DISCUSSION DRAFT

DRAFT WHITE PAPER:
INTERNATIONAL COOPERATION IN CLIMATE CHANGE SCIENCE

In support of Chapter 14 of the

Strategic Plan for the Climate Change Science Program

Draft dated 26 November 2002

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Preface

On 11 November 2002, the US Climate Change Science Program issued a discussion draft of its *Strategic Plan*. The strategy for each major area of the program is summarized in specific chapters of the draft plan, and for four chapters is described in greater detail in white papers. The white papers, including this one focused on international research and cooperation, represent the views of the authors and are not statements of policy or findings of the United States Government or its Departments/Agencies. They are intended to support discussion during the US Climate Change Science Program Planning Workshop for Scientists and Stakeholders being held in Washington, DC on December 3 – 5, 2002.

Both the chapters of the plan and the white papers should be considered drafts.

Comments on the chapters of the draft *Strategic Plan* may be provided during the USCCSP Planning Workshop on December 3 – 5, 2002, and during a subsequent public comment period extending to January 13, 2003. The chapters of the *Strategic Plan* will be subject to substantial revision based on these comments and on independent review by the National Academy of Sciences. A final version of the *Strategic Plan*, setting a path for the next few years of research under the CCSP, will be published by April 2003. Information about the Workshop and opportunities for written comment is available on the web site www.climatescience.gov.

Comments that are specific to this white paper – and that are not already conveyed through comments on the related chapter of the plan – should be directed to: Jessica Orrego [jorrego@usgcrp.gov].

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Draft dated 25 November 2002

In this paper…

Introduction

President Bush has highlighted the importance of international cooperation to develop an effective and efficient global response to the complex and long-term challenge of climate change. The President announced on June 11, 2001 that he is "committing the United States of America to work within the United Nations framework and elsewhere to develop with our friends and allies and nations throughout the world an effective and science-based response to the issue of global warming." He launched three initiatives: (1) the Climate Change Research Initiative (CCRI) to guide climate policy by science; (2) the National Climate Change Technology Initiative (NCCTI) to develop new technologies; and (3) promotion of increased cooperation in the "Western Hemisphere and Beyond."

The President re-emphasized the importance of international cooperation, both multilateral cooperation (through his commitment to the UN Framework Convention on Climate Change (UNFCCC)) and bilateral cooperation in his climate strategy announcement of February 14, 2002. He indicated that he intended "to work with nations, especially the poor and developing nations, to show the world that there is a better approach, that we can build our future prosperity along a cleaner and better path."

To implement international cooperation in climate change science, the United States works through a comprehensive array of international global change research and observational programs and projects that steadily are evolving as new scientific needs are identified and addressed. Such programs and projects increasingly are seeking to develop a useful understanding of the patterns, anomalies, and impacts of climate on critical sectors and regions, and to apply this information in a decision-support mode.

Our U.S. sponsored international programs are designed to understand the Earth system processes that underlie global change and the interplay between global change and human activity, and to apply this knowledge to take advantage of opportunities, reduce vulnerability, increase resilience, and foster more sustainable links between the environment and economic growth. This goal is achieved through (1) stimulation and support of problem-oriented, place-based research that responds to the needs of regional and local stakeholders; (2) development of the scientific, technical, and institutional capacity required to successfully apply results of research to practical challenges; and (3) regular interaction between the scientific community, their sponsoring agencies, and stakeholders.

Goals Of International Cooperation In Climate Change Science

The broad scope and complexity of U.S. climate science research requires that the United States join with its partners across the world to develop and maintain a broad, well-organized international framework within which:

- Local, regional, and global-scale cooperative research and observational programs can be planned and implemented;
- The full and open exchange of scientific observations and data needed for research results can be encouraged and the results of such research can be exchanged;
- Research needed to support decision-making can be identified, developed and communicated effectively;
- Early indications of emerging environmental issues can be obtained;
- The research and observational capabilities of all countries, especially developing countries, can be improved.

The International Framework for Cooperation in Climate Science

U.S. scientists, the U.S. Government, and our colleagues and counterparts in other countries have developed an international framework to promote and encourage both research and observational requirements. This framework includes a series of global-scale research programs; non-governmental and intergovernmental international organizations at both the global and regional level; various networks for coordination of observing systems—both in situ and remote sensing—and data exchange and management; and organizations that focus on education, training, and capacity-building.

THE GLOBAL-SCALE INTERNATIONAL RESEARCH PROGRAMS

Within these global-scale research programs, scientists from many countries address the physics and related chemistry of global change, with a special focus on climate, through the World Climate Research Program (WCRP); the biology and chemistry and related geosciences of global change, through the International Geosphere-Biosphere Program (IGBP); the human dimensions of global change, through the International Human Dimensions Program (IHDP); and biodiversity science, through the Diversitas program.

These four programs are strengthening their cooperation through a new Earth System Science Partnership (ESSP) to promote interdisciplinary and cross-program research. IGBP, WCRP, and IHDP also co-sponsor, under the aegis of ICSU, the SysTem for Analysis, research and Training (START), which provides a framework for fostering scientific and institutional capacity, especially in developing regions of the world, for global change research. DIVERSITAS is also considering co-sponsorship of START.

These programs link to international scientific unions through the International Council for Science (ICSU) and link with ICSU committees as well, such as the Scientific Committee for Ocean Research (SCOR); the Scientific Committee on Problems of the Environment (SCOPE); and the Scientific Committee on Antarctic Research (SCAR).

The International Geosphere-Biosphere Program (IGBP)

The IGBP, with cooperation from the other three global-scale programs, is developing a series of new interdisciplinary programs that are intended to integrate research that has evolved from their initial, focused core projects. The IGBP has identified the following as key future new programs:

> **The Global Environmental Change and Food Systems (GECAFS) Program.** The program's goals are to determine how global change will affect food provision and vulnerability; how societies and producers might adapt to global change and changing demands; and what the environmental and socioeconomic consequences of such adaptations would be;

The Surface Ocean - Lower Atmosphere Study (SOLAS). The objective of SOLAS is to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere and (of) how this coupled system affects, and is affected by, climate and environmental change; and

The Global Carbon Project (GCP). Its objective is to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions, together with the interactions and feedbacks between them.

These new programs clearly are directed more towards study of the interactions of global change processes and the socioeconomic system than the more discipline-oriented initial projects. To plan, sponsor, and conduct such complex and wide-ranging research will require scientists, research institutions, and funding agencies to develop new ways to interact and cooperate at the national, regional, and global level.

Of the present IGBP core projects, U.S. scientists chair the scientific steering groups (SSGs) for the core projects on: Global Change and Terrestrial Ecosystems (GCTE), the International Global Atmospheric Chemistry Program (IGAC), and the Joint Global Ocean Flux Study (JGOFS). The United States also hosts the international project offices for IGAC and for the IGBP's Global Analysis, Integration, and Modelling Project (GAIM).

The World Climate Research Program (WCRP)

The World Climate Research Program was the first of the major international global change research programs. It was established under the sponsorship of the World Meteorological Organization (WMO) and ICSU in 1980. The Intergovernmental Oceanographic Commission (IOC) became a co-sponsor in 1993. The objectives of the program are to develop the scientific understanding of the physical climate system and climate processes in order to determine the extent to which climate can be predicted and the extent of human influence on climate. WCRP programs completed successfully include the Tropical Ocean Global Atmosphere study (TOGA) and the World Ocean Circulation Experiment (WOCE). TOGA led to a better understanding of and predictive capability for the El Nino-Southern Oscillation (ENSO) process while WOCE provided the first quantitative description of the circulation of the ocean and its variability.

The current key components of the WCRP are the study of climate variability and predictability (CLIVAR); the Global Energy and Water Cycle Experiment (GEWEX); the study of Stratospheric Processes and their Role in Climate (SPARC); and the Arctic Climate System Study (ACSYS), now being expanded into the Climate and Cryosphere Initiative (CLiC).

The Study of Climate Variability and Predictability (CLIVAR)

Key objectives of CLIVAR include:

- Describing and understanding the physical processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time-scales, through the collection and application of observations and the development and application of models of the coupled climate system; and

- Understanding and predicting the response of the climate system to increases of radiatively active trace gases and aerosols and to compare these predictions to the observed climate record in order to detect the anthropogenic modification of the natural climate signal.

The Global Energy and Water Cycle Experiment (GEWEX)

GEWEX is studying the atmospheric and thermodynamic processes that determine the global hydrological cycle and water budget and their adjustment to global changes. GEWEX is implementing a series of regional atmospheric/hydrological studies such as the GEWEX Continental-scale International Project (GCIP) involving the Mississippi River basin, the GEWEX Asian Monsoon Experiment (GAME), and the Baltic Sea Experiment (BALTEX).

The Study of Stratospheric Processes and their Role in Climate (SPARC)

SPARC addresses stratospheric indicators of climate change; stratospheric processes and their relationship with climate; and modeling stratospheric effects on climate. Recent research results suggest that stratospheric processes play a much larger role than previously thought in influencing climate variability and change, for example, in regard to one of the major natural atmospheric modes of climate variability, the Arctic Oscillation (or AO) (see Chapter 6, Question 2).

The Arctic Climate System Study (ACSYS) and the Study of Climate and Cryosphere (CliC)

The WCRP's Arctic Climate System Study (ACSYS), a study of Arctic Ocean variability that includes sea ice processes, is being broadened into CLiC, a study of the entire cryosphere and its interaction with climate change. CLiC will coordinate the cryospheric elements of WCRP projects to identify gaps in WCRP global cryospheric research and will develop cryosphere research projects to fill these gaps.

The United States plays a very strong leadership role in these and other WCRP programs. A U.S. scientist co-chairs with a German scientist the Scientific Steering Group (SSG) for CLIVAR and a U.S. scientist also chairs the SSG for GEWEX, while a Canadian scientist chairs the ACSYS SSG. Each of these programs is supported by International Project Offices (IPOs). The United States hosts the IPO for GEWEX; the UK hosts the CLIVAR Office; and the ACSYS/CLiC Office is in Norway.

The International Human Dimensions Program (IHDP)

The aims of the IHDP are to describe, analyze, and understand the human dimensions of global environmental change. IHDP's science projects address key issues of concern to human dimensions of global environmental change research. New IHDP research activities in priority areas are developed by groups of scientists, the Scientific Committee of IHDP, and/or National IHDP Committees.

IHDP research activities are guided by four overarching questions:

1. What factors determine the capacity of coupled systems to endure and produce sustainable outcomes in the face of social and biophysical change?

2. How can we recognize long-term trends in forcing functions and ensure orderly transitions when thresholds are passed?

3. How can we steer tightly coupled systems towards desired goals or away from undesired outcomes?

4. How can we stimulate social learning in the interest of managing the dynamics of tightly coupled systems?

IHDP presently includes core projects on Global Environmental Change and Human Security (GECHS); the Institutional Dimensions of Global Environmental Change (IDGEC); Industrial Transformation (IT); and Land-Use and Land-Cover Change (LUCC), co-sponsored with the IGBP. A new major focus of the IHDP is urbanization and its relationship to global change. Among the topics being considered within this focus are the relationships between cities and water and between cities and health. Sustainability of mega-cities is another.

U.S. scientists are involved substantively in the IHDP and its projects, for example, the United States hosts the IPO for the IDGEC.

Diversitas

Diversitas is the newest of the four major global-scale programs. Its aims are to improve understanding of: how biodiversity supports life on Earth; the impacts of loss of biodiversity on human and ecosystem survival; and how humans can sustainably use and conserve biodiversity. Diversitas intends to address the complex scientific questions posed by the loss of and change in biodiversity globally through establishment and coordination of international, multidisciplinary networks of scientists working on these /issues. Diversitas has identified three core projects for its initial emphasis: discovering biodiversity and predicting its changes; assessing impacts of biodiversity changes; and developing the science of conservation and sustainable use of biodiversity.

U.S. scientists played a major role in the Diversitas task force that developed the first scientific plan for the program and are actively involved in present planning and implementation of the research identified within Diversitas.

BILATERAL COOPERATION IN CLIMATE CHANGE RESEARCH AND TECHNOLOGY

The United States has strengthened its efforts to implement bilateral cooperation in climate change science and technology to complement the wide array of cooperative, climate change science programs such as those cited above. These bilateral efforts demonstrate that the United States is actively engaged with other countries in addressing climate change. Efforts are well underway with Italy, Japan, and Australia. Discussions are in progress with the People's Republic of China, the Republic of Korea, Canada, India, seven Central American countries, and the European Union. Discussions with other countries are planned.

The U.S. and Italy, in January of 2002, identified more than twenty joint climate change research activities for immediate implementation, and more topics are under consideration in the critical areas of global and regional climate modeling, atmospheric studies related to climate, carbon cycle research, low-carbon technologies, and other related areas. The climate science research activities for immediate implementation will improve the capability to understand, monitor and predict climatic variations and their impacts. In addition, the technology research activities for immediate implementation will contribute to the development of advanced low carbon technologies to limit net emissions of greenhouse gases.

Initial bilateral efforts with Japan will address: development of regional climate change prediction models; changes in the ocean environment resulting from global climate change; carbon dioxide flux observations to determine the ability and capacity of forests to fix carbon and for prediction of carbon fluctuations; and to build a partial carbon dioxide measurement network for the Pacific, utilizing voluntary observing ships for determining the spatial and temporal variability of oceanic carbon dioxide fluxes.

Cooperation with Australia is intended to enhance cooperation in research to understanding of southern hemisphere climate systems and to address key areas of climate change uncertainty. Specific areas under consideration for future cooperation include: evaluation and improvement of climate systems models to simulate climate variability and to represent processes in the climate system; interactions among radiation, aerosols, and clouds; and the roles of the Indian Ocean, the Southern Ocean, and Antarctica in climate.

INTERNATIONAL COOPERATION AMONG NATIONAL RESEARCH FUNDING AGENCIES AND IN AGRICULTURAL RESEARCH

The International Group Of Funding Agencies For Global Change Research (IGFA)

Through IGFA, national agencies that fund global change research exchange information and identify issues of mutual interest and ways to address these through national and, when appropriate, coordinated international action. Important issues now being considered by IGFA include:

- Information exchange about national global change research programs, and supporting initiatives and facilities;
- Approaches to integration and implementation of global change research;
- Optimal allocations of available resources for global change research and its international coordination;
- Infrastructure issues, including data accessibility and observation systems;
- Ways to improve interaction between science and policy; and
- The changing scope of the international research programs.

The Consultative Group on International Agricultural Research (CGIAR)

The United States is one of the largest donors to CGIAR, which sponsors sixteen 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 strategic and applied research that is intended to increase production of basic food crops and livestock; to maintain and enhance the natural resource base relating to soil, water, aquatic resources, agroforestry and forestry; to improve policies; and to strengthen national research systems in developing countries.

The individual centers also conduct social science research, and one center is devoted to food policy research. Another facilitates international programs in plant genetic resources (the CGIAR centers maintain, in aggregate, the world's largest collection of plant resources). While the emphasis is on applied research, the centers also carry out training programs and try to assist national research programs.

FOCUSED INTERNATIONAL RESEARCH PROGRAMS

International collaboration between scientists is required in order to plan and develop the focused research programs and field campaigns that are necessary to comprehensively study Earth system processes under a broad range of geophysical and biogeochemical conditions.

Scientific Ocean Drilling

The Ocean Drilling Program (ODP) contributes to improved understanding of global change through its focus on examination of earth, ocean, and climate processes.

International participation has grown from the initial five countries in the predecessor program that began in 1974 to over 20 nations today. Over 600 ocean and earth scientists have completed an internationally coordinated planning effort to examine the scientific objectives for a new phase of ocean drilling, the Integrated Ocean Drilling Program (IODP).

The initial science plan for the IODP identifies as one of the three primary objectives for initial emphasis "The Processes and Effects of Environmental Change". Ocean sediments provide a unique record of Earth's climate fluctuations and permit detection of climate signals on three time scales: tectonic (longer than 500,000 years), produced by changes in continent positions and continental seaways); orbital (20,000 to 40,000 years), produced by changes in the earth's orbit); and oceanic (hundreds to a few thousand years), produced by changes in ocean circulation). Using a global array of sites, these sediment records will 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.

The U.S. National Science Foundation (NSF) and Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan have agreed to co-lead the IODP. European countries have expressed serious interest as well and may participate as a consortium with additional support from the European Commission. Negotiations between NSF and MEXT are underway, as are discussions involving interested European countries.

Major Field Campaigns

Field campaigns are an essential element of climate science. Such campaigns can involve ships, aircraft, satellites, balloons, surface-based measurements, and laboratory studies. An especially important example is project Asian Brown Cloud (ABC). ABC is sponsored by the United Nations Environment Programme (UNEP) and will involve a wide range of scientists and institutions on the study of Asian haze and its impact on climate (especially monsoon change), water balance, agriculture, and human health, among others. It is expected that satellite observations will be augmented by a network of ground-based observing systems to provide critical inputs for models and thus to enhance their predictive capabilities. The project will also promote capacity building by providing opportunities for scientists and students from the region to participate in research; by facilitating training; and promoting development of several regional centers (e.g., for climate modeling, regional training and data integration).

The Global Observation of Forest and Land Cover Dynamics program (GOFC-GOLD) is an international effort to provide accurate, reliable, quantitative space-based and in situ observations of forests and other vegetation cover for sustainable development of terrestrial resources. This program also contributes to improving understanding of the terrestrial carbon budget. Potential users include global change researchers, international conventions (such as the Framework Convention on Climate Change). One of the most important challenges facing GOFC-GOLD is to develop method and implement systems that provide both research and operational information on a regular sustained basis.

In another major field effort the NSF and National Oceanographic and Atmospheric Administration (NOAA) are cooperating with several international partners, as part of their support of CLIVAR and Integrated Carbon Cycle Research activities, to support a fifteen-year program starting in 2003 to make repeat hydrographic and carbon system measurements along a number of sections that were previously occupied under WOCE and the Joint Global Ocean Flux Study (JGOFS).

INTERNATIONAL COOPERATION IN REMOTE SENSING

From the remote sensing perspective, development of collaborative, international, ground-based networks requires the presence of instruments on the ground, their maintenance, and assurance of calibration relative to widely recognized standards that can only be carried out through collaboration among scientists from all nations. Such ground-based observations also form an important link for the calibration and validation of satellite data that are obtained by the space agencies that constitute the Committee of Earth Observing Satellites (CEOS).

The Committee on Earth Observing Satellites (CEOS)

CEOS coordinates civil spaceborne observations of the Earth. Participating agencies strive to address critical scientific questions and to harmonize satellite mission planning to address gaps and overlaps. The three primary objectives of CEOS are:

1. To optimize benefits of spaceborne Earth observations through cooperation of its members in mission planning and in development of compatible data products, formats, services, applications, and policies;

2. To serve as a focal point for international coordination of space-related Earth observation activities; and

3. To exchange policy and technical information to encourage complimentarity and compatibility of observation and data exchange systems. NOAA will Chair CEOS from November 2002 through November 2003.

Focused Cooperation in Remote Sensing Systems

The United States is involved in numerous significant partnerships with other nations to develop and implement climate-related satellite programs. For example, NOAA and EUMETSAT are collaborating under the Initial Joint Polar System (IJPS) agreement and further cooperation as partners in the U.S. National Polar-Orbiting Environmental Satellite System (NPOESS) is under discussion.

The development of an operational altimetry program between the U.S. and Europe has led to letters of intent among CNES, EUMETSAT, NASA, and NOAA for pursuit of Jason-2/Ocean Surface Topography Mission (OSTM) collaboration. Jason-2/OSTM, when launched, will represent the transition of ocean altimetry from research to operations.

Other examples of recent cooperation in remote sensing include the following:

- French partnership with the United States was vital to the success of the TOPEX/POSEIDON mission over the past 10 years to measure ocean topography;

- Japan provided satellite and launch for the U.S. ocean surface wind instruments (NSCAT on ADEOS I and SeaWinds on ADEOS II) and the precipitation radar and launch for the very successful Tropical Rainfall Measuring Mission;

- Japan also is providing the Advanced Microwave Sounding Radiometer (AMSR-E) on NASA's Earth Observing System (EOS) Aqua satellite mission;

- Brazil contributed the HSB atmospheric sounding instrument on Aqua;

- Canada has provided the MOPITT instrument on the EOS Terra satellite; and

- German partnership was key to the successful recent launch of the GRACE satellite to measure time variations in the Earth's gravity field.

These partnerships not only make a fundamental contribution to the mission flight success, but also have substantially broadened the science and end-user communities for climate-related satellite observations.

In addition, the University Corporation for Atmospheric Research (UCAR) and a number of U.S universities are working closely with Taiwan's National Space Program Office (NSPO) to develop the COSMIC program. COSMIC is a follow-on to the Global Positioning System/Meteorology System (GPS/MET) which demonstrated atmospheric limb sounding from low-earth-orbit (LEO) with high vertical resolution, high accuracy, and global coverage in all weather. COSMIC, the "Constellation Observing System for Meteorology, Ionosphere and Climate), will provide valuable information for weather and climate research, space weather and geodetic science. Plans provide for launching six LEO satellites in 2005, each of which retrieve about 500 profiles daily of key ionospheric and atmospheric properties from the tracked GPS radio signals as they are occulted behind the Earth limb. COSMIC will provide high vertical resolution temperature, pressure and water vapor information for a variety of atmospheric process studies and improve the forecast accuracy of numerical weather prediction measurements.

COOPERATION IN *IN SITU* OBSERVATIONAL SYSTEMS AND DATA EXCHANGE

Intergovernmental Coordination through United Nations Agencies and their Partners

Five components of the United Nations provide fora in which the United States interacts with other countries to identify and address issues related to global change that require review and action at the intergovernmental level. These agencies are the World Meteorological Organization (WMO), UNESCO and its Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Program (UNEP), and the Food and Agriculture Organization (FAO). Among other things, these agencies are involved in sponsorship of a number of the key scientific bodies involved in international cooperation in global change research, e.g., the World Climate Research Program. They also sponsor and oversee coordination of many of the observational systems that support global change research, including the Global Climate Observation System (GCOS), Global Ocean Observation System (GOOS), and the Global Terrestrial Observation System (GTOS).

Of special note, the WMO and the IOC have established a new Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) to which the two organizations have entrusted development, maintenance, coordination, and guidance of the operation of their global marine meteorological and oceanographic observing systems to meet the needs of, among others, WMO and IOC programs, in particular the Global Ocean and Climate Observing Systems (GOOS and GCOS) and the World Weather Watch (WWW). JCOMM will also assist WMO and IOC developing member states to enhance their capacity to participate in and benefit from WMO and IOC marine meteorological and oceanographic programs. JCOMM will also work closely with the data management bodies of IOC, ICSU, and WMO to provide for comprehensive data sets (comprising both real-time and delayed-mode data) to meet the needs of secondary users of the data for future long-term studies.

The WMO and the IOC also are responsible for international cooperation in many areas of meteorological and oceanographic data exchange. The U.S. very actively advocates, in these agencies and in their appropriate subsidiary bodies, maintaining the full and open international exchange of scientific data needed for global change research.

National agencies that fund global observing systems, including earth satellite remote sensing systems and ground-based observing systems, coordinate their efforts with counterpart agencies in other countries through a number of organizations and networks. These include CEOS discussed above and the Integrated Global Observing Strategy Partnership (IGOS-P), one purpose of which is to help integrate the observational strategies of the GCOS, GOOS, and GTOS.

The Integrated Global Observing Strategy Partnership (IGOS-P)

IGOS-P brings together the efforts of a number of international bodies concerned with the observational component of global environmental issues, both from a research and a long-term operational program perspective. The IGOS-P members include the WMO, UNESCO and IOC, UNEP, ICSU, and the FAO. NOAA will co-chair IGOS during the same period it chairs CEOS. The principal objectives of the IGOS-P are to address how well user requirements are being met by the existing mix of observations, including those of the global observing systems, and how they could be met in the future through better integration and optimization of remote sensing (especially space-based) and in situ systems. Identification of priorities has begun in the following areas: oceans, integrated carbon cycle, global water cycle, atmospheric chemistry, geohazards, and coral reefs.

The three observation system programs for climate, oceans, and terrains are known collectively as G3OS. GCOS was established to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modeling and prediction of the climate system.

GOOS is a permanent global system for observations, modeling and analysis of marine and ocean variables to support operational ocean services worldwide. The objectives of GOOS are (1) to specify the marine observational data required to meet the needs of users of the oceanic environment; (2) to develop and implement an internationally coordinated strategy for the gathering, acquisition and exchange of these data; and (3) to facilitate means by which less-developed nations can increase their capacity to acquire and use marine data.

GTOS is a program for observations, modeling, and analysis of terrestrial ecosystems to support sustainable development. GTOS facilitates access to information on terrestrial ecosystems so that researchers and policy makers can detect and manage global and regional environmental change. GTOS promotes international networking for this purpose and develops regional programs and coordinates demonstration projects.

The Argo Program

The United States has taken a lead in and expects to continue development and implementation of a broad-scale global array of temperature/salinity (T/S) profiling floats, known as Argo, which is planned as a major component of the ocean observing system. Conceptually, Argo builds on the existing upper-ocean thermal observation networks, extending their spatial and temporal coverage, depth range, and accuracy and enhancing them through addition of salinity and velocity measurements. For the first

time, the physical state of the upper ocean will be systematically measured and assimilated in near real-time.

Objectives of Argo include providing a quantitative description of the evolving state of the upper ocean and patterns of ocean climate variability, including heat and freshwater storage and transport. Argo data will be used for initialization of ocean and coupled forecast models, data assimilation, and dynamical model testing. A primary focus of Argo is seasonal to decadal climate variability and predictability, but a wide range of applications for high-quality global ocean analyses is anticipated.

Argo will provide 100,000 T/S profiles and reference velocity measurements per year from about 3000 floats distributed over the global oceans at three-degree spacing. Floats will cycle to 2000 m depth every ten days, with a four- to five-year lifetime for individual instruments. All Argo data will be publicly available in near real-time via the GTS, and in scientifically quality-controlled form with a few months delay. Global coverage should be achieved during the Global Ocean Data Assimilation Experiment (GODAE), which together with CLIVAR and GCOS/GOOS provide the major scientific and operational impetus for Argo. The U.S. has now deployed around 600 active Argo floats.

International planning for Argo is provided by an Argo Science Team. Nations presently having Argo plans that include float procurement or production include Australia, Canada, France, Japan, the UK, and the U.S.; the European Union may become involved as well. Combined deployments from these nations are expected to exceed 700 floats per year by 2002.

THE GLOBAL ENVIRONMENT FACILITY (GEF)

Established in 1991, the GEF funds projects that promote clean and efficient energy use (including reduction of greenhouse gases), conserve biodiversity, clean up international waters and phase out ozone-depleting chemicals. New focal areas will help combat problems caused by persistent organic pollutants and fight land degradation with a focus on desertification and deforestation in some of the world's poorest countries. During the last decade, the GEF has provided support for more than 270 climate change projects in 120 countries for a sum of about $1 billion, with an additional $5 billion expected in co-financing. The United States is the largest contributor to the GEF. The Bush Administration in 2002 pledged $500 million over the next four years for the GEF. The commitment is a 16 percent increase over the U.S. contribution to the previous replenishment. The 2002 U.S. pledge includes $107.5 million per year for each of the four years of the replenishment period, plus another $70 million in the fourth year if the GEF meets a set of performance measurements agreed by donors. In addition, the Administration is requesting $70.3 million from Congress annually for the next three years to pay off U.S. arrears accumulated during the previous replenishment period.

REGIONAL COOPERATION IN GLOBAL CHANGE RESEARCH

In addition to the global-scale climate change research and observational programs described above, the U.S. also promotes and encourages a wide range of regional global

change research and observational efforts. Most importantly, President George H. W. Bush hosted in April, 1990, the Conference on Scientific and Environmental Research Related to Global Change at which the United States proposed—and the Conference agreed—to establish hemisphere-scale regional global change research networks. The first of these, the Inter-American Institute for Global Change Research (IAI) was established in 1992 and the Asia-Pacific Network for Global Change Research (APN). The Asia Pacific Network for Global Change Research (APN) was established in 1996.

The Inter-American Institute for Global Change Research (IAI)

The mission of the IAI is to develop the capacity to understand the integrated impacts of present and future global change on regional and continental environments in the Americas and to promote collaborative research and informed action at all levels.

The IAI has an evolving Scientific Agenda identifying priority areas for research, many of which complement the research priorities of the U.S. Climate Change Research Initiative. The IAI's emphasis on extremely high quality multidisciplinary projects and its robust merit-based peer-review system have resulted in their support of over 200 research projects, workshops, training exercises, and scholarships since 1995. The research has in turn yielded hundreds of publications in the peer-reviewed literature. The IAI's network of over 100 research institutions in the hemisphere is an example looked to by other regions. Research directly supported by the IAI has led to new management methods for hydropower complexes, better planning for public health campaigns, improvement in sugarcane crop forecasts, reallocation of funds for crop insurance, and other scientific and human capital improvements in the region.

The IAI structure enables U.S. researchers to work effectively with their counterparts throughout the Americas, and cooperation with local organizations allows comparative research to be carried out on a scale not previously possible. For example, a cooperative of Argentine farmers has recently agreed to share all of its data with a team of climatologists, agronomists, soil scientists, economists, and sociologists who now will be able to study the complicated set of variables that influence decisions on farms ranging from small plots to highly mechanized operations and to make direct comparisons and forecasts about possible impacts of climate change on agribusiness.

The Asia-Pacific Network for Global Change Research (APN)

The APN has as its primary purposes to foster global environmental change research in the Asia-Pacific region; to increase developing country participation in such research; and to strengthen links between the scientific community and policy makers. The APN brings together 21 countries of the region and supports research on change in complex climate, ocean, and terrestrial systems and on the related physical, chemical, biological,

and socio-economic processes. APN is presently focusing its research effort on changes in coastal zones and inland waters; climate change and variability; changes in atmospheric composition; and changes in terrestrial ecosystems and biodiversity.

The APN will sponsor a series of workshops in 2003 that are indicative of the scientific range and geographic scope of its activities. These workshops will address global change impact assessment for the Himalayan mountain region and its relationship to sustainable development; water resources in South Asia and their vulnerability to climate change; intercomparison of regional climate models for Asia; and biodiversity and sustainable livelihoods of uplands in Southeast Asia.

Asian Networks for Climate Information and Decision Support

In Southeast Asia, NOAA is focusing on development of end-to-end networks for climate information and decision support through applications development and implementation. Regional partners involve the Asian Disaster Preparedness Center (ADPC) and the ASEAN Specialized Meteorology Center (ASMC); international partners include the WMO and the IRI. Similar network-building activities occur in the Pacific Islands, with key regional players including the Pacific ENSO Applications Center (PEAC), the East-West Center, the South Pacific Commission (SOPAC), and the South Pacific Regional Environmental Program (SPREP). NOAA/OGP is also developing a program of activities in conjunction with the IRI and the National Center for Atmospheric Research (NCAR) in Central Asia.

The Northern Eurasia Earth Science Partnership Initiative (NEESPI)

NEESPI is a planning strategy that has the goal of establishing a large-scale, interdisciplinary program of funded research aimed at developing a better understanding of the interactions between the ecosystem, atmosphere, and human dynamics in northern Eurasia in support of international science programs with particular relevance to U.S. global climate change research, as well as the concerns that face national and international decision-makers of the partnering countries.

Regional Cooperation In Global Change Research In Africa

The United States also supports regional cooperative efforts in Africa, for example, collaborative research with West African nations on the sequestration of atmospheric carbon dioxide as soil organic matter. Results of the research are expected to enable farming communities to reverse land degradation and increase agricultural productivity while simultaneously reducing greenhouse gas levels in the atmosphere.

In Africa, the SysTem for Analysis, Research, and Training (START) has established a Pan-African START Regional Committee (PACOM). START and PACOM are involved in designing and implementing regional cooperative research in such areas as climate variability and climate change; water and food security; and land use change, ecosystems,

and biodiversity. Regional networks directed at GOFC-GOLD objectives have also been established in Central Africa and the Miombo region in southern Africa.

Another example is the Famine Early Warning System Network (FEWS NET) to provide decision-makers with the information to effectively respond to drought and food insecurity in Africa. FEWS NET analyzes remote sensing data and ground-based meteorological, crop, and range-land observations to track progress of rainy seasons in semi-arid regions of Africa to identify early indications of potential famine. In addition to using data produced by host governments for its analyses, FEWS NET uses data from satellite imagery (NDVI or "Greenness" images and Meteosat/Rainfall Estimation images) that it receives every ten days throughout the year. FEWS NET draws from databases of rainfall, cereal prices, agricultural production, and population/census data. Geographic Information Systems (GIS) are used to conduct spatial analyses of available data, which are included in the System's regular reporting.

BROADLY-BASED COOPERATION WITH DEVELOPING COUNTRIES IN GLOBAL CHANGE RESEARCH

The U.S. hosts two organizations that promote research and capacity-building in and/or related to many regions of the world, especially those where research and related capabilities are limited. These organizations are the SysTem for Analysis, Research, and Training (START) and the International Research Institute for Climate Prediction (IRI).

The SysTem for Analysis, Research, and Training (START)

The START program that was cited earlier is an international non-governmental organization under the aegis of ICSU. The International START Secretariat is hosted by the U.S. at the American Geophysical Union in Washington, D.C. START's purpose is to build capacity in developing countries to conduct research on global environmental change and the challenges these changes pose for human health, agriculture, water, and food security and to apply the results of such research in decision-making. START has ongoing activities in Africa, Asia, and Central/South America. START also collaborates with multilateral international organizations (IAI, APN, and IPCC). START has identified a number of challenges that it intends to address in the future. These include:

- Moving beyond thematic/sectoral studies toward integrated regional studies that couple biophysical and human components, and coordinate observations, modeling, and process studies that address the two-way linkages between regional- and global-scale change;
- Learning more about biophysical impacts of urbanization (including the rise of megacities) and effects of alternative development pathways on the carbon cycle;
- Developing a second-generation approach to impact assessment, with emphasis on vulnerabilities and on risks posed by combined regional and global environmental change, that employs methods of risk assessment to better link science to policy formulation; and

- Finally, accelerating efforts to increase research-driven capacity building and research partnerships between science communities in the developed and developing worlds.

The International Research Institute for Climate Prediction (IRI)

The IRI is an innovative scientific institution working to accelerate the ability of societies worldwide to cope with climate fluctuations, especially those that cause devastating impacts on humans and the environment, thereby reaping the benefits of decades of research on the predictability of the El Nino-Southern Oscillation phenomenon and climate variations.

The IRI recognizes that the benefits of climate predictions arise from the application of those predictions and not simply from their production. Thus, IRI research on climate prediction is strongly coupled with research on applications science and is supported by IRI's interactions with partners across the diverse worlds of prediction science and applications science, sector groups, other producers and consumers of climate information.

Private foundation seed monies have supported efforts to explore how specific sectors and populations might better utilize climate prediction information. These activities have contributed to involvement of the IRI in major application projects. The IRI provides guidance and leadership in training, climate fora, and numerous other outreach activities around the world.

INTERNATIONAL COOPERATION ON GLOBAL CHANGE RESEARCH IN POLAR REGIONS

The United States also actively promotes global change research in the Antarctic and Arctic, the former through cooperation with other parties to the Antarctic Treaty and Scientific Committee on Antarctic Research (SCAR); and the latter through the International Arctic Sciences Committee (IASC) and the Arctic Ocean Sciences Board (AOSB).

The Antarctic

The United States has undertaken cooperative research with all of the other 34 countries that are consultative nations to the Antarctic Treaty. This research includes large-scale science projects such as deep rock core drilling and glaciological exploration. SCAR promotes research in Antarctica and is presently active in the following areas: Antarctic climate evolution; Antarctic sea-ice processes and climate; Antarctic tropospheric aerosols and their role in climate; and evolution and biodiversity in Antarctica.

Study of the West Antarctic Ice Sheet (WAIS)

An important subject of Antarctic research related to climate change is the study of the West Antarctic Ice Sheet (WAIS), the only remaining marine ice sheet from the last glacial period. It has been hypothesized that this ice sheet may be susceptible to run-away grounding line retreat, leading to rapid disintegration and sea level rise. The Amundsen Sea Embayment (Pine Island Bay/Thwaites Glacier area) is the only major West Antarctic drainage not buttressed by a large ice shelf and thus is the drainage most likely to participate in a collapse.

Recent observations using interferometric SAR and repeat satellite altimetry show a speed-up, thinning, and grounding-line retreat of ice flowing into Pine Island Bay. Model studies focused on this drainage are needed to assess the possibility that the ongoing thinning will lead to retreat from a prominent bedrock sill, which in turn might trigger major changes in the ice sheet, contributing to sea level rise.

U.S. scientists and their counterparts in other countries will cooperate to establish the mass balance and ice dynamic regime of the Pine Island/Thwaites drainage system of the West Antarctic ice sheet. To do so, the network of automatic weather stations over the West Antarctic ice sheet will have to be expanded to include the Pine Island/Thwaites ice drainage system. A program of mass balance studies and ice dynamics measurements will also be established.

Research will be undertaken to quantify the boundary conditions of the Pine Island/Thwaites drainage system in a fashion suitable for three-dimensional ice sheet modeling and atmosphere/ocean/ice models will be developed to assess the likely stability of this part of the ice sheet. To support these efforts geophysical data will be collected to provide a better picture of subglacial topography, using airborne remote sensing techniques. These data will provide input for a new generation of coupled ice sheet-ocean-atmosphere models. In addition, aerogeophysics is expected to produce information about the nature of the sub ice-sheet materials (e.g., bedrock or sediments) that is important to models of ice streaming.

The Arctic

The International Arctic Science Committee (IASC) encourages and facilitates cooperation in all aspects of Arctic research and encourages, in particular, cooperation and integration of human, social and natural sciences concerned with the Arctic. Present IASC programs relevant to climate include studies of Arctic coastal dynamics; contaminants and human health; mass balance of Arctic glaciers and ice sheets in relation to climate and sea level change; the tundra-taiga interface; and sustainable use of living marine resources.

The Arctic Ocean Sciences Board (AOSB) has the long-term mission of facilitating Arctic Ocean research through the support of multinational and multidisciplinary science programs. Current AOSB programs include the Arctic Paleo-River Discharge program

(APARD); the International Arctic Polynya Program (IAPP); and the Shelf-Basin Interactions Program (SBI). The AOSB has also actively promoted the Arctic Sub-Arctic Ocean Flux Study (ASOF) and is encouraging a series of wide international discussions of the interactions between climate and sea ice in the Arctic.

The scientific programs of both the IASC and AOSB also contribute to the Arctic Climate Impact Assessment (ACIA) that is intended to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences for the Arctic. This Assessment is scheduled to be completed in 2004.

The Arctic and Subarctic Ocean Flux Study

ASOF aims to monitor and understand the oceanic fluxes of heat, salt, and freshwater at high northern latitudes and their effect on global ocean circulation. The flows of water into and out of the Arctic Ocean and Nordic Seas play a major role in the global thermohaline circulation, including the Gulf Stream, that keeps northwest Europe warmer than other maritime regions at similar latitudes. Some theories and observations suggest that climate change could lead to changes in fluxes around the Arctic Ocean that could result in weakening or even shutdown of the thermohaline circulation in this region. However, factors influencing the thermohaline circulation in the Arctic and Subarctic regions are poorly understood, in large part because these regions are poorly monitored.

ASOF scientists in a number of countries bordering the Arctic and North Atlantic are working together to define the system of critical measurements that will be needed to understand the role of the high-latitude oceans in climate variability over decadal to centennial time scales. ASOF then plans to develop an ocean flux observing system that would be deployed on a coordinated basis across the Arctic to provide the databases needed to better understand the overall role of the Arctic in abrupt climate change.

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.

Climate modeling capabilities have improved dramatically in recent years and can be expected to continue to do so. To continue to improve such modeling 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 regions include remote regions, especially those with harsh environments, and areas where existing capabilities to make observations and collect data are limited, such as oceanic and interior land areas of the Southern Hemisphere and of both polar regions.

THE PRESIDENT'S INITIATIVE

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;
- Fully fund the Global Environmental Facility (GEF);
- Support transfer of energy and sequestration technologies to developing countries to promote sustainable development while limiting their greenhouse gas emissions growth;
- Expand cooperation in climate change research and technology with a number of key countries and regional organizations; and
- Work with the IAI and other institutions to better understand regional aspects of climate change.

To complement these efforts, the Climate Change Science Program intends to:

- Continue to encourage and provide leadership for ongoing international cooperation in climate change research and observational programs, especially the four major international global change research programs (the IGBP, WCRP, IHDP and Diversitas) and the IGOS Partnership (IGOS-P);
- Work closely with the international global change research programs to promote effective transition of a number of their present focused programs to cross-cutting programs (such as the Global Environmental Change and Food Security Program (GECAFS)) that are intended to relate global change research more directly to major societal and economic factors.
- Encourage expanded cooperation in biodiversity research, especially though the Diversitas program;
- Promote further development and expansion of, as well as identification of requirements for, global observing systems (such as the GCOS, GOOS, and GTOS) and the Argo program for ocean observations, through greater incorporation of user requirements and further multilateral and bilateral cooperative efforts analogous to those already initiated;
- Encourage expanded regional cooperation in climate change science, especially in Africa, working in cooperation with ICSU, the Third World Academy of Science (TWAS), and START, possibly leading to a hemisphere-scale regional network for global change research in Africa; and
- Enhance efforts to bring science and technology to bear on increasingly complex planning challenges of natural resource management.