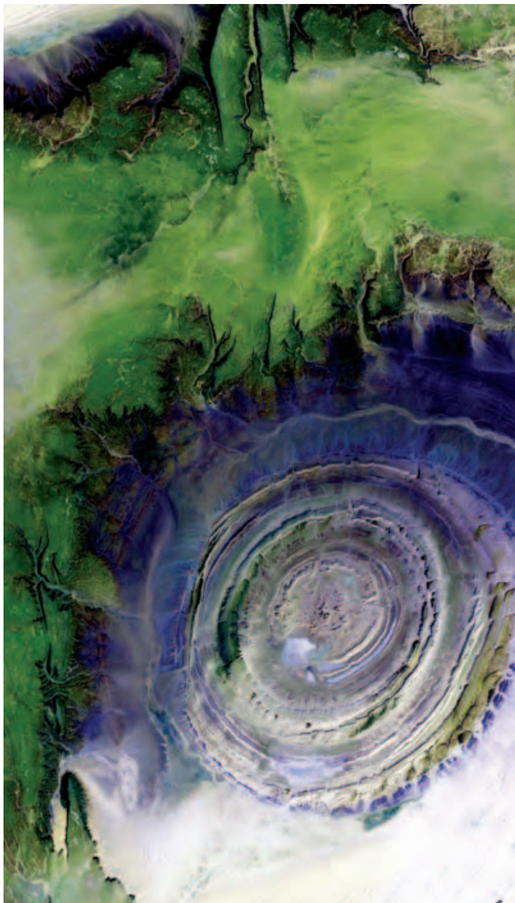


8 | Observing and Monitoring the Climate System

Observing and Monitoring the Climate System

Goal 12.1: Design, develop, deploy, and integrate observation components into a comprehensive system.
Goal 12.2: Accelerate the development and deployment of observing and monitoring elements needed for decision support.
Goal 12.3: Provide stewardship of the observing system.
Goal 12.4: Integrate modeling activities with the observing system.
Goal 12.5: Foster international cooperation to develop a complete global observing system.
Goal 12.6: Manage the observing system with an effective interagency structure.

Data Management and Information

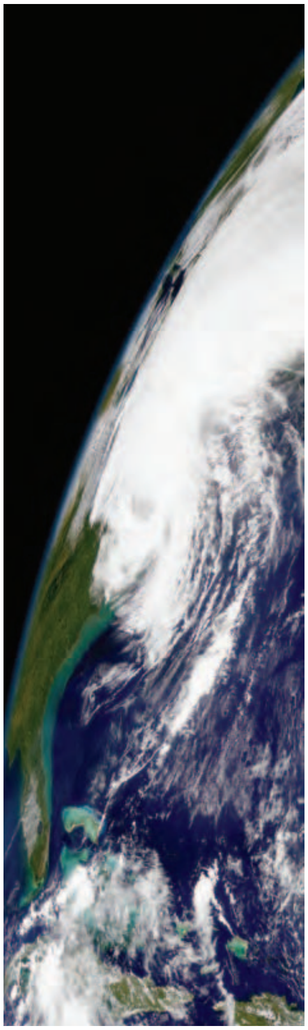
Goal 13.1: Collect and manage data in multiple locations.
Goal 13.2: Enable users to discover and access data and information via the Internet.
Goal 13.3: Develop integrated information data products for scientists and decisionmakers.
Goal 13.4: Preserve data.

See Chapters 12 and 13 of the *Strategic Plan for the U.S. Climate Change Science Program* for detailed discussion of these goals.

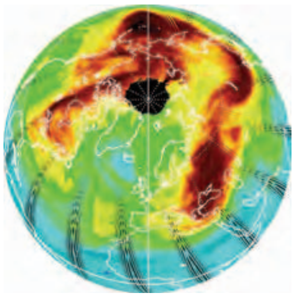
The CCSP Strategic Plan identifies two overarching questions for "Observing and Monitoring the Climate System" (Chapter 12) and "Data Management and Information" (Chapter 13):

- How can we provide active stewardship for an observation system that will document the evolving state of the climate system, allow for improved understanding of its changes, and contribute to improved predictive capability for society?
- How can we provide seamless, platform-independent, timely, and open access to integrated data, products, information, and tools with sufficient accuracy and precision to address climate and associated global changes?

The United States is contributing to the development and operation of several global observing systems that collectively attempt to combine data streams from both research and operational observing platforms to provide a comprehensive measure of climate system variability and climate change processes. These systems provide a baseline Earth-observing system and include NASA, NOAA, and USGS Earth-observing satellites and extensive *in situ* observational capabilities. U.S. observational and monitoring activities contribute significantly to several international observing systems including the Global Climate Observing System principally sponsored by the World Meteorological Organization (WMO); the Global Ocean Observing System sponsored by the United Nations Educational, Scientific and Cultural Organization's Intergovernmental Oceanographic Commission; and the Global Terrestrial Observing System sponsored by the United Nations Food and Agriculture Organization. The latter two have climate-related elements being developed jointly with the Global Climate Observing System.

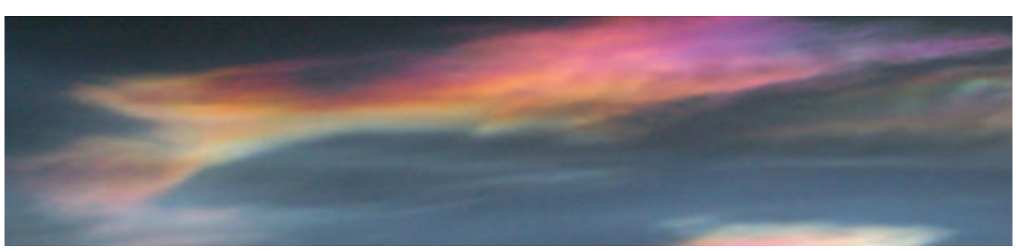


The United States is also playing an important role in the Global Earth Observation System of Systems (GEOSS), which is an international framework for coordinating and sustaining the aforementioned (and other) systems. Information from GEOSS is expected to revolutionize understanding of the Earth and how Earth observations may benefit society. A 10-year implementation plan for GEOSS was adopted in February 2005 by nearly 60 countries, including the United States (see <earthobservations.org> for a copy of this plan, as well as other information on GEOSS). The United States Group on Earth Observations (USGEO) has drafted a strategic plan for integrated Earth observations, which contributes directly to GEOSS. CCSP coordinates USGEO's climate and global change-related activities. USGEO is focusing on the following areas, many of which are directly or indirectly related to CCSP: understanding, assessing, predicting, mitigating, and adapting to climate variability and change; weather forecasting; reducing loss of life and property from disasters; protecting and monitoring ocean resources; supporting sustainable agriculture and combating land degradation; understanding the effect of environmental factors on human health and well-being; developing the capacity to make ecological forecasts; protecting and monitoring water resources; and monitoring and managing energy resources.



A critical challenge is to maintain existing observing capabilities in areas of importance to CCSP. For example, maintenance of the observational record of stratospheric ozone is essential to discern the nature and timing of expected ozone recovery. Other key variables requiring maintenance include radiative energy fluxes of the Sun and Earth, atmospheric carbon dioxide (CO_2) concentration, and global surface temperature. The long-term record of global land cover begun by Landsat-1 in 1972 and continued into 2003 by Landsat-7, ended with a mechanical failure in Landsat-7 on 31 May 2003. While Landsat-7 data are still being collected, 20% of the data contain holes and are not useable for scientific study. While scientists are looking to use other U.S. and international satellite instruments to provide interim land-cover data, a recognized need exists to ensure the continuing availability of high-quality land-cover measurements into the future. The details of an observing strategy to meet this requirement are under serious discussion now within the U.S. Government. The record of precipitation that has in recent years been extended to include oceanic as well as land areas using measurements from the Tropical Rainfall Measuring Mission (TRMM) is clearly a key climate data set that needs to be maintained and extended. These few examples of key climate variables are essential elements of the comprehensive observing system needed to monitor changes in the cycles of carbon, energy, water, and related biogeochemical processes that drive Earth's climate. Since the value of existing climate data sets greatly increases as the record is extended in time, it is imperative that existing observing capabilities be maintained and improved, while at the same time incorporating new requirements.

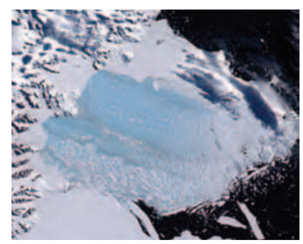
One of the priorities for observations and monitoring in FY 2006 is to further define the U.S. role in GEOSS, including the development of an information management system to help integrate the system's distributed resources. Another priority is to enhance observational capabilities in polar regions, both through remote sensing and *in situ* approaches. Observations of aerosols, including the Atmospheric Brown Cloud project (described in this chapter) and approaches outlined in the "Atmospheric Composition" chapter of this report, are also a priority. Improving understanding of the carbon cycle, which CCSP has identified as a near-term priority, will be facilitated by enhanced observations in FY 2006 and beyond. A longer list of some of the planned observational and monitoring activities is provided in the latter portion of this



chapter. Data management and distribution activities, including those mentioned in the box on "Systems for Data Management and Distribution," will play a key role in making accessible the information necessary to fulfill CCSP's mission to provide the "Nation and the global community with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems."

Many measurement and monitoring technologies and derived data systems benefit from the ongoing research and development under the aegis of CCSP, and from other Earth observation activities that are currently underway. All such measurement and monitoring systems constitute an important component of and complement to the measurement and monitoring research and development portfolio of the Climate Change Technology Program (CCTP). For additional information on CCTP measurement and monitoring research and development activities, see <www.climatetechnology.gov>.

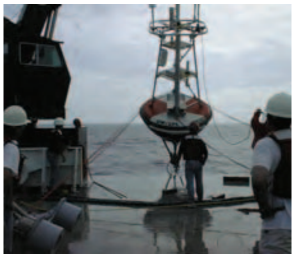
HIGHLIGHTS OF RECENT ACTIVITIES AND ACCOMPLISHMENTS



The following are selected highlights of observations and monitoring activities supported by CCSP participating agencies. The principal focus of this chapter is on describing progress in implementing the observations that contribute to the CCSP mission. As a result, the chapter touches on some observing systems that are crucial to CCSP but are not included within the CCSP budget because they primarily serve other purposes.

Observations and Monitoring

Global Climate Observing System (GCOS). GCOS integrates global networks placed strategically across the atmospheric, oceanic, and terrestrial domains, permitting better understanding of climate variability and change. In recent years, GCOS has accomplished a number of positive actions on international, regional, and bilateral levels that have led to success in improving climate observations worldwide. A number of workshops have been held in developing nations, highlighting the importance of GCOS observations. These workshops have resulted in a series of regional action plans that will help guide observational improvements in these regions. Spearheaded by the United States, a GCOS Cooperation Mechanism has been established to leverage the resources of developed nations to ensure that dormant GCOS network stations begin to be retrofitted. This will facilitate the collection of valuable surface and upper air data used in climate studies (see, e.g., CCSP Synthesis and Assessment Product 1.1, which is briefly described in the "Climate Variability and Change" chapter.).



Key ocean observations are being made by the United States that are important to both science and society. They include sea level observations, measured using tide gauge stations and satellite observations; ocean carbon sources and sinks; ocean storage and global transport of heat and fresh water; and exchange of heat and fresh water between the ocean and atmosphere. To collect data on these variables, it is necessary to enhance the *in situ* component of the global ocean observing system, including an array of sensors situated across the global oceans. The number of instruments being deployed in the oceanic observing networks is increasing steadily.

The United States has a three-tiered approach to *in situ* land-surface climate observations. In the first tier, a few sites, such as the Atmospheric Radiation Program sites, are heavily instrumented, providing a vast array of high-quality, frequent observations of virtually all key variables measurable from the surface. The second tier, known as the Climate Reference Network (CRN), will include more than 100 sites that make long-term, homogeneous observations of temperature and precipitation (and a few other variables) that can be coupled to long-term historical observations for the detection and attribution of present and future climate change. The third tier, which provides greater spatial coverage than the CRN, is composed of more than 1,000 stations in the existing Historical Climatology Network, selected based on homogeneity and quality standards. This tiered approach provides the spatial coverage necessary to detect regional climate variability and change, as well as the quality controls necessary to ensure that the observations are as bias-free as possible. U.S. contributions to GCOS also include ecosystem, hydrosphere, cryosphere, and atmospheric composition measurements.

Atmospheric Brown Cloud Project. Satellite data reveal thick, polluted layers of haze scattered all over the globe. From populated regions to the once pristine Pacific and Atlantic Oceans, atmospheric brown clouds (visible areas of brown-colored atmosphere) form across the United States, southern Europe, the Amazon, southern Africa, and most of Southeast Asia. Through observations and analyses of atmospheric brown clouds, scientists can learn how dust and pollution particles are transported and what their impacts are on the environment, climate, agricultural cycles, and quality of life. The aim of the Atmospheric Brown Cloud (ABC) project is to integrate air pollution and climate science, using observations (see Figure 25) and impacts modeling and assessment, in order to enhance the scientific basis for informed decisionmaking. ABC is focusing initially on the Indo-Asian and Pacific regions. A primary thrust of ABC is to assess the impact of air pollution and greenhouse gases on the Asian monsoon, which brings much needed rainfall to over 3 billion people in this region.

The ABC project was initiated in 2003 as a long-term multinational effort being carried out under the auspices of the United Nations Environment Programme and the WMO. DOE, NASA, and NOAA support the U.S. component of the project, with participation by several universities. Global Atmosphere Watch, the atmospheric chemistry component of GCOS, will provide observing stations to be used as platforms for the measurement of aerosols and atmospheric chemical composition. The first new observatory was established in the Republic of the Maldives in October 2004 (see <www-abc-asia.ucsd.edu>). An intensive field observation test period as part of an ABC campaign at Gosan, Korea, was carried out in March 2005.

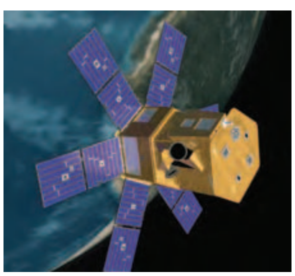
Polar Observations: ICESat. Polar systems may be especially sensitive to climate change and might provide early indications of climate change. They also interact with climate variability and change through several important feedback processes. Monitoring polar climate and understanding its feedbacks are key priorities described in the *CCSP Strategic Plan*. CCSP supports the creation of systematic data sets for parameters such as sea-ice thickness, extent, and concentration; land-ice and snow-cover mass balance; and surface temperature. Impacts of changes in these and other variables were highlighted in the 2004 Overview report of the Arctic Climate Impact Assessment, *Impacts of a Warming Arctic*.

ABC Observatories

Figure 25: Atmospheric Brown Cloud (ABC) Network. Map of operational and planned observatories that comprise the Atmospheric Brown Cloud (ABC) network, May 2005. *Credit: V. Ramanathan, Scripps Institution of Oceanography.*

Significant contributions are being made to CCSP's polar observations by NASA's Ice, Cloud, and Land Elevation Satellite (ICESat), launched in 2003 (see <icesat.gsfc.nasa.gov>). ICESat measures surface elevations of ice and land, vertical distributions of clouds and aerosols, vegetation canopy heights, and other features with unprecedented accuracy and sensitivity. The primary purpose of ICESat has been to acquire time series of ice-sheet elevation changes for determination of the present-day mass balance of the ice sheets, study of associations between observed ice changes and polar climate, and improvement of estimates of the present and future contributions to global sea-level rise. ICESat has achieved remarkable successes with a number of first-of-their-kind observations. Among these are:

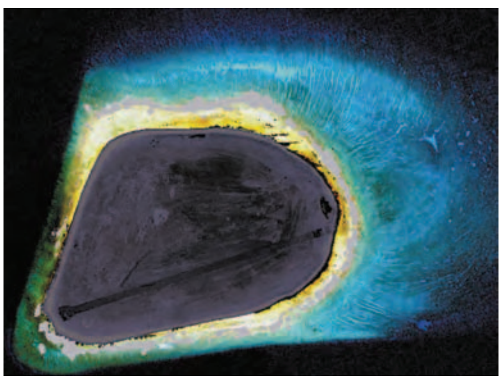
- The most accurate elevation maps to date of the Greenland and Antarctic ice sheets
- Detection of change in the Greenland and Antarctic ice sheets
- Demonstrated ability to characterize detailed topographic features on ice sheets, ice shelves, and ice streams
- Capability of detecting ice-sheet elevation changes as small as centimeters per year
- Pioneering sea-ice thickness mapping (distributions and means)
- Global mapping of heights of clouds and aerosols with unprecedented sensitivity and detail
- Sensing of vegetation canopy heights and density
- Precision mapping of land elevations.



Solar Variability: SORCE. The Sun is the Earth's primary energy source and external driver of climate variability. The Solar Radiation and Climate Experiment (SORCE) satellite, launched in 2003, is equipped with four instruments that measure variations in solar radiation much more accurately than previous measurements. SORCE is now making the first contiguous observations of solar variability across the full solar spectrum, from the far ultraviolet to near-infrared wavelengths. In June 2004, SORCE measured small changes in solar luminosity caused by the transit of Venus, demonstrating unprecedented precision. On 4 November 2004, SORCE documented the largest solar X-ray flare ever recorded and measured associated changes in total solar irradiance. SORCE's operational life is expected to extend across the upcoming 2006-2007 solar minimum, a crucial period for estimating any long-term trend, such as that indicated by indirect measurements of past solar forcing. SORCE is expected to overlap with the Glory mission that will carry forward the total solar irradiance record after 2008, as discussed below. The follow-up to the ultraviolet and other solar spectral measurements of SORCE is not expected until sometime after 2010 when both the total and spectral measurements may become operational as part of the National Polar-Orbiting Operational Environmental Satellite System (NPOESS). Continuity of the solar spectral record will require that SORCE last beyond its design life of 5 years.

ARM Mobile Facility. The primary goal of the Atmospheric Radiation Measurement (ARM) Program is to improve the treatment of cloud and radiation physics in global climate models in order to improve the climate simulation capabilities of these models. These efforts have been enhanced by the addition of the ARM mobile facility (AMF) to study cloud and radiation processes in multiple climatic regimes. The AMF can be deployed to sites around the world for durations of 6 to 18 months. Data streams produced by the AMF will be available to the atmospheric community for use in testing and improving parameterizations in global climate models. The first deployment of the AMF is a collaboration between DOE and the DOD Office of Naval Research, which will make observations of marine stratus clouds and cloud-aerosol interactions (see <www.arm.gov/sites/amf.stm>).

Coral Ecosystem Integrated Observing System. Coral reefs are some of the most biologically diverse ecosystems on Earth. They buffer coastal areas from oceanic swells and tides and provide economic benefits through tourism and fisheries. Recent estimates have shown a loss varying from 15 to 25% of the global population of coral reef ecosystems (Buddemeier *et al*., 2004). While the causes for this degradation may vary, the effects are felt throughout other marine ecosystems and ultimately by the economies of nations dependent on the beauty and bounty of coral reefs to attract tourism and fisheries.



A team of scientists assembled on-site monitoring instruments and satellite remote-sensing data to enhance understanding of the magnitude and complexity of environmental, physical, and biological factors causing coral reef degradation. The integration of monitoring systems is also an effective tool to more fully understand the effects of climate change on coral reef ecosystem health, and to assess the effects of climatic trends on the diversity and abundance of coral reefs through time. The Coral Reef Ecosystem Integrated Observing System (CREIOS) was formed to provide a diverse suite of long-term ecological and environmental observations and information products over a broad range of spatial and temporal scales. The goal is to understand the condition and health of, and processes influencing, coral reef ecosystems, to assist stakeholders in making improved and timely ecosystem-based management decisions to conserve coral reefs. The newly formed CREIOS and NOAA's Coral Reef Watch (see the "Ecosystems" chapter) are at the forefront of integrated research observations spanning domestic and international arenas (see <www.nmfs.hawaii.edu/crd/oceanography.html>).

Data Management and Information

The following are selected data management and information activities supported by CCSP participating agencies.

Integrated Climate Data in the Pacific Islands Region. Efforts to improve climate data integration in the Pacific Islands region are being explored for the purpose of producing more useful end-user-driven products. The Pacific Region Integrated Data Enterprise (PRIDE) is currently underway in Hawaii. This activity efficiently uses existing resources via a newly created NOAA Integrated Environmental Applications Information Center that will be a new-generation data center for the purpose of developing more customer-focused and integrated environmental products. NOAA is partnering with academic and other Federal agencies in the region (e.g., USGS) to provide information on issues related to Pacific islands, including past, current, and future trends in patterns of climate and weather-related extreme events (e.g., tropical cyclones, flooding, drought, and ocean temperature extremes) and their implications for key sectors of the economy such as agriculture, tourism, and fisheries; and options for coastal communities and marine ecosystem managers to adapt to and manage effects of variable and changing environmental conditions (see <apdrc.soest.hawaii.edu/PRIDE>).

Climate Extremes Index. The Climate Extremes Index (CEI) was originally introduced in 1996 as a way to determine whether, and by how much, climate extremes in the United States are changing. The index initially consisted of five separate climate change indicators, combined to yield an overall extremes index summarized on an annual basis. The individual indicators used to investigate possible extremes included mean monthly maximum and minimum temperature, daily precipitation, and the monthly Palmer Drought Severity Index. In recent years, a revised CEI was released that includes a sixth indicator related to extremes in land-falling tropical storm and hurricane wind speed. In addition, the CEI is now evaluated for eight standard periods or seasons, including spring (Mar-May), summer (Jun-Aug), autumn (Sep-Nov), winter (Dec-Feb), warm (Apr-Sep), cold (Oct-Mar), hurricane (Jun-Nov), and annual (Jan-Dec). Newly digitized pre-1948 data have also been included to improve spatial coverage without compromising completeness of data. With the addition of near real-time data, the CEI became an operational index in June 2004 and is now updated within the first few weeks after a particular season has ended. Graphs of the most current CEI and the individual indicators that comprise the CEI may be viewed on the CEI web site (see <www.ncdc.noaa.gov/oa/climate/research/cei/cei.html>).

Data Rescue: Climate Database Modernization Program. Through the Climate Database Modernization Program, millions of deteriorating film and paper images were

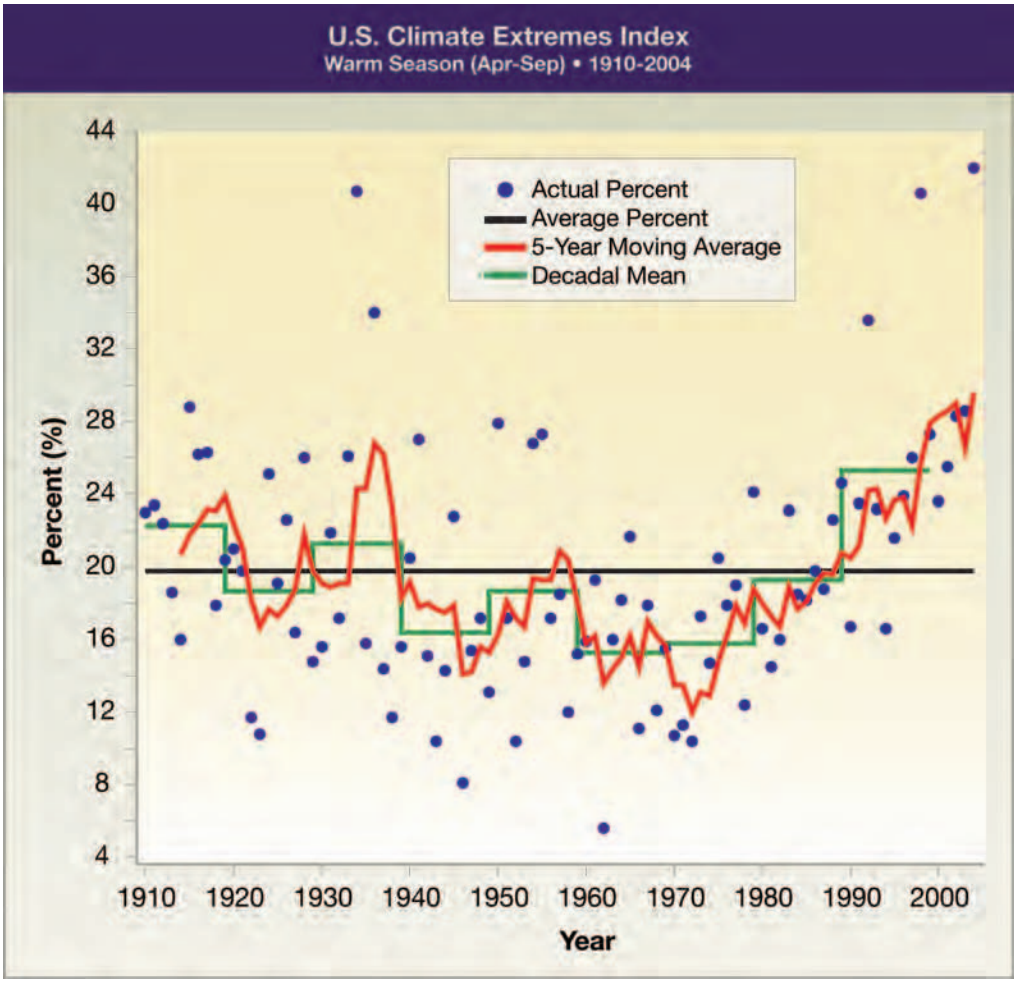


Figure 26: U.S. Climate Extremes Index. U.S. climate extremes index—warm season (April-September), 1910–2004. *Credit: K.L. Gleason, NOAA/National Climatic Data Center*.

preserved through imaging and manual data entry. The program is a partnership between NOAA and private industry to image and manually enter paper and microfilm records and make them available on the web to members of the climatological research community. Currently there are nearly 42 million images available. Without these data rescue efforts, irreplaceable records of past climate would be lost – records that are vital for maximizing the Nation's ability to assess the nature of past climate variability and change (see <www.ncdc.noaa.gov/oa/climate/cdmp/cdmp.html>).

Improved Access to Radar Data. NOAA significantly improved access to archived Weather Surveillance Radar-88 Doppler data (WSR-88D NEXRAD) and has made these data available for use in retrospective climate studies, particularly in regard to precipitation. With increased bandwidth and advanced information technology, NEXRAD data are now available within hours as opposed to days and weeks (see <www.ncdc.noaa.gov/oa/radar/radarresources.html> and Figure 27).

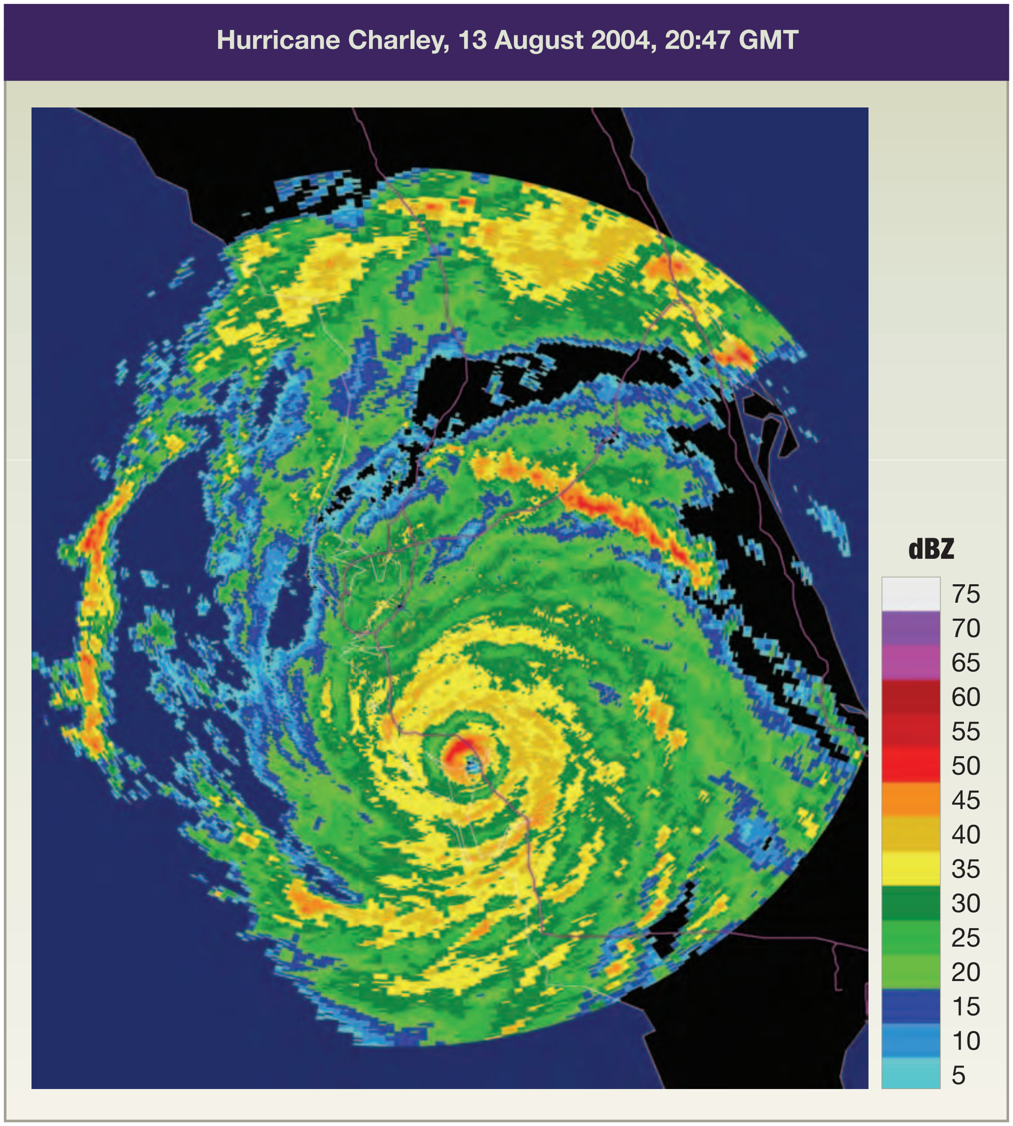


Figure 27: Hurricane Charley, 13 August 2004. Hurricane Charley moving across Florida, August 2004. Image captured by the NOAA/National Weather Service Tampa Bay, Florida, Weather Forecast Office's WSR-88D doppler weather radar. *Credit: NOAA/ National Climatic Data Center*.

REASoN Program. Forty Cooperative Agreement projects that are part of NASA's Earth Science REASoN – Research, Education, and Applications Solutions Network – completed their first year. The REASoN projects are part of NASA's strategy to work with its partners to improve its existing data systems, guide the development and management of future data systems, and focus performance outcomes to further Earth science research objectives. In order to achieve these goals, the REASoN projects are organized to engage the science community and peer review process in the development of higher level science products; use these products to advance Earth system research; develop and demonstrate new technologies for data management and distribution; and contribute to interagency efforts to improve the maintenance and accessibility of data

SYSTEMS FOR DATA MANAGEMENT AND DISTRIBUTION

Cooperative efforts by NASA, NOAA, and other CCSP agencies are moving toward providing an integrated and more easily accessed Earth information system that will effectively preserve, extend, and distribute information about the evolving state of the Earth. A few examples of specific agency efforts are given below. Although each activity has a single lead agency, participation involves many CCSP agencies, as well as State, local, and non-governmental partners.

These activities address Goals 12.3, 12.6, 13.1, 13.2, and 13.4 of the CCSP Strategic Plan.

Earth Observing System Data and Information. NASA's Earth Observing System Data and Information System (EOSDIS) provides convenient mechanisms for locating and accessing products of interest either electronically or via orders for data on media. EOSDIS facilitates collaborative science by providing sets of tools and capabilities such that investigators may provide access to special products (or research products) from their own computing facilities. EOSDIS has an operational EOS Data Gateway (EDG) that provides access to the data holdings at all the Distributed Active Archive Centers (DAACs) and participating data centers from other U.S. and international agencies. Currently, there are14 EDGs around the world that permit users to access Earth science data archives, browse data holdings, select data products, and place data orders.

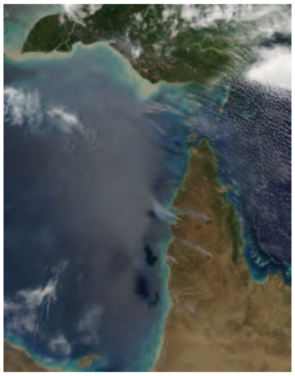
Distributed Active Archive Centers. Eight NASA DAACs representing a wide range of Earth science disciplines comprise the data archival and distribution functions of EOSDIS. The DAACs carry out the responsibilities for processing certain data products from instrument data, archiving and distributing NASA's Earth science data, and providing a full range of user support. There are more than 2,100 distinct data products archived at and distributed from the DAACs. These institutions are custodians of Earth science mission data until the data are moved to long-term archives. They ensure that data will be easily accessible to users. NASA and NOAA have initiated a pilot project to develop a prototype system for testing candidate approaches for moving MODIS data into long-term NOAA archives. This pilot project is part of the evolution of the Comprehensive Large Array-data Stewardship System (CLASS) developed by NOAA. Acting in concert with their users, DAACs provide reliable, robust services to those whose needs may cross traditional discipline boundaries, while continuing to support the particular needs of their respective discipline communities. The DAACs are currently serving a broad and growing user community at an increasing rate.

Global Change Master Directory. The Global Change Master Directory (GCMD) is an extensive directory of descriptive and spatial information about data sets relevant to global change research. The GCMD provides a comprehensive resource where a researcher, student, or interested individual can access sources of Earth science data and related tools/services. At present the GCMD database contains over 17,200 metadata descriptions of data sets from more than 1,200 government agencies, research institutions, archives, and universities worldwide; updates are made at the rate of 900 descriptions per month. The GCMD contains descriptions of data sets covering all disciplines that produce and use data to help us understand our changing planet. Although much research is focused on climate change, the GCMD includes metadata from disciplines including atmospheric science, oceanography, ecology, geology, hydrology, and human dimensions of climate change. This interdisciplinary approach is aimed at researchers exploring the interconnections and interrelations of multidisciplinary global change variables (e.g., how climate change may impact human health). The GCMD has made it easier for such data users to locate the information they desire. A portal has been created in support of GEOSS. The professional relationship between the system developers and the scientists has yielded an environment where the developers respond to the needs of potential users.

Scientific Data Stewardship. Scientific Data Stewardship (SDS) is a new paradigm in data management at NOAA, consisting of an integrated suite of functions to preserve and exploit the full scientific value of environmental data. These functions are careful monitoring of observing system performance for long-term applications; generation of authoritative long-term records from multiple observing platforms; assessment of the state of the atmospheric, oceanic, land, cryospheric, and space environments; and proper archival of and timely access to data and metadata. In this process, SDS will correct many data problems identified by the scientific community and permit more significant applications to economic and social issues to help fulfill NOAA's environmental stewardship mission. Successful implementation of SDS will ensure that the Nation's environmental data (initially from NOAA and NASA) are of maximum use to the Nation now and in the future.

National Data Centers. NOAA's National Data Centers and their worldwide clientele of customers look to CLASS as the primary NOAA information technology infrastructure project in which all of its current and future large-array environmental data sets will reside. CLASS builds upon systems already in place to implement an integrated, national environmental data access and archive system to support a comprehensive data management strategy. CLASS provides permanent, secure storage and safe, efficient access between Data Centers and customers. CLASS is able to ingest, archive, and provide access to data produced from large-array data sources, such as existing and future environmental satellite systems. This includes the next generation of NOAA polar-orbiting satellites, which will provide a significant increase in observing capability, and also a significant increase in data rates. Recent accomplishments include implementation of free Internet-based customer access to NOAA geostationary satellite data and the start of the NPOESS Preparatory Project to ensure that CLASS is ready for the launch of this next-generation polar-orbiting satellite mission in late 2006.

and information systems. A list of ongoing activities under this program can be found at <research.hq.nasa.gov/code_y/nra/current/CAN-02-OES-01/winners.html>.)



Highlights of Plans for FY 2006 and Beyond

CCSP will support the development and implementation of integrated systems for observations and monitoring of climate and global change, and associated data management and information systems. Selected key planned activities for FY 2006 and beyond follow.

Global Climate Observing System. The first element of GCOS that is expected to be completed in 2005 is the global drifting buoy array, a group of 1,250 drifting buoys measuring sea surface temperature and other variables. In FY 2006, the full complement of 3,000 Argo floating buoys will be deployed. Sea-level measurements, provided by the Absolute Altimeter Calibration Station, will transition from NASA to NOAA funding. Continued upgrading of the Global Sea-Level Observing System tide gauge network from 43 to 170 stations is planned for the next few years. Ocean carbon inventory surveys funded by both NOAA and NSF in a 10-year repeat survey cycle will help determine the uptake of anthropogenic carbon by the oceans. Plans for enhancement of the global Tropical Atmosphere Ocean network include advances into the Indian Ocean, with three moorings in the Indian Ocean in 2005 followed by two more in both FY 2006 and 2007. This will enhance the tropical networks currently monitoring above-surface, surface, and subsurface conditions in the Pacific and Atlantic Oceans. Work will continue in FY 2006 to reestablish GCOS Upper Air Network sites in key developing country locations as determined by the GCOS atmospheric science community.

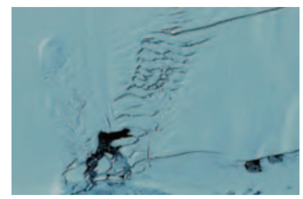
Ocean analysis activities will be initiated in FY 2006 to advance data assimilation and analysis subsystems. Long-range planning includes building the number of ocean observing networks with a focus on the polar regions, especially the Arctic, for impacts of climate change; ocean circulation changes to monitor for possible indications of abrupt climate change; and ocean-atmosphere exchange of heat and water, particularly in support of drought early warning and diagnostics.

These activities will address Goals 12.3 and 12.5 of the CCSP Strategic Plan.

Atmospheric Brown Cloud Sites. The fundamental goal of ABC is to integrate air pollution and climate science to assess the impacts on the environment and society. Since Asia is the source of more than 50% of sulfur dioxide and black carbon emissions, ABC's first focus is on the Asian region. Ten new observatories will be established in the Indo-Asia-Pacific region over the next 3 to 5 years. These will be combined with three existing observatories in the region. Plans are in place to bring the second ABC super site at Gosan, Korea, into operation.

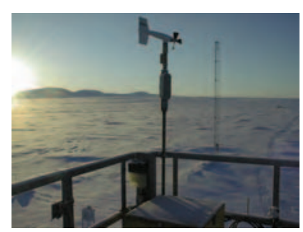
ABC will generate a database for estimating the radiative forcing due to aerosols, including black carbon and aerosol-cloud interactions. With respect to impact assessment, ABC will estimate the effects of aerosol and greenhouse gas radiative forcing on climate and hydrological cycles and the resulting impacts on agriculture and water budgets. As noted previously, ABC is coordinating an integrated regional and global modeling effort. The ABC observations, integrated with NOAA and NASA satellite observations, will provide the input (e.g., climate forcing at monthly time scales and regional spatial scales) for these models. In turn, these models will provide links between observations and policy by assessing the possible impacts of past emissions and "business-as-usual" emissions scenarios.

These activities will address Goals 12.2, 12.4, and 12.5 of the CCSP Strategic Plan.



Polar Region Observations: International Polar Year. Polar climate observations will continue to be a CCSP focus as preparations are made for the International Polar Year (IPY), which will begin in 2007. The IPY coincides with the 50th anniversary of the International Geophysical Year, which in 1957 initiated the systematic observation of key climate variables such as atmospheric CO_2. For further information on the IPY, see <dels.nas.edu/us-ipy>.

The United States plans to increase its efforts on observations of the Arctic atmosphere, sea ice, and ocean. Working with Canada, NOAA will deploy an atmospheric observatory in northeastern Canada to mirror current activities in Barrow, Alaska. Together, these observatories will provide an improved high-resolution characterization of clouds and aerosols, and of incoming and outgoing radiation. A wealth of satellite data will also be available for polar regions in 2007. Two satellites to be launched early in FY 2006, CALIPSO and Cloudsat, will use lidar and radar to provide three-dimensional distributions of aerosols and layered clouds. Data from these surface- and space-based observatories will provide high-quality records needed to detect potential future climate change. Calibration and validation field programs utilizing airborne and balloon-borne sensors associated with these satellite missions and other programs will greatly aid in the intensive characterization of the Arctic.



Additional effort will be made to detect changes in sea ice through deployment of buoys to measure sea-ice properties directly, and also through new satellite sensors (see, e.g., ICESat description above) whose calibration can be enhanced by the availability of an increased set of buoy data. Changes in the temperature and salinity structure of the ocean beneath sea ice could be a critical indicator of changes in the climate system, and new efforts will be made to gather such data. The Bering, Chukchi, and Beaufort Seas off Alaska are home to many valuable living resources, including fish, marine mammals, and birds, that are affected by ocean currents and the seasonal progression of sea ice. There is evidence that these areas are warming and that the annual period of ice cover is diminishing. The biotic response to these physical changes will be studied through enhanced observations by automated systems and ship-based activities.

These activities will address Goals 12.1 and 12.5 of the CCSP Strategic Plan.

Earth System Science Pathfinder Program. NASA's Earth System Science Pathfinder (ESSP) program is the primary source of exploratory missions to complement the EOS satellites Terra, Aqua, and Aura. The ESSP program consists of smaller missions developed and implemented on a faster schedule, proposed by the scientific community to address specific research questions. The first ESSP mission, the Gravity Recovery and Climate Experiment, was launched in March 2002. A second launch, planned for fall 2005, will deploy two more ESSP satellites, CloudSat and CALIPSO, as mentioned in the previous subsection. After initial testing and quality control, science data from these key missions will be available beginning in 2006.

CloudSat, a joint mission involving NASA, the U.S. Air Force, and the Canadian Space Agency, is designed to measure cloud properties that are critical for understanding clouds' effects on both weather and climate. These cloud properties are not obtainable from current satellite measurement systems. The mission's primary science goal is to furnish data needed to evaluate and improve the way clouds are parameterized in global models, thereby contributing to better predictions of clouds and to a better

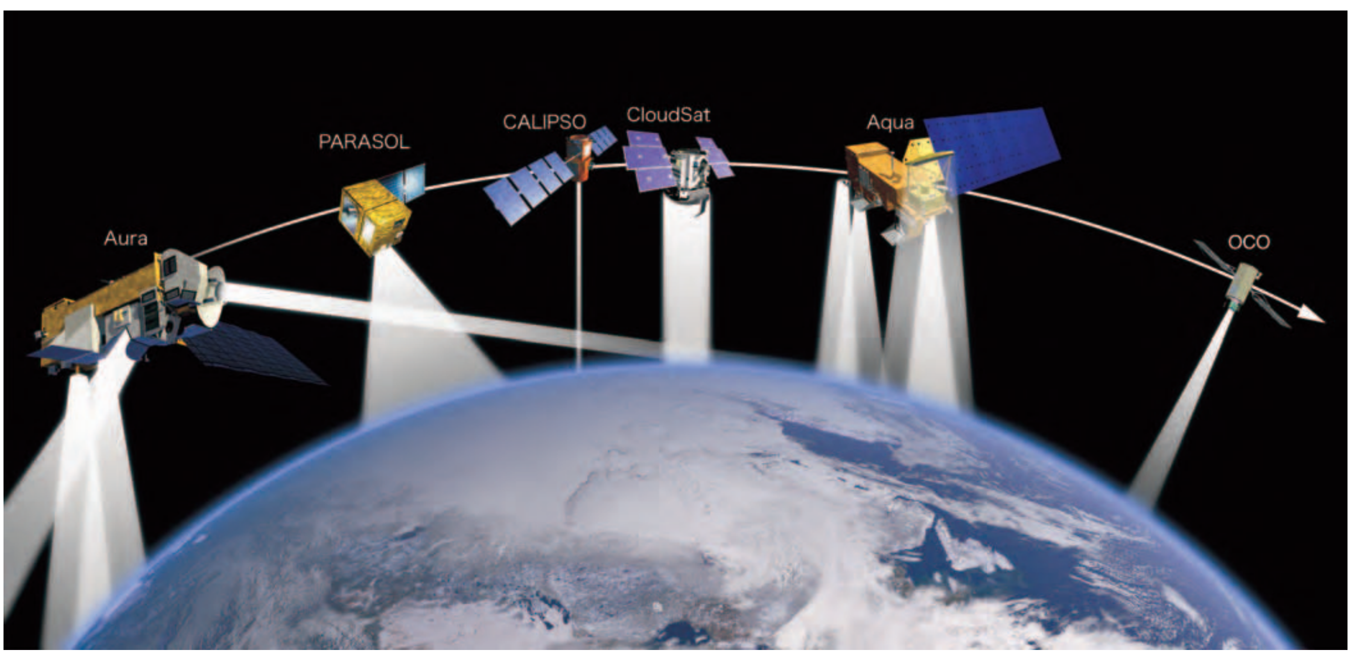
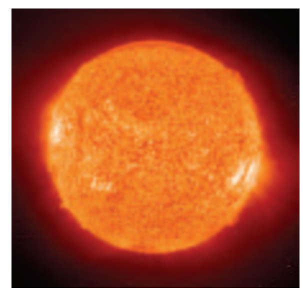


Figure 28: The "A-Train". This figure illustrates the constellation of satellites known as the "A Train," which will make nearly contiguous observations of many facets of the Earth system. *Credit: NASA*.

understanding of poorly understood cloud-climate feedbacks. CloudSat's key observations are the vertical profiles of cloud liquid-water and ice-water content and related physical and radiative properties. It will fly in tight formation with the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite. CALIPSO is being developed to provide new information about the effects of thin clouds and aerosols on changes in the Earth's climate. Global measurements of the three-dimensional distributions of aerosols and clouds will provide scientists with a more comprehensive data set that is essential for a better understanding of the Earth's climate forcings and feedbacks. The CALIPSO mission is implemented in collaboration with the French space agency, Centre National d'Etudes Spatiales. CloudSat and CALIPSO will follow behind the Aqua satellite as part of the multi-satellite formation termed the "A-train" (see Figure 28). Also included in the "A-train" satellite formation will be the PARASOL mission to measure cloud and aerosol properties using polarization of reflected sunlight. The combination of these data with coincident measurements from Aqua and Aura will provide a rich source of information that can be used to assess the role of clouds in both weather and climate.

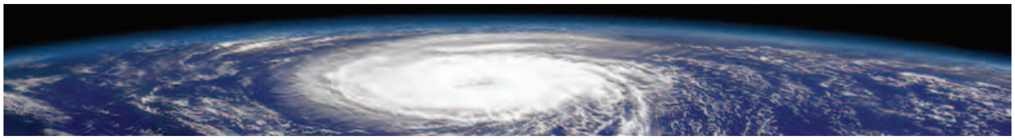
These activities will address Goals 12.1 and 12.5 of the CCSP Strategic Plan.



Solar Variability: Glory. The Glory mission will continue to be developed in FY 2006, and is planned for 2008 launch. It will carry a Total Irradiance Monitor (TIM) based on the SORCE TIM design, with the same high-precision phase-sensitive detection capability. Glory will also carry an Aerosol Polarimeter Sensor (APS), which will improve our ability to distinguish among aerosol types by measuring the polarization state of reflected sunlight. Both TIM and APS will provide key measurements beginning in 2007, the minimum of solar cycle 24. This less active portion of the 11-year solar cycle is especially crucial in estimating any long-term trends in solar output – a key to understanding the 20th-century context of global change, as the Sun is the single entirely "external" forcing of the climate system that is unaffected by climate change itself. Glory is described at <www.esa.ssc.nasa.gov/m2m/mission_report.aspx?mission_id=233>. The International Heliophysical Year is summarized at <ihy.gsfc.nasa.gov>.)

These activities will address Goals 12.1 and 12.5 of the CCSP Strategic Plan.

Global Precipitation Measurement Mission. Motivated by the successes of the TRMM satellite and recognizing the need for a more comprehensive global precipitation measuring program, NASA and the Japan Aerospace Exploration Agency conceived a new Global Precipitation Measurement (GPM) Mission. A fundamental scientific goal of the GPM Mission is to make substantial improvements in global precipitation observations, especially in terms of measurement accuracy, sampling frequency, spatial resolution, and coverage, thus extending TRMM's rainfall time series. To achieve this



goal, the mission will consist of a constellation of low-Earth-orbiting satellites carrying various passive and active microwave measuring instruments. The GPM Mission will be used to address important issues central to improving the predictions of climate, weather, and hydrometeorological processes, and also to stimulate operational forecasting and to underwrite an effective public outreach and education program, including near-real-time dissemination of televised regional and global rainfall maps. Assessment of how natural and anthropogenic aerosols affect precipitation variability (therefore the water cycle) is a complex and important problem. The capability to monitor the diurnal cycle of rainfall globally with GPM is expected to enable significantly improved understanding of the links between aerosols, climate variability, weather changes, hydrometeorological anomalies, and small-scale cloud macrophysics and microphysics.

These activities will address Goals 12.1 and 12.5 of the CCSP Strategic Plan.

Orbiting Carbon Observatory. The Orbiting Carbon Observatory (OCO) is a new mission, being prepared to launch in 2008, to provide the first space-based measurements of atmospheric CO_2 (total column) with the precision, resolution, and coverage needed to characterize carbon sources and sinks on regional scales and to quantify their variability. Analyses of OCO data will regularly produce precise global maps of CO_2 in the Earth's atmosphere that will enable more reliable projections of future changes in the abundance and distribution of CO_2 in the atmosphere and the effect that these changes may have on the Earth's climate.

These activities will address Goals 12.2 and 12.5 of the CCSP Strategic Plan.

Sea Surface Temperature. Both short-term numerical weather prediction and longer term climate change detection require sea surface temperature (SST) measurements made frequently, on a global scale, and at fine spatial resolution. Currently there are many different satellite-derived SST data sets available with a number of options in terms of product content, coverage, spatial resolution, timeliness, format, and accuracy. Realizing that the existing SST data products are less than ideal for numerical weather prediction and regional-scale climate change detection, the international Global Ocean Data Assimilation Experiment steering committee initiated a pilot project in 2005 to develop an operational demonstration system that will deliver a new generation of global-coverage high-resolution (better than 10-km and collected approximately every 6 hours) SST data products. The data products will be derived by combining readily available but complementary satellite and *in situ* observations in real-time to improve spatial coverage, temporal resolution, cross-sensor calibration stability, and SST product accuracy.

These activities will address Goals 12.1 and 12.5 of the CCSP Strategic Plan.

African Monsoon Multidisciplinary Analysis. African Monsoon Multidisciplinary Analysis (AMMA) is an international project to improve our knowledge and understanding of the West African monsoon (WAM) and its variability, with an emphasis on daily-to-interannual time scales. AMMA is motivated by an interest in fundamental scientific issues and by the societal need for improved prediction of the WAM and its impacts on West African nations. As noted in the "Climate Variability and Change" chapter, U.S. involvement in AMMA will focus on climate, weather, and related aerosol issues associated with the African monsoon regions. A multidisciplinary field program is planned, combining long-term monitoring over several seasons with intensive observations in the summer of 2006. The field measurements will be used to test and improve predictive models for the environment and climate of Africa, and for the impact of the African monsoon on the global environment. U.S. participation in AMMA may include ship, aircraft, and oceanographic sensors proposed for support from multiple CCSP agencies. The ARM Mobile Facility will be deployed in 2006.

These activities will address Goals 12.2 and 12.3 of the CCSP Strategic Plan.

USGEO Near-Term Opportunity. USGEO was established in March 2005 as a standing subcommittee of the National Science and Technology Council Committee on Environmental and Natural Resources to replace the ad hoc IWGEO. USGEO has outlined a process for the development of a modern information management system, based on Federal Enterprise Architecture principles. The process follows contemporary commercial and academic practices for integrating distributed resources within a virtual organization framework based on a service-based architecture. It uses existing data management planning as its foundation, and relies heavily on an articulation of how data are used to drive the system design. USGEO is developing specific guidance to advance existing agency efforts that address the six "Near-Term Opportunities" outlined in the *USGEO Strategic Plan*: disaster warning, global land cover, sea level, drought, air quality, and enhanced data management (see <iwgeo.ssc.nasa.gov>).

These activities will address Goals 12.6 and 13.3 of the CCSP Strategic Plan.

OBSERVING AND MONITORING CHAPTER REFERENCE

1) **Buddemeier**, R.W., J.A. Kleypas, and R. Aronson, 2004: *Coral Reefs and Global Climate Change. Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems*. Prepared for the Pew Center for Global Climate Change, 42 pp. Available at <www.pewclimate.org/global-warming-in-depth/all_reports/coral_reefs/index.cfm>.