NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Principal Areas of Focus

The National Aeronautics and Space Administration provides worldwide science and technology leadership to understand the integrated global Earth system through pioneering advancements of Earth system observations, research, and modeling enabled by satellites. NASA's programs encompass virtually every element and component in the *Strategic Plan for the U.S. Climate Change Science Program*. NASA has the largest agency investment in the 13-agency Climate Change Science Program (CCSP), and the Science Mission Directorate Earth Science Division (ESD) is the NASA leader for CCSP.

ESD encompasses the 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 and land; the ecosystems in the air, oceans, and land; and all the interactions between the atmosphere, oceans, land, snow, ice, and associated ecology, including humans. The multitude of integrated global Earth system processes and their interactions have important time scales from hours to centuries that include weather over short- and long-term climate time periods, and have horizontal distances from kilometers (regional) to the entire globe. NASA's Heliophysics Division contributes to integrated global Earth system science through studies of the Sun and the interaction of its radiation with the Earth's upper atmosphere. ESD is rapidly advancing the knowledge for reliable determination of the predictability of many interrelated natural phenomena, including the societal impacts and feedback on natural and anthropogenic phenomena. ESD accelerates the realization of societal benefits from knowledge of how, when, where, and why different regions of the globe experience non-uniform environmental variability, which is important for economic growth, environmental sustainability, national security, and homeland security. ESD continues the NASA tradition of creating breakthrough scientific and technological advancements on enormously challenging issues such as global climate change.

ESD programs are also embodied in several Presidential interagency initiatives that complement the climate initiative, including the "U.S. Ocean Action Plan" (17 December 2004) and the "Strategic Plan for the U.S. Integrated Earth Observation System" (6 April 2005). ESD applies knowledge of global Earth system science obtained through space-based observations and research to improve quality of life through enhanced capabilities for prediction and mitigation of the effects of environmental hazards.

ESD pioneered the interdisciplinary field of integrated global Earth system science, which explores the global interactions among land, oceans, atmosphere, ice, and life. To study these interactions, ESD developed and deployed the constellation of Earth Observing System (EOS) satellites named Aqua, Aura, Terra, GRACE, Jason, QuikScat, TRMM, and others, along with aircraft- and surface-based sensors for extensive calibration and validation required for the development of climate-quality satellite measurements. ESD created the world's largest data and information system for collecting, processing, archiving, and distributing EOS data.

ESD focuses on integrated global Earth system science through observation, research, and modeling enabled by satellites, and technology development to address the overarching question "How is the

Earth changing, and what are the consequences for life on Earth?" Five subordinate questions describe ESD's integrated global Earth system science approach:

- 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?
- How well can we predict future changes in the Earth system?

To accomplish integrated global Earth system science, ESD organized focus areas—some of which are shown in the accompanying table, aligned with the CCSP elements. Other focus areas are Weather and the Earth Surface and Interior, as well as a cross-cutting theme of Earth system science education and literacy.

CCSP RESEARCH ELEMENTS	NASA 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 2007

ESD will make significant progress in contributing to increased scientific knowledge in six high-priority CCSP research areas: aerosols and clouds, carbon cycle, glacier motions, global climate-quality observations, numerical model simulations of integrated global Earth system variability, and decision-support resources development for adaptive management and planning. ESD will determine the three-dimensional structure of clouds and aerosols with satellite data recently acquired from CloudSat (a joint project with Canada) and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations, a joint project with France), which were launched on a single rocket on 28 April 2006. CALIPSO and CloudSat orbits are virtually the same as the orbits of Aura and Aqua and the French spacecraft PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled Observations from a Lidar). Only 8 minutes (or a distance of approximately 3,100 km on the Earth) separate the first and last satellites. This unique constellation of five satellites—known as the Afternoon- or A-Train—represents a technological breakthrough and provides for the first time near-simultaneous co-located measurements of atmospheric gases, aerosols, clouds, temperature, relative humidity, and radiative fluxes. Analyses of A-Train data will reduce the large uncertainty of the roles of clouds and aerosols in global climate change.

ESD will continue to have a leading role in understanding the global carbon cycle through the North American Carbon Program and the Ocean Carbon and Climate Change Program. ESD will contribute substantial investments in satellite and *in situ* observations and in developing ecosystem and biogeochemical models to reduce scientific uncertainties of carbon sources, sinks, and fluxes within North America and the surrounding oceans, which has recently been a subject of intense scientific interest for both scientists and decisionmakers. ESD will continue developing the Orbiting Carbon Observatory (OCO) satellite to measure for the first time global atmospheric carbon dioxide on regional scales with unprecedented accuracy to determine sources and sinks. OCO is scheduled for launch in 2008, when it will join the A-Train.

The Ice, Cloud, and land Elevation Satellite (ICESat) is measuring for the first time ice-sheet mass balance in Greenland and Antarctica, an important quantity in understanding global sea-level rise, which TOPEX and Jason data indicate was about 2 mm yr^{-1} over the past 15 years. ESD investigators will develop the first-ever vertical profiles of glacier motion from the surface to depths of hundreds of meters using simultaneous satellite synthetic aperture radar measurements recorded at X, C, and L frequencies, respectively, by partner agencies in Germany, Canada, and Japan. This is a key project of the International Polar Year 2007-2008.

To accomplish the very stringent characteristics of global climate-quality data recorded from satellites, ESD state-of-the-art calibration and validation capabilities assess climate data homogeneity, usually during a scientific campaign. Validation of Aqua, Aura, CloudSat, and CALIPSO data is planned for summer 2007, when the ER-2, WB-57, and DC-8 aircraft, balloon-borne sensors, and enhanced ground-based atmospheric networks will be deployed for simultaneous correlative measurements during the NASA-led Tropical Composition, Cloud, and Climate Coupling (TC4) experiment. TC4 will investigate integrated Earth system processes in convective weather systems over the eastern tropical Pacific and Gulf of Mexico.

ESD will implement an advanced integrated global Earth system model through NASA's new Project Columbia supercomputing facility which, in April 2006, was the fourth fastest in the world. The current version of the model—which will assimilate chemical and physical variables, initially in the atmosphere and then in the ocean—will, for example, simulate global carbon sources and sinks. A new emphasis on cyberinfrastructure through the NASA-led interagency Earth System Model Framework will be initiated.

Related Research

ESD—in partnership with other Federal agencies, State and local governments, academia, and industry—explores new uses of global Earth system observations and science results to mitigate societal problems of national importance. In FY 2007, ESD will complete the benchmark for the assimilation of Aqua, Aura, and Terra observations in the Centers for Disease Control and Prevention (CDC) warning system for airborne particles in Atlanta.