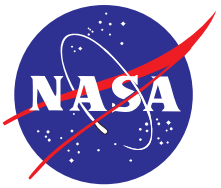
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Principal Areas of Focus



The National Aeronautics and Space Administration conducts a program of research to advance knowledge on the most important questions in Earth science through space-based observation and development and deployment of enabling technologies, as authorized in the NASA Authorization Act of 2005 and in the Presidential National Space Policy of 2006. NASA's end-to-end program of calibrated and validated observations, scientific and technological research and modeling, and application of this knowledge for societal benefits encompasses all themes of the *Strategic Plan for the U.S. Climate Change Science Program*. NASA's FY 2008 investment in the 13-agency Climate Change Science Program is 56% of the total amount of the President's FY 2008 Budget Request for CCSP. In addition, NASA contributes substantially to other interagency initiatives complementary with CCSP, including the *U.S. Ocean Action Plan* and the Strategic Plan for the *U.S. Integrated Earth Observation System*.

NASA continues to fulfill the National Research Council vision for U.S. leadership in interdisciplinary Earth science research to understand the complexity of the changing environment, its interaction with life, and how human activities affects the environment, and, in association with national and international agencies, to apply this understanding for the well-being of society (described in the January 15, 2007, report entitled *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, known as the NRC Decadal Survey).

NASA climate science and technology encompass Earth's global atmosphere from the surface of the land and sea to the top of the stratosphere; the global oceans including sea ice; all land surfaces including snow and ice; the solid Earth beneath the ocean; the ecosystems in the air, oceans, and land; and all the interactions between the atmosphere, oceans, land, snow, ice, and associated ecology, including humans. NASA studies the Sun and the interaction of its radiation with the Earth's upper atmosphere, not only through its Earth Science program as reported here, but through its Heliophysics Program, which emphasizes solar physics and the mechanisms of the Sun-Earth connection.

NASA pioneered the interdisciplinary field of global integrated Earth system science, which explores the interactions among land, oceans, atmosphere, ice, and life. To study the components of the global integrated Earth system and interactions between components, NASA developed and deployed a constellation of satellites. The following NASA satellites are currently operating: ACRIMSAT, Aqua, Aura, CALIPSO, CloudSat, EO, GRACE, ICESat, Jason, Landsat-7, QuikSCAT, SORCE, Terra, and TRMM. NASA deploys aircraft- and surface-based instruments for calibration, validation, and increased level of interpretation of satellite data that are required for development of climate-quality satellite measurements. To accomplish its mission on understanding the global integrated Earth system, NASA possesses state-of-the-art computing capability and capacity for extensive global integrated Earth system modeling and maintains the world's largest data and information system for collecting, processing, archiving, and distributing scientific data.

NASA addresses the overarching climate question "How is the Earth changing, and what are the consequences for life on Earth?" Five subordinate questions describe both the NASA and CCSP approach to understanding the global integrated Earth system: How is the global Earth system changing;

what are the primary causes of change in the Earth system; how does the Earth system respond to natural and human-induced change; what are the consequences of change in the Earth system for human civilization; and how well can we predict future changes in the Earth system?

To understand the global integrated Earth system, NASA, within the Earth Science Division Research Program, organized science focus areas, some of which are aligned with CCSP research elements. Four NASA science focus areas—Atmospheric Composition, Climate Variability and Change, Global Water and Energy Cycle, and Carbon Cycle and Ecosystems—are aligned directly with CCSP research elements. The NASA Earth Science Division Applied Sciences Program has many features that are aligned with the CCSP research element Human Contributions and Resources. Weather and Earth Surface and Interior are additional NASA science focus areas.

CCSP RESEARCH ELEMENTS	NASA GLOBAL INTEGRATED EARTH SYSTEM SCIENCE FOCUS AREAS
Atmospheric Composition	Atmospheric Composition
Climate Variability and Change	Climate Variability and Change
Global Water Cycle	Global Water and Energy Cycle
Land-Use/Land-Cover Change Global Carbon Cycle Ecosystems	Carbon Cycle and Ecosystems
Human Contributions and Responses	Applied Sciences

Program Highlights for FY 2008

In the summer of 2007, NASA held workshops to initiate planning of four new satellite missions that were recommended by the NRC Decadal Survey. These missions would measure spectrally resolved incident solar radiation and outgoing Earth radiation at the top of the atmosphere (CLARREO), land surface and ice deformations and vegetation structure (DESDynI), ice sheet structure (ICESat-II), and soil moisture and freeze/thaw conditions (SMAP). These missions would contribute to FY 2008 CCSP interagency implementation priorities, which have multi-year lifetimes: aerosol forcing, clouds, and radiation (CLARREO); abrupt climate change (DESDynI and ICESat-II); carbon cycle, ecosystem productivity, and land cover (DESDynI); and water cycle and drought (SMAP). In FY 2008, NASA intends to continue evaluating technical and scientific aspects of satellite missions recommended by the NRC Decadal Survey.

NASA will make significant progress in FY 2008 to expand scientific knowledge in each of the eight CCSP interagency implementation priorities. These contributions draw from NASA's capabilities in obtaining global space-based observations, and using them, together with ground- and aircraft-based observations, to improve knowledge of Earth system processes and to improve predictive capability for addressing the future evolution of the Earth system. Some examples of NASA's activities in each high-priority CCSP research area follow.

Integrated Earth System Analysis Capability

NASA's Modern Era Retrospective-Analysis for Research and Applications (MERRA) project focuses on data assimilation in implementing a national capability for studies of the global integrated Earth system. MERRA utilizes the version 5 Goddard (Space Flight Center) Earth Observing System (GEOS-5) atmospheric general circulation model with Gridpoint Statistical Interpolation (GSI) assimilation of satellite and *in situ* observations to produce global analyses of the atmosphere during the satellite era 1979 to present. Variability and predictability of the hydrological cycle will be emphasized. An External Users Group participating in MERRA's development showed that assimilating rain rates improved precipitation analyses and estimates of the outgoing longwave radiation. In FY 2008, MERRA will be operational and will provide the highest quality atmospheric reanalysis for the satellite era.

Integration of Water Cycle Observations, Research, and Modeling

The NASA Energy- and Water-cycle Study (NEWS) program integrates observations and models to close the water cycle budget for limited regions. NEWS is expected to provide a comprehensive depiction of regional water stocks and fluxes over the globe. GRACE data will be used to estimate monthly water volume variations in ocean, ice, land, and atmosphere reservoirs, including distribution of source and sink regions of freshwater between storage reservoirs. TRMM and other measurements recorded over the United States will be analyzed to test a hypothesis that aerosols can reduce the orographic enhancement of precipitation downwind of urban areas. The fundamental relationship between global hydrological cycle and Earth's radiative energy balance will be studied with data from the A-Train (MODIS/Aqua, AMSR/Aqua, Cloudsat). NEWS data sets of all three phases of water—vapor, ice, liquid—will explore the coupled dynamics and thermodynamics of tropical intraseasonal fluctuations, which degrade the predictability of tropical weather. The strong linkage between MERRA and NEWS will improve understanding of the causes and predictability of droughts, including the impact of global warming on drought.

Carbon Cycle Research Integration

NASA will support scientific studies in FY 2008 that provide unique information to characterize and quantify carbon stocks and fluxes for North America and adjacent oceans. Landsat data, available since 1972, will be utilized in estimating sources and sinks of carbon in the continental United States over the past 3 decades. In the North American boreal region where black spruce forests are a major carbon reservoir, trajectories of post-fire succession will be determined with MODIS/Aqua, MODIS/Terra, and Landsat data. NASA will test a new technique to measure methane, which has a global warming potential more than twenty times that of carbon dioxide on a per molecule basis. The timing and duration of surface and soil freeze-thaw states, which impact emissions and uptake of atmospheric carbon, will be determined over North America with QuikSCAT data. The hypothesis that the coastal ocean is a sink for atmospheric carbon dioxide will be tested with SeaWiFS, MODIS/Aqua, and MODIS/Terra data.

Understanding Aerosol Forcing and Interactions with Clouds and non-CO_2 Gases

NASA's Tropical Composition, Cloud and Climate Coupling (TC4) project involved three aircraft (ER-2, DC-8, and WB-57), seven satellites [Aqua, Aura, CALIPSO, CloudSat, PARASOL (non-NASA), Terra, and TRMM], and high-altitude balloons during a 17 July - 8 August 2007 campaign focusing on an area near Costa Rica. TC4 involved more than 400 scientists, students, and support staff. In addition to calibration and validation of satellite instruments, TC4 examined the production and aging of clouds and the transport of chemicals in the vicinity of the tropical tropopause transition layer at about

12- to 17-km altitude where vigorous vertical motion in the atmosphere over the ocean carries gases and aerosols up from the troposphere. High-resolution balloon observations of ozone and water reached the middle stratosphere. NASA's aircraft instruments measured radiation, aerosols, and a wide range of chemical constituents, including total water and water vapor that influence Earth's climate. Water vapor isotopic abundance measurements will be used to understand vertical transport across the tropopause. In FY 2008, the large volume of data will be processed, analyzed, and synthesized by more than 50 NASA-supported research groups. Identifying the key processes in the tropical tropopause-stratosphere region is important for progress on global climate change, stratospheric ozone depletion, and global tropospheric chemistry.

Abrupt Changes in a Warming Climate

NASA will continue its scientific leadership on studies of rapid or abrupt climate change through its research on Greenland and Antarctica ice sheets, Arctic Ocean ice coverage, global sea level, Atlantic Ocean meridional circulation, and global integrated Earth system modeling, which introduced the concept of "climate tipping point" with regard to a dangerous level of atmospheric greenhouse gas concentration. Measurements from GRACE and ICESat showed that the total volume of the world's ice sheets are getting smaller through melting, with a consequence of increasing sea level evidenced by TOPEX/Poseidon and Jason observations, which indicated global annual mean sea level was rising faster than that predicted by the Intergovernmental Panel on Climate Change. In FY 2008, the first-ever measurement of the total discharge of ice from the grounded Antarctic Ice Sheet will be estimated with ICESat and Landsat data. Greenland ice sheet thicknesses recorded in September 2007 with a high-frequency radar instrument on a NASA aircraft will be analyzed in FY2008. The dramatic decline of Artic Ocean ice coverage over the past 25 years, primarily in summer months and also during winter, dictates the need for improved knowledge of Pan-Arctic sea ice export and efficacy of Arctic Ocean sea ice models, which NASA will emphasize in FY2008. Preparations will continue for the launch in 2009 of the sea surface salinity satellite mission Aquarius, which will contribute substantially to predictions of future behavior of the Atlantic meridional overturning circulation, a feature associated with abrupt climate change.

Impacts of Climate Variability and Change on Ecosystem Productivity and Biodiversity

NASA will complete a number of studies in FY 2008 analyzing the vulnerability of biodiversity to changing climates in various ecosystems, including coastal and high-elevation ecosystems. Examples of studies include the impact of El Niño on fisheries off California, ocean upwelling dynamics in the Galapagos Marine Reserve, intertidal biogeography, biodiversity changes with mountain altitude in Ecuador, impacts of land-cover changes on montane cloud forests in Costa Rica, estimation of the number of tree species in ecoregions of the continental United States, and biophysical and land-use controls on biodiversity in North America. These activities involve a wide range of satellite sensors, including MODIS/Aqua, MODIS/Terra, and ASTER/Terra.

Land Use and Land Cover Change and Climate Interactions

The Mid-Decadal Global Land Survey (MDGLS), a project of NASA and USGS, assembled a global 30-m spatial resolution land cover data set for 2004-2007 using Landsat-5, Landsat-7, ASTER/Terra, and EO measurements. In 2008, NASA will generate and distribute MDGLS data products for comparative studies on land-use and land-cover (LULC) change with similar data products developed for the 1970s, 1990s, and circa 2000. Additionally, in FY 2008, NASA will initiate five to seven scientific studies on the environmental, social, economic, and human health consequences of LULC

changes projected over the next 5-50 years. A subset of the NASA selected projects will support the Northern Eurasia Earth Science Partnership Initiative (NEESPI) and the Monsoon Asia Integrated Regional Study (MAIRS) on carbon and water cycle processes and land-cover changes including fires.

Coping With Drought Through Research and Regional Partnerships

NASA works with governmental organizations to infuse NASA observations and scientific research results into operational data products that benefit society. In FY 2008, NASA will continue its partnership with the Northern Colorado Water Conservation District and the Bureau of Reclamation in utilizing MODIS/Aqua, MODIS/Terra, ASTER/Terra, and Landsat-7 data to estimate weekly evapotranspiration for real-time water management applications. NASA is investigating potential improvement of the weekly NOAA-USDA Drought Monitor of intensity and extent of drought conditions over North America through a partnership with USGS and others working with NOAA and USDA to utilize MODIS/Aqua and MODIS/Terra data.