positive and negative, of economic growth and globalization on ecosystems?" and "What policies and actions concerning ecosystems can best contribute to the alleviation of poverty?" In particular, it assesses the current and historical trends in ecosystems and their contribution to human health; choices for conserving and sustainably managing ecosystems to augment their contribution to human well-being; and scenarios for changes in ecosystems and their impacts on human well-being. By taking an integrated multi-scale approach that brings the latest scientific data, MA will provide information that will allow decisionmakers to review the trade-offs associated with choices they need to make.

WMO and UNEP established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to conduct multidisciplinary reviews of current scientific and socioeconomic information pertaining to climate change. IPCC performs its critical task through an organizational structure composed of three working groups and a task force: Working Group I assesses the science of the climate system and climate change; Working Group II assesses the vulnerability of socioeconomic and natural systems to climate change; Working Group III assesses options for limiting greenhouse gas emissions and mitigating climate change; and the Task Force focuses on inventories of national greenhouse gases. CCSP participates extensively in the IPCC process, including support of the Working Group I Technical Support Unit, support for the IPCC Task Group on Scenarios for Climate and Impact Assessment, and support for scientist participation in IPCC activities.

The Famine Early Warning System Network is an example of how climate information can and is directly supporting decisionmaking in areas that are highly susceptible to both man-made and natural hazards, including change. The network combines food economy analysis, which analyzes the structure of poor urban and rural households in Africa, with a variety of data including climate to determine the risk of food shortage. These analyses are conducted on a seasonal basis and in response to predicted and observed hazards as well as other conditions that may threaten food security (e.g. natural disasters, market data).

Engaging the International Global Change Research Community

The United States and U.S. scientists engage the international global change research community in a variety of ways—for example, by sponsoring and contributing to climate change science-related workshops that foster cutting-edge science collaborations.

The Interagency Working Group for International Research and Cooperation (IWG-IRC) brings together the U.S. federal agencies interested in international cooperation in climate change science. This group traces its beginnings to the International Cooperation in Global Change Research Act of 1990 (Title II). The primary purpose of the working group is to provide international affairs support to the research programs of CCSP. It consists of representatives of 11 U.S. agencies that have major interests in global climate change science and technology. Meeting regularly, member agencies exchange information on international issues pertaining to climate change research and develop interagency approaches directed at resolving these issues. The working group coordinates U.S. interagency support for the international infrastructure that provides coordination for the major international global change research programs.

U.S. participation in IGFA aids in efforts to engage the national funding agencies of over 20 member countries. This group ensures that national funding agencies are regularly informed about national global change research programs, supporting initiatives, facilities, and related issues. The agencies then identify topics of mutual interest that they address through their respective national processes and, in some cases, coordinated international efforts. IGFA is also concerned with the reduction of barriers to international collaborative research at all levels—for example, constraints on the exchange of scientists and equipment.

The United States actively promotes global change research in the Antarctic and Arctic. Regarding the Antarctic, the United States works through cooperation with parties to the Antarctic Treaty and the Scientific Committee on Antarctic Research (SCAR). Regarding the Arctic, the United States works through the Arctic Council, the International Arctic Sciences Committee (IASC), and the Arctic Ocean Sciences Board (AOSB). Work with these organizations will advance fundamental knowledge of the polar regions as well as provide observations that are critical to our understanding of climate. The Arctic Climate Impact Assessment (ACIA), conducted under the auspices of the Arctic Council and IASC, is assessing the consequences of climate change on the circum-Arctic environment, its resources, economy, and peoples.

An especially important example of U.S. efforts to engage scientists in other countries in cooperative research involves Japan. The United States is involved in a focused cooperative effort with Japan in the geosciences and environment. Within this effort, a series of 10 annual workshops have been conducted on global change research. This year, the United States hosted the 10th U.S.–Japan workshop in this series, on the topic of "Water and Climate." Workshop topics for the two previous years were "Health and the Environment" and "Carbon Cycle Management in Terrestrial Ecosystems." These meetings have proven to be an excellent forum for the exchange of ideas and information and are serving to stimulate international scientific collaborations.

A new series of bilateral discussions has recently been added to the United States' international affairs repertoire as a result of the Climate Change Research Initiative (CCRI) of 2001. This initiative provides yet another means to engage other countries in scientific collaboration on climate change science and technology. These activities are described in detail in the following section.

Bilateral Discussions

President Bush's climate change policy announcements on 11 June 2001 and 14 February 2002 highlighted the importance of international cooperation to develop an effective and efficient global response to the complex and long-term challenge of climate change. Under the leadership of the Department of State, the United States adopted a Bilateral Climate Change Strategy, focusing on countries or regional entities that are responsible for nearly 75% of the world's greenhouse gas emissions. Through this important network of bilateral and regional partnerships, the United States is advancing the science of climate change, enhancing the technology to monitor and reduce greenhouse gases, and assisting developing countries through capacity building and technology transfer.

Working with a mix of developed and developing countries, the Bilateral Climate Change Cooperation effort builds upon and supplements the four U.S. international research and cooperation activity goals: research, observations, data management and distribution, and capacity building. Examples from the range of activities included under the bilateral climate change effort are: global climate observing systems; evaluation of climate systems models; observations and data exchange; research on polar regions, aerosols, and clouds; ocean and atmospheric research; research on greenhouse gas sinks including land use, land-use change, and forestry; advancement of clean and renewable energy technologies; and energy efficiency. Capacity building and technology transfer activities with developing countries also include cooperation in economic and environmental/climate modeling, carbon cycle measurements, monitoring and measurement of greenhouse gases,

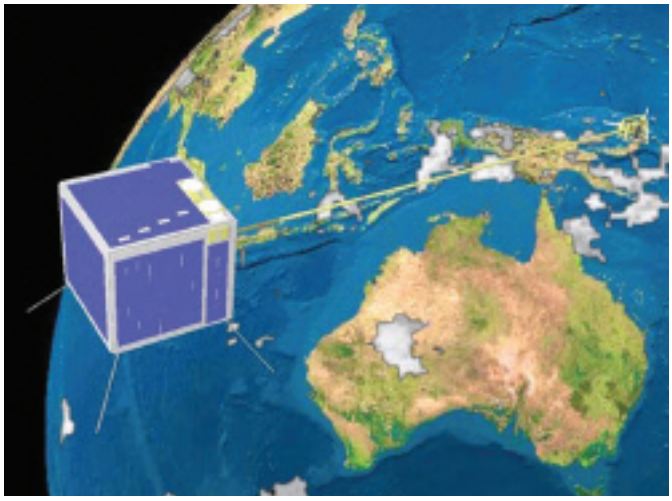

Figure 15-1: Australia's Federation Satellite carrying NASA's Global Positioning System receiver.

development of adaptive capacity to improve resource management, implementation of integrated environmental strategies, investments in climate observing systems, and creating partnerships for energy efficiency.

The United States has made significant progress on many aspects of the President's international climate change agenda through the establishment of results-oriented "action plans" with bilateral and regional partners. These partners include Australia, Japan, the seven Central American countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), the People's Republic of China, the European Union (EU), India, Italy, New Zealand, Canada, the Russian Federation, the Republic of Korea, Mexico, and South Africa. Specific examples follow.

Under the U.S.–Australia Climate Action Partnership (CAP) the focus is on practical approaches towards dealing with climate change. Specific priority areas included under CAP are climate change science and monitoring; renewable and reduced emission stationary energy technologies; engagement with business on technology development; policy design and implementation; capacity building in developing countries; and greenhouse gas accounting in the forestry and agriculture sectors (see Figure 15-1).

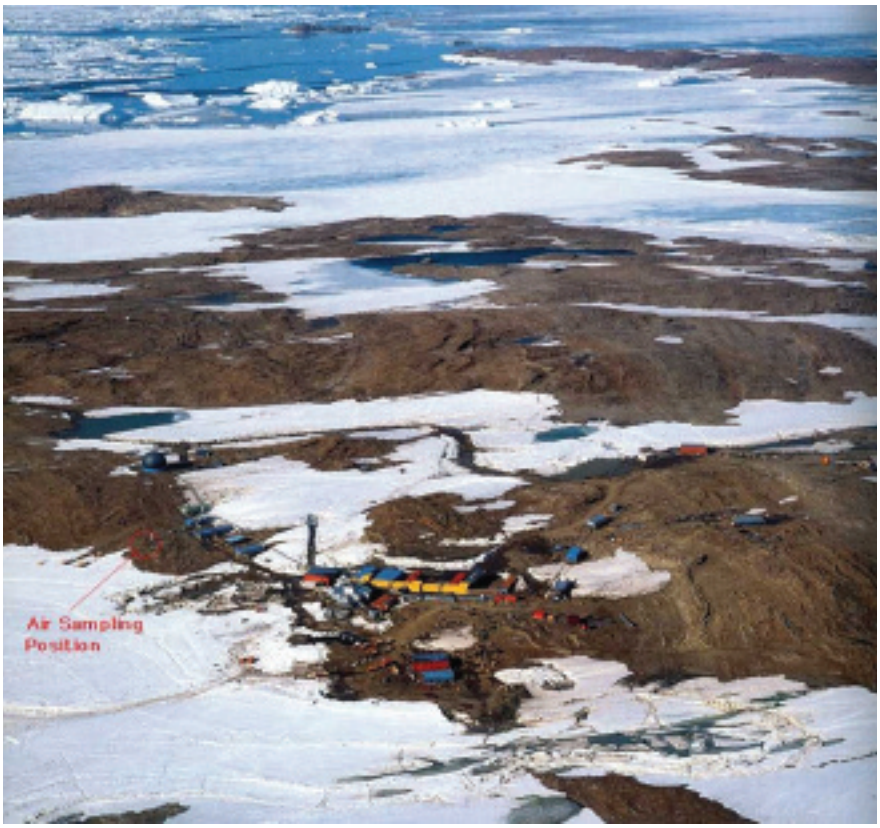

Figure 15-2: The NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) Carbon Cycle Greenhouse Gases (CCGG) Group's Cooperative Air Sampling Network at Syowa, Antarctica, is a collaboration with Japan's National Institute of Polar Research. The flasks collected here are analyzed for 12 chemical species including greenhouse gases and related isotopes.

The U.S.-Japan High Level Consultations on Climate Change (HLC) Working Group on Science and Technology focuses on seven priority areas: improvements of climate models; impacts and adaptation/mitigation policy assessment employing emission-climate impact integrated models; observation and international data exchange and quality control (see, for example, Figure 15-2); research on greenhouse gas sinks including land use, land-use change, and forestry; research on polar regions; and development of mitigation and prevention technologies. Experts also are collaborating on issues relating to developing countries and market-based approaches.

The United States and seven Central American countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) agreed to enhance climate change collaboration under the auspices of the Central American-United States of America Joint Accord, known by its Spanish acronym CONCAUSA. The partnership emphasizes the need for intensified cooperative efforts to address climate change through scientific research, estimating and monitoring greenhouse gases, investing in forestry conservation, enhancing energy efficiency, utilizing new environmental technologies, enhancing capacity to adapt to climate change, and collaborating to better understand its regional impacts. In March 2002, the State Department announced a CONCAUSA Action Plan that included $2 million in new funds from USAID, with supplemental project support from EPA and NASA.

The United States and the People's Republic of China have agreed under an approved charter to collaborate on a broad suite of climate change science and technology issues, including cooperative research on and analysis of gases other than carbon dioxide, economic/environmental modeling, integrated assessments and evaluation strategies for adaptation, capture and sequestration, observations and measurements, institutional partnerships, energy and environment follow-up to the World Summit on Sustainable Development, and existing clean energy protocols and annexes.

Under the agreement of representatives to the U.S.–EU High Level Dialogue on Climate Change on 23 April 2002, a "U.S.–EU Joint Meeting on Climate Change Science and Technology Research" convened in Washington on 5-6 February 2003, to enhance cooperation on climate-related science and research. The two sides identified cooperative research activities in six areas: (1) carbon cycle research; (2) aerosol-climate interactions; (3) feedbacks, water vapor, and thermohaline circulation; (4) integrated observation systems and data; (5) carbon capture and storage; and (6) hydrogen technology and infrastructure.

The United States and Italy have developed a bilateral partnership encompassing a wide range of cooperative science and technology projects and activities, including climate change modeling, atmospheric processes, the carbon cycle, remote sensing, human and ecosystem health, and ocean observations and the ocean ecosystem. On the technology side, the partnership is advancing cooperative efforts on hydrogen infrastructure and energy technologies, including fuel cells, renewable energy, advanced power systems, and advanced

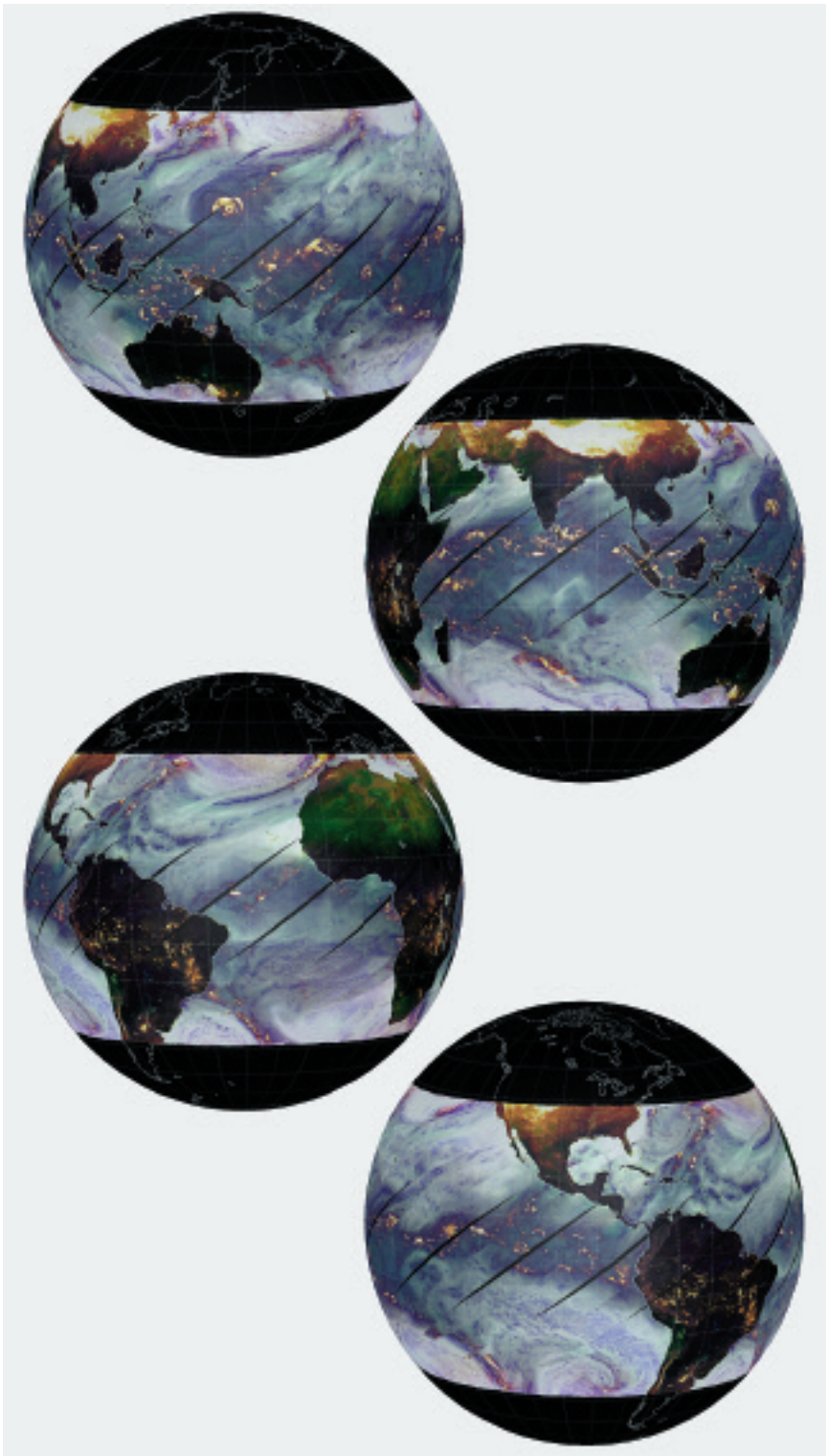

Figure 15-3: NASA/NASDA Tropical Rainfall Measuring Mission (TRMM) microwave imager data.

energy technologies including carbon capture and sequestration. The two countries have announced their intention to promote the exchange of graduate students, young scientists, and senior scientists in the area of climate change science and technology.

Most recently, the United States and India identified a broad range of cooperative programs, including science and technology activities. The two countries have identified collaborative efforts in the area of climate change science—for example, the NASA/Japanese Space Agency (NASDA) Tropical Rainfall Measuring Mission (see Figure 15-3). Additional anticipated areas of collaboration are adaptation, land-use change and forestry, climate modeling, ocean observations for the Indian Ocean, economic and environmental modeling, source-level measurement and monitoring, and a broad range of energy issues.

Research

As discussed in the opening section, the United States has a number of goals with respect to climate change science research. International cooperation in research has an important role in focusing the world's scientific resources on the highest priority global change research issues, in helping to reduce scientific redundancy in a world of limited financial resources, and in improving the exchange of information internationally. U.S. research efforts are significantly enhanced through international cooperation. By developing both conceptual and research frameworks, international research programs provide models that aid U.S. program managers to plan and coordinate their efforts. CCSP will to continue to facilitate cutting-edge climate change research by providing appropriate venues and resources for scientists to meet, to identify research areas of common interest, and to plan and implement joint projects.

Much of the research conducted and sponsored through CCSP benefits from and contributes to projects sponsored by the four major international research programs: IGBP, WCRP, IHDP, and the Diversitas program (see Table 15-1). The Diversitas program is dedicated to fostering global research on biodiversity in order to provide information to be integrated into conservation and sustainable management of biodiversity.

Examples of the links between the CCSP research elements and international programs include the Climate Variability and Predictability (CLIVAR) program and the Global Energy and Water Cycle Experiment (GEWEX), both core programs of WCRP. The CCSP Climate Variability and Change research element will continue to work with CLIVAR, Stratospheric Processes and their Role in Climate (SPARC), Past Global Changes (PAGES), and Climate and Cryosphere (CliC) programs. Both the CCSP Climate Variability and Change and Water Cycle research elements will continue their work in close coordination with the GEWEX program.

The CCSP research elements maintain regular exchanges with the various international projects to which they are related. The U.S. scientists leading CCSP projects have offered substantial input to the design and implementation of many of these projects that are now underway. In addition to programs and projects that operate under the auspices of the international global change research programs, the CCSP research elements interact with many others (see Table 15-2). For example, the scientists involved in the U.S. North American Carbon Program (NACP) will, in order to realize the research goals of the program, expand their interaction with

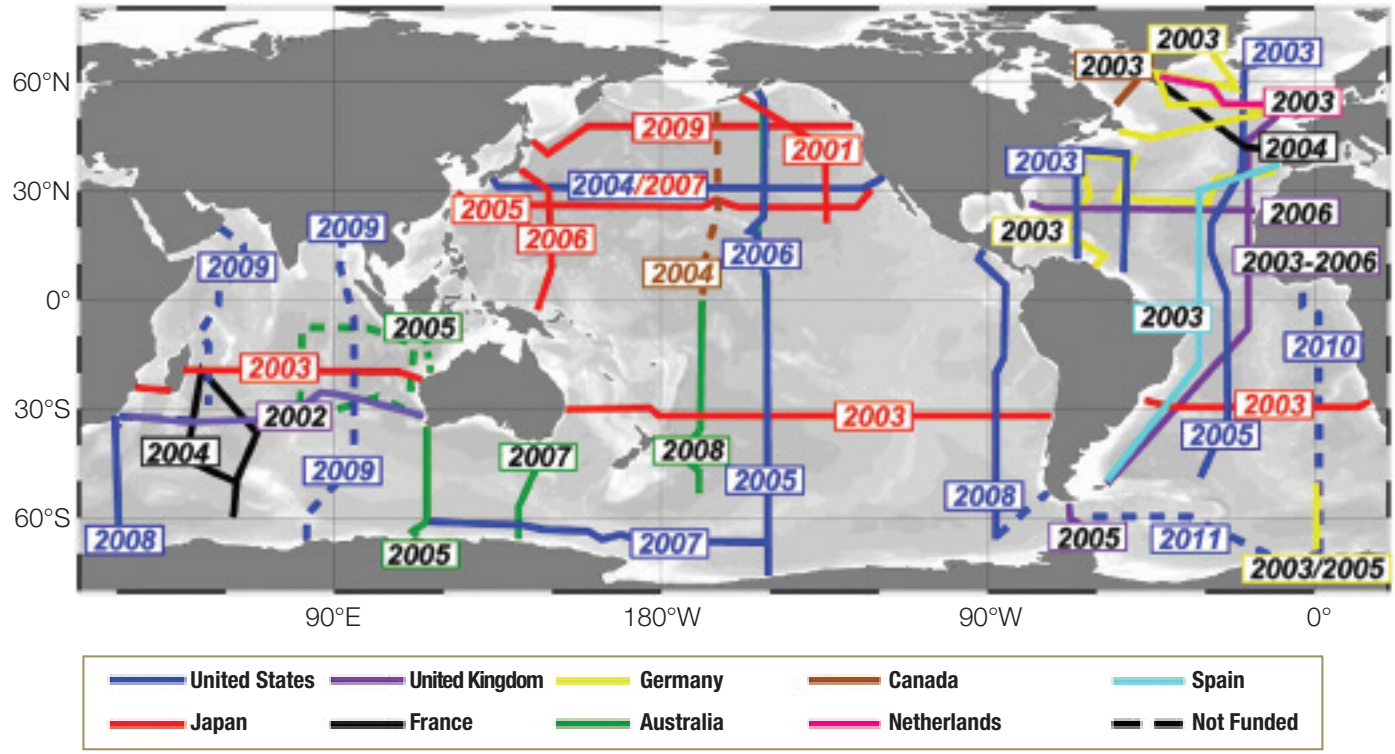

Figure 15-4: Map of planned deep-ocean, repeat hydrography cruises to address scientific objectives of the U.S. CLIVAR and Carbon Cycle Science Program objectives. Source: Chris Sabine, NOAA-PMEL.

colleagues in Canada and Mexico and with the Carboeurope cluster, the International Global Observing Strategy Partnership (IGOS-P), and the Global Carbon Project as well (see Chapter 7). The programs described in these two tables represent the primary international interactions of the research programs within CCSP.

The synergies and coordination developed by such parallel programs are instrumental in addressing global and regional issues. For example, representatives of the world's major climate modeling centers form the WCRP/CLIVAR Working Group on Coupled Modeling (WGCM) to collectively address needed advancements in coupled

TABLE 15-1

Examples of key programs and projects with which the CCSP research elements cooperate, coordinated through the four international research programs

Project	Description
International Geosphere-Biosphere Programme (IGBP)	
International Global Atmospheric Chemistry (IGAC)	IGAC is dedicated to understanding the processes that determine atmospheric composition. This includes detailed examination of the interactions between atmospheric and chemical composition, physical, biospheric, and climatic processes. They also investigate the prediction of impacts on atmospheric composition associated with natural and anthropogenic forcing (see Chapter 3).
Past Global Changes (PAGES)	The primary objective of PAGES is to facilitate international cooperation in paleo-environmental research. PAGES coordination embraces paleoclimatic aspects of the interactive physical, chemical, and biological processes that regulate the Earth system, concentrating on those aspects which best inform our understanding of potential future changes of relevance to human concerns (see Chapter 4).
Joint Global Ocean Flux Study (JGOFS)	The JGOFS program was designed to advance our understanding of the processes that control carbon exchanges between the atmosphere, surface ocean, ocean interior, and continental margins, and the sensitivity of these fluxes to climate change.
GLOBal ocean ECosystems dynamics (GLOBEC)	The GLOBEC program is designed to investigate and advance our knowledge of the global ocean ecosystem, its major subsystems, and its response to physical forcing, with emphasis on natural variability (see Chapter 8).
Global Climate and Terrestrial Ecosystems (GCTE)	The GCTE program investigates the effects of climate changes, atmospheric composition, and land use on the structure and function of terrestrial ecosystems and how they lead to feedbacks to the atmosphere and the climate system (see Chapter 8).
Land-Ocean Interface in the Coastal Zone (LOICZ)	LOICZ studies biogeochemical processes and changes in the fluxes of materials from within river catchments to coastal shelf boundaries, the influence of human activities on these changes, and the impact of flux changes on human welfare. LOICZ also provides science information to the global community, especially decisionmakers and coastal zone managers (see Chapter 8).
Biospheric Aspects of the Hydrological Cycle (BAHC)	BAHC is an interdisciplinary project that fosters and promotes research to better understand the role that the terrestrial biosphere plays in the Earth system, and the increasing human-induced changes (see Chapter 8).
World Climate Research Programme (WCRP)	
Climate Variability and Change (CLIVAR)	The CLIVAR program is one of the major research efforts of WCRP concerned with climate variability, extending predictions of climate variation and refining estimates of anthropogenic climate change. CLIVAR will advance the findings of the successfully completed Tropical Ocean and Global Atmosphere (TOGA) project, and continues its valuable work with the World Ocean Circulation Experiment (WOCE) (see Chapter 4).
Stratospheric Processes And their Role in Climate (SPARC)	SPARC concentrates on the interaction of dynamic, radiative, and chemical processes in the stratosphere and what role they play in climate. SPARC is constructing a stratospheric reference climatology; improving the understanding of trends in temperature, ozone, and water vapor in the stratosphere; and improving the understanding of gravity waves (see Chapter 4).
The Global Energy and Water Cycle Experiment (GEWEX)	GEWEX focuses on the study of atmospheric and thermodynamic processes that determine the hydrological cycle and water budget as well as their adjustments as a function of climate change (see Chapters 4 and 5).
Climate and Cryosphere, Arctic Climate System Study (CliC, ACSYS)	ACSYS—a regional project studying climate of the Arctic region including its atmosphere, ocean, sea ice, and hydrological regime—is being expanded into a global project, CliC, to investigate the role of the entire cryosphere in global climate.
World Ocean Circulation Experiment (WOCE)	The WOCE program was designed to understand and predict changes in the world's ocean circulation, volume, and heat storage that would result from changes in atmospheric climate and net radiation with a variety of *in situ*, remote-sensing, and modeling methodologies.
International Human Dimensions Programme (IHDP)	
Land-Use and Land- Cover Change (LUCC)	LUCC, co-sponsored by IGBP, focuses on the understanding of the interrelationship between land use and land-cover change, biogeochemistry, and climate. It addresses these issues with an interdisciplinary approach utilizing case studies, models, and integrative analyses. Topics such as climate change, food production, health, urbanization, coastal zone management, transboundary migration, and the availability and quality of water are addressed in LUCC research (see Chapter 6).

TABLE 15-1 (CONTINUED)

Examples of key programs and projects with which the CCSP research elements cooperate, coordinated through the four international research programs

Project	Description
Jointly Sponsored IGBP/WCRP/IHDP Projects	
Global Environmental Change and Food Systems (GECAFS)	GECAFS tries to address the suite of issues associated with population growth and globalization of economies as they relate to food stability in the context of global environmental change. This includes consideration of the potential impacts of global change on both individuals and societies (see Chapter 8).
The Global Carbon Project (GCP)	GCP integrates atmospheric, oceanic, terrestrial, and human dimension aspects of the carbon cycle with commitment and balanced input from the global environmental change programs. It has developed an international framework for carbon research and investigates system-wide questions of interactions between humans and the carbon cycle. National and regional studies contribute to the implementation of the project (see Chapter 7).
The Global Water System Project (GWS)	A joint water project, sponsored by all four global environmental change programs, is in the planning phase and will take an integrative look at the global water system. GWS aims at understanding impacts of global change on local and regional coupled water-human systems, and how local and regional anthropogenic activities in turn affect global environmental change. Approaches to establish more sustainable water systems will be identified (see Chapter 5).
Global Change SysTem for Analysis, Research, and Training (START)	START focuses on regional interdisciplinary global change research. Its objective is to build scientific capacity in developing countries through regional research and training to address the science and policy issues relevant to environmental change and sustainable development. START has regional offices in East Asia, South Asia, Southeast Asia, Oceania, Africa, and the Mediterranean.
Surface Ocean-Lower Atmosphere Study (SOLAS)	SOLAS is a new international research initiative to carry out research at the interface between the oceans and the atmosphere in order to achieve a quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and how this coupled system affects and is affected by climate and environmental change (see Chapter 8).

modeling of the global physical climate system. Research activities coordinated by WCRP elements have led to major advancements in the understanding and modeling of the North Atlantic Oscillation/Northern Hemisphere Annular Mode (NAO/NAM), improved precipitation and solar insulation products, and advanced representations of the Arctic in models.

The CLIVAR Variability of the American Monsoon (VAMOS) program has been instrumental in enlisting the participation of South and Central American scientists to focus on observing, modeling, and assessing variability of the American monsoon system and our ability to predict its changes. A new era of cooperation between participating scientists and key organizations responsible for national meteorological and oceanographic observational systems is not only entraining key scientists, but is also enhancing existing observational systems, initiating new observation capabilities (e.g., rain gauge and sounding networks) for climate and application research, and providing improved practical knowledge for decisionmakers.

U.S. scientists play an important role in the research programs carried out by the Inter-American Institute for Global Change Research (IAI), and in bringing together the more than 200 research universities and government institutions in the Western Hemisphere that make up its research network. Research programs sponsored by IAI have aided in the development of new decision and management tools in diverse areas, ranging from the incorporation of long-range forecasts into dam management for hydropower and irrigation to the establishment of a tri-national sardine fishery forum that regularly brings together regulatory agencies, resource managers, fishermen, and researchers from Canada, Mexico, and the United States. In addition, IAI research enabled the first rigorous scientific ranking of the drivers of global change, based on scenarios of changes in global biodiversity.

Some of the most productive international cooperative interactions are developed through international research expeditions and field experiments. The Ocean Drilling Program (ODP) is an outstanding example of a long-term field study that has obtained cores of sediments and crustal rock from the oceans to improve understanding of the history of changes in the oceans and climate. The National Science Foundation (NSF) and Japan's Ministry of Education, Culture, Sport, Science, and Technology (MEXT) signed a memorandum of understanding in April of 2003 to further advance scientific ocean drilling through a new Integrated Ocean Drilling Program (IODP—see Figure 15-5). IODP will develop ocean sediment records from a global array of sites to allow a sophisticated and detailed analysis of the causes, rates, and severity of changes in the Earth's climate system and their relation to major pulses in biologic evolution on time scales ranging from a few hundred years to more than 500,000 years.

Other recent examples of successful field campaigns include the Indoex campaign off of India and over the Indian Ocean to study atmospheric aerosols; the ACE-Asia and TRACE-P field campaigns to study atmospheric trace constituent and aerosol observations over East Asia and the Western Pacific Ocean; and the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) campaign to study the ecology and hydrology of the Amazon region. Such field campaigns and others have demonstrated the great value of having good relationships with host countries to ensure the highest quality scientific observations.

Observing Systems

Although climate modeling capabilities have progressed in recent years, sustained improvements will require substantial expansion of Earth observing systems, both remote and *in situ*, in order to fill gaps in existing databases, especially in those areas of the world for which existing data is sparse. Such data-sparse areas include remote regions, especially those with harsh environments, and areas where existing capabilities to make observations and collect data are limited, such as the oceanic and interior land areas of the Southern Hemisphere and both polar regions.

The United States hosted an Earth Observation Summit in July 2003 to engage the international community in a continuing dialogue on the issues associated with building a comprehensive, integrated Earth observation system. The Earth Observation Summit had four

TABLE 15-2

Additional examples of key international and regional programs and projects with which CCSP research elements cooperate and/or coordinate

Organization	Project	Description
	Intergovernmental Organizations	
World Meteorological Organization (WMO)	Hydrology and Water Resources Programme	This group focuses on the application of hydrology to sustainable development, the mitigation of water-related disasters, and effective environmental management at national and international levels (see Chapter 5).
United Nations Educational, Scientific, and Cultural Organization (UNESCO)	International Hydrological Programme	This is an intergovernmental capacity-building program and information center for information pertaining to water resources. It is dedicated to building the capacity of member states to better manage and develop their water resources (see Chapter 5).
WMO/UNESCO	Hydrology for Environment, Life, and Policy (HELP) Program	HELP is a joint initiative of UNESCO and WMO, led by the International Hydrological Programme. HELP is creating a new approach to integrated catchment management through the creation of a framework for water law and policy experts, water resource managers, and water scientists to work together on water-related problems (see Chapter 5).
Northern Eurasia Earth Science Partnership Initiative (NEESPI)		NEESPI will identify the critical science questions and establish a program of coordinated research on the state and dynamics of terrestrial ecosystems in northern Eurasia and their interactions with the Earth's climate system to enhance scientific knowledge and develop predictive capabilities to support informed decisionmaking and practical applications (see Chapter 6).
Intergovernmental Oceanographic Commission (IOC)/ Scientific Committee on Ocean Research (SCOR)	Global Ecology and Oceanography of Harmful Algal Bloom (GEOHAB)	The GEOHAB program is an international program designed to improve international capabilities for effective management and mitigation of harmful algal blooms. This research program utilizes a comparative approach at a variety of scales from the cellular to the ecosystem level. This research effort will improve understanding of the distribution of and trends in harmful algal blooms and the influences of anthropogenic and climate-related factors (see Chapter 8).
	Intergovernmental and Similar Organizations and Activities	
International Research Institute for Climate Prediction (IRI)		IRI is dedicated to improving and providing climate predictions to help societies worldwide cope with climate fluctuations, particularly extreme events that have great impacts on both human populations and the environment.
European Commission	Carboeurope	The Carboeurope cluster is a research program dedicated to understanding the terrestrial carbon cycle for a range of environments in Europe, including carbon fixation and carbon sources and sinks. These issues are considered in the context of climate variability, the availability of nutrients, nitrogen deposition, and management. Their research effort is complemented by research in the Amazon forests.
Inter-American Institute for Global Change Research (IAI)		IAI is an intergovernmental research organization supported by 19 countries in the Americas. It is dedicated to the understanding of global change and its socioeconomic implications. This includes study of the natural and social sciences, the full and open exchange of data relevant to global climate change, augmenting the capacity of countries to conduct scientific research, and the provision of information in a timely manner and in a useful form for policymakers (see Chapter 9).
Asia-Pacific Network for Global Change Research (APN)		APN fosters global environmental change research in the Asia-Pacific region, increases the participation of developing countries in that research, and strengthens the connection between the science community and policymakers.
International Long-Term Ecological Research (ILTER)		ILTER is an international organization dedicated to ecological research on long temporal scales and large spatial scales (see Chapter 8).

Figure 15-5: The January 2002 launch of the Japanese riser drill ship Chikyu (Earth) in Kobe, Japan. This vessel and a U.S.-provided non-riser drill ship will be the primary global scientific ocean drilling platforms for the new Integrated Ocean Drilling Program. IODP will address many fundamental and societally important questions in Earth and ocean science including improving our understanding of past climate and climate change.

major goals: to promote the international exchange of *in situ*, aircraft, and satellite observations in a full and open manner and in a timely fashion with minimal cost; to gain international agreement on the concept of an international, comprehensive, integrated, and sustained Earth observation system that will meet collective requirements for observations, minimize data gaps, and maximize the utility of the system; to establish an intergovernmental ad hoc working group to develop a 10-year implementation plan for the system; and to help improve observing systems and advance the scientific capacity in developing countries.

The United States supports a number of international observing systems and networks with which the CCSP research programs work closely (see Chapters 5, 6, 7, and 8). The International Global Observing Strategy Partnership (IGOS-P) incorporates a number of large-scale observing systems that are designed to cover land, through the Global Terrestrial Observing System (GTOS); the ocean, through the Global Ocean Observing System (GOOS); and climate, through the Global Climate Observing System (GCOS) and the Global Observing System/Global Atmosphere Watch (GOS/GAW). The United States not only supports these programs directly, but also encourages the international global change research programs to ensure that the observational needs of research scientists are fed into IGOS-P and that the partners also benefit from the observational expertise developed in research projects.

In the Arctic, the United States is also involved in a number of international observing projects such as the Arctic and Subarctic Ocean Fluxes Study (ASOF) and the North Pole Environmental Observatory (NPEO). The ASOF program, which the European Commission also provides support for, will monitor and advance understanding of the oceanic fluxes of heat, salt, and freshwater and their effect on global ocean circulation. NPEO, coordinated with Japan and Canada, is a series of drifting buoys, oceanographic moorings, and hydrographic casts that serve collectively as an observing system.

The CCSP research programs will need to continue to work closely with these observational program groups in order to benefit from and contribute to them. CCSP assigns very high priority to the Argo ocean observations program, a global array of free-drifting profiling floats that measures the temperature and salinity of the upper 2,000 meters of the ocean. The United States is actively seeking, through a wide range of multilateral and bilateral cooperative efforts, to encourage and promote a wide range of international participation to complement the U.S. efforts. Cooperation in Argo has been initiated successfully with Japan, Australia, the European Commission, China, the Russian Federation, India, the Republic of Korea, Canada, Spain, Norway, Germany, Denmark, France, the United Kingdom, and New Zealand. Another important example of a focused observing system of importance to CCSP is the program for the Global Observation of Forest Cover and Global Observations of Land Cover Dynamics (GOFC-GOLD—see Chapter 6).

Satellite remote-sensing systems are continually being developed to take advantage of new technologies to collect an ever-widening range of data on both global and regional scales. Successful implementation of such systems requires development of collaborative international ground-based networks, maintenance of these networks, and assurance of calibration relative to widely recognized standards. This can be accomplished only through collaboration among scientists and national and international agencies from many nations. NASA and NOAA work closely with their counterpart agencies in other countries, such as the European Space Agency (ESA) and the Japanese Space Development Agency (NASDA) to coordinate planning and implementation of new satellite remote-sensing systems. These agencies interact directly with one another regularly and as a group in CEOS.

NASA also partners on a bilateral basis with its counterpart agencies in other countries in algorithm development [e.g., with Canada, Measurement of Pollution in the Troposphere (MOPITT)], instrument development [e.g., with the United Kingdom on the High-Resolution Dynamics Limb Sounder (HRDLS) and Brazil on the Humidity Sounder for Brazil (HSB)], and mission implementation (e.g., with Japan on the TRMM project and instrumentation for the AQUA spacecraft). The United States and Japan are now actively discussing the possibility of leading a multi-national Global Precipitation Measurement (GPM) mission in the future. Similarly, the United States and France have jointly provided for two satellites measuring ocean surface height (TOPEX/Poseidon in 1992, Jason-1 in 2002), and are actively exploring further investments in this area as part of a strategy to transition these research measurements to operations.

Data Management

Climate change science depends critically on the full and open exchange of scientific observations and data both within and across national borders. It is essential that scientists have the widest possible access to scientific data in order to conduct effective research and to develop reliable climate forecasts. Scientists involved in both research and forecasting must also be able to make the data that they use available for others to test, to replicate their research results and forecasts, and to indicate lines for future research and forecasting. Furthermore, these data must also be made available in a timely and useful manner to policymakers and decisionmakers in order to assist in efforts to mitigate the impacts of climate variability and change.

As a leader in and major supporter of climate change research, the United States has the opportunity to influence the rest of the world on issues pertaining to data management and thus to continue to advocate the full and open exchange of scientific data across international boundaries. It is also important to develop and promote wide application of common methodologies and protocols in order that collected data are of high quality, comparable, and easily accessible, especially through an effective international network of data archival and exchange systems.

A number of international efforts to manage and exchange data have been underway for many years. The World Data Center System (WDCS), established by the International Council of Scientific Unions (ICSU), has successfully collected, maintained, archived, and distributed scientific data, including climate change data. Since it was founded, WDCS has expanded into a number of worldwide independent sites. The Data and Information System (DIS) is the data management portion of IHDP and links social science data to scientists and institutions researching climate change.

CCSP expects to continue to interact closely with data management and dissemination efforts such as NASA's Global Change Master Directory (GCMD) and the International Directory Network (IDN). GCMD is the set of data and information systems from individual agencies that support climate change science and serves as the U.S. coordinating node of CEOS. The GCMD system utilizes a standard format, known as the Directory Interchange Format (DIF), that provides a simple user interface allowing access to over 1,800 data sets. Using the DIF system, CEOS developed IDN, which allows worldwide access to data and information about climate change. The Global Observation Information Network (GOIN) project is an example of U.S.-Japan bilateral cooperation in Earth observation information networks including satellite and *in situ* data. All of these programs are examples of the ideals of data sharing the United States continues to work toward internationally.

Capacity Building

CCSP and the major international research programs have recognized that to address the myriad of issues associated with understanding and responding to global change will require a truly global research effort. They have and will continue to provide resources in order to build scientific capacity in developing countries and thus to improve the ability of developing countries to undertake global change research and to benefit more fully from the results of such research. CCSP therefore supports a number of efforts to build scientific capacity in the developing world.

A key component of this effort is the System for Analysis, Research, and Training (START) that is sponsored jointly by IGBP, WCRP, IHDP, and Diversitas. Its mission is to build capacity in developing countries in order that they can conduct research on global change and be better prepared to understand and thus mitigate the potential impacts those changes may have for human health, agriculture, natural resources, water, and food security.

The START program is hosted by the United States, and supported in large part by CCSP, while also receiving direct support from USAID and EPA. START is undertaking capacity building on a regional basis in Africa, Southeast Asia, temperate East Asia, the Mediterranean, and Oceania. The START program also sponsors fellowships and training workshops, and is currently developing a young global scientists' network that will link young scientists in the developing world with their peers in the United States.

Another example of a science project with a strong capacity-building component is the Large-Scale Biosphere-Atmosphere Experiment in Amazonia. LBA is designed to promote understanding of the effects of climate, land-use change, ecology, and biogeochemical and hydrological cycling in Amazonia. In the LBA campaign, capacity-building issues are addressed by requiring the involvement of Brazilian scientists and students, and has become a critical criterion in the selection of participants for the program.

Established in 1991, the Global Environment Facility funds environmental projects in developing countries. Climate change projects constitute approximately 40% of GEF's activities—its largest single focus. The United States has pledged $500 million over the next 4 years for GEF, a 16% increase that leveraged $2.2 billion and helped bring about the largest funding commitment in GEF's history. A significant portion of this funding is to help build capacity by supporting the transfer of advanced energy and sequestration technologies to the developing world. The Administration has also pledged to pay U.S. arrears that had built up over the course of the previous replenishment period.

The United States also supports two regional efforts that grew out of the "White House Conference on Scientific and Economic Research Related to Global Change" hosted by President George Bush in 1990: the Inter-American Institute for Global Change Research, and the Asia-Pacific Network for Global Environmental Change Research (APN). The United States is the primary supporter of IAI, and has joined with Japan in supporting APN. A goal of both IAI and APN is to increase participation of developing countries in global climate change research and to strengthen links between the science community and policymakers. Both institutions, independently and in collaboration with organizations like START, have strong capacity-building programs. The United States seeks to complement support of IAI and APN regions by advancing regional cooperation in Africa. These efforts will not only contribute to improving the

capabilities of African countries to conduct climate change science, but in the long term also will result in improved databases for this data-sparse region that, in turn, can improve models of climate change around the world.

U.S. Plans and Objectives for Future International Cooperation

The overall framework for international cooperation in global change research and observations has been responsive to the needs of U.S. global change science. However, this framework should be broadened and strengthened to keep pace with the evolving needs of this science with respect to both research and observations.

To expand cooperation internationally, the President has announced that the United States intends to:

- Commit $25 million to support the implementation of climate observation and response systems in developing countries
- Expand funding of GEF
- Support the transfer of advanced energy and sequestration technologies to developing countries in order to limit their greenhouse gas emissions growth
- Expand cooperation in climate change research and technology with a number of key countries and regional organizations
- Work with IAI and other institutions to better understand regional aspects of climate change.

CCSP also will:

- Continue to support and advance regional cooperation in Africa, possibly through a workshop that could lead to improved and expanded hemisphere-scale regional cooperation in global change research in Africa
- Expand international cooperation by continuing to support bilateral discussions in climate change science and technology
- Support further development and expansion of global observing systems through IGOS-P and three of its partners—GCOS, GOOS, and GTOS—and the Argo program for ocean observations, through further multilateral and bilateral cooperative efforts analogous to those already initiated
- Expand cooperation in biodiversity research, especially through the Diversitas program
- Enhance efforts to bring science and technology to bear on increasingly complex problems of natural resource development (e.g., the application of climate information for improved adaptation and disaster preparedness)
- Work with the international global change research programs—WCRP, IGBP, IHDP, and Diversitas—to promote effective transition of a number of their present focused programs to cross-cutting programs (such as the new programs on water, carbon, and global change and food security) that are intended to relate global change research more directly to major societal and economic factors
- Continue to work with and be supportive of international assessments such as those of IPCC.

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