The United States National Report on Systematic Observations for Climate for 2008:
National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan

Prepared for Submission to the United Nations Framework Convention on Climate Change (UNFCCC)

**Compiled by the
Observations Working Group of the
U.S. Climate Change Science Program (CCSP)
On Behalf of the United States Government**

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Preface

Long-term, high-accuracy, stable environmental observations are essential to define the state of the global integrated Earth system, its history and its future variability and change. Observations for climate include: (1) operational weather observations, when appropriate care has been exercised to establish high accuracy; (2) limited-duration observations collected as part of research investigations to elucidate chemical, dynamical, biological, or radiative processes that contribute to maintaining climate patterns or to their variability; (3) high accuracy, high precision observations to document decadal-to-centennial changes; and (4) observations of climate proxies, collected to extend the instrumental climate record to remote regions and back in time to provide information on climate change at millennial and longer time scales. This report is an update of the U.S. GCOS Report done for the UNFCCC in August 2001 that can be found at http://www.ncdc.noaa.gov/oa/usgcos/documents/soc_long.pdf. Subsequent to the August 2001 report, updates on systematic observational activities in the U.S., were provided to the UNFCCC in the U.S. 3rd Climate Action Report (CAR) in 2002, and the U.S. 4th CAR published in 2007.

In accordance with the UNFCCC guidelines, the sections of the report delineate specific U.S. climate monitoring activities in several distinct yet integrated areas as follows: (1) common issues; (2) non-satellite atmospheric observations; (3) non-satellite oceanic observations; (4) non-satellite terrestrial observations; (5) satellite global atmospheric, oceanic, and terrestrial observations; and (6) data and information management related to systematic observations. The various federal agencies involved in observing the environment provide the required long-term observations. Space-based systems provide unique global measurements of solar output, the Earth's radiation budget; vegetation type and primary production; land surface conditions; ocean and terrestrial biomass primary productivity; tropospheric and stratospheric ozone; tropospheric and stratospheric water vapor; tropospheric aerosols; greenhouse gas distributions; sea level; ocean surface conditions and winds; weather; and tropical precipitation, among others.

Satellite and non-satellite instruments record different portions of the space-time continuum of climate variability and change. Also, both types of data are needed to calibrate and validate each other. To meet the need for the documentation of global climate changes, the U.S. integrates observations to produce, usually through data assimilation in a dynamical model, gridded fields for analyses. The goal of the U.S.' observation and monitoring program is to ensure long-term, well-calibrated, high-accuracy, stable observations. The U.S. will continue to support systematic observations in support of observing global climate change, and will provide reports of this nature, as required, in the future.

William J. Brennan, Director U.S. Climate Change Science Program
September 2008

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Executive Summary

Since 1998, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have noted with concern the mounting evidence of a decline in the global observing capability and have urged Parties to undertake programs of systematic observations and to strengthen their capability in the collection, exchange, and utilization of environmental data and information. It has long been recognized that the range of global observations needed to understand and monitor Earth processes contributing to climate and to assess the impact of human activities cannot be satisfied by a single program, agency, or country. The U.S. supports the need to improve global observing systems for climate, and we join other Parties in submitting information on national plans and programs that contribute to the global capability. This report was prepared in line with UNFCCC Decision 11/CP.13, which requested Annex I Parties to the Convention to provide a detailed report on systematic observations in accordance with the UNFCCC reporting guidelines on global climate change observing systems, as revised by Annex 1 to UNFCCC Decision 11/CP.13.

As such, under the overall guidance of the Global Climate Observing System (GCOS) Steering Committee, the GCOS Secretariat is preparing a report on progress in the implementation of the global observing system for climate. The action follows a conclusion from the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) in Montreal in December 2005, where it issued a "request to the GCOS Secretariat to provide, for consideration by the SBSTA at its thirtieth session (June 2009), a comprehensive report on progress with the GCOS implementation plan." The intent for the GCOS Secretariat report is to supplement and synthesize the reports submitted by Parties to the Convention on systematic observation, which they provide in conjunction with their regular national communications in accordance with decisions 4/CP.5, 5/CP.5, and 11/CP.13. Previous U.S. National Reports of this nature in 2001, 2002, and 2007 can be found at the following 3 links:

- 2001 Report: http://www.ncdc.noaa.gov/oa/usgcos/documents/soc_long.pdf
- 2002 Report: http://www.gcrio.org/CAR2002/car2002ch8.pdf
- 2007 Report: http://www.state.gov/documents/organization/89656.pdf

The U.S. National Report will be used as input to help prepare the comprehensive GCOS report that will (1) confirm ongoing requirements and report on progress against the GCOS Implementation Plan and its Satellite Supplement and (2) focus on new actions and drivers such as observing requirements for impacts, adaptation and vulnerability, as well as regional climate observation needs.

The U.S. actively supports the Global Climate Observing System (GCOS) through its participation in and support of the GCOS networks, and through its support of related climate observing activities. The U.S. recognizes that international cooperation both in the data collection and sharing of the information is essential to provide the climate information required by the UNFCCC.

This report will be organized in accordance with the UNFCCC guidelines that delineate [global] climate monitoring by the U.S. in several distinct yet integrated areas as follows:

(1) common issues; (2) non-satellite atmospheric observations; (3) non-satellite oceanic observations; (4) non-satellite terrestrial observations; (5) satellite global atmospheric, oceanic, and terrestrial observations; and (6) data and information management related to systematic observations**.** The report attempts to include observation systems now known to be relevant, but is representative of the larger U.S. effort to observe the GCOS Essential Climate Variables (ECV).

There is no comprehensive system designed to observe climate change and climate variability in the U.S. Basically, sustained observing systems in the US, which provide continuing observations, provide data principally for non-climatic purposes, such as predicting weather, advising the public and managing resources. Research observing systems collect well calibrated, high accuracy, sustained data for climate purposes. U.S. observations of climate change are based upon a combination of operational and research programs. The observing systems collectively provide voluminous and significant information about the spatial and temporal variability of global climate change.

Working in partnership with other nations is a central precept of the U.S. global climate observation strategy. All of the U.S. contributions to global climate observations are coordinated internationally in cooperation with a variety of international, regional, and bilateral partnerships. The United States supports the long-term deployment, operation, and improvement of the global climate observation system that is necessary to drive, evaluate, and improve forecast models, and to document the changing state of the climate, including building capacity for data stewardship. As such, the U.S. Climate Change Science Program has endorsed the "*Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC - October, 2004"* that can be found at http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP.pdf as the guiding strategic document in support of building a long-term and sustainable global climate observing system. This GCOS Implementation Plan stresses building a system of integrated non-satellite and remote-sensing atmospheric, oceanic, and terrestrial climate systems in order to best observe the set of ECVs which at a minimum are required to characterize the changing climate of the Earth. A global observing system by definition crosses international boundaries, with potential for both benefits and responsibilities to be shared by many nations.

Since 2002, the United States has entered into a number of important bilateral climate agreements, funding projects with Australia, China, New Zealand, South Africa., and South Korea. These wide-ranging projects deal with climate prediction, ocean observation, stratospheric detection, water vapor measurements, capacity building and training, and communication of information, and focus the attention and resources of these countries on developing a more sustainable and robust GCOS program.

Finally, the U.S. is a very active participant in the intergovernmental Group on Earth Observations (GEO) and its development of the Global Earth Observation System of Systems (GEOSS). The purpose of GEOSS is to achieve *comprehensive, coordinated, and sustained* observations of the Earth system in order to improve monitoring of the changing state of the planet, increase understanding of complex Earth processes, and enhance the prediction of the impacts of environmental change, including climate change.

Finally, GEOSS provides the overall conceptual and organizational framework to build towards integrated global Earth observations to meet user needs and to support decision making in an increasingly complex and environmentally stressed world. It is a "system of systems" consisting of existing and future Earth observation systems, supplementing but not supplanting the mandates and governance arrangements of those systems, such as GCOS. The established Earth observation systems, through which many countries cooperate as members of the U.N. Specialized Agencies and Programs and as contributors to international scientific programs, provide essential building blocks for GEOSS.

Chapter 1: Common Issues

In this chapter we will describe the U.S. GCOS National Program and report on actions undertaken to introduce and/or enhance national coordination. We will also address planning activities for the production and adoption of national implementation plans for observing, archiving and analysing their national contribution of Essential Climate Variables (ECV). In addition, the chapter features information on a number of related areas. These include efforts undertaken to ensure high-quality data record stewardship and issues such as international data exchange and the use of sound data management principles related to international and World Data Center activities, including the preparation of data sets and metadata. Capacity building activities in least-developed countries, small island developing states and countries with economies in transition related to the collection, exchange and/or utilization of observations of the ECVs, including implementation of the Regional Action Plans developed from the GCOS Regional Workshop Program are important areas supported by the U.S. and will be detailed. Those initiatives include the acquisition of paleoclimatic data, in particular to extend the data record in time and into new regions, and to improve the synthesis of these data. Finally, we describe relevant multinational and international projects.

The U.S. contributes to the development and operation of several research and operational global observing systems that provide a comprehensive measure of climate system variability and climate change processes. These systems are a baseline Earth-observing system and include the National Aeronautics and Space Administration (NASA), NOAA, and the U.S. Geological Survey (USGS) Earth-observing satellites and extensive non-satellite observational capabilities. CCSP also supports several ground-based measurement activities that provide the data used in studies of the various climate processes necessary for better understanding of climate change. U.S. observational and monitoring activities contribute significantly to several international observing systems including the Global Climate Observing System (GCOS) principally sponsored by the World Meteorological Organization (WMO); the Global Ocean Observing System (GOOS) sponsored by the United Nations Educational, Scientific and Cultural Organization’s Intergovernmental Oceanographic Commission (IOC); the Global Geodetic Observing System sponsored by the International Association of Geodesy; and the Global Terrestrial Observing System (GTOS) 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 U.S. is also a major participant in and contributor to the Global Earth Observation System of Systems (GEOSS) in which GCOS, GOOS, and GTOS are contributing systems.

A specific subset of the GCOS observing activities for 2007-2008 (and into 2009) are the CCSP sponsored polar climate observations made in cooperation with the International Polar Year (IPY). During 2009, the IPY will come to a formal conclusion. However, many polar observing systems will continue to operate in the polar environment. Several agencies are working together to establish an Arctic Observing Network that will build on systems deployed during the IPY and provide for coordinated efforts to sustain key climate observations. This cooperation will extend to international partners to encourage a pan-Arctic approach to observation and data sharing.

Remotely sensed observations continue to be a cornerstone of CCSP. For example, the NASA Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Lidar and NASA CloudSat Radar instruments are providing an unprecedented examination of the vertical structure of aerosols and clouds over the entire Earth. These data, when combined with data from the Aqua, Aura, and the Polarization and Anisotropy of Réflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL) satellites orbiting in formation and called the A-train, will enable systematic pursuit of key issues including the effects of aerosols on clouds and precipitation, the strength of cloud feedbacks, and the characteristics of difficult-to-observe polar clouds. There are also a number of other very important satellite missions that are more fully documented in Chapter 5 of this report. The increasing volume of data from remote sensing and non-satellite observing systems produces a continuing challenge for agencies in the U.S. to ensure that data management systems are able to handle the expected increases.

Additional efforts are being explored to improve climate data integration in the Pacific Islands region and produce more useful, end-user-driven climate products. NOAA's recently created NOAA Integrated Data and Environmental Applications (IDEA) Center is developing more customer-focused, integrated environmental products. The IDEA Center is partnering with academic institutions and other federal and local agencies in the region to provide information on (1) 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); (2) their implications for key sectors of the economy, such as agriculture, tourism, and fisheries; and (3) options for coastal communities and marine ecosystem managers to adapt to and manage the effects of variable and changing environmental conditions.

U.S. priorities for advancement of the atmospheric, oceanic, and terrestrial observing components of GCOS include: (1) reducing the uncertainty in the global carbon inventory (in the atmospheric, oceanic, and terrestrial domains), sea-level change, and sea surface temperature; (2) continuing support for existing non-satellite atmospheric networks in developing nations; and (3) planning for surface and upper air GCOS reference observations consistent with CCSP Synthesis and Analysis Report 1.1 [see http://www.climatescience.gov/Library/sap/sap1-1/finalreport/sap1-1-final-all.pdf]. As such, the global ocean observing system will make incremental advances, building out to 62% completion: 50 surface drifters will be equipped with salinity sensors for satellite validation and salinity budget calculations, particularly in the polar regions; a new reference array will be added across the Atlantic basin, to measure changes in the ocean's overturning circulation—an indicator of possible abrupt climate change; a pilot U.S. coastal carbon observing network will enter sustained service, to help quantify North American carbon sources and sinks and to measure ocean acidification caused by carbon dioxide (CO_2) sequestration in the ocean; and dedicated ships will target deployments of ARGO and surface drifters in undersampled regions of the world oceans. The North American Carbon Program (NACP), under the auspices of the U.S. CCSP, aims heavily at terrestrial uncertainties and these are supported by a growing set of atmospheric measurements to place constraints on flux estimates. These observations are on-going and involve participation from numerous agencies and institutions.

Since 2002, the U.S. has entered into 19 important bilateral climate agreements, funding climate projects with, among others, Australia, China, New Zealand, South Africa., and South Korea. These wide-ranging projects address climate prediction, ocean observation, stratospheric detection, water vapor measurements, capacity building and training, and communication of information. They focus the attention and resources of these countries on developing a more sustainable and robust GCOS program.

Finally, planning activities will continue for developing a GCOS Reference Upper Air Network (GRUAN) to aid in enhancing the quality of upper tropospheric and lower stratospheric water vapor measurements at a subset of present GCOS Upper Air Network (GUAN) stations. Reductions in sea level uncertainty will focus on the deployment of Global Navigation Satellite System (GNSS) positioned tide gauges, the launch of new altimetry satellites, and the significant upgrade in the global geodetic networks to achieve sub-millimeter measurement stability.

As an introductory note for the following chapters, it should be noted that in past reports we have categorized observing systems as being either satellite-based, or *in-situ* to indicate a ground-based system. However, many people believe that the use of the term "*in-situ*" is seriously misused as it appears to include all non-satellite measurements which it does not. In the past, remote sensing from the ground, balloons, or aircraft have been included in this *in-situ* designation, and this is clearly wrong and misleading. For example, atmospheric observations necessary for climate studies include both real *in-situ* measurements (where we directly sample the air mass surrounding the instrument) as well as non-satellite remote sensing measurements. Therefore, this report will simply distinguish observing systems as being either non-satellite or satellite in nature.

Chapter 2: Non-Satellite Atmospheric Observations

The U.S. actively participates in the GCOS Surface Network (GSN), the GCOS Upper Air Network (GUAN), and the Global Atmospheric Watch (GAW). The U.S. supports 75 GSN stations, 21 GUAN stations, and 4 of the GAW designated baseline stations, and these networks sites are distributed geographically as prescribed in the GCOS and GAW network designs. The data (metadata and observations) from these stations are shared according to GCOS and GAW protocols. The GSN and GUAN stations are part of larger meteorological networks, which were developed primarily for weather forecasting purposes, but nonetheless, the stations fully meet the GCOS requirements for climate observing. GAW also supports comprehensive networks for various constituents, each of which can exceed 100 sites. The U.S. for example provides nearly 2/3 of the approximately 100 observing sites in the GAW comprehensive network for CO_2, methane (CH_4) and other greenhouse and ozone-depleting gases. The U.S., via NOAA, also maintains the World Calibration Scales for these gases.

Since publishing its last full GCOS report to the UNFCCC in 2001, the U.S. has begun fielding and commissioning a system known as the U.S. Climate Reference Network (USCRN). The USCRN is designed to answer the question: How has the U.S. climate changed over the past 50 years at national, regional, and local levels. Data from USCRN sites will be used in operational climate monitoring activities and for placing current climate anomalies into an historical perspective, and has the potential for doing this on a global scale for sites in up to 20 least developed countries (LDC). NOAA's NCDC has experience in organizing workshops in developing countries to aid persons in utilizing such reference climate data for applications ranging from creating national climate normals, drought forecasting, and determining climate trends to aid in seasonal predictions. Data and information regarding the USCRN program can be found at http://www.ncdc.noaa.gov/crn.

By the end of September 2008, all 114 of the planned USCRN stations in the conterminous U.S will have been formally commissioned for operations. Beginning in 2008, planning began to field 29 USCRN sites in the state of Alaska, and the U.S. GCOS program has funded some initial prototype sites fielded in both Alaska and Hawaii. The U.S. GCOS program supports a number of climate observing systems and projects in developing nations. In 2002, there were 20 non-transmitting GCOS Upper Air Network (GUAN) stations around the globe. Through focused projects, the number of non-transmitting stations has dropped to zero. The GCOS program continues to ensure the long-term sustainability of all stations through the establishment of regional technical and maintenance support centers for southern and eastern Africa, the Caribbean, and the Pacific Islands. Related to this capacity-building activity, the program has for example supported an intensive upper-air campaign as part of the African Monsoon Multidisciplinary Analysis with the installation of a new hydrogen generator at the upper-air site in Dakar, Senegal. Other GCOS renovation projects sponsored by the U.S. GCOS program are documented at http://www.ncdc.noaa.gov/oa/usgcos/renovationprojects.htm.

Long-term surface-based reference climate sites are essential for creating a continuous and homogeneous climate data record. Such a climate record is utilized by the

Intergovernmental Panel on Climate Change and the United Nations Convention on Climate Change, regarding global climate assessments. Such a reference climate data record is also applicable and essential for use by least developed nations for local and regional planning related to societal benefit areas related to protecting and monitoring water resources (e.g., drought forecasting) understanding the effects of climate change on human health, and understanding, assessing, predicting, mitigating and adapting to climate variability and change. Additionally, this kind of data reference data record is a key element in reducing uncertainties in global temperature and precipitation variances, providing reference ground truth data to aid in the evaluation of climate model simulations, and aiding in the provision of climate quality data for the calibration and validation of satellite data.

The USCRN is a network of climate stations now being deployed for such long-term climate monitoring for the U.S. with plans to deploy in other global locations. The USCRN's primary goal is to provide future long-term homogeneous observations of temperature, precipitation, wind, surface pressure, and radiation that can be coupled to long-term historical observations for the detection and attribution of present and future climate change that also meets the long-term monitoring requirements of GCOS. Beginning in 2008 funding was received to begin to deploy over the next several years soil moisture, soil temperature, and relative humidity sensors at the network of 114 USCRN stations in order to better characterize those ECVs in support of drought forecasting and mitigation activities.

The primary mission of the USCRN is to determine national climatic trends; however, there is great recognition of the importance of monitoring regional trends as well. A regional observing network is therefore in the process of being developed. To implement this, NOAA is leveraging the existing more densely populated network of Historical Climatology Network (HCN) sites across the U.S. (including Alaska and Hawaii). The HCN is a subset of 1221 cooperative observer sites (out of 8,000) that take daily temperature, precipitation, snowfall, and snowdepth observations. NOAA is going to modernize a set of 1000 HCN sites (HCN-M) to more fully align their monitoring capability with the Climate Monitoring Principles. The HCN-M configuration will be based on a scaled-down version of the USCRN sensor technology. Plans for implementing HCN-M stations call for initial deployment in the Southwest U.S. where drought over the last decade rivals any other of the past century and complex topography confounds interpretation of national trends. Plans for Alaska and Hawaii have not been developed yet, but implementation in these areas is a future goal.

In 2009, one USCRN station will be deployed at the Russian Arctic site in Tiksi, and possibly an additional USCRN site will be installed in Yakutsk; both in line with some bilateral U.S./Russia work in various IPY activities. Currently the U.S. GCOS Program is working with the World Bank to utilize USCRN technology in a tropical glacier monitoring project they are sponsoring in 4 Andean nations (Bolivia, Colombia, Ecuador, and Peru).

The integration of a series of surface observing system networks is intended to sustain the Nation's climate record of land surface measurements essential to monitor and assess the surface climate. It integrates land surface observations from regional, national, as well as an international perspective. Four major surface climate networks constitute the U.S. region: (1) USCRN sites; (2) the Surface Energy Budget Network (SEBN); (3) a modernized Historical Climatology Network; and (4) the NACP. The Automated Surface Observing System, NOAA's Voluntary Cooperative Observer network, and other federal agency mesonet observing systems including; state observing systems, and private sector observations are integrated into the system. These surface observing systems contribute measurements of 11 key GCOS Essential Climate Variables: (1) air temperature; (2) precipitation; (3) atmospheric pressure; (4) surface radiation; (5) vector winds; (6) water vapor; (7) clouds; (8) soil temperature; (9) soil moisture; (10) snow depth; and (11) CO_2.

The integrated network of SEBN stations will be “benchmark” locations that consist of the high-quality Baseline Surface Radiation Network (BSRN) stations. In the U.S., BSRN stations consist of Surface Radiation (SURFRAD) stations, coupled with high-quality Global Energy and Water Cycle Experiment (GEWEX) flux measurement sites. There will be a significant improvement in the reliability and accuracy of ground-based surface radiation observations. To the maximum extent suitable, SEBN sensor suites will be located adjacent or near USCRN stations. USCRN stations measure total incoming solar radiation (note that these solar measurements are made with much lower level of accuracy than with BSRN methods) and IR ground (skin) temperature, as well as surface air temperature and precipitation.

A primary U.S. objective is to continue support for the international commitments to global programs such as BSRN a project of the international GEWEX Radiation Panel, which is under the World Climate Research Program (WCRP). More recently BSRN has become part of GCOS activities. BSRN makes contributions to the SEBN work. The SEBN objective is to have a spatial distribution that optimizes U.S. coverage (and some non-U.S. locations related to U.S. contributions to WCRP-GCOS BSRN) and provides observations for the major ecosystems and land-use types that comprise the U.S.

Solar radiation and soil moisture are two critical parameters that are not adequately addressed or measured by the current or planned observing systems in any of the ten critical areas of user needs as examined by the WMO Rolling Requirements Review[1]. The integration of existing solar observation networks (e. g. SURFRAD, ARL-GEWEX) into the Surface Energy Budget Network (SEBN), and the deployment of sensors for soil temperature and moisture sensors at USCRN stations and elsewhere, are efforts to rectify this critical deficiency.

Surface skin temperature and soil moisture play crucial roles in controlling the exchange of energy and water between the atmosphere and the land surface. Solar radiation and precipitation are the main surface forcings for soil moisture. Numerical simulations of land surface process and precipitation prediction indicate that the key to correctly predict precipitation is to correctly simulate soil moisture - particularly for dry areas. Different models on how to improve the prediction of drought and precipitation, with different

[1] *Current Statements of Guidance Regarding How Well Satellite and In Situ Sensor Capabilities Meet WMO USER Requirements in Ten Application Areas*; see report at http://www.wmo.ch/pages/prog/sat/documents/SOG.pdf

physical parameterizations, were discussed, but all indicated that there are not adequate soil moisture observations available to validate the parameterizations. Of course, drought prediction skill should be greatly improved if the high-quality soil moisture and skin temp observations from a wide and dense network could be directly assimilated into the models.

Use of satellite radiance data to infer these measurements is the most practical means to acquire global coverage continuously over time, as soil moisture and temperature, solar radiation, evaporation, transpiration, and other surface energy fluxes are not conventionally observed at meteorological weather stations but are restricted only to discrete measurements at specific locations. These include networks such as the U.S. Department of Agriculture (USDA) Soil Climate Analysis Network (SCAN), FluxNet stations, Atmospheric Radiation Measurement (ARM) locations, and the stations proposed for the SEBN. Such sparse measurements are not able to reveal large-sale surface characteristics and are inadequate to carry out regional and global studies.

While it is difficult to list all observing campaigns and systems, there are several others that need to be noted here for their global climate significance. The Southern Hemisphere ADditional OZonesondes (SHADOZ) [see http://croc.gsfc.nasa.gov/shadoz/] provides a consistent dataset from balloon-borne ozonesondes for ground verification of satellite ozone measurements at 13 sites across the tropics and subtropics. Beginning in 1998 with 8 southern hemisphere stations, gradually since 2001, five northern hemispheric tropical and subtropical stations have been added. Another key system along these lines is the Aerosol Robotic NETwork (AERONET) [see http://aeronet.gsfc.nasa.gov/data_frame.html] which is a federation of ground based remote sensing aerosol networks established in part by NASA and France's Centre National de la Recherche Scientifique (CNRS).

AERONET provides a long-term, continuous and readily accessible public domain database of aerosol optical properties for research and characterization of aerosols, validation of satellite retrievals, and provides synergy with other databases. Aeronet collaboration provides a series of globally distrinbuted observations of spectral aerosol optical depth, inversion products, and precipitable water in diverse aerosol regimes. The collaborative effort between NASA's Advanced Global Atmospheric Gases Experiment (AGAGE) and NOAA's Flask Monitoring Network has been instrumental in measuring the composition of the global atmosphere continuously since 1978. The AGAGE is distinguished by its capability to measure over the globe at high frequency almost all of the important species in the Montreal Protocol to protect the ozone layer and almost all of the significant non-CO2 greenhouse gases in the Kyoto Protocol contributing to climate change. Both NASA and NOAA demonstrate great collaborative research efforts in this key climate monitoring activity [see http://agage.eas.gatech.edu/ and http://www.esrl.noaa.gov/].

AERONET retrievals of atmospheric particulate absorption will continue to be utilized in climate forcing studies and in the validation of current and future satellite missions, such as the Glory satellite (early 2009 launch), which will measure aerosol light absorption from space. Network expansion will continue, with focus on regions that are not adequately sampled and that are important for understanding of global climate change such as Asia. An experimental effort is underway to investigate the possibility of measuring sunlight reflected off the moon to make aerosol measurements at night. In addition, an experimental algorithm is under development to make measurements of atmospheric carbon dioxide. In the future, lidar data will be used in studies of the influence of polar stratospheric clouds on ozone formation over the South Pole, arctic haze impacts on polar climate, generation of climatological aerosol and cloud properties at several Micro Pulse Lidar (MPL) NETwork (MPLNET) sites. To enhance data value, MPL instrument designs and hardware will be continually improved. In addition, several new MPLNET data products will be made available to the research community.

The primary goal of the Department of Energy's (DOE) ARM Climate Research Facility (ACRF) is to provide the infrastructure needed for studies investigating atmospheric processes in several climatic regimes and for climate model development and evaluation. The ACRF consists of three stationary facilities, an ARM Mobile Facility (AMF), and the ARM Aerial Vehicles Program (AAVP). The stationary sites provide scientific testbeds in three climatically significant regions (mid-latitude, polar, and tropical), and the AMF provides a capability to address high priority scientific questions in regions other than the stationary sites. The AAVP provides a capability to obtain non-satellite cloud and radiation measurements that complement the ground and satellite measurements. Data streams produced by the ACRF will be available to the atmospheric community for use in testing and improving parameterizations in global climate models. The AMF was deployed in Niamey, Niger, in 2006 measuring radiation, cloud, and aerosol properties during the monsoon and dry seasons.

The stationary ARM sites provide scientific testbeds in three climatically significant regions (mid-latitude, polar, and tropical), and the AMF provides a capability to address high priority scientific questions in regions other than the stationary sites. The AAVP provides a capability to obtain non-satellite cloud and radiation measurements that complement the ground measurements. Data streams produced by the ACRF are available to the atmospheric community for use in testing and improving parameterizations in global climate models. In 2007 the AMF was deployed in the Black Forest region of Germany, where scientists studied rainfall resulting from atmospheric uplift (convection) in mountainous terrain, otherwise known as orographic precipitation. Using measurements from the ARM Tropical Warm Pool International Cloud Experiment (TWP-ICE), a dataset has been created that allows climate and cloud models to simulate tropical weather allowing for direct comparison of observations and model simulations. Publications are now available from two recent campaigns, TWP-ICE and the Mixed-Phase Arctic Cloud Experiment. The AMF will be deployed in China in 2008 to study indirect aerosol effects.

Water vapor is the most important greenhouse gas in our atmosphere, exhibiting large gradients in concentration and mixing ratio between the Earth's surface and the upper troposphere/lower stratosphere (UT/LS). Fitting in with the GRUAN planning work outlined above, understanding changes in the distribution of water vapor, whether due to natural or anthropogenic causes, are essential to understanding the potential for climate change. As a result of the first international GRUAN workshop held in Lindenberg, Germany, in February 2008, NOAA and the DOE ARM program are partnering on contributions to the new international GRUAN effort, and the elements of that potential support fall into the following 4 categories: (1) site support and operation; (2) reference radiosonde development and testing; (3) data management and access, and QA/QC; and (4) international support for both the GCOS Working Group on Atmospheric Reference Observations, as well as for developing nation support that will be key for GRUAN to succeed. The ultimate support will depend, as with most things, on the availability of resources, but the U.S. involvement is in line with the report from the Lindenberg workshop [see http://www.wmo.ch/pages/prog/gcos/Publications/gcos-121.pdf] as well as the overall requirements of GRUAN that are documented at http://www.wmo.ch/pages/prog/gcos/Publications/gcos-112.pdf.

The international Network for the Detection of Atmospheric Composition Change, (NDACC) [formerly the Network for the Detection of Stratospheric Change (NDSC)] was formed to provide a consistent standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed research stations. Since its inception in the late 1980's and onset of official operations in 1991, the NDACC objectives have grown considerably. While the NDACC remains committed to its initial objective of monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization and expected recovery), it's measurement and analysis priorities have broadened to encompass both the stratosphere and free troposphere as well as to explore the interface between changing atmospheric composition and climate. These can be summarized as:

- detecting trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere,
- establishing links between climate change and atmospheric composition,
- calibrating and validating space-based measurements of the atmosphere,
- supporting process-focused scientific field campaigns, and
- testing and improving theoretical models of the atmosphere.

This dual goal of long-term global measurement and understanding has led to the implementation of a ground-based network of "primary" NDSC stations equipped with a suite of remote sensing instruments (such as UV/Visible spectrometers, various types of lidars, Fourier transform infrared spectrometers, microwave radiometers, radiosondes, etc.), allowing the quasi-simultaneous study of a large number of chemical compounds and physical parameters identified as priority targets for the Network. Over forty "complementary" sites equipped with a subset of such instruments and/or operating less regularly than the primary stations, contribute to the global coverage of the Network and provide substantial support during coordinated campaigns targeted at special process studies, at calibration/validation phases of space-based sensors, and at more regional subtle atmospheric characteristics.

NASA and NOAA provide the U.S. support for the NDACC via direct funding of more than a dozen investigator teams as well as the operation of the primary station at Mauna Loa, Hawaii; and the complementary station at Table Mountain, California. U.S. investigators operate instruments at both U.S. and foreign sites and operate mobile intercomparators for instrument validation throughout the Network. Examples of

NDACC measurement and analysis accomplishments as well as details about the network (its implementation, structure and operation, data archiving, and related protocols and publications) can be found at the NDACC web site at http://www.ndacc.org.

Atmospheric observations form a critical component of the NACP. This effort involves a host of universities and many U.S. agencies, including NOAA, NASA, DOE, USDA, USGS, and the Environmental Protection Agency (EPA), among others. The goal is to build an observation system that could measure the transfer of carbon between land and atmosphere across the continent to vastly improve our understanding of its cycling with the terrestrial biosphere. Atmospheric measurements are necessary to constrain surface flux estimates from ecosystem-based measurements. This atmospheric observing system for CO_2, CH4, and other greenhouse gases, referred to as the CarbonTracker Observing System because of its link to the reanalysis product, CarbonTracker, currently consists of 16 Aircraft Sites retrieving weekly vertical profiles up to 10 km, six (6) very tall towers (300-600 m) with continuous measurements at three to five heights, and 13 surface sites sampling flasks weekly. It is expanding slowly to its stage I goal of 24 aircraft sites and 12 tall towers, and more information on that system can be found on-line at **http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/**. This system has linkages to the GAW network and is intended to coordinate with measurements through other continental scale observing systems such as CarboEurope.

Sea level change is associated with numerous factors including the mass balance of the Earth's cryosphere, the storage of water within land reservoirs and aquifers, and the changes in ocean temperature. Sea level change is associated with trends in mass transfer within the Earth system. The Global Geodetic Observing System (GGOS) has provided the essential framework for the measurement of this mass transfer through the development and refinement of the International Terrestrial Reference Frame (ITRF) and the positioning of sensors such as tide gauges, altimetry, and gravity satellites. The ITRF and the global geodetic network that supports it are a critical component of the monitoring global climate change. The GGOS recognizes the importance of its contributions to the climate change record and is seeking to improve the stability of the ITRF to achieve sub-millimeter stability.

Table 1a. National Contributions to the Surface-based Atmospheric ECVs

Contributing Networks specified in the GCOS Implementation Plan	ECVs[2]	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Surface Network (GSN)	Air-Temperature	75	75	75	75	75
	Precipitation	75	75	75	75	75
Full World Weather Watch/Global Observing System (WWW/GOS) surface network [incl. USCRN]	Air-Temperature Air-Pressure Wind Speed/ Direction Water Vapour	624	624	624	624	624
	Precipitation	624	624	624	624	624
Baseline Surface Radiation Network (BSRN)	Surface Radiation	10	10	10	10	10
Solar radiation and radiation balance data	Surface Radiation	7	7	7	7	7
Ocean drifting buoys	Air-Temperature Air-Pressure	1000	1000	1000	1000	1000
Moored buoys	Air-Temperature Air-Pressure	87	87	87	87	87
Voluntary Observing Ship Climate Project (VOSClim) ships	Air-Temperature Air-Pressure Wind Speed/ Direction Water Vapour	910	910	910	910	910
Ocean Reference Mooring Network and sites on small isolated islands	Air-Temperature Wind Speed/ Direction Air-Pressure	43	43	43	43	43
	Precipitation	43	43	43	43	43

[2] Parties should note that the list of ECVs given for each network is indicative of the expected observations from that network. A single response is expected for the network except in the case of precipitation where a separate response is requested due its particular importance to the Convention.

Table 1b. National Contributions to the Upper-Air Atmospheric ECVs

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Upper Air Network (GUAN)	Upper-Air-Temperature Upper-Air Wind Speed/ Direction Upper-Air Water Vapour	21	21	21	21	21
Full WWW/GOS Upper Air Network	Upper-Air-Temperature Upper-Air Wind Speed/ Direction Upper-Air Water Vapour	92	92	92	92	92

Table 1c. National Contributions to the Atmospheric Composition

ECVs Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
World Meteorological Organization/Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO_2 & CH_4 Monitoring Network	Carbon Dioxide (CO_2)	49	49	49	49	49
	Methane (CH_4)	49	49	49	49	49
	Other greenhouse gases	49	49	49	49	49
WMO/GAW ozone sonde network[3]	Ozone	8	8	8	8	8
WMO/GAW column ozone network[4]	Ozone	16	16	16	16	16
WMO/GAW Aerosol Network[5]	Aerosol optical depth	6	6	6	6	6
	Other Aerosol Properties	6	6	6	6	6

[3] Including SHADOZ, NDACC, remote sensing and ozone sondes.
[4] Including filter, Dobson and Brewer stations.
[5] Including AERONET, SKYNET, BSRN and GAWPFR.

Chapter 3: Non-Satellite Oceanic Observations

Ocean waters cover 70 percent of the Earth's surface. The ocean is the memory of the climate system and is second only to the sun in effecting variability in the seasons and long-term climate change. The ocean has potential to store 1000 times more heat than the atmosphere and 50 times more carbon. Eighty-five percent of the rain and snow that water our Earth comes directly from the ocean. Prolonged drought is influenced by persistent patterns of ocean temperature. Ocean regimes such as El Niño change weather and storm patterns around the world. Sea level rise is one of the most immediate impacts of climate change, and the key to the possibility of rapid climate change may lie in deep ocean circulation with a cycle on a timescale of hundreds of years.

Observation is the foundation for all climate information. As such, the U.S. is dependent upon a global ocean observing system to fulfill both its climate and weather forecast missions. The memory of the global atmosphere is eight days, whereas the memory of the ocean is a few hundred years. So any forecast of weather conditions beyond one week, or at most two, needs the ocean. Under many storm conditions even short-term weather forecasts are improved by including ocean-atmosphere interaction. The longer the time-scale of concern, the more important the ocean becomes. Predictions of climate conditions in the next decades depend essentially on ocean data.

Ocean observations are needed not only to drive forecast models, but also to assess the changing state of the climate. Hundreds of research papers cited in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) depended upon ocean data. One example involved the global carbon budget; at present it is believed that the ocean absorbs about half of the carbon that mankind puts into the atmosphere. Only with sustained ocean observations will we know if this will continue and if resulting ocean acidity will continue to increase.

Although many impacts of climate variability are felt locally, climate is a global phenomenon. It is critical that the U.S. work with partners to establish a global ocean climate observing system now and commit to sustaining it, so that the Nation and the world will have the best possible information from which to initiate climate projections, and so that future generations will have the information necessary to resolve questions about long-term trends in Earth's ever changing climate.

At present, the U.S. is the world leader in implementing the non-satellite elements of the global ocean observing system for climate and sponsors the majority of the Global Component of the U.S. Integrated Ocean Observing System (IOOS), which is the U.S. contribution to the international GOOS program and the ocean baseline of the GEOSS. The U.S sponsors nearly half of the platforms presently deployed in the global ocean (3860 of 7723) with 72 other countries providing the remainder. The U.S. has historically contributed about half of the international system and has been a leader in fostering an international systems approach to the implementation of GOOS.

The ocean observing system, while expanding in coverage, is not yet complete. The global system is currently at just 60% of the initial design. The demand for ocean data and the products/forecasts derived from these data require that we work cooperatively with other nations in order to complete deployment as soon as possible.

The goal of NOAA's Climate Observation Division is to build and sustain a global climate observing system that will respond to the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments. The focus is on building the *non-satellite* ocean component. Our objectives are to:

- document long term trends in sea level;
- document ocean carbon sources and sinks;
- document the ocean's storage and global transport of heat and fresh water;
- document ocean-atmosphere exchange of heat and fresh water.

The ocean climate observing system must have the capability to deliver continuous instrumental records and global analyses of:

- Sea level to identify changes resulting from climate variability and change;
- Ocean carbon content every ten years and the air-sea exchange seasonally;
- Sea surface temperature and surface currents to identify significant patterns of climate variability;
- Sea surface pressure and air-sea exchanges of heat, momentum, and fresh water to identify changes in forcing function driving ocean conditions and atmospheric conditions;
- Ocean heat and fresh water content and transports to: 1) identify changes in the global water cycle; 2) identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change; and 3) identify where anomalies enter the ocean, how they move and are transformed, and where they re-emerge to interact with the atmosphere; and
- Sea ice extent, concentrations, and thickness to identify changes resulting from, and contributing to, climate variability and change.

The GCOS requirements for ocean observations are the same as the climate requirements for GOOS. Both are based on the Ocean Observing System Development Panel (OOSDP) Report, which can be found on-line at the following link at http://www-ocean.tamu.edu/OOSDP/FinalRept/t_of_c.html. The strategy for GOOS, like that for GCOS, is based on a number of airborne and ocean-based *non-satellite* and remote sensing, and space-based observing components. The U.S. contributes to all of these components. It supports surface and marine observations through 149 fixed buoys, over 500 surface drifting buoys, nearly 200 sub-surface floats, and over 1500 volunteer observing ships as part of the Integrated Global Ocean Observing System (IGOSS). It provides support for 244 sea-level tide gauges through the Global Sea Level Observing System (GLOSS). It currently provides satellite coverage of the global oceans for sea surface temperatures, surface elevation, ocean surface winds, sea ice, ocean color, and other variables of climate relevance. These satellite activities are coordinated internationally through the Committee on Earth Observation Satellites (CEOS).

The first element of the climate portion of GOOS, completed in September 2005, is the global drifting buoy array, which is a network of 1,250 drifting buoys measuring sea-surface temperature and other variables as they flow in the ocean currents. . The U.S. also supports a significant component of the GGOS, which provides for the positioning of the tidal gauges and altimetry satellites within a stable geodetic reference frame for multi-decadal comparisons of sea level trends and periodicities.

In 1998 an international consortium presented plans for an array of 3,000 autonomous instruments that would revolutionize the collection of critical, climate-relevant information from the upper 2 km of the worlds' oceans – The Argo Array. These instruments drift at depth, periodically rising to the sea surface, collecting data along the way, and report their observations in real-time via satellite communications. The initial deployment objective of 3,000 instruments distributed homogenously throughout the world's oceans has been attained and the Array now provides over 100,000 high-quality temperature and salinity profiles annually along with global scale velocity data, all without a seasonal bias. The Argo array has been deployed through the collaboration of more than 40 countries plus the European Union.

A guiding principle of Argo is that the program should benefit everyone, thus, the data are openly and immediately available to anyone wishing to use them. Argo data coupled with global scale satellite measurements from radar altimeters has made possible huge advances in the representation of the oceans in coupled ocean atmosphere models for climate forecasts and the routine analysis and forecasting of the state of the subsurface ocean. Argo data are being used in an ever-widening range of research applications that have led to new insights into how the ocean and atmosphere interact in extreme as well as normal conditions. Two examples are the processes in polar winters when the deep waters that fill most of the ocean basins are formed and the transfer of heat and water to the atmosphere beneath tropical cyclones. Both conditions are crucial to global weather and climate and could not be observed by ships.

The present generation of instruments has a design life 4 years when profiling to 2 km depth every 10 days. Maintaining the array will require annual deployments of around 800 floats. Having deployed the array and built the data delivery system, the challenge is to maintain the full array, including ensuring the availability of the platform resources to maintain it, for a decade in a pre-operational "sustained maintenance" phase. This will allow the array's design to be optimized and its value fully demonstrated. The U.S. has committed to maintaining half of the array and other contributing nations are striving to continue the array's strong international nature.

Continued upgrading of the Global Sea Level Observing System (GLOSS) tidal gauge network from 43 to 170 stations are planned for the period from 2006-10. Ocean carbon inventory surveys in a 10-year repeat survey cycle help determine the anthropogenic intake of carbon into the oceans. Plans for advancement of the global Tropical-Atmosphere-Ocean (TAO) network of ocean buoys include an expansion of the network into the Indian Ocean (the Pacific Ocean has a current array of 70 TAO buoys). From 2005-07, 8 new TAO buoys were installed in the Indian Ocean in collaboration with partners from India, Indonesia, and France. Plans call for a total of 38 TAO buoys in the Indian Ocean by 2013 that forms the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) network. RAMA is a multinationally supported element of the Indian Ocean Observing System (IndOOS), a combination of complementary satellite and non-satellite measurement platforms for climate research and forecasting purposes. NASA is currently investing in the development of new prototype geodetic instruments for deployment later this decade in development of a next generation geodetic network for the improvement of the terrestrial reference frame.

These moorings will enhance the tropical networks currently monitoring above-surface, surface, and subsurface conditions in the Pacific and Atlantic Oceans. By the end of 2008, 60 percent of the GOOS suite of ocean climate observing platforms will have been fielded; the full system of ocean climate sensors is scheduled for completion by 2013. IOOS is the U.S. coastal observing component of the Global Ocean Observing System and is envisioned as a coordinated national and international network of observations, data management and analyses that systematically acquires and disseminates data and information on past, present and future states of the oceans. A coordinated IOOS effort is being established by NOAA via a national IOOS Program Office collocated with the Ocean.US [http://www.ocean.us/] consortium of offices consisting of NASA, National Science Foundation (NSF), NOAA, and the U.S. Navy. The IOOS observing subsystem employs both remote and non-satellite sensing. Remote sensing includes satellite-, aircraft- and land-based sensors, power sources and transmitters. Non-satellite sensing includes platforms (ships, buoys, gliders, etc.), non-satellite sensors, power sources, sampling devices, laboratory-based measurements, and transmitters. More information on U.S. IOOS efforts can be found on-line at **http://ioos.noaa.gov/**.

Table 2a. National contributions to the Oceanic ECVs - Surface

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
Global surface drifting buoy array on 5x5 degree resolution	Sea -Surface Temperature, Sea -Level Pressure, Position-change-based Current	1000	1000	1000	1000	1000
GLOSS Core Sea-level Network	Sea level	26	26	26	26	26
Voluntary Observing Ships (VOS)	All feasible surface ECVs	435	435	435	435	435
Ship of Oppor. Programme.	All feasible surface ECVs	41	41	51	41	41

Table 2b. National contributions to the Oceanic ECVs – Water Column

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
Global reference mooring network	All feasible surface and subsurface ECVs	43	43	43	43	43
Global tropical moored buoy network	All feasible surface and subsurface ECVs	87	87	87	87	87
Argo network	Temperature, Salinity, Current	1500	1500	1500	1500	1500
Carbon inventory survey lines	Temperature, Salinity, Ocean Tracers, Biogeochemistry variables	41	41	51	41	41

Chapter 4: Non-Satellite Terrestrial Observations

For terrestrial observations, the requirements for climate observations were developed jointly between GCOS and the Global Terrestrial Observing System (GTOS) through the Terrestrial Observations Panel for Climate (TOPC); see GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 2.0 June 1997, GCOS-32 (WMO/TD-No. 796).

GCOS and GTOS have identified permafrost thermal state and permafrost active layer as key variables for monitoring the state of the cryosphere. GCOS approved the development of a globally comprehensive permafrost monitoring network to detect temporal changes in the solid earth component of the cryosphere. As such, the Global Terrestrial Network for Permafrost (GTN-P) is quite new and still very much in the developmental stage. The International Permafrost Association (IPA) has taken the responsibility for managing and implementing the GTN-P.

In the U.S., contributions to the GTN-P network are provided by the USGS and the NSF, through grants to various universities. All the U.S. GTN-P stations are located in Alaska. The active layer thickness is currently being monitored at 27 sites. Many of these instrumented sites also monitor soil temperature (at several depths), soil moisture, snow depth, and air temperature. Sixteen of the active layer sites are co-located with boreholes where the permafrost thermal state can be monitored. All sites are appropriate for characterizing national climate. The first of the GTN-P active layer monitoring stations were installed in 1991. Forty-eight boreholes exist in Alaska where permafrost thermal state can be determined. Of these, 4 are classified as *Surface* (0-10 m) sites, 1 is *Shallow* (10-25 m), 22 are *Intermediate Depth* (25-125 m), and 21 are *Deep Boreholes* (>125 m). U.S. contribution to the GTN-P network comes from short-term (3-5 yr) research projects. The frequency of measurement varies greatly according to the total depth of the boreholes.

The Geological Survey of Canada is providing the international data management, including archiving, for the GTN-P borehole temperature monitoring (permafrost thermal state) program (see http://www.gtnp.org/). The GTN-P includes sites from the Circumpolar Active Layer Monitoring (CALM) program as well, but data from these are archived at the University of Delaware (see http://www.udel.edu/Geography/calm/). The National Snow and Ice Data Center (NSIDC) in Boulder, CO, has a periodically updated summary on global permafrost and frozen ground as part of a State of the Cryosphere presentation that can be found on-line at http://nsidc.org/sotc/permafrost.html.

The U.S. operates a long-term "benchmark" glacier program to intensively monitor climate, glacier motion, glacier mass balance, glacier geometry, and stream runoff at a few select sites. The data collected are used to understand glacier-related hydrologic processes and improve the quantitative prediction of water resources, glacier-related hazards, and the consequences of climate change. The approach has been to establish long-term mass balance monitoring programs at three widely spaced glacier basins in the U.S. that clearly sample different climate-glacier-runoff regimes. The three glacier basins are South Cascade Glacier in Washington State, and Gulkana and Wolverine Glaciers in Alaska. Mass balance data are available beginning in 1959 for the South Cascade Glacier, and beginning in 1966 for the Gulkana and Wolverine Glaciers. Additional information and data for the benchmark glaciers is available at http://ak.water.usgs.gov/glaciology/.

The Ameriflux network generally endeavors to establish an infrastructure for guiding, collecting, synthesizing, and disseminating long-term measurements of CO_2, water, and energy exchange from a variety of ecosystems. Its objectives are to collect critical new information to help define the current global CO_2 budget, enable improved predictions of future concentrations of atmospheric CO_2, and enhance the understanding of carbon fluxes, Net Ecosystem Production (NEP), and carbon sequestration in the terrestrial biosphere. The NACP is a major focus of the U.S. CCSP, and is an effort to measure and understand the source and sinks of CO_2, CH_4, and Carbon Monoxide (CO) in North America and in adjacent ocean regions.

The terrestrial section of the report examines non-satellite climate monitoring and involves, in addition to the GTN-P, Global Terrestrial Network for Glaciers (GTN-G), and AmeriFLUX programs, streamflow and surface water gaging, ground water monitoring, snow and soil monitoring, the U.S. paleoclimatology program, ecological observation networks, fire weather observation stations, as well as global, national, and regional land cover characterization. The U.S. contributes to all of these components, and supports 77 GTN-P sites, 3 GTN-G sites, and 52 Fluxnet sites.

The USDA's SNOpack TELemetry (SNOTEL) and SCAN monitoring networks provide automated comprehensive snowpack, soil moisture, and related climate information designed to support natural resource assessments. SNOTEL operates more than 660 remote sites in mountain snowpack zones of the western U.S. SCAN, which began as a pilot program, now consists of more than 120 sites. These networks collect and disseminate continuous, standardized soil moisture and other climate data in publicly available databases and climate reports. Uses for these data include inputs to global circulation models, verifying and ground truthing satellite data, monitoring drought development, forecasting water supply, and predicting sustainability for cropping systems. Please see http://www.wcc.nrcs.usda.gov/ for more details on both SNOTEL and SCAN.

Polar climate observations will continue to be a focus of U.S. activities as these efforts continue for the IPY. Currently, the U.S. maintains soil-moisture climate stations in both Alaska and Antarctica, and plans to increase efforts on observations of the Arctic atmosphere, sea ice, and ocean. Working with a number of Arctic nations via the International Arctic Systems for Observing the Atmosphere (IASOA), the U.S. will deploy and/or participate in a number of observing activities to produce a higher-resolution characterization of clouds and aerosols and of both incoming and outgoing radiation, to provide the high-quality records needed to detect climate change and to improve calibration of broad-scale satellite observations in the Arctic. For example, through the IASOA process, the U.S. will be working with its international partners in establishing a super-site climate observatory in the Russian Arctic in Tiksi, north of the Arctic Circle at latitude 71.50º north.

The USGS operates a network of about 6,760 stream-gauging stations at which continuous records of water level (stage) and streamflow (discharge) are obtained. The USGS compiles, analyzes, and publishes data for these stations annually. In addition, the USGS publishes furnished data for about 630 streamgaging stations operated by other Federal, state, and local agencies. These 7,400 stations have a mean record length of 39 years, with a maximum record length of 126 years. Historical streamflow data for all of the stream-gauging stations and real-time data for about 5,350 stations that are equipped with telemetry can be retrieved from the Internet at http://water.usgs.gov/nwis.

Most of the streamgaging stations in the USGS network are not useful for analyzing changes in climate because the stations are affected by human influences, such as diversions, dam regulations, and urban land uses. A group of 1,659 stations, named the Hydro-Climatic Data Network (HCDN), was identified and data was compiled for the stations for use in studies of climate change. Periods of data collection spanned 44 years on average for the HCDN stations in 1988, when the data were compiled. Data collection began as early as 1874. Since 1988, however, 444 of the original 1,659 HCDN stations have ceased operating, primarily because of lack of funding.

Concern about losses to its stream-gauging network has prompted the USGS and its partners to develop the National Streamflow Information Program (NSIP). Information on NSIP can be obtained at http://water.usgs.gov/nsip/. The NSIP plan would increase the level of streamflow information available for National needs, improve the way streamgaging stations are funded and located, and develop new ways to collect, store, and distribute streamflow information. Those streamgaging stations providing data that meet Federal needs, such as analyses of climate change, would be funded entirely through Federal appropriations under the NSIP plan rather than funded in cooperation with other agencies, as is the current practice. During the previous two fiscal years, the USGS has received increased appropriations that were used to begin implementing the NSIP. In addition to monitoring streamflow, the USGS also monitors groundwater quality by providing unbiased, timely, and relevant information and studies about ground-water resources that can be found on-line at http://water.usgs.gov/ogw/.

The USGS began the Land Cover Characterization Program (LCCP) in 1995 to develop land cover and other land characterization databases to address national and international requirements that were becoming increasingly sophisticated and diverse. To meet these requirements, USGS develops multiscale land cover characteristics databases used by scientists, resource managers, planners, and educators (Global and National Land Cover Characterization), and contributes to the understanding of the patterns, characteristics, and dynamics of land cover across the Nation and the Earth (Urban Dynamics and Land Cover Trends). The program also conducts research to improve the utility and efficiency of large-area land cover characterization and land cover characteristics databases.

The initial goal to develop a global 1-km land cover characteristics database was achieved in 1997. Current efforts focus on revising the database utilizing input from users around the world. The USGS, the University of Nebraska-Lincoln, and the European Commission's Joint Research Centre generated the initial 1-km resolution Global Land Cover Characteristics database using 1-km NOAA AVHRR data from April 1992 through March 1993. This was done on a continent-by-continent basis using standard map projections and 1-km nominal spatial resolution; each continental database contains unique elements based on the geographic aspects of the specific continent. The continental databases are combined to make seven global data sets, each representing a different landscape based on a particular classification legend.

Two versions of the Global Land Cover Characteristics database are now available (http://edcdaac.usgs.gov/glcc/glcc.html). The first version (Version 1.2) was released to the public in November 1997. It was produced as an International Geosphere-Biosphere Program Data and Information System (IGBP-DIS) initiative lead by the Land Cover Working Group and has been subjected to a formal accuracy assessment (the IGBP DISCover classification). Many users of the land cover data set provided suggestions for additions and improvements that have been incorporated into Version 2.0.

The National Ecological Observatory Network (NEON) is a continental-scale research platform for discovering and understanding the impacts of climate change, land-use change, and invasive species on ecology. The intent of NEON is to gather long-term data on ecological responses of the biosphere to changes in land use and climate, and on feedbacks with the geosphere, hydro sphere, and atmosphere. NEON is a national observatory, not a collection of regional observatories. It will consist of distributed sensor networks and experiments, linked by advanced cyber infrastructure to record and archive ecological data for at least 30 years. Using standardized protocols and an open data policy, NEON will gather essential data for developing the scientific NEON is a critical step toward forecasting how ecosystems and organisms interact with changes in climate and land use, and what the impact of these changes might be on people and their enterprises. NEON data will be readily available to researchers, teachers and students, and all citizens with an interest in ecological science and environmental processes. NEON will be a sentinel system for environmental change, a national laboratory focused on understanding complex ecological processes at the continental scale. NEON is designed to serve as a U.S. terrestrial contribution to GEOSS. For more information regarding NEON, please reference the project web site at http://www.neoninc.org/.

Table3. National Contributions to the Terrestrial Domain ECVs.

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2010	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Baseline River Discharge Network (GTN-R)	River Discharge	10,879	5,240	5,240	5,240	5,240
GCOS Baseline Lake Level/ Area/Temperature Network (GTN-L)	Lake Level/Area/ Temperature	520	520	520	520	520
WWW/GOS synoptic network	Snow Cover	1,870	1,870	1,870	1,870	1,870
GCOS Glacier monitoring network (GTN-G)	Glaciers mass balance and length, also Ice sheet mass balance	3	**3**	3	3	3
GCOS Permafrost Monitoring Network (GTN-P)	Permafrost borehole-temperatures and active-layer thickness	29	29	29	29	29

Chapter 5: Satellite Global Atmospheric, Oceanic, and Terrestrial Observations

Space-based, remote-sensing observations of the atmosphere–ocean–land system have evolved substantially since the early 1970s when the first operational weather satellite systems were launched. Over the last decade satellites have proven their observational capability to accurately monitor nearly all aspects of the total Earth system on a global basis. Currently, satellite systems monitor the evolution and impacts of El Niño and La Niña, weather phenomena, natural hazards, and vegetation cycles; the ozone hole; solar fluctuations; changes in snow cover, sea ice and ice sheets, ocean surface temperatures, and biological activity; coastal zones and algal blooms; deforestation and forest fires; urban development; volcanic activity; tectonic plate motions; aerosol and 3-dimensional cloud distributions; water distribution; and other climate-related information.

Satellite observations provide a unique perspective of the global integrated Earth system and are necessary for good global climate coverage. Non-satellite observations are required for the measurement of parameters that cannot be estimated from space platforms (e.g., groundwater, carbon sequestration at the root zone, subsurface ocean parameters, and particular elements of biodiversity). Certain non-satellite observations also provide long time series of observations required for the detection and diagnosis of global change, such as surface temperature, precipitation and water resources, weather and other natural hazards, the emission or discharge of pollutants, and the impacts of multiple stresses on the environment due to human and natural causes. One critical challenge to the Earth observation field is to maintain existing observation capabilities in a variety of areas. For example, maintaining the observational record of stratospheric ozone is essential in discerning the effects of climate change on the nature and timing of ozone recovery. Other key areas include radiative energy fluxes of the Sun and Earth, atmospheric carbon dioxide, and global surface temperature. Efforts to create a long-term record of global land cover, started by Landsat in the 1970s, are currently being prepared for the transition to a Landsat Data Continuity Mission (LDCM) being planned by NASA and USGS. The LDCM is expected to have a 5-year mission life with 10-year expendable provisions, and is planned to launch in 2011.

In August 2007, the U.S. announced a new National Land Imaging Program (NLIP), to be managed by the U.S. Department of the Interior and implemented by USGS. Through this program, the U.S. would provide a new level of global leadership in land research and land management, including enhanced monitoring of the effects of global climate and land use change. The new program will consolidate responsibility for user needs assessment, satellite and data acquisition, technology advancement, data archiving and distribution, and advanced applications development for U.S. civil operational land imaging. Of particular interest to the international research community is the fact that under NLIP, long-standing U.S. non-discriminatory access and distribution policies will be continued for land imaging data.

The current generation of U.S. satellite instruments exceeds the GCOS requirements for the absolute calibration of sensors, something that was lacking in the early satellite platforms used for real-time operational purposes. Regarding historical satellite data, several of the data series from operational satellites have been re-processed using substantially improved retrieval algorithms and, therefore, provide good quality global data products for the purposes of GCOS and climate system variability and climate change research and applications. Improving the on-board capabilities for calibration on operational satellites will be one of the objectives considered in the deployment of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program.

The potential contribution of NPOESS to climate monitoring over the next decade has been significantly affected due to cost constraints. A decision was made in June 2006 to drop many of the climate-related instruments from NPOESS. These sensors included those for earth radiation budget, solar irradiance (total and spectrally resolved), high resolution ozone vertical profile, aerosol optical properties, and sea surface topography. While the prospect of this may lead to gaps in several climate parameters the potential for restoring some of these sensors is currently being evaluated by NASA and NOAA. To date, three sensors have been restored to NPOESS as follows: (1) the ozone vertical profile sensor known as the Ozone Mapping and Profiling Suite – Limb instrument; (2) the Total Solar Irradiance Sensor (TSIS); and (3) the Clouds and Earth Radiant Energy System (CERES) sensor which provides earth radiation budget data. The concern to maintain climate observing continuity on a global scale is an issue that the U.S. takes seriously and as such is examining and evaluating strategies to prioritize and reduce the impacts.

Prior to the launch of NPOESS in 2013, the NPP satellite will serve as a bridge mission between the NASA Earth Observing System (EOS) program and NPOESS. The mission of NPP is to demonstrate advanced technology for atmospheric sounding, continuing observations of global change after EOS-Terra and EOS-Aqua. It will supply data on atmospheric and sea surface temperatures, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties. NPP will contribute to instrument risk reduction by offering early instrument and system level testing and lessons learned for design modifications in time to ensure NPOESS launch readiness, ground system risk reduction, and early user evaluation of NPOESS data products, such as algorithms, and instrument verification, and opportunities for instrument calibration.

A number of U.S. satellite operational and research missions form the basis of a robust national remote-sensing program that fully supports the requirements of GCOS. These include instruments on the Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES), the series of Earth Observing Satellites (EOS), the Landsats 5 and 7, and the Jason satellite measuring sea-surface height, winds, and waves. Additional satellite missions in support of GCOS include (1) the Active Cavity Radiometer Irradiance Monitor for measuring solar irradiance; (2) QuickSCAT; (3) the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) for studying ocean and productivity, as well as aerosols; (4) the Shuttle Radar Topography Mission (SRTM); (5) the Tropical Rainfall Measuring Mission for measuring rainfall, clouds, sea-surface temperature, radiation, and lightning; (6) the Ocean Surface Topography Mission (OSTM), an altimetry mission to provide sea surface heights for determining ocean circulation, climate change and sea-level rise; (7) ICESat, and the Gravity Recovery and Climate Experiment (GRACE) that measure the transport of mass between the cryosphere, oceans and land; (8) Tropical Rainfall Measuring Mission (TRMM); and (9) Laser Geodynamics Satellite (LAGEOS), Global Position Satellites (GPS) and other geodetic satellites that provide for an accurate Terrestrial Reference Frame for the measurement of sea level change.

A major upgrade to the GOES system, known as GOES-R, is under development, with a first launch currently planned for 2015. It should also be noted that a number of new missions will be launched over the next several years as follows [launch year in brackets]: (1) Orbiting Carbon Observatory (OCO) [2009] mission to measure CO_2; (2) Glory mission [2009] that will measure black carbon soot and other aerosols, as well as total solar irradiance; (3) Aquarius [2010] intended to measure global sea surface salinity; and (4) Global Precipitation Measurement (GPM) mission [2013].

The accurate, climate-quality record of sea surface topography measurements, started in 1992 with TOPEX/POSEIDON and continued in 2001 with the Jason satellite mission, will be extended with the OSTM. These missions have provided accurate estimates of regional sea-level change and of global sea-level rise unbiased by the uneven distribution of tide gauges. Ocean topography measurements from these missions have elucidated the role of tides in ocean mixing and maintaining deep ocean circulation. Further, quantitative determination of ocean heat storage from satellite measurements have confirmed climate model predictions of the Earth's energy imbalance which is primarily due to greenhouse gas forcing. The high levels of absolute accuracy and cross calibration make these missions uniquely suited for climate change studies. OSTM, launched in 2008, is a collaborative effort among NASA, NOAA, the French space agency Centre National d'Etudes Spatiales (CNES), and the European meteorological agency EUMETSAT.

Launched in 1997, TRMM is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. TRMM was the first mission dedicated to observing and understanding the tropical rainfall and how this rainfall affects the global climate. The primary instruments for measuring precipitation are the Precipitation Radar, the TRMM Microwave Imager, and the Visible and Infrared Scanner. Additionally, TRMM carries the Lightning Imaging Sensor and the Clouds and the Earth's Radiant Energy System Instrument. These instruments all can function individually or in combination with one another.

Motivated by the successes of the TRMM satellite and recognizing the need for a more comprehensive global precipitation measuring program, NASA and JAXA conceived a new Global Precipitation Measurement (GPM) Mission, which is still in the formulation phase. 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, 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 (and 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.

The Glory mission is planned to launch in 2009. 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 2009, a period of expected low solar activity. 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.

The Aquarius satellite mission will measure changes in sea surface salinity over the global oceans to a precision of 2 parts in 10,000 (equivalent to about 1/6 of a teaspoon of salt in 1 gallon of water). By measuring global sea surface salinity with good spatial and temporal resolution, Aquarius will answer long-standing questions about how our oceans respond to climate change and the water cycle, including changes in precipitation, evaporation, ice melting, and river runoff. Aquarius is a collaborative effort between NASA and Comisión Nacional de Actividades Espaciales (CONAE), the Argentine space agency, with an expected launch date in 2010.

The "A-Train" is a sun-synchronous earth-orbiting satellite formation that studies the atmosphere. The "A" in "A-Train" stands for "Atmosphere" and is a collaboration between NASA and the space agencies of Canada and France. The A-Train constellation consists of five satellites flying in close proximity to each other, with a 6th satellite, the Orbiting Carbon Observatory (OCO), due to be added late in early 2009. The first satellite in the A-Train constellation, Aqua, was launched in 2002. The second satellite, Aura, was launched in June 2004, while the CloudSAT, CALIPSO and PARASOL satellites were launched in October 2004. The A-Train satellites cross the equator within a few minutes of one another at around 1:30 p.m. local solar time. By combining the different sets of observations from the A-Train, a better understanding of atmospheric composition, clouds, and aerosols has resulted that has led and is leading to major advances in atmospheric knowledge. More details on the six A-Train components are as follows:

- The NASA Aura satellite was launched in July 2004 with 4 instruments to extensively monitor the composition of the atmosphere. Two of these instruments, the Microwave Limb Sounder (MLS) and High Resolution Dynamics Limb Sounder (HIRDLS), obtain limb viewing observations to obtain highly resolved altitude profiles of the stratosphere and upper troposphere for understanding photochemical and dynamical processes in these altitude ranges. The Tropospheric Emission Spectrometer (TES) obtains column and partial altitude profiles for ozone and tropospheric trace gases, while the Ozone Monitoring Instrument (OMI) obtains nearly daily global ozone column maps as well as columns for other important air quality parameters. Aura observes the atmosphere to answer the following three high-priority environmental questions: (1) is the Earth's ozone layer recovering; (2) is air quality getting worse; and (3) how is the Earth's climate changing.

- PARASOL is a French CNES microsatellite project. It has improved the characterization of cloud and aerosol microphysical and radiative properties. This has led to a substantial increase in our understanding of the radiative impact of clouds and aerosols that in turn has led to improving numerical modeling of these processes in general circulation models.

- The NASA Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and NASA CloudSat satellites were successfully launched in April 2006. CALIPSO and CloudSat are highly complementary and together provide new, three-dimensional perspectives of how clouds and aerosols form, evolve, and affect weather and climate. Both CALIPSO and CloudSat fly in formation as part of the NASA A-Train constellation (e.g., Aqua, Aura, and the French PARASOL spacecraft), providing the benefits of near simultaneity and thus the opportunity for synergistic measurements made with complementary techniques. After the launch of NASA's OCO satellite in 2009, it will join the A-Train.

- The NASA Aqua satellite is designed to acquire precise atmospheric and oceanic measurements that provide a greater understanding of these components in the Earth's climate. Other instruments on Aqua, such as the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, provide regional to global land cover, sea surface temperature, and ocean color. Data from the A-Train instruments will help answer these important questions: (1) what are the aerosol types and how do satellite observations match global emission and transport models; (2) how do aerosols contribute to the Earth Radiation Budget and to what extent are they a climate forcing; (3) how does cloud layering affect the Earth Radiation Budget; (4) what is the vertical distribution of cloud water/ice in cloud systems; and (5) what is the role of Polar Stratospheric Clouds in ozone loss and de-nitrification of the Arctic vortex.

- NASA's OCO is a new mission, expected to launch in early 2009, which will provide the first dedicated, 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. These maps will enable more reliable projections of future changes in the abundance and distribution of atmospheric CO_2 and enhance understanding of the effect these changes may have on the Earth's climate.

Some other significant existing missions since the last report to the UNFCCC include the following:

- NASA's Ice, Cloud, and Land Elevation Satellite (ICESat), launched in 2003, has been measuring 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 determining the present-day mass balance of the ice sheets, to study associations between observed ice changes and polar climate, and to improve estimates of the present and future contributions to global sea level rise.

- NASA's 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 and observe some of the spectral properties of solar radiation for the first time.

- NASA's Gravity Recovery and Climate Experiment (GRACE) twin satellites celebrated their sixth anniversary on orbit in March 2008, completing a successful primary mission which has provided improved estimates of the Earth's gravity field on an on-going basis. In conjunction with other data and models, GRACE has provided observations of terrestrial water storage changes, ice-mass variations, ocean bottom pressure changes and sea-level variations.

- The US-Taiwan Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) GPS Radio Occultation (GPSRO) constellation, and the NASA supported GPSRO Occultation devices aboard the Challenging Minisatellite Payload (CHAMP), GRACE, and SAC-C satellite missions are providing absolute measurements of atmospheric and ionospheric refractivity related to atmospheric temperature and water vapor and ionospheric electron content. GPSRO is inherently a stable measurement because of its sole reliance upon the transfer of time which and be achieve with superb accuracy.

In 2007, the U.S. National Academy of Sciences' National Research Council's (NRC) Committee on Earth Science and Applications from Space published a study entitled, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" [see http://books.nap.edu/catalog.php?record_id=11820] which recommended four satellite missions for launch in the 2010-2013[6] time frame as follows:

- The Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission is one in which NASA and NOAA share responsibility.   The NOAA component involves the continuity of measurements of incident solar irradiance and Earth energy budget by flying the TSIS and CERES sensors that were removed from NPOESS. The NASA portion involves the measurement of spectrally resolved thermal IR and reflected solar radiation at high absolute accuracy. Coupled with measurements from on-board GPS radio occultation

[6] Chapter 2 of the NRC report details several other missions recommended for the periods of 2013-2016 and 2016-2020 that while reflected in the ECV Tables 4-6 will not be described in detail in this report.

receivers, these measurements will provide a long-term benchmarking data record for the detection, projection, and attribution of changes in the climate system. In addition, the SI traceable radiances will provide a source of absolute calibration for a wide range of visible and infrared Earth observing sensors, greatly increasing their value for climate monitoring.

- The Deformation Ecosystem Structure and Dynamics of Ice (DESDynI) is a dedicated Interferometric Synthetic Aperture Radar (InSAR) and LIDAR mission optimized for studying hazards and global environmental change. The mission objectives are to (1) determine the likelihood of earthquakes, volcanic eruptions, and landslides; (2) predict the response of ice sheets to climate change and impact on the sea level; (3) characterize the effects of changing climate and land use on species habitats and carbon budget; and (4) monitor the migration of fluids associated with hydrocarbon production and groundwater resources. This mission combines two sensors that, taken together, provide observations important for solid-Earth (surface deformation), ecosystems (terrestrial biomass structure) and climate (ice dynamics).

- The ICESat-II mission is to deploy an ICESat follow-on satellite to continue the assessment of polar ice changes. ICESat-II is also expected to measure vegetation canopy heights, allowing estimates of biomass and carbon in aboveground vegetation in conjunction with related missions, and allow measurements of solid earth properties. ICESat-II is expected to launch in 2015.

- The Soil Moisture Active and Passive (SMAP) mission is one of four missions recommended by the SMAP will use a combined radiometer and high-resolution radar to measure surface soil moisture and freeze-thaw state, providing new opportunities for scientific advances and societal benefits. Direct measurements of soil moisture and freeze/thaw state will aid understanding of regional and global water cycles, ecosystem productivity and the processes that link the water, energy, and carbon cycles. Soil moisture and freeze/thaw state information provided by SMAP at high resolution will enable improvements to weather and climate forecasts, flood prediction and drought monitoring, and measurement of net CO_2 uptake in forested regions.

The U.S. recognizes the critical role that satellite data play in contributing to the long-term climate record; such remotely sensed data must be part of a system implemented and operated so as to ensure that these data are highly accurate, well calibrated and sustained for the duration of the climate phenomenon being studied. Finally, in addition to meeting the needs of the UNFCCC, the real-time and near-real-time information obtained through such a system would provide an equally large benefit to the needs of many other key societal benefit areas, and as such, the US strives to lead the implementation of such satellite climate requirements as documented in GCOS' satellite requirements document at http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf.

UNFCCC Parties in December 2004 adopted Decision 5/CP.10, which addressed implementation of the GCOS Implementation Plan and *inter alia* invited Parties with space agencies involved in global observations to request those agencies to provide a coordinated response to the recommendations in the GCOS implementation plan. Those Parties with space agencies are coordinating their response through the Committee on Earth Observation Satellites (CEOS), the primary focal point for international coordination of space-related Earth observation activities. Subsequently, CEOS reported to the UNFCCC in 2005, 2006, and 2007. Their reports have been welcomed, accepted and commended by the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA). In December 2007 the SBSTA invited CEOS to provide an updated progress report at its session in December 2008, and it noted the continued close working relationship between GCOS and the CEOS for linking space-based capabilities with global climate observing requirements. The U.S. supports this development as it lends itself to a coordinated, cross-cutting analysis of space agency responses to approximately 59 recommendations in the GCOS Implementation Plan requiring space-based observations.

CEOS also provides active and engaged support to GEO, especially acting as the space component of the GEOSS. The climate component of the GEOSS Implementation Plan is closely linked to the GCOS Implementation Plan. In 2007, CEOS developed an Implementation Plan for Space-based Observations for the GEOSS, which identifies the targets and actions required for delivery of the space segment of the GEOSS and the efforts of space agencies to implement it. As part of this effort, CEOS developed the concept of virtual, space-based Constellations, which is a set of space and ground segment capabilities operating together in a coordinated manner, in effect a virtual system that overlaps in coverage in order to meet a combined and common set of Earth Observation requirements. The individual satellites and ground segments can belong to a single or to multiple owners. The Constellation concept builds upon or serves to refocus already existing projects and activities. The four existing Constellations -- Land Surface Imaging; Ocean Surface Topography; Atmospheric Composition; and Precipitation – all contribute to meeting climate requirements and the provision of observations for ECVs. The cross-cutting Constellations are equally important in providing resources and attention to the issue of continuity of space-based observations for key measurements of ocean, atmosphere, and land.

The following Tables 4-6 will cross reference atmospheric, oceanic, and terrestrial ECVs to the various U.S. satellite missions that are either current or planned.

Table 4: Global Products requiring Satellite Observations – Atmospheric ECVs

ECVs / Global Products requiring Satellite Observations	**Associated Missions – Current and Planned *Planned Missions in italics***
Surface Wind Speed and Direction Surface vector winds analyses, particularly from reanalysis	EOS-Aqua, EOS-Aura, EOS-Terra, GOES, POES, QuikSCAT, *GOES-R, NPP, NPOESS, 3D-WINDS,* DMSP
Upper-air Temperature Homogenized upper-air temperature analyses: Extended MSU-equivalent temperature record; New record for upper-troposphere and lower-stratosphere temperature using data from radio occultation; Temperature analyses obtained from reanalyses	EOS-Aqua, EOS-Aura, EOS-Terra, GOES, POES, QuikSCAT, *GOES-R, NPP, NPOESS, CLARREO, PATH*
Water Vapor Total column water vapor over the ocean and over land; Tropospheric and lower- stratospheric profiles of water vapor	COSMIC, EOS-Aura, EOS-Aqua, EOS-Terra, GOES, POES, *GOES-R, NPOESS, TIMED, JASON, NPP, GPM, CLARREO, PATH*
Cloud Properties Cloud radiative properties (initially key ISCCP products)	Calipso, CloudSat, TRMM, TERRA, AQUA, *ICESAT-1, ICESAT-2, NPP, ACE*
Precipitation Improved estimates of precipitation, both as derived from specific satellite instruments and as provided by composite products	TRMM, *GPM*
Earth Radiation Budget Top-of-atmosphere Earth radiation budget on a continuous basis	SORCE, *CLARREO, Glory, NPOESS*
Ozone Profiles and total column of ozone	EOS-Aura, POES, NPOESS, TIMED, EOS-Aqua, *GACM*
Aerosol Properties Aerosol optical depth and other aerosol properties	Calipso, CloudSat, Terra, EOS-Aqua, *ACE, GACM, GEO-CAPE, Glory*
Carbon Dioxide, Methane and other Greenhouse Gases (GHG) Distribution of greenhouse gases, such as CO2 and CH4, of sufficient quality to estimate regional sources and sinks	*ASCENDS, OCO*
Upper-air Wind Upper-air wind analyses, particularly from reanalysis	EOS-Aqua, EOS-Aura, EOS-Terra, GOES, POES, QuikSCAT, *GOES-R, NPP, NPOESS, 3D-WINDS*
Atmospheric Reanalyses	EOS-Aqua, EOS-Aura, EOS-Terra, GOES, POES, *GOES-R, NPP, NPOESS*

Table 5: Global Products requiring Satellite Observations – Oceans

ECVs / Global Products requiring Satellite Observations	**Associated Missions – Current and Planned** ***Planned Missions in italics***
Sea Ice Sea-ice concentration	DMSP, GRACE-1, Landsat, Terra, Aqua, NPP, IceSAT, *HyspIRI, ICESAT-2, GRACE-2, DESDynI, LIST*
Sea Level Sea level and variability of its global mean	GPS, GRACE, LAGEOS, OSTM, JASON, SWOT
Sea Surface Temperature Sea surface temperature	EOS-Aura, EOS-Aqua, EOS-Terra, GOES, POES, Aquarius, *NPOESS, GOES-R, PATH*
Ocean Color Ocean color and oceanic chlorophyll-a concentration derived from ocean color	SeaWIFS, EOS-Aqua, EOS-Terra, *ACE, GEO-CAPE*
Sea State Wave height and other measures of sea state (wave direction, wavelength, time period)	EOS-Aqua, OSTM, QuikSCAT, Jason, *HyspIRI*
Ocean Salinity Research towards the measurement of changes in sea-surface salinity	*Aquarius*
Ocean Reanalyses Altimeter and ocean surface satellite measurements	GPS, GRACE, LAGEOS, OSTM

Table 6: Global Products requiring Satellite Observations – Terrestrial

ECVs / Global Products requiring Satellite Observations	**Associated Missions – Current and Planned** ***Planned Missions in italics***
Lakes Maps of lakes; lake levels; and surface temperatures of lakes in the Global Terrestrial Network for Lakes	Landsat 5 and 7, EOS-Aqua, EOS-Terra, NPP, *LDCM, SWOT, LIST*
Glaciers and Ice Caps Maps of the areas covered by glaciers other than ice sheets; Ice sheet elevation changes for mass balance determination	GRACE-1, GOES, POES, IceSAT-1, EOS-Terra, EOS-Aqua, *NPOESS, GOES-R, ICESAT-2, GRACE-2*
Snow Cover Snow areal extent	GOES, POES, EOS-Aqua, EOS-Terra, Landsat, *NPP, NPOESS, GOES-R, LDCM*
Albedo Directional hemispherical (black sky) albedo	EOS-Aqua, EOS-Terra, Landsat, GOES, *HyspIRI, NPP, NPOESS, GOES-R*
Land Cover Moderate-resolution maps of land cover type; High-resolution maps of land cover type, for the detection of land cover change	Landsat 5 and 7, SRTM, EOS-Aqua, EOS-Terra, *LDCM, DESDynI, HyspIRI, LIST, NPP, NPOESS*
fAPAR Maps of fAPAR	SeaWIFS, EOS-Aqua, EOS-Terra, Landsat 5 and 7, *HyspIRI, LDCM, NPP, NPOESS,*
LAI Maps of LAI	SeaWIFS, EOS-Aqua, EOS-Terra, Landsat 5 and 7, *LDCM, NPP, NPOESS,*
Biomass Research towards global, above ground forest biomass and forest biomass change	SeaWIFS, EOS-Aqua, EOS-Terra, Landsat 5 and 7, *LDCM, NPP, NPOESS, DESDynI, LIST,*
Fire Disturbance Burnt area, supplemented by active fire maps and fire radiated power	EOS-Aqua, EOS-Terra, GOES, Landsat 5 and 7, POES, *NPOESS, GOES-R, LDCM*
Soil Moisture[7] Research towards global near-surface soil moisture map (up to 10cm soil depth)	EOS-Terra, QuikSCAT, *SMAP*

[7] Soil moisture is not listed as an ECV, but has been recognized by the GCOS Implementation Plan as an emerging ECV.

Chapter 6: Data and Information Management Related to Systematic Observations
Data management is an important aspect of any systematic observing effort. U.S. agencies have unique mandates for climate-focused and -related systematic observations, and for the attendant data processing, archiving, and use of the important information from these observing systems. Cooperative efforts by the various federal agencies that make up the U.S. Climate Change Science Program (CCSP) are moving towards providing integrated and more easily accessible Earth observations. Currently operating CCSP systems for data management and distribution highlighted in the 2008 Our Changing Planet report [http://www.usgcrp.gov/usgcrp/Library/ocp2008/ocp2008.pdf] include NASA's Global Change Master Directory and Earth Observing System Data and Information System, and DOE's Carbon Dioxide Information Analysis Center; NOAA NCDC's Climate Data Online site provides climate data from multiple stations around the world.

Plans for 2008 and beyond include the participation in IPY through a focus on polar climate observations. Finally, efforts are being explored to improve climate data integration in the Pacific Islands region and produce more useful, end-user-driven climate products. NOAA's recently created IDEA Center is developing more customer-focused, integrated environmental products. Operating under the auspices of NOAA's NCDC, the IDEA Center is partnering with academic institutions and other federal and local agencies in the region to provide information on (1) 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); (2) their implications for key sectors of the economy, such as agriculture, tourism, and fisheries; and (3) options for coastal communities and marine ecosystem managers to adapt to and manage the effects of variable and changing environmental conditions.

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 (DAAC) and participating data centers from other U.S. and international agencies. Currently, there are14 EDGs around the world which permit users to access Earth science data archives, browse data holdings, select data products, and place data orders.

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. CLASS is NOAA's on-line facility for the distribution of NOAA and U.S. Department of Defense POES data, NASA mission data, as well as NOAA GOES data, and derived data. CLASS is an electronic library of NOAA environmental data, and provides capabilities for finding and obtaining such satellite data, and can be found at the following web site at: http://www.nsof.class.noaa.gov/saa/products/welcome.

The USGS' Landsat 35-year record of the Earth's surface will soon be available to users at no charge. Under a transition towards the NLIP, the USGS is pursuing an aggressive schedule to provide users with electronic access to any Landsat scene held in the USGS-managed national archive of global scenes dating back to Landsat 1, launched in 1972. By February 2009, any Landsat archive scene selected by a user will be automatically processed, at no charge; in addition, newly acquired scenes meeting a cloud cover threshold of 20% or below will be processed and placed on-line for at least 3 months, after which time they will remain available for selection from the archive. More details on this are available at http://landsat.usgs.gov.

NASA's 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 and services. At present the GCMD database contains over 21,000 metadata descriptions of data sets and data-related services from approximately 2,800 government agencies, research institutions, archives, and universities worldwide; updates are made at the rate of over 1000 descriptions per month. The GCMD contains descriptions of data sets covering all disciplines that produce and use data to help 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 affect human health). The GCMD has made it easier for such data users to locate the information they desire. The latest version of the GCMD software was released in March 2008 as MD9.8. Software upgrades are made in response to user needs and to capitalize on new technology. Several virtual subsets, also known as "portals" have been created in support of the tasks that are part of GEOSS; see http://globalchange.nasa.gov or http://gcmd.nasa.gov.

The Arctic Observing Network (AON) is a developing system of 34 land, atmosphere and ocean observation programs, some already operating and some newly funded by the National Science Foundation. This International Polar Year initiative is acquiring much of the data needed to drive the interagency Study of Environmental Arctic Change (SEARCH). AON will succeed in supporting the science envisioned by its planners only if it functions as a system and not as a collection of independent observation programs. Data management plays an essential role. AON planners envision an ideal data management system that includes a portal through which scientists can find all data relevant to a location or process; all data have browse imagery and complete documentation; time series or fields can be plotted online, and all metadata are in a relational database so that multiple data sets and sources can be queried.

This level of integration requires that data be in a limited number of formats or in self-describing formats. To be able to find the data, and use it in this way, data must have both high level (collection level) and use (inventory level) metadata. But AON data are quite heterogeneous; most projects are acquiring data that are in ASCII files of various configurations and few have complete metadata. Complicating the picture further, investigators want to find and use not only AON data but data from other sources as well without having to deal with a multitude of formats.

The Cooperative Arctic Data and Information Service (CADIS) will provide AON with near-real-time data delivery, a repository for data storage, a portal for data discovery, and tools to manipulate data by building on existing tools like the Unidata Integrated Data Viewer. Our approach to the data integration challenge starts by asking investigators to provide data in netCDF format that is compliant with the Climate and Forecast conventions. We also developed a "CADIS metadata profile" to guide the metadata structure of data contributed to the CADIS project. Structuring metadata according to this profile, and providing data in a limited set of standard formats, ensures that the metadata and data are immediately compatible with CADIS tools and can be visualized and manipulated online in various ways. Selected gridded or non-satellite data sets that are not in a standard format but are of high value to the AON community are converted to netCDF with special purpose software. A staffed Help Desk directs other users toward data conversion tools to encourage use of standard formats. An entry tool assists PIs in writing metadata and submitting data. CADIS is a joint effort of the University Corporation for Atmospheric Research (UCAR), the National Snow and Ice Data Center (NSIDC), and the National Center for Atmospheric Research (NCAR). In the first year, we are concentrating on establishing metadata protocols that are compatible with international standards, and on demonstrating data submission, search and visualization tools with a subset of AON data. These capabilities will be expanded in years 2 and 3. By working with AON investigators and by using evolving conventions for non-satellite data formats as they mature, we hope to bring CADIS to the full level of data integration imagined by AON planners.

DOE’s Carbon Dioxide Information Analysis Center (CDIAC) provides comprehensive, long-term data management support, analysis, and information services to the global climate change research programs, the global climate research community, and the general public. The CDIAC data collection is designed to answer questions pertinent to both the present-day carbon budget and temporal changes in carbon sources and sinks. The data sets provide quantitative estimates of anthropogenic CO_2 emission rates, atmospheric concentration levels, land–atmosphere fluxes, ocean–atmosphere fluxes, and oceanic concentrations and inventories. In 2008, CDIAC will augment its ocean holdings by offering CO_2 measurements from buoys, research cruises, and Volunteer Observing

Ships lines along U.S. coastlines to support the NACP. In 2008, CDIAC will also release the final CARbon dioxide In the North Atlantic ocean (CARINA) synthesis database including both discrete and underway measurements. CDIAC will release of the final North Pacific Marine Science Organization (PICES) synthesis database, which will replace the previous North Pacific discrete measurement component of the Global Ocean Data Analysis Project.

Precipitation chemistry remains as a major environmental issue due to concerns over eutrophication, ecosystem health, biogeochemical cycling, and global climate change. Although global modeling assessments require data of high and known quality, many of the laboratories supporting the approximately 200 site global network require expert assistance and ongoing oversight. As such, the quality assurance for the GAW Precipitation Chemistry Program that is performed by NOAA's Air Resources Laboratory, in close cooperation with the State University of New York at Albany, Environment Canada, European, East Asian, South African, and other scientists, has been an important component in addressing these problems through the development and provision of a guidance manual for program participants, and the development of a tool for rapid assessment of laboratory quality by data users. Global laboratory intercomparison data are presently posted at http://www.qasac-americas.org/ and may be displayed by clicking on the "Data" link and then on "Ring Diagram Assessments". Intercomparisons have been conducted annually beginning in 1985 and biannually beginning in 2001. In addition to complete quality assurance information, it is the goal of this program to make all GAW precipitation chemistry data freely downloadable on the Web.

Given its widespread applications and importance as a GCOS ECV, sea surface temperature (SST) observations and products are developed by numerous groups around the world. Global and near-global SST analyses are created using a wide range of statistical reconstructions and interpolations that are applied to data sets from a variety of input platforms. The result of these different analysis routines is a collection of products that can say subtly or significantly different things about the changing climate. The GCOS SST/Sea Ice (SI) Working Group seeks to gain an understanding of the differences between these SST analyses and recommend actions and criteria to ensure quality and consistency among them. Collaborating with members of the Working Group, NOAA's National Oceanographic Data Center (NODC) has created an online intercomparison framework at http://ghrsst.nodc.noaa.gov/intercomp.html. The website, an extension of the NODC Group for High Resolution Sea Surface Temperature (GHRSST) Long Term Stewardship and Reanalysis Facility, provides value-added access to a large collection of satellite, non-satellite, and blended SST analysis products. Each product is available in both Matlab and netCDF formats, following the GHRSST convention. This is a widely accepted standard within the operational SST and climate communities and provides important metadata facilities. A standard set of intercomparison diagnostics, including global and hemispheric anomalies, standard deviation, and RMS differences has been calculated for each SST analysis product. These diagnostics evaluate each product against both a common climatology and against every other product. Active online graphics make all of the intercomparison diagnostic data easily viewable and interactive. In addition to understanding differences between

SST analyses, an ultimate goal of the SST/SI Working Group is to connect satellite-based analyses with the longer, non-satellite-based historical SST record. Accordingly, the NODC is currently working on incorporating data beginning in the 1800s into the intercomparison framework. Concurrently the NODC continues to improve the online interface by incorporating additional diagnostics, SST analysis products, and interactive tools for users.

The annual State of the Climate Report–Using Earth Observations to Monitor the Global Climate publication, done in partnership with the WMO along with numerous national and international partners, consists of operational monitoring, analysis, and reporting on atmosphere, ocean, and land surface conditions from the global to local scale. By combining historical data with current observations, this program places today's climate in historical context and provides perspectives on the extent to which the climate continues to vary and change as well as the effect that climate is having on societies and the environment. More than 150 scientists from over 30 countries are now part of an annual process of turning raw observations collected from the global array of observing systems into information that enhances the ability of decision makers to understand the state of the Earth's climate and its variation and change during the past year, with context provided by decades to centuries of climate information. Many observing and analysis systems are unique to countries or regions of the world, but through this effort, the information from each system is openly shared, which is essential to transitioning data to operational use and filling critical gaps in current knowledge about the state of the global climate system. A State of the Climate report is distributed through publication in the Bulletin of the American Meteorological Society each year. Working with the WMO, this report is also translated into other languages and distributed to all 187 WMO member nations. The State of the Climate Report seeks to report on as many of the ECVs as possible as identified by GCOS Second Adequacy Report. The 2007 edition was published in July 2008, and an archive of these reports from 2000-07 can be found at http://www.ncdc.noaa.gov/oa/climate/research/state-of-climate/. Since this report began the monitoring of ECVs in 2001, and in line with the recently published 2007 version of the report, we have now doubled the number of monitored ECVs to a total of 22.

Drought events have far reaching impacts on many aspects of our daily lives, from water management to health to energy consumption and conservation. To mitigate these impacts, NOAA, other Federal and state agencies, partners, and countries, developed the plan for the National Integrated Drought Information System (NIDIS). NIDIS is a dynamic and accessible drought-risk information system that was created in response to extended drought conditions, especially in the Western U.S., over the past decade. In 2007, the U.S. unveiled a new, interactive website called the U.S. Drought Portal (USDP) that allows the public and civic managers to monitor U.S. drought conditions, get forecasts, assess the impacts of drought on their communities, and learn about possible mitigation measures. This website at http://drought.gov is useful internationally as nations work to coordinate drought preparedness, response, mitigation, and recovery activities; and this fits in well with drought related bilateral activities the U.S. is engaged in with partners in Canada and Mexico. In 2008, NOAA, along with its partners including USDA, began to institute geographic information system (GIS) mapping capabilities into the USDP. In 2009, the program will work to integrate enhanced GIS capabilities into the USDP. Additionally, communities will be unveiled in the portal, serving as a location for subject matter experts to share improvements in drought monitoring, forecasting, and mitigation. These communities will also serve as a coordinating and communications mechanism for NIDIS regional pilot projects. NIDIS was featured at the 2007 GEO Plenary meeting as a major contribution to GEOSS.

GEOSS architecture and data management builds on and adds value to existing Earth-observation and data management systems by providing a conceptual and organizational framework to build towards integrated global Earth observations, addressing critical gaps, supporting their interoperability, sharing information, reaching a common understanding of user requirements, and improving delivery of information to users. The success of GEOSS depends on data and information providers accepting and implementing a set of interoperability arrangements, based on non-proprietary standards with preference given to formal international standards. Interoperability is focused on interfaces, thereby minimizing any impact on affected systems other than where such systems have interfaces to the shared architecture.

The transition of the Global Observing Systems Information Center (GOSIC) [see http://gosic.org] from a developmental activity at the University of Delaware to an operational global data facility at NOAA's NCDC was completed on behalf of and with the concurrence of the global observing community in October 2006. GOSIC provides information, and facilitates easier access to data and information produced by GCOS, GOOS, and GTOS and their partner programs. GOSIC provides explanations of the various global data systems, as well as an integrated overview of the myriad global observing programs, which includes on-line access to their data, information, and services. GOSIC offers a search capability across international data centers, to enhance access to a worldwide set of observations and derived products.

The WMO's Commission for Basic Systems (CBS) "Lead Centers for GCOS' activity is a relatively new tool aimed at improving both the performance of the GSN and GUAN, as well as the basic quality of the data. Worldwide, there are now nine CBS Lead Centers for GCOS, including NOAA's NCDC whose area of responsibility encompasses North and Central America. Furthermore, NCDC is also responsible for building and maintaining a permanent database of all historical GSN and GUAN daily and monthly data submissions, along with the appropriate station metadata history, and for providing free and open user access to this information. To that end, NCDC has built a number of relationships with focal points at meteorological services around the world to allow for the exchange of historic climate data in support of fulfilling GCOS data requirements.

Finally, unlike instrumental data, the paleoclimate data in Table 7 come from a variety of sources. Each source represents a "proxy" for climatic conditions that are derived from these biological or environmental data. Temperature measurements in deep boreholes provide a direct signal of past temperatures at the surface. Using mathematical inversion techniques, temperature records at decadal to millennial scales can be computed. Geochemical analyses of coral skeletons provide seasonal to annual scale records of past temperature, rainfall, cloudiness, and environmental factors. Growth rings and inclusions in the skeleton can yield additional annual records of climate. Flora and fauna change in their distributions as they experience changes in climate. These lower time-resolution data can be dated radiometrically with high precision, but response times of the organisms must be factored in as well. This applies to faunal records, plant macrofossils, and pollen. Records from paleolimnological and paleoceanographic sources provide annually dated records in some locales and decadal scale records in others.

However, the abundance of biota in lakes and oceans can change rapidly (within a season) in response to climate signals, thus avoiding problems of response time. These can provide records as to temperature, rainfall, wind, upwelling, and other environmental changes. Trees respond to climate and change their ring growth patterns at sub-seasonal time scales. These annually resolved records provide air temperature, precipitation and other environmental data that have been critical in regional to global reconstructions of temperature and drought and can provide information as detailed as mean annual streamflow. Most reconstructions use a multi-proxy approach, mathematically building climate fields from spatially distributed networks of data from multiple data types. This effort is not without its difficulties, and the reconstructions are becoming better each year. The data sources in Table 7 include the best reconstructions and data sets of pre-instrumental climate available today. These reconstructions and the proxy data in the table below can be found at the NOAA Paleoclimatology Program and World Data Center for Paleoclimatology [see http://www.ncdc.noaa.gov/paleo/].

Table 7. U.S. National Paleoclimatic Contributions

Systems useful for national climate monitoring	*Total # stations*	*Time Series #stations/platforms (#Data Digitized)*	
		>100 years	*>300 years*
Paleoclimatic Data, U.S.			
Borehole Data	133		133
Corals	7	5	2
Fauna	219		219
Paleolimnology	36		36
Paleoceanography	19		19
Plant Macrofossils	185		185
Pollen	510		510
Tree Ring	1368	411	957
Other Paleoclimate Data	0		
Total U.S. Paleoclimate	**2477**	**416**	**2061**
Paleoclimatic Data, non-U.S.			
Borehole Data	704		704
Corals	140	103	37
Fauna	1		1
Ice Cores	23		23
Insecta	7		7
Paleolimnology	42		42
Paleoceanography	1415		1415
Plant Macrofossils	111		111
Pollen	1151		1151
Tree Ring	1492	774	718
Other Paleoclimate Data	5		5
Total non-U.S. Paleoclimate	**5091**	**877**	**4214**

Appendix - Acronyms

3-D Winds	Three-Dimensional Tropospheric Winds from Space-based Lidar
AAVP	ARM Aerial Vehicles Program
ACE	Aerosol-Cloud-Ecosystems
AERONET	Aerosol Robotic NETwork
AGAGE	Atmospheric Gases Experiment
AON	Arctic Observing Network
APS	Aerosol Polarimeter Sensor
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
ASCENDS	Active Sensing of CO_2 Emissions over Nights, Days, and Seasons
BSRN	Baseline Surface Radiation Network
CADIS	Cooperative Arctic Data and Information Service
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CAR	Climate Action Report
CARINA	CARbon dioxide In the North Atlantic Ocean
CBS	Commission for Basic Systems
CDIAC	Carbon Dioxide Information Analysis Center
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CH_4	Methane
CHAMP	Challenging Minisatellite Payload
CLARREO	Climate Absolute Radiance and Refractivity Observatory
CLASS	Comprehensive Large Array-data Stewardship System
CNES	Centre National d'Etudes Spatiales
CNRS	Centre National de la Recherche Scientifique
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CONAE	Comisión Nacional de Actividades Espaciales
COP	Conference of the Parties
COSMIC	Constellation Observing System for Meteorology, Ionosphere and Climate
DAAC	Distributed Active Archive Centers

DESDynI	Deformation Ecosystem Structure and Dynamics of Ice
DIS	Data and Information System
DOE	U.S. Department of Energy
ECV	Essential Climate Variable
EDG	EOS Data Gateway
EOS	Earth Observing System
EPA	U.S. Environmental Protection Agency
ETM	Enhanced Thematic Mapper
GACM	Global Atmospheric Composition Mission
GAW	Global Atmosphere Watch
GCMD	Global Change Master Directory
GCOS	Global Climate Observing System
GDP	Global Drifter Program
GEO	Group on Earth Observations
GEO-CAPE	Geostationary Coastal and Air Pollution Events
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GGOS	Global Geodetic Observing System
GHCN	Global Historical Climatological Network
GHRSST	Group for High Resolution Sea Surface Temperature
GIS	Geographic Information System
GLOSS	Global Sea Level Observing System
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GOSIC	Global Observing Systems Information Center
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GPSRO	GPS Radio Occulation
GRACE	Gravity Recovery and Climate Experiment
GRUAN	GCOS Reference Upper Air Network
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network for Glaciers

GTN-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
GUAN	GCOS Upper Air Network
HCDN	Hydro-Climatic Data Network
HCN	Historical Climatology Network
HCN-M	Historical Climatology Network Modernization
HIRDLS	High Resolution Dynamics Limb Sounder
HyspIRI	Hyperspectral Infrared Imager
IASOA	International Arctic Systems for Observing the Atmosphere
ICESat	Ice, Cloud, and Land Elevation Satellite
IDEA	Integrated Data and Environmental Applications Center (Honolulu)
IGBP	International Geosphere-Biosphere Program
IOC	Intergovernmental Oceanographic Commission
IndOOS	Indian Ocean Observing System
InSAR	Interferometric Synthetic Aperture Radar
IOOS	Integrated Ocean Observing System
IPA	International Permafrost Association
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
ITRF	International Terrestrial Reference Frame
JAXA	Japan Aerospace Exploration Agency
LAGEOS	Laser Geodynamics Satellite
LCCP	Land Cover Characterization Program
LDC	Least Developed Countries
LDCM	Landsat Data Continuity Mission
LIST	Lidar Surface Topography
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectroradiometer
MPL	Micro Pulse Lidar
MPLNET	Micro Pulse Lidar Network
NACP	North American Carbon Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research

NCDC	National Climatic Data Center
NEON	National Ecological Observatory Network
NIDIS	National Integrated Drought Information System
NLIP	National Land Imaging Program
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRC	National Research Council
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSIP	National Streamflow Information Program
OCO	Orbiting Carbon Observatory
OMI	Ozone Monitoring Instrument
OSTM	Ocean Surface Topography Mission
PARASOL	Polarization and Anisotropy of Réflectances for Atmospheric Sciences coupled with Observations from a Lidar
PATH	Precipitation and All-Weather Temperature and Humidity
PICES	North Pacific Marine Science Organization
POES	Polar Operational Environmental Satellite
RAMA	Research Moored Array for African-Asian-Australian Monsoon Analysis
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCAN	Soil Climate Analysis Network
SCLP	Snow and Cold Land Processes
SEARCH	Study of Environmental Arctic Change
SEBN	Surface Energy Budget Network
SeaWiFS	Sea-viewing Wide-Field-of-view Sensor
SHADOZ	Southern Hemisphere ADditional Ozonesondes
SI	Sea Ice
SMAP	Soil Moisture Active and Passive
SNOTEL	Snowpack Telemetry System
SOOP	Ships of Opportunity
SORCE	Solar Radiation and Climate Experiment

SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
SURFRAD	Surface Radiation Network
SWOT	Surface Water Ocean Topography
TAO	Tropical Atmosphere Ocean
TES	Tropospheric Emission Spectrometer
TIM	Total Irradiance Monitor
TRMM	Tropical Rainfall Measuring Mission
TSIS	Total Solar Irradiance Sensor
TWP-ICE	Tropical Warm Pool International Cloud Experiment
USCRN	United States Climate Reference Network
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USDA	United States Department of Agriculture
USDP	United States Drought Portal
USGS	United States Geological Survey
VOS	Voluntary Observing Ship
WMO	World Meteorological Organization