National Aeronautics and
Space Administration

Earth Science Applications Plan

Office of Earth Science
NASA Headquarters | 300 E Street SW | Washington, DC 20546
http://earth.nasa.gov

July 2004

A Message from the Deputy Associate Administrator

What makes Earth unique in our solar system? The answer to this question is scientifically compelling and societally relevant. The NASA exploration vision and the search for life beyond Earth begin with understanding what makes supporting and sustaining life on Earth possible. The knowledge we gain from studying and understanding Earth—as a system of atmosphere, oceans, continents, and life—is key to our ability to search for life beyond Earth, the solar system, and ultimately our galaxy.

The knowledge of Earth system functioning also enables predictions of future courses of change, which have profound implications in supporting current and future generations of Earth's inhabitants and their quality of life.

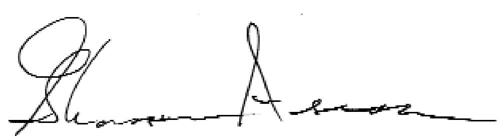
During the last 50 years, world economic output grew sevenfold, and grain yields nearly tripled. Today, global population exceeds 6 billion and is projected to grow to 8 billion by 2025. Can the Earth system sustain this pace of development? The challenge is to understand how the Earth system is changing and anticipate the effects of the changes for life on Earth.

From the unique vantage point of space we can see and, more importantly, understand how the components of the Earth system (i.e., atmosphere, oceans, land, and life) interact to create the air we breathe, the water we drink, the food and fiber we depend on, and the weather and climate we experience. We can observe and characterize local and regional phenomena, such as droughts and floods and fire, in their global context, and we can assess the impacts of global changes on these local and regional events.

The NASA Earth Science Applications theme was created to accelerate and expand the delivery of Earth system science research results to serve decision-support for American citizens and the world. Activities conducted under the Earth Science Applications theme serve the Nation by benchmarking practical uses of NASA-sponsored observations from remote sensing systems, predictions from Earth system models, and knowledge from scientific research to aid decisionmakers. NASA and our partners focus on innovative approaches for using Earth science information to enable enhanced decision-support that can be adapted in applications worldwide.

We invite you to share in our plan to address applications of national priority by expanding and accelerating the realization of economic and societal benefits from NASA research and development of Earth science, information, and technology.

Cordially,



Ghassem R. Asrar, Ph.D.
Deputy Associate Administrator
Science Mission Directorate

NASA Earth Science
Applications Plan
Preface

The Earth Science Applications Plan presents NASA's approach to expand and accelerate the economic and societal benefits from Earth science, information, and technology.

This plan articulates the goals and direction of the Earth Science Applications Program for the period from 2004 to 2012. In preparing this plan, the Sun-Earth Systems Division incorporated recommendations from a 2002 National Academy of Sciences review of the previous plan (*Earth Science Applications Strategy: 2002–2012; http://www7.nationalacademies.org/ssb/esefinal.pdf*).

- The primary audiences are key stakeholders in Congress and the NASA Administration, partner organizations, and individuals and organizations that may respond to program solicitations.
- The intent of the plan is to articulate the purpose of the program and our strategy to fulfill our mission with the resources available.
- The plan describes the scope of the program, including NASA's role in partnerships, our focus on decision-support tools, and the types of Earth science research results we seek to extend.
- The plan describes direct linkages to the NASA Strategic Plan and the Earth Science Strategy, and the plan presents drivers related to Earth science research priorities, U.S. Government initiatives, and international commitments that influence the design, direction, and activities of the program.
- Within the Sun-Earth Systems Division, the plan also serves a program management function, describing the program structure, functional mechanisms, performance measures, and general principles that our activities follow.
- The plan provides examples that illustrate how Earth science research results can be applied to decisionmaking and demonstrate their socioeconomic benefits.

We welcome this opportunity to share with you the Earth Science Applications Plan, and we encourage you to explore with us the benefits of Earth science for society.

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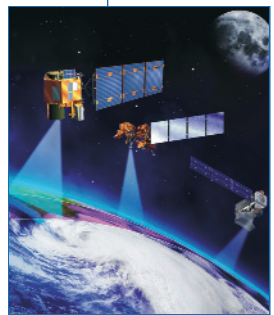
The mind may, as it appears to me, divide science into three parts. The first comprises the most theoretical principles, and those more abstract notions whose application is either unknown or very remote. The second is composed of those general truths which still belong to pure theory, but lead nevertheless by a straight and short road to practical results. Methods of application and means of execution make up the third. Each of these different portions of science may be separately cultivated, although reason and experience show that none of them can prosper long, if it be absolutely cut off from the other two.

- Alexis DeTocqueville, *Democracy in America (1835)*



1 Earth Science Exploration Serving Society

1 Earth Science Exploration Serving Society

The Earth Science Applications Program plans its endeavors in accord with the NASA Vision and Mission and the Science Mission Directorate with regard to current societal, scientific, and national imperatives.

1.1 NASA Vision and Mission

The NASA Vision—
To improve life here,
To extend life to there,
To find life beyond.

The NASA Mission—
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
. . . as only NASA can.

NASA seeks to improve life on Earth as we search for life beyond our planet and establish a permanent presence in the solar system. From the first weather satellites to today's capabilities to observe all major components of the complex Earth system, NASA enables people to use measurements of our home planet in valuable ways to improve life here.

1.2 Earth Science Mission

The Earth Science Applications Plan is administered by the Applied Sciences Program within the Sun-Earth Systems Division of the NASA Science

The "A-train" formation of atmospheric remote sensing satellites Aqua, Parasol (France), CALIPSO (with France), CloudSAT, Aura, and the Orbiting Carbon Observatory. Flying theses satellites in formation facilitates the integration of their data on clouds, aerosols, and atmospheric properties and chemical composition into greatly–enriched scientific information products.

The Aura spacecraft was successfully launched on a Delta II rocket on July 15, 2004, at 3:02 a.m. PDT from Vandenberg Air Force Base, CA. Aura measurements support EPA and NOAA air quality forecasts and many other applications.

Mission Directorate. Building on 40 years of a solid scientific and technological foundation, the Sun-Earth Systems Division plays a leading role in NASA's mission to understand and protect our home planet. NASA pursues answers to the fundamental question, "How is Earth changing, and what are the consequences of change for life on Earth?" To this end, NASA develops space systems to study the Earth system and uses the resulting observations and knowledge to improve prediction of Earth system change.

The Sun-Earth Systems Division has primary responsibility for two Agencywide, Earth-oriented themes in the NASA Strategic Plan: Earth system science and Earth science applications. In serving these themes, the Division works with its domestic and international partners to provide accurate, objective scientific data and analysis to advance our understanding of Earth system processes and to help policymakers and citizens achieve economic growth and effective, responsible stewardship of Earth's resources.

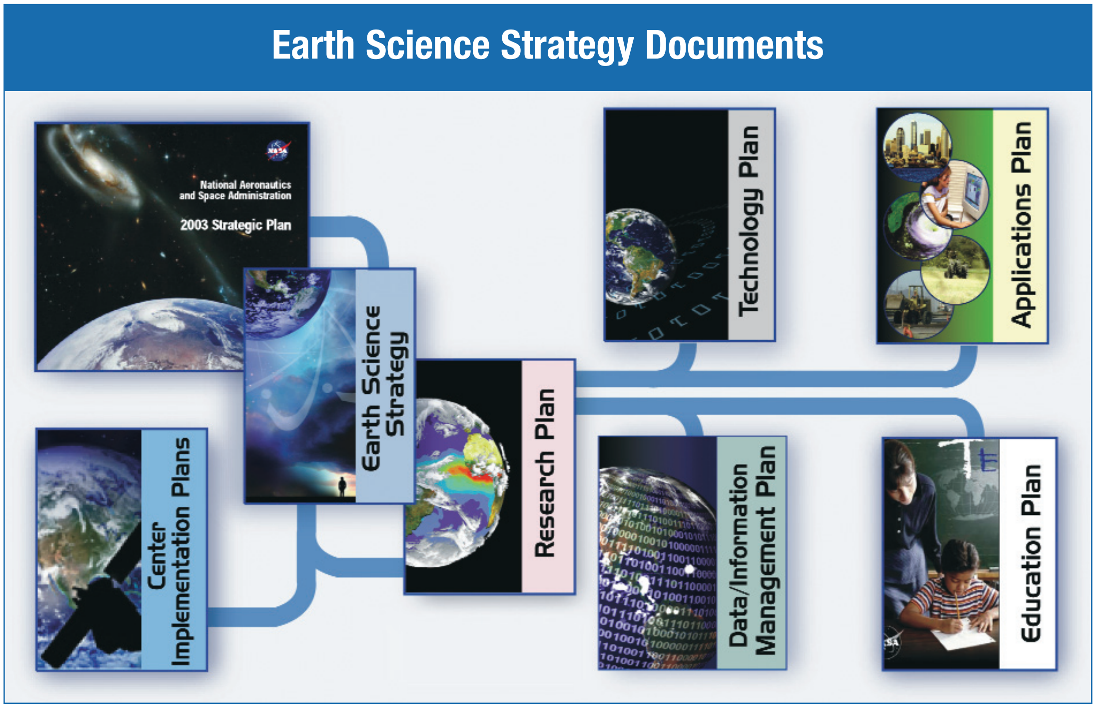
NASA contributes uniquely to research and development of aerospace science and technology. Within the Directorate, NASA has significant experience managing networks of Earth-observing satellite systems, operating complex and integrated information systems, and understanding complex Earth systems as they change. NASA, with its systems engineering experience, is uniquely positioned to support partners' applications of measurements and predictions from Earth science research.

NASA's unique contributions to Earth system science include the following:

- Creating the ability to study Earth as an integrated physical and biological system
- Pursuing new remote sensing capabilities from a variety of vantage points in space to examine global-scale changes and the global context of local–regional changes
- Advancing computational modeling for scientific purposes and interdisciplinary research
- Forging domestic and international partnerships to explore the Earth system and transition mature observations to operational partner agencies that provide essential services using Earth science information

The Earth Science Strategy presents NASA's approach to its valuable Earth-focused endeavors and outlines five program components—research, observation and information management, advanced technology, education, and applications. Associated with these program components, the Division has functional plans (figure 1.1) and an outreach plan, which are integrated to execute the overall strategy and achieve the

Figure 1.1



goals for the Directorate and the Agency. NASA Field Centers have implementation plans for their respective dimensions and contributions to NASA and the Directorate.

The Sun-Earth Systems Division contributes to domestic interagency partnerships for climate change, weather, and natural hazards (e.g., Climate Change Science and Technology Programs, U.S. Weather Research Program) as well as international intergovernmental partnerships (e.g., Intergovernmental Panel on Climate Change, International Strategy on Disaster Reduction, and the ad hoc Group on Earth Observations).

1.3 Earth Science Applications

Earth science applications is one of the 18 Agencywide themes in the NASA Strategic Plan. The Division has primary responsibility for the Earth Science Applications theme and the objective to expand and accelerate the economic and societal benefits from Earth science, information, and technology.

To achieve this theme, the primary goal of the Earth Science Applications Program is to enhance organizations' decision-support capabilities by enabling their expanded use of Earth science results, information, and technology to serve their management and policy responsibilities to society.

NASA's activities to enable and enhance Earth science applications build on capabilities developed from NASA's Earth science research efforts (section 1.4).

NASA forms partnerships with public, academic, and private organizations to pursue innovative approaches for using Earth science research results in decision-support tools. The Earth Science Applications Program focuses on facilitating the integration of Earth science observations, model outputs, and technologies into partners' decisionmaking processes.

The Earth Science Strategy and functional plans are available through the following Web site: *http://www.earth.nasa.gov*

Figure 1.2

The program uses a systems engineering approach—involving evaluation, validation and verification, and benchmarking—to identify Earth science results of value to the partners, develop prototype products and address systems integration issues with the partners, and document value of the results to support the partners' adoption or adaptation in their operational use.

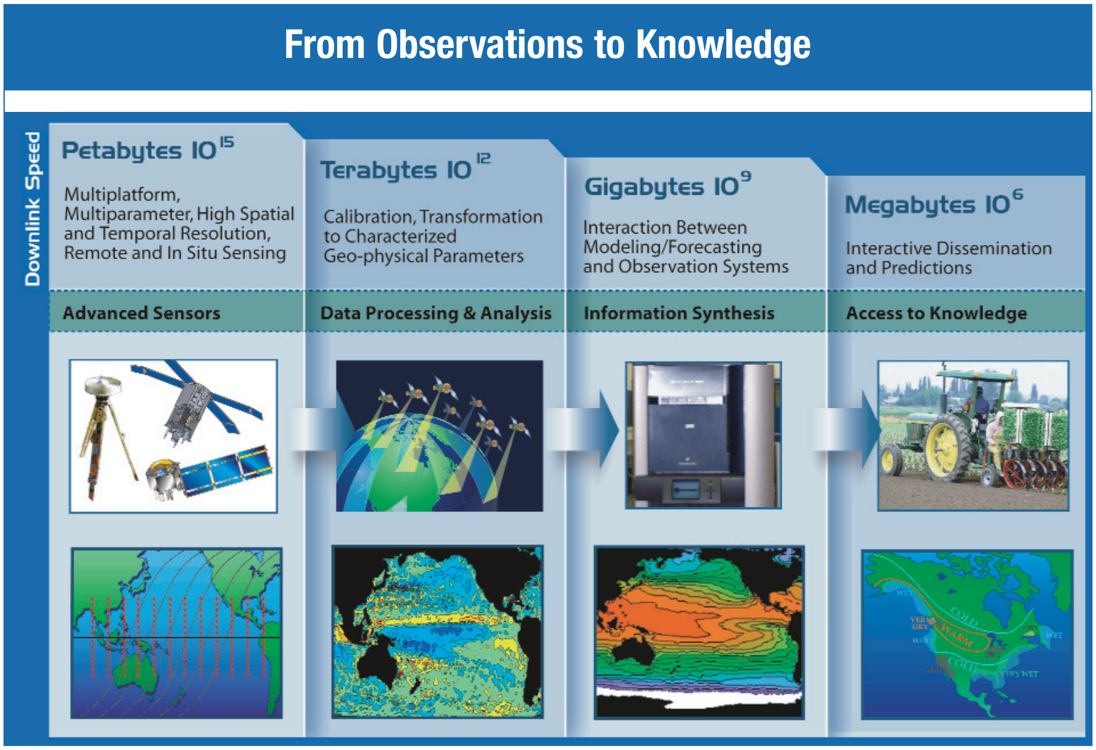
The program's desired outcome is for organizations (e.g., Government, not-for-profit, and private-sector companies) to use project results, such as prototypes and benchmark reports, to enable expanded use of Earth science products and enhance their decision-support capabilities. The program's impacts are manifest in enhanced decision-support for economic and environmental security benefits that are realized through improved decisionmaking, public information, economic returns, and efficient and effective management.

Through the process of benchmarking beneficial uses and applications of Earth science measurements and technology, the Earth Science Applications Program enables significant scientific and technological returns on the Federal investments in NASA.

The program selected 12 application topics of national priority (figure 1.2) based on prioritization criteria described in the Earth Science Strategy. The program works with organizations that have decision-support tools and policy and management responsibilities associated with the 12 application topics.

Activities are underway in each of the applications of national priority. For example, in disaster management, NASA works with the National Oceanographic and Atmospheric Administration (NOAA) to integrate innovative scientific knowledge of technologies to improve warnings and predictions of hurricanes, tornadoes, and other severe weather events. The resulting solutions enable more cost-effective damage mitigation, emergency preparation, and

Figure 1.3



response through the Federal Emergency Management Agency (FEMA). The U.S. Department of Agriculture (USDA) works with NASA to use satellite measurements to improve the accuracy and timeliness of global forecasts of major agricultural commodities.

Throughout this plan, there are examples of accomplishments in improving decision-support through Earth science results, including detailed examples at the end of chapters on the following application topics:

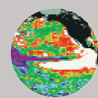
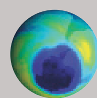
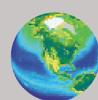
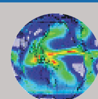
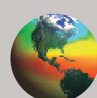
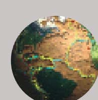
- Disaster Management: Wildfires (Chapter 1)
- Air Quality: Air Quality Forecasts (Chapter 2)
- Disaster Management: Hurricane Prediction (Chapter 4)
- Aviation: Volcanic Ash and De-Icing (Chapter 5)

Chapter 2 of this plan describes the program's systems engineering approach and the integrated systems solution architecture it pursues. Chapter 3 contains the program's goals and objectives, including detailed information on the specific applications of national priority. Chapter 4 describes the mechanisms and guidelines the program follows in managing its activities and measures used to evaluate performance. Chapter 5 discusses challenges and risks the program faces and activities used to mitigate them.

1.4 Earth System Science Research

In Earth system science, researchers view the Earth as a whole system and take a contextual approach to scientific inquiry. This approach leads to the exploration of complex interactions and the discovery of causes and effects in response to natural and human influences. The Earth Science Research Plan articulates NASA's priorities and approach to Earth system science research (*http://www.earth.nasa.gov*). Through observations and computational models of Earth system processes, NASA and its partners are establishing predictive capabilities for the Earth system.

Table 1.1

NASA Earth System Science Focus Areas		
Science Focus Area	**Prediction Question**	**10-Year Outcomes (With Research Partners)**
Climate Variability and Change 	How can predictions of climate variability and change be improved?	Predict near-and long-term climate change, implications for global sea level change, regional temperature, precipitation, and soil moisture.
Atmospheric Composition 	How will future changes in atmospheric composition affect ozone, climate, and air quality?	Predict the course of recovery of Earth's atmospheric ozone shield and assess the quality of the air we breathe.
Carbon Cycle and Ecosystems 	How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?	Predict global terrestrial and ocean biological productivity, ecosystem health, and interactions with the climate system.
Global Water and Energy Cycle 	How will water and energy cycle dynamics change in the future?	Improve intermediate range forecasts for droughts and seasonal water supply; predict global scale energy storage and transport in the atmosphere.
Weather 	How can weather forecast duration and reliability be improved?	Significantly improve short-term and severe weather-forecasting capabilities for hurricanes, winter storm hazards, and extreme weather events.
Earth Surface and Interior 	How can our knowledge of Earth surface change be used to predict and mitigate natural hazards?	Predict volcanic activity within a month and estimate earthquake probabilities for selected tectonic zones.

NASA Earth science research improves scientific understanding and generates new knowledge of the Earth system to serve society. The Applications Program draws on the satellite observations and predictive models from the Earth Science Research Program to maximize the social and economic benefits derived from the investment in NASA's Earth science research. Figure 1.3 illustrates the enormous quantities of data acquired by NASA's Earth observing satellites and how they can be distilled and distributed to users beyond the immediate science community. As of this report, NASA is acquiring data from 18 Earth-observing satellites and 80 sensors that it designed, built, or launched for Earth science research. *(http://www.earth.nasa.gov/ese_missions).*

The Earth Science Distributed Active Archive Centers receive and process over 3 terabytes of data daily and produce hundreds of specific products characterizing geophysical parameters of the Earth system. Researchers at Earth system science laboratories, NASA Centers, and academic institutions develop complex and robust Earth system algorithms and models using the observations and geophysical parameter products. Partner agencies and the commercial remote sensing industry provide additional observations, models, predictions, and products. (Note: The back cover

Table 1.2

Earth Science Research and Applications Matrix

	Carbon Management	Public Health	Energy Management	Aviation	Water Management	Homeland Security	Coastal Management	Disaster Management	Agricultural Efficiency	Invasive Species	Ecological Forecasting	Air Quality
Atmospheric Composition	◐	●		◐		◐			◐			●
Carbon Cycle and Ecosystems	●	●	◐				◐		●	●	●	
Climate Variability and Change	◐	●	●		◐		●	◐	◐	◐	◐	◐
Earth Surface and Interior				●	◐	●	◐	●				
Water and Energy Cycles	◐		●		●		●	◐	●	◐	◐	
Weather		◐	●	●	◐	◐	◐	●	●			◐

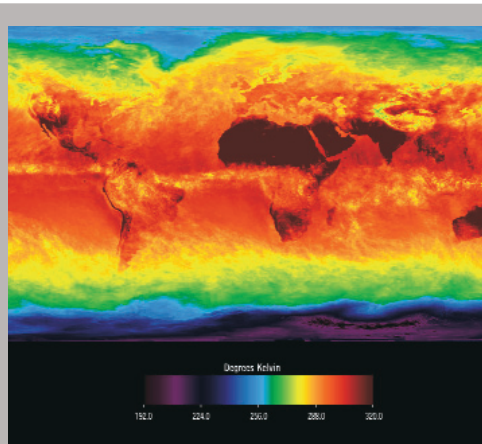
● Primary Linkages ◐ Secondary Linkages

Table 1.3

Representative U.S. and International Committees Related to NASA Earth Science

	Domestic	International
Climate Change	Climate Change Science Program (CCSP) Climate Change Technology Program (CCTP)	Intergovernmental Panel on Climate Change (IPCC)
Weather	U.S. Weather Research Program (USWRP)	World Meteorological Organization (WMO)
Natural Hazards	Committee on Environment and Natural Resources (CENR) Subcommittee on Disaster Reduction (SDR)	International Strategy for Disaster Reduction (ISDR)
Sustainability	Roundtable on Science and Technology for Sustainability (National Academy of Sciences)	World Summit on Sustainable Development (WSSD)
Earth Observation Systems	CENR Interagency Working Group on Earth Observations (IWGEO)	Group on Earth Observations (GEO)
Geospatial Interoperability	Geospatial One Stop (GOS) Federal Geographic Data Committee (FGDC)	World Summit on the Information Society Intl. Organization for Standardization (ISO)

Climate Change Research Initiative



On June 11, 2001, President Bush announced the establishment of the U.S. Climate Change Research Initiative (CCRI) to study areas of uncertainty about global climate change science and identify priority areas where investments can make a difference. In announcing the CCRI, the President directed the reestablishment of priorities for climate change research, called for improved coordination amongst Federal agencies, and directed that research results be made available. He committed resources to build climate observation systems and proposed joint ventures with international partners to develop state-of-the-art climate models to improve our limited understanding of the causes and impacts of climate change.

CCRI was developed in collaboration with the U.S. agencies involved in climate and global change research. CCRI represents a focusing of resources and attention on those elements of the U.S. Global Change Research Program (USGCRP) that can best support improved public debate and decisionmaking in the near term. Thus, CCRI moves a "period of discovery and characterization" since 1990 into a "period of differentiation and strategy investigation."

In particular, a goal of the CCRI is to improve the integration of scientific knowledge, including measures of uncertainty, into effective decision-support systems. The CCRI will adopt performance metrics and deliverable products useful to policymakers in a short time frame (2–5 years) to assist the Nation's evaluation of optimal strategies to address global change risks. The CCRI aims to: (i) reduce the most important uncertainties in climate science and advance climate modeling capabilities; (ii) enhance observation and monitoring systems to support scientific and trend analyses; and (iii) improve decision-support resources.

provides a fold-out synopsis of the missions, geophysical parameters, and other Earth system science components.)

The Earth System Science Research Program structures its research on the following six focus areas:

- Climate Variability and Change
- Atmospheric Composition
- Carbon Cycle and Ecosystems
- Global Water and Energy Cycle
- Weather
- Earth Surface and Interior

Table 1.1 briefly describes the six science focus areas. Table 1.2 presents a crosswalk between the six science focus areas and the program's 12 applications of national priority.

1.5 Earth Science and Program Drivers

The world faces unprecedented challenges to sustainable management of natural resources. Population increase, economic and technological progress, and environmental changes present potential challenges to supplying food and fresh water, protecting public health, and conserving fragile ecosystems. The U.S. Census Bureau estimates that the world's human population will increase to 8.0 billion by 2025. Information on weather, climate, and natural hazards, and the ability to predict Earth system processes with accuracy can help public and private decision-makers anticipate, respond, mitigate, and adapt to these challenges.

Current and evolving domestic and international programs address key dimensions needed to develop and sustain solutions for decision-support related to Earth and the environment (table 1.3). These programs are supported by national and international organizations with the interest and commitment to contribute science, technology, planning, and associated activities to work toward viable solutions. These programs influence policy priorities, business and management practices, and the direction of Earth science research.

Key drivers affecting the direction, design, and activities of the Earth Science Applications

Program fall in three main categories—Earth science research priorities, international commitments, and U.S. Government priorities.

Earth Science Research Priorities

In 2003, the Climate Change Science Program (CCSP) published the strategic plan for U.S. climate change research priorities, focusing on key areas of scientific uncertainty and identifying priority areas for research and development. The plan promotes an effective use of scientific knowledge in policy and management decisions, as well as continual evaluation of management strategies. *http://www.climatescience.gov*

Working closely with the CCSP, the U.S. Climate Change Technology Program (CCTP) promotes the development and deployment of key technologies that may achieve substantial greenhouse gas (GHG) emissions reductions. CCTP supports the use of Earth science information and technology to assess alternatives and changes related to adaptation and mitigation activities and policies.
http://www.climatetechnology.gov

The National Science and Technology Council (NSTC) and its committees and subcommittees coordinate research and development activities across Federal agencies. The committees, such as the Committee on Environment and Natural Resources (CENR), set direction on integrated activities and set priorities on research and development topics, affecting activities the program pursues with partner agencies. *http://www.ostp.gov/NSTC/html/committee/cenr.html*

International Commitments

In 2003, the U.S. hosted the Earth Observation Summit, which established a declaration for a 10-year plan for Earth observation systems to serve society. The 10-year implementation plan is chartered by the ad hoc Group on Earth Observations (GEO) and coordinates international and national inputs for global observations. NASA participates in GEO and the U.S.-organizing group, the Interagency Working Group on Earth Observations (IWGEO).
http://www.earthobservationsummit.gov

At the 2003 Summit of the Group of Eight (G8) countries, the G8 established the top three priorities for science and technology as: energy, agriculture, and Earth observations. This level of acknowledgment influences program priorities and NASA commitments related to Earth observations. *http://www.g8.fr*

The 2003 meeting on the United Nations Framework Convention on Climate Change established the importance of Earth observations and predictions for addressing societal impacts of climate change. The convention invited the GEO to treat global climate monitoring as a priority and to adopt a balanced approach to the application of in situ and remote sensing systems for climate monitoring. *http://unfccc.int*

U.S. Government Directives

The President's Management Agenda (PMA) specifies principles by which Federal agencies and programs should manage: strategic management of human capital; competitive sourcing; improved financial performance; expanded electronic government (E-gov); and budget and performance integration. These principles drive the design, activities, and reviews of the program. For example, the Office of Management and Budget (OMB) directs NASA to use competitive sourcing to allocate significant portions of its budget. NASA reports its objectives and budget through the Integrated Budget and Performance Document (IBPD), and OMB reviews NASA and the program through the Performance Assessment Rating Tool (PART). Within E-gov, the Geospatial One-Stop initiative promotes the ability of the Government and public to use geospatial information, including Earth science data.
http://www.whitehouse.gov/omb/budintegration/pma_index.html

President Bush signed the Commercial Remote Sensing Space Policy in 2003 to advance and protect U.S. national security and foreign policy interests, and sustain and enhance the U.S. remote sensing industry. Objectives of the policy include contributions to economic growth, environmental stewardship, and scientific and technological excellence. *http://crsp.usgs.gov*

1.6 Geoscience Information Cycle

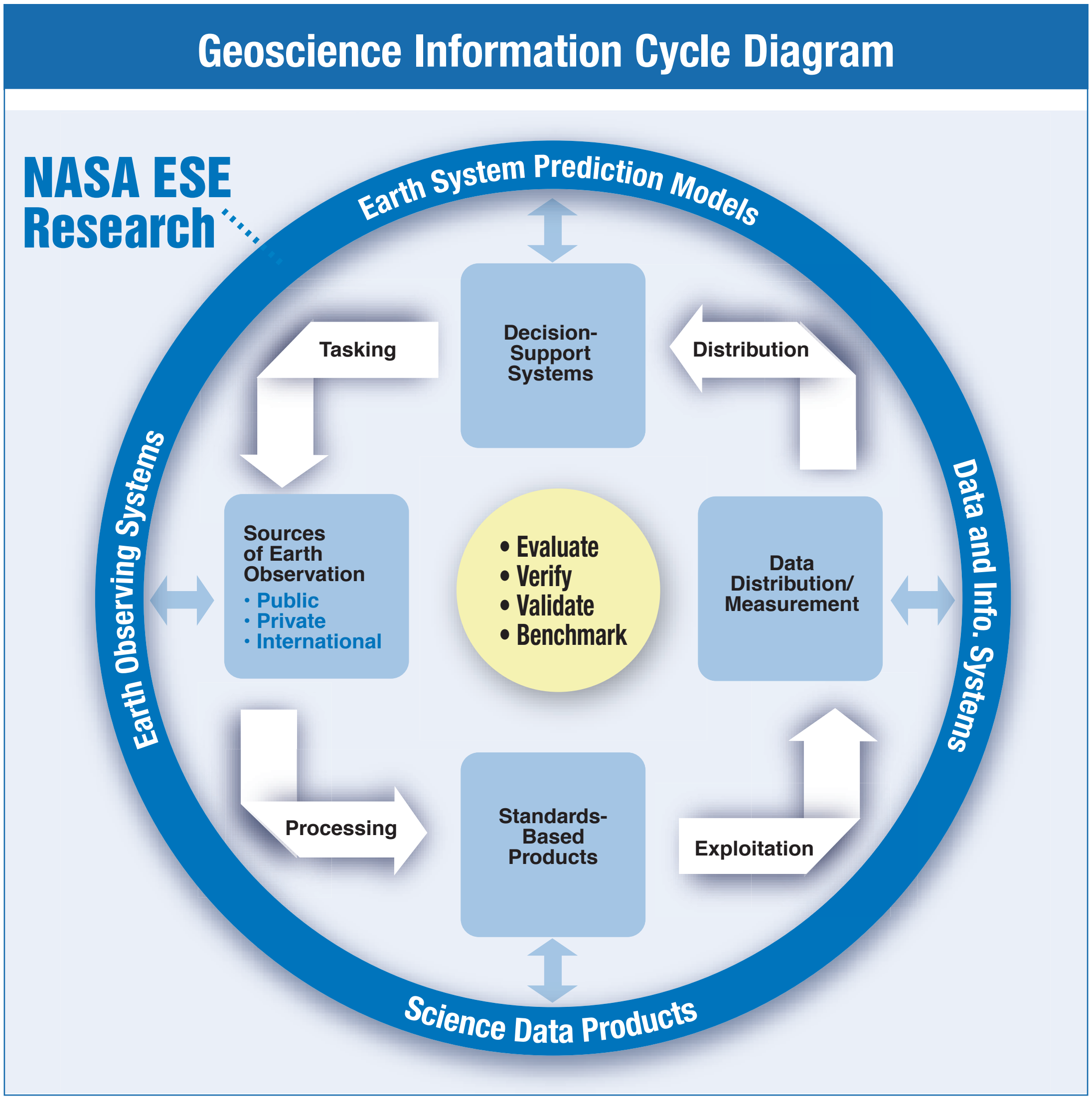
NASA Earth science supports collection, processing, delivery, and use of Earth science measurements and model outputs for research and decision-support. Figure 1.4 illustrates a geoscience information cycle that serves as a framework for NASA's role in remote sensing and the application of Earth science data and products to decisionmaking. This cycle encompasses the path from Earth observations to standards-based products, to the delivery and assimilation in Earth system models and decision tools. Different organizations may manage different elements of the cycle.

Counterclockwise from the upper left, public and private organizations task Earth observation systems, such as Aqua or commercial imaging systems, and process the measurements to develop a set of standards-based products. Researchers and others exploit the data products by transforming them into algorithms and models to create predictions, model products, and information. Data-handling systems incorporating interoperability principles enable effective distribution of the information products and knowledge to decisionmakers. These information products resulting in societal and economic benefits.

The Earth Science Applications Program provides systems engineering support to bridge gaps between the elements in this cycle and enable use of Earth science data in applications of national priority. In addition, the program serves as a bridge between Division's research domain and the operational domain of the public and private-sectors. NASA conducts research and development that contribute results to the research domain of this cycle. NASA extends discrete research results (such as global land-use/land-cover maps, ozone vertical profiles, ocean vector winds, cloud system structures, and sea ice extent) to be integrated into solutions for operational decision-support. In the opposite direction, NASA evaluates discrete capabilities available in the operational domain (such as higher-resolution commercial remote sensing systems, high-bandwidth communications systems, and high-speed computers) for use in supporting Earth science research.

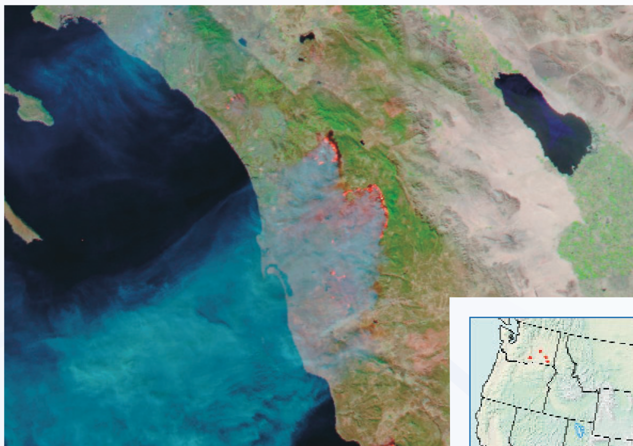
Managers and analysts integrate Earth science observations and model products into decision-support tools to evaluate alternative scenarios and assess management options.

Figure 1.4


Geoscience Information Cycle Diagram
NASA ESE Research
Earth System Prediction Models
Earth Observing Systems
Data and Info. Systems
Science Data Products
Decision-Support Systems
Tasking
Distribution
Sources of Earth Observation
• Public
• Private
• International
• Evaluate
• Verify
• Validate
• Benchmark
Data Distribution/ Measurement
Processing
Standards-Based Products
Exploitation

Accomplishment:
Wildfire Management

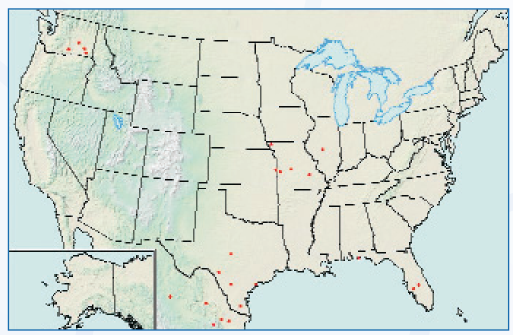
Wildfires coincident with widespread summer drought challenge the resources of the USDA Forest Service (USFS) and other agencies responsible for monitoring, assessment, and remediation of forest fires. USFS and land management agencies need and combine information on numerous factors (e.g., thermal anomalies, topography, fuel load) in a timely manner to create more accurate predictions of probable fire areas and rates of spread. Through daily near-real-time observations from NASA's Moderate Resolution Imaging Spectro-radiometer (MODIS) sensors on the Earth observing research satellites Terra and Aqua, USFS is better able to mobilize resources to combat fires.



Terra-MODIS image of fires in southern California.

Societal Benefits

Each day, MODIS (on board NASA's Terra and Aqua satellites) provides an image of fires across most of the United States. The data help Federal agencies manage wildfires more effectively, both during and after the event. As delivery times are shortened and imagery becomes more generally available and better understood by fire managers, the images from this instrument are becoming a valuable part of the USFS's and other land management agencies' fire monitoring tool kits.



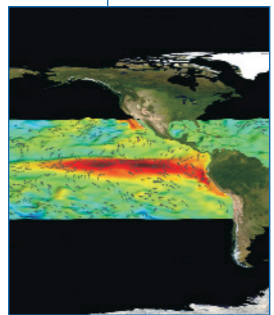
U.S. Forest Service national fire map indicating areas of fires, based on MODIS and other satellite remote sensing.

NASA's Unique Capacity and Contributions

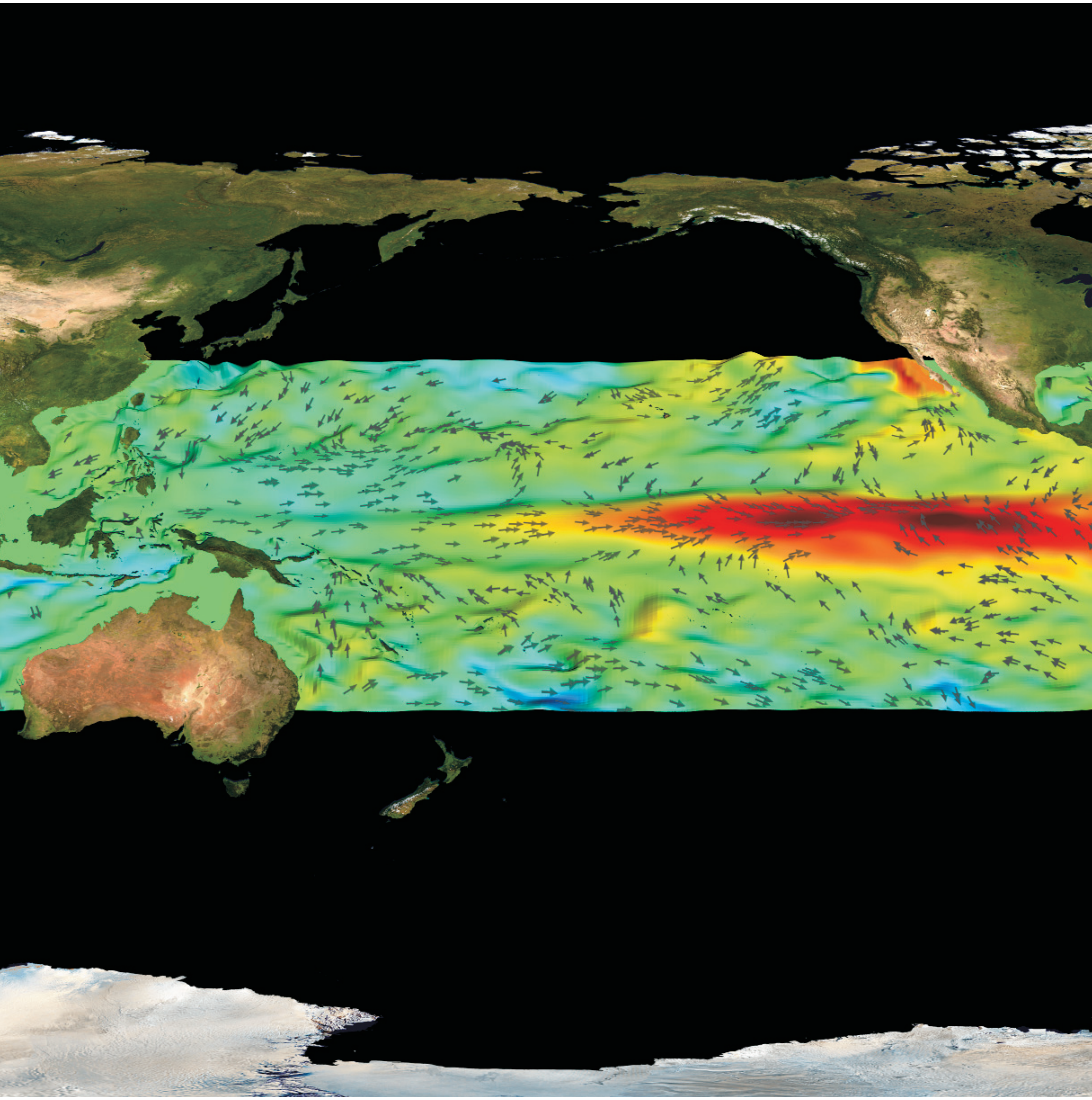
In addition to its primary mission of monitoring and observing global environmental and climate change, MODIS sensors beam daily images of U.S. wildfires to NASA and receiving stations at USFS research and remote sensing centers. Maps derived from these images show daily active fires and areas that were burned during previous days. In the future, other MODIS-derived images will help teams of scientists rehabilitate burned areas. They will use burn severity maps—derived from Earth observing satellite and ground measurements—to help make decisions on appropriate treatments to minimize post-fire erosion and adverse impacts to water quality. MODIS-derived temperature intensity information will provide early estimates of fire severity, which can then be refined on the ground. The maps also will help scientists identify critical wildlife habitats affected by fires and facilitate rehabilitation and reforestation planning. Images showing the locations of active fires are transmitted to the Forest Service and then coupled with other maps containing complementary spatial information to expedite and improve response planning.

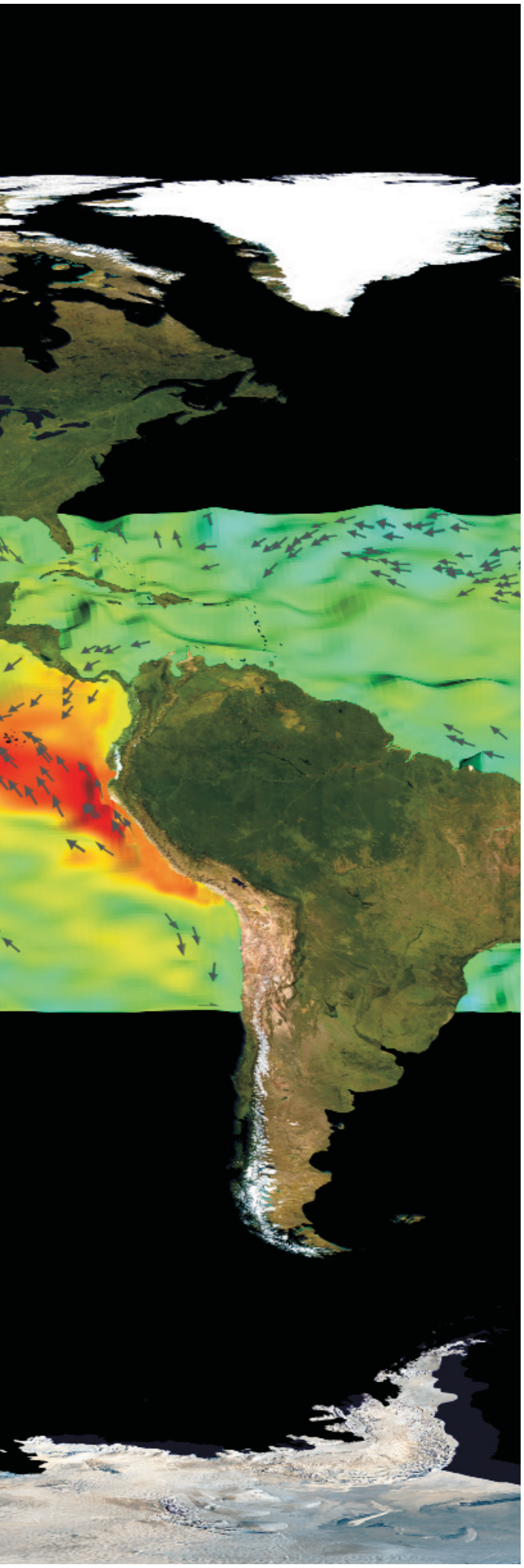
Decision-Support Solutions

Using the USFS MODIS direct broadcast receiving stations to downlink from Terra and Aqua reduces the transmission time from days to minutes. The MODIS fire imagery, integrated with the MODIS Land Rapid Response system, allows officials to more quickly react and respond to wildfire situations that threaten life and property. The MODIS Land Rapid Response system is a joint project of NASA, the USFS, the National Interagency Fire Center, and the University of Maryland.



2 Extending Earth System Science Results





2 Extending Earth System Science Results

The Earth Science Applications Program's approach to extend the benefits of Earth science observations and predictions to decision-support tools is based on fundamental systems engineering principles. The program uses the principles in working with its partners to validate and document integrated solutions that the partners can adopt in their operations and decisionmaking.

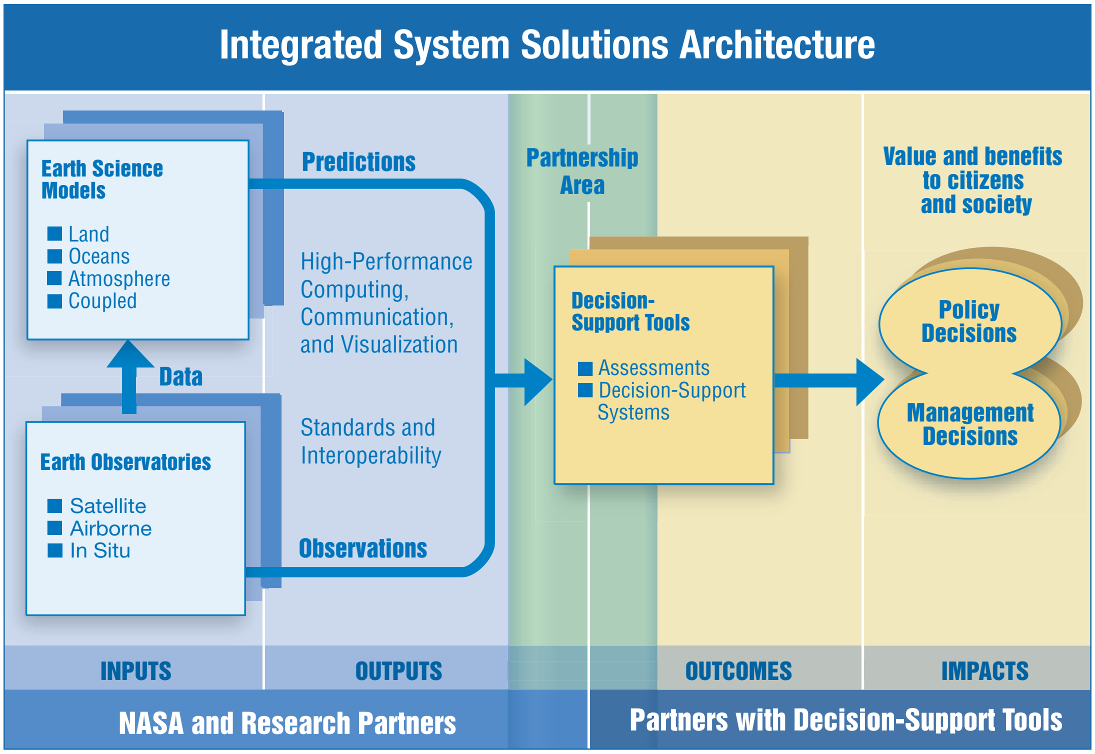
2.1 Integrated System Solutions Architecture

Figure 2.1 illustrates the architecture underlying the activities of the Earth Science Applications Program. To the right, partner agencies and organizations own, develop, and operate decision-support tools to analyze scenarios, identify alternatives, assess risks, and so on, to inform their decision-making processes. Federal agencies use these tools to support their responsibilities to the public, such as resource management, security, regulations, public health, and economic development.

On the left side of the figure, NASA, as a research and development agency, extends the observations, model predictions, and computational techniques from its Earth science research to support the partners. Where the Earth science products have been determined to have potential value, NASA and the partners will collaborate to facilitate and streamline the flow of products to the tools (middle green area), drawing on

Forecast produced in May 1997 from the NSIPP/GMAO coupled model forecast system of El Niño in December 1997. The variables shown are anomalies for sea-surface temperature (color), sea-surface height (texture), and wind stress (arrows). El Niño forecasts support agricultural efficiency, aviation, and disaster management applications.

Figure 2.1



interoperability practices to support data sharing and system integration. NASA works with its partners to provide benchmark integration of observations and predictions into their decision-support tools. Following an appropriate transition, the partners assume the responsibility to adopt the products and techniques into their operations, and NASA shifts its focus to the next products to which it will extend benefits.

The program's approach is to enable the assimilation of Earth science outputs—especially observations and model predictions—to serve as inputs to decision-support tools, such as decision-support systems (see inset). The outcomes are manifest in the partners' enhanced policy and management decisions, and the impacts are the resulting socioeconomic benefits from the improved decisions being made.

Decision-Support Tools

For the program, decision-support tools (DST) refer to assessments and decision-support systems (DSS) that serve policy and management decisions. Generally, decision-support systems are interactive, computer-involved systems that provide organizations with methods to retrieve information, analyze alternatives, and evaluate scenarios to gain insight into critical factors, sensitivities, and possible consequences of potential decisions. Given the copious volumes of Earth science data and the computationally demanding scientific models, decision-support systems typically provide systematic mechanisms to incorporate data products and document the value derived from the inputs.

2.2 Systems Engineering Approach

In collaborating with partners to pursue integrated system solutions, the program employs the functional systems engineering steps of evaluation, verification and validation, and benchmarking. Figure 2.2 presents an example of the systems engineering approach applied to agriculture.

Evaluation

This phase provides an initial match of user-defined requirements relative to Earth science research results. Activities typically include identifying decision-support tools associated with an application area; examining the partners' plans for developing its decision-support tool; assessing the potential value and technical feasibility of current and future Earth science results in the tools; and, assessing partner commitment and the project value relative to the program's funds, objectives, and portfolio. Following this evaluation phase, the program and the partners decide whether to pursue further collaboration on a project.

Verification and Validation

This phase focuses on developing prototype products to address requirements, devise system integration approaches, and resolve technical issues related to the introduction of the Earth science products into the decision-support tools.

In this phase, NASA and the partners measure the performance characteristics of Earth science products (i.e., NASA outputs) to meet the input requirements of the decision-support tools by addressing issues associated with bringing data and model outputs into the partners' internal systems. The purpose is to ensure that the end-to-end system meets the intended objectives with the new inputs.

Verification determines how the actual performance of an observation, prediction, or other Earth science product meets the user-defined requirements within a specified tolerance. Validation determines if the performance of the algorithms (or logic) using the Earth science data or product can achieve the intended outcomes.

Benchmarking

This phase applies a rigorous process to compare the performance of a decision-support tool using Earth science products to a standard benchmark, current practice, or reference scenario in order to document the value of the Earth science products in the tool. Where partners have existing metrics and performance standards to evaluate their tools and decisions, NASA uses those metrics for assessment and those standards as benchmarks.

Figure 2.2

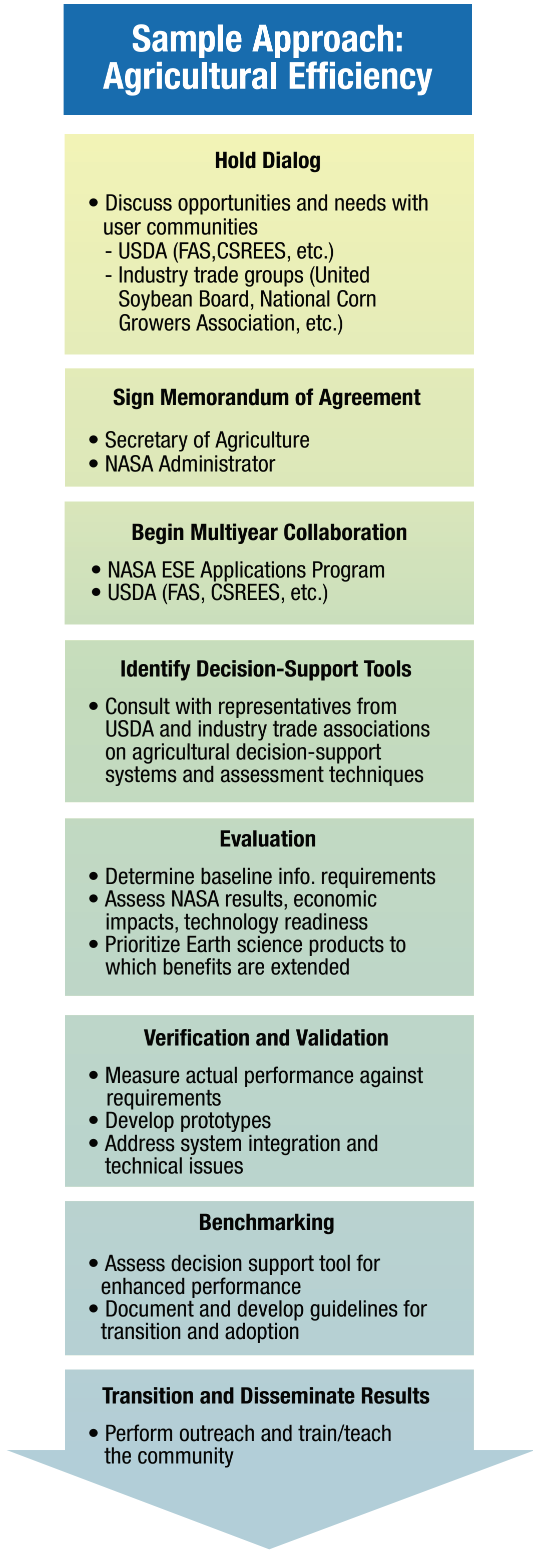


Table 2.1

Applications, Partners, and Decision-Support Tools

National Application	Partner Organizations	Decision-Support Tools—Current Priority (supporting decision processes)
Agricultural Efficiency	USDA, NOAA	CADRE—Crop Assessment Data Retrieval and Evaluation (USDA)
Air Quality	EPA, NOAA, USDA	CMAQ—Community Multiscale Air Quality Modeling System AIRNow and AQI—Air Quality Index
Aviation	DOT/FAA, NOAA	NAS_AWRP—National Air Space—Aviation Weather Research Program
Carbon Management	USDA, DOE, NOAA	CQUEST—Support to the Energy Act of 1992, Section 1605b
Coastal Management	NOAA, EPA, NRL	HAB—Harmful Algal Bloom Bulletin/Mapping System CREWS—Coral Reef Early Warning System
Disaster Management	DHS/FEMA, NOAA, USGS, USFS	HAZUS-MH—Hazards U.S.—Multi-Hazards
Ecological Forecasting	USAID, NOAA, NPS, CCAD, USGS	SERVIR—Regional Visualization and Monitoring System
Energy Management	DOE, UNEP, NOAA, NRC	RETScreen—Energy Diversification Research Laboratory (CEDRL)
Homeland Security	DHS, USGS, NOAA, NGA, DOD	IOF—Integrated Operations Facility
Invasive Species	USGS, USDA, NOAA	ISFS—Invasive Species Forecasting System
Public Health	NIH, CDC, DOD, EPA	PSS—Plague Surveillance System EPHTN—Environmental Public Health Tracking Network MMS—Malaria Monitoring and Surveillance RSVP—Rapid Syndrome Validation Project
Water Management	EPA, USDA, USGS, BoR	RiverWARE—Bureau of Reclamation decision-support Tool AWARDS—Agricultural Water Resources and decision-support Tool BASINS—Better Assessment Science Integrating Point and Nonpoint Source

To support adoption by the partners, this phase includes a robust documentation of procedures and guidelines to describe the steps to access and utilize the Earth science research results.

These three phases provide a systematic approach to follow the integrated system solutions architecture and apply NASA's systems engineering expertise. The purposes of this rigorous approach are to identify and resolve data exchange problems, build partners' confidence and reduce risk in adopting Earth science products, and strengthen partners' abilities to use the data and predictions in their decision-support tools.

2.3 Program Structure

The Earth Science Applications Program consists of two program elements: national applications and crosscutting solutions. Each element has subelements that target specific activities, which collectively serve the Division and program goals and objectives. (Chapter 4 describes the functional activities of the program elements in greater detail.)

National Applications

The national applications element focuses on applications in 12 areas of national priority. The purpose of the national applications is to enable and enhance the use of NASA's Earth science research results, products, and models in decision-support tools operated by Federal agencies and partners with responsibilities related to the 12 areas.

The national applications element has subelements for each of the 12 areas, and each subelement identifies specific partners and decision-support tools. Each subelement manages activities to follow the systems engineering approach and the integrated system solutions architecture to extend Earth science results.

Table 2.1 presents the 12 applications of national priority, the respective Federal agency partners, and the decision-support tools. This table reflects current priorities, and numerous other partners and decision-support tools exist.

Crosscutting Solutions

The crosscutting solutions element represents a programmatic resource that addresses requirements spanning multiple applications. Crosscutting solutions focuses on developing resources and services that enable the program and the national applications element to achieve their objectives while benefiting from economies of scale to achieve high standards of quality and cost-effectiveness. This program element provides support to the systems engineering approach and evaluation, validation, verification, and benchmarking of integrated solutions for the national applications element. The crosscutting solutions element also achieves long-term benefits for the Division and the Applications Program by developing human capital and promoting improved Earth science data accessibility.

2.4 Partners and Community of Practice

The Program works with government, academia, not-for-profit, international, and private-sector organizations to extend the benefits of Earth science research results. The Program comprises a community of people and organizations that provide Earth science results and utilize the results in their decision-making activities.

Partners

NASA develops partnerships and formal agreements with national/international organizations to coordinate the application of Earth science products in operational management and policy making. The program pursues partnerships with private, academic, and public organizations. Generally, the program pursues partnerships with entities that have responsibilities related to the applications of national priority, adequate information infrastructure and decision-support tools to accommodate Earth science information, and

Figure 2.3

Representative Federal Agency Partners

Table 2.2

NASA Centers Supporting Earth Science Applications

	ARC	DFRC	GSFC	JPL	LaRC	MSFC	SSC
Agricultural Efficiency	●		●			●	●
Air Quality			●	●	●	●	
Aviation	●	●			●	●	
Carbon Management	●		●	●		●	●
Coastal Management	●		●	●			●
Disaster Management	●		●	●	●	●	●
Ecological Forecasting	●		●	●		●	
Energy Mangement			●		●	●	●
Homeland Security	●	●	●	●			●
Invasive Species	●		●				●
Public Health			●			●	●
Water Management			●	●		●	●
Crosscutting Solutions			●		●		●

the capacity to extend results to their respective communities.

Initially, the program has focused its efforts toward U.S. Federal agencies. Federal agencies develop decision tools and issue guidelines at a national level that are implemented on regional, State, and local levels. By working with Federal agencies to validate and incorporate Earth science products in the tools, NASA and the Earth Science Applications Program can leverage the established relationships the agencies have with their constituent communities.

Figure 2.3 includes logos of some Federal agencies in partnership with NASA on using Earth science research results.

Community of Practice

Within NASA, the program operates through connections with NASA Field Centers, Earth science laboratories, and the Distributed Active Archive Centers to identify Earth science results, design products, and streamline dataflow supporting activities with the partners. Externally, the program participates in interagency programs to coordinate activities. The program also works with commercial businesses, academic research institutions, and not-for-profit organizations regarding their expertise, innovations, and talents to extend Earth science research results into operational environments.

NASA Field Centers

NASA Centers support the Sun-Earth Systems Division and the Earth Science Applications Program. The Centers have unique capabilities and expertise related to Earth science, research, technology, systems engineering, project management, technology transfer, and so on. The program supports and utilizes capabilities and expertise from the appropriate Centers to serve

Table 2.3

Representative Earth Science Laboratories

Laboratory	Agency Sponsor	Primary Activities
Goddard Institute for Space Studies *http://www.giss.nasa.gov*	NASA	Emphasizes a broad study of global change, including prediction of atmospheric and climate changes in the 21st century
Laboratory for Atmospheres *http://atmospheres.gsfc.nasa.gov*	NASA	Dedicated to advancing knowledge and understanding of the atmospheres of the Earth and other planets
Laboratory for Terrestrial Physics *http://ltpwww.gsfc.nasa.gov*	NASA	Explores the physics and dynamics of the Earth, as well as of other planets and their satellites
Global Hydrology and Climate Center *http://www.ghcc.msfc.nasa.gov*	NASA	Understands the Earth's global water cycle, the distribution and variability of atmospheric water, and the impact of human activity as it relates to global climate change
Short-Term Prediction Research and Transition Center *http://wwwghcc.msfc.nasa.gov/sport/sport_home.html*	NASA	Accelerates the infusion of NASA's observations, data assimilation, and modeling research into National Weather Service forecast operations and decisionmaking at the regional and local level
National Centers for Environmental Prediction *http://wwwt.ncep.noaa.gov*	NOAA	Delivers national and global weather, water, climate and space weather guidance, forecasts, warnings, and analysis to partners and external user communities
Geophysical Fluid Dynamics Laboratory *http://www.gfdl.noaa.gov*	NOAA	Understands and predicts the Earth's climate and weather, including the impact of human activities
Joint Center for Satellite Data Assimilation *http://www.jcsda.noaa.gov*	NASA/NOAA	Accelerates the use of observations from Earth-observing satellites in weather and climate prediction models
National Center for Atmospheric Research *http://www.ncar.ucar.edu/ncar*	NSF (Primary sponsor)	Recognized for its scientific contributions to our understanding of Earth's system, including climate change, changes in atmospheric composition, Earth-Sun interactions, weather formation and forecasting, and the impacts of all of these components on human societies
Sandia National Laboratories *http://www.sandia.gov*	DOE	Chemistry and Earth sciences apply science and technology solutions to issues relating to environment, water, and energy. The focus on atmospheric sciences, hydrology, and geosciences contributes to energy policy, environmental management of energy sources, and water management.

the applications of national priority, the partners, and the Division objectives. The Centers coordinate and collaborate as appropriate for the overall success of the Program.

The NASA Centers supporting the Earth Science Applications Program include the following:

Ames Research Center (ARC)
Dryden Flight Research Center (DFRC)
Goddard Space Flight Center (GSFC)
Jet Propulsion Laboratory (JPL)
Langley Research Center (LaRC)
Marshall Space Flight Center (MSFC)
Stennis Space Center (SSC)

Table 2.4

NASA DAACs and Data Centers

DAACs and Data Centers	Ownership	Primary Activity
Alaska Satellite Facility *http://www.asf.alaska.edu*	University of Alaska	Acquires, processes, archives, and distributes satellite Synthetic Aperture Radar (SAR) data for the U.S. Government and research communities
GSFC Earth Sciences *http://daac.gsfc.nasa.gov*	NASA/GSFC	Archives NASA's ocean color, hydrology, atmospheric chemistry and dynamics, and land biosphere data and information
Global Hydrology Resource Center *http://ghrc.msfc.nasa.gov* *(NASA Data Center and former DAAC)*	NASA/MSFC	Provides both historical and current Earth science data, information, and products from satellite, airborne, and surface-based instruments
Land Processes *http://lpdaac.usgs.gov*	USGS	Processes, archives, and distributes land-related data collected by EOS sensors
Langley Atmospheric Sciences Data Center *http://eosweb.larc.nasa.gov*	NASA/LaRC	Processes, archives, and distributes Earth science data in the areas of radiation budget, clouds, aerosols, and tropospheric chemistry
National Snow and Ice Data Center *http://nsidc.org/daac*	University of Colorado/NOAA	Serves as a cryospheric focal point for NASA Earth Science
Oak Ridge National Laboratory *http://www.daac.ornl.gov*	DOE	Sources for biogeochemical and ecological data useful for studying environmental processes
Physical Oceanography *http://podaac.jpl.nasa.gov*	NASA/JPL	Archives and distributes data relevant to the physical state of the ocean
Socioeconomic Data and Applications Center *http://sedac.ciesin.columbia.edu*	Columbia University	Focuses on human interactions with the environment, climate impacts, and integration of Earth science and socioeconomic data

Table 2.2 illustrates the connections between these Centers and the program's 12 applications of national priority and crosscutting solutions. The table reflects the Centers' significant Earth science expertise, research, and capabilities related to the applications of national priority. In any given year, the level of Center activity is a function of competitive sourcing. The program attempts to utilize capabilities from all appropriate Centers based on the partners' requirements and application priorities. (Chapter 4 describes the Centers' roles.)

Earth Science Laboratories

Numerous Earth science laboratories support the Sun-Earth Systems Division to further the purpose of understanding Earth's system and improving predictions of Earth-system change. NASA and other agencies directly operate some of the laboratories and provide funding to other laboratories. The Earth Science Applications Program draws on results and support from the Earth science laboratories to extend Earth science data and predictions. Table 2.3 presents representative Earth science laboratories that NASA, the National Oceanic and Atmospheric Administration (NOAA), the National Science

Foundation (NSF), and the Department of Energy (DOE) support.

Distributed Active Archive Centers

The Distributed Active Archive Centers (DAACs) are the data management and user services branches of NASA's Earth Observing System Data and Information System (EOSDIS). The DAACs process, archive, document, and distribute data from NASA's past and current Earth science research satellites and field measurement programs. Established in the 1990s, each DAAC serves one or more specific scientific disciplines (table 2.4). The DAACs maintain close ties to the science user communities and with remote sensing instrument teams in order to provide useful products. The DAACs collaborate with each other to provide standard services and documentation, to provide access to common search tools, and to preserve data for future generations of scientists.

A Federation of Earth Science Information Partnerships (ESIPs; *http//:www.esipfed.org*) also promotes the distribution of Earth science data. ESIPs are composed of Government agencies, national laboratories, NASA Centers, universities, businesses, and other collaborators to elicit user needs and share experiences to improve the distribution of scientific data and information. The program works closely with the DAACs and ESIPs to identify data products and streamline the flow of products to users.

Academia

The program supports and draws on expertise from numerous academic institutions. Researchers at colleges and universities conduct applied research and develop innovations in applying Earth science research to decision-support activities. The program supports academic institutions through multiyear projects selected through competitive processes. Figure 2.4 presents representative academic institutions that were involved with the program in 2003–2004 to extend Earth science research results to decision-support activities.

Private-sector

The program works with private-sector companies to coordinate and apply remote sensing and modeling expertise to address the requirements for information products that serve the applications of national priority and the national interest. Companies possess expertise in remote sensing, satellite systems, computing and modeling, information management, downlink systems, and other key topics related to Earth science and its applications. In addition, the Program evaluates private-sector, commercially available data for use in NASA's Earth science research.

The private-sector and market elements represent large potential audiences for the use of Earth science data. In working with the Federal agencies, the program enables the industries associated with the agencies, such as public health, insurance, avi-

Figure 2.4

ation, and agriculture, to utilize Earth science data in developing their business practices. Each application of national priority has relationships with relevant professional and trade associations, such as the American Public Health Association and the Air & Waste Management Association, in order to extend Earth science data into industry and operational practices.

Nongovernmental and Not-for-Profit Organizations

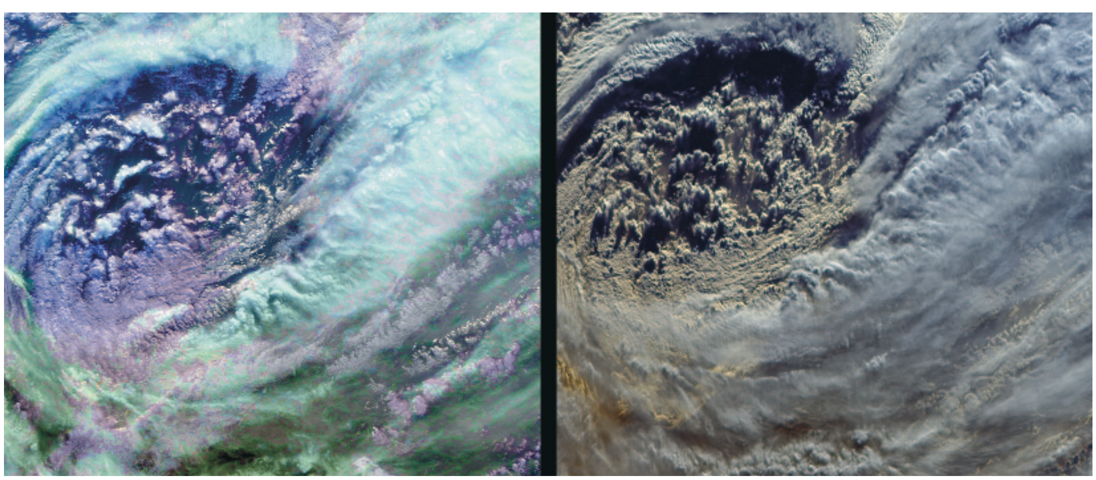
Nongovernmental organizations (NGOs) conduct in-depth scenario assessments and policy alternatives that can utilize Earth science data. For example, the Heinz Center for Science, Economics, and the Environment published a State of the Nation's Ecosystems report in 2002. The report included a vision for periodic, nonpartisan reporting on the condition of the Nation's natural resources and identified specific indicators on current conditions and trends. Such reports and annual updates can use Earth science measurements in preparing information for decisionmakers. The program also works with not-for-profit organizations that provide in-depth analyses on trends and directions of information systems and other key technologies in order to anticipate changes in decision-support tools.

NGOs and not-for-profit organizations also disseminate information on applications of Earth science results to their respective communities. For example, the Program works with the National States Geographic Information Council and the Aerospace States Association to inform State and local governments about opportunities for Earth science to support applications of national priority.

International

The program draws on agreements and relationships that NASA has with other countries and international organizations that coordinate the collection and sharing of Earth science data. For example, NASA and the French Centre National d'Etudes Spatiales (CNES) collaborate on TOPEX/Poseidon. NASA and the Japan Aerospace Exploration Agency (JAXA) cooperate on the Tropical Rainfall Measurement Mission (TRMM). NASA is part of the ad hoc GEO to coordinate a decade-long approach to Earth science collection. The program draws on international data sets as appropriate to support the partners' use of Earth science products in their decisionmaking tools.

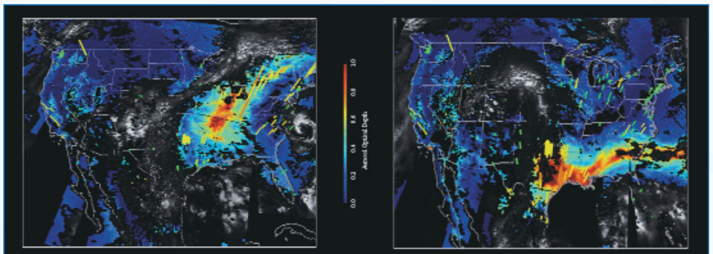
The program's applications of national priority have international dimensions beyond their domestic importance. Internationally, the program works through U.S. partners that have an international mission (e.g., U.S. Agency for International Development), groups the United States is a member of (e.g., United Nations Environment Programme), and international initiatives with U.S. involvement (e.g., World Summit on Sustainable Development). The program's international activities also focus on extending Earth science products to partners' decision-support tools.



The complex structure of polar clouds are highlighted by these images acquired by the Multi-angle Imaging SpectroRadiometer (MISR) aboard Terra (April 23, 2003). These clouds occur at multiple altitudes and exhibit a noticeable cyclonic circulation over the Southern Indian Ocean, to the north of Enderbyland, East Antarctica.

Accomplishment:
Air Quality Forecasting

In October 2003, the U.S. Environmental Protection Agency (EPA) began providing forecasts of fine particulate matter for 100 metropolitan areas. Particulate matter (PM) can be small enough to travel deep into lungs, contributing to health problems and aggravating respiratory conditions like asthma and bronchitis. The EPA's AIRNow program maintains a ground network of PM2.5 (PM less than 2.5 microns) monitors to assist local forecasters in issuing air quality forecasts. EPA also uses data from NASA satellites to estimate PM2.5 levels in between the monitors and to track PM2.5 transport across regions for use in forecasts.



September 10, 2002: Satellite data and ground measures confirm aerosol levels. Bands of high aerosols into Canada and south toward Texas.

September 12, 2002: Satellite images indicate high aerosol levels over large parts of Texas and transport across much of the Southeast U.S.

Data products from Terra/Aqua indicate the amount of aerosols and PM across North America (blue-low; red-high). Images show the initiation of a pollution event in the Midwest and movement to Texas and the Southeast. Transport information can help air quality forecasts.

Air Quality and PM2.5

Aerosols and PM are the general terms for mixtures of solid particles and liquid droplets in the air. PM is classified as coarse or fine, and it can be emitted directly into the atmosphere (e.g., dust from roads) or formed in the atmosphere through chemical reactions (e.g., sulfates and nitrates formed from automobile and power plant emissions). Fine PM2.5, in particular, is associated with numerous health problems (e.g., aggravated respiratory conditions, asthma, and heart attacks). PM also contributes to reduced visibility and wear on buildings.

The EPA's AIRNow program supports a ground network of air quality monitors and allows public access to air quality information. AIRNow manages the Air Quality Index (AQI) for reporting daily air quality—the AQI level reflects the pollutant ground concentrations and their associated health effects. Local agencies and the media use the AIRNow data to create forecasts and report the local AQI to the public. Current PM2.5 forecasting methods are performed on local scales only; however, PM2.5 from surrounding areas can influence the air quality of the forecast area. The exclusion of information about these surrounding areas can impact on the accuracy of the forecasts.

NASA Satellite Data Application

NASA scientists use measurements from the Terra and Aqua satellites to gather information about aerosols and dust to answer fundamental Earth science issues, such as their effects on climate. The satellite sensors can distinguish between clouds and aerosols, and they can track the severity and movement of pollution events across regions and continents. In 2003, EPA and NASA scientists examined the satellite data to support EPA's AQI forecasts.

The NASA satellite-based aerosol products correlated well with EPA PM2.5 ground measurements. EPA and NASA developed products to identify high concentrations of PM2.5 and provide insight into the transport of PM2.5 on a continental scale. This product could then be used as a tool by PM2.5 forecasters to improve the accuracy of next-day AQI forecasts, which are routinely delivered to the media and the public. The resulting product was a data fusion visualization incorporating NASA aerosol measurements, NASA cloud measurements, wind and fire observations from NOAA's GOES satellite, a NOAA air trajectory model, and EPA surface observations. The data fusion product depicts temporal and spatial relationships to provide a synoptic view of aerosol events across North America and support forecasting efforts.

In 2004, EPA, NOAA, and NASA are transitioning the demonstrated forecast tools to continuous operations. With improved air quality forecasts of PM2.5, the public can avoid unnecessary exposure to PM, resulting in fewer hospital admissions, fewer absences from work or school, and healthier and more productive citizens.

3 Goals and Objectives: 2004–2012

3 Goals and Objectives: 2004–2012

The Earth Science Applications Program sets challenging goals and objective to contribute to the Science Mission Directorate, NASA, and the Nation in an expeditious, cost-effective manner. Our goals and objectives provide the basis for sound public management practices in a research and development environment and establish realistic expectations with the Administration, Congress, partner agencies, and the public. The program employs roadmaps to illustrate the evolution and progress toward planned outcomes and impacts.

3.1 NASA and Earth Science Goals

The Sun-Earth Systems Division has primary and supporting responsibilities for several goals and objectives within the NASA Strategic Plan, including the Earth Science Applications theme and its objective to expand and accelerate the economic and societal benefits of Earth science information and technology.

Table 3.1 presents the NASA Strategic Plan goals and objectives directly related to the Earth Science Applications Program.

3.2 Program Goals

The NASA Earth Science Applications Program pursues the following goals:

- Promote socioeconomic value and enable economic, environmental, and national security through the benefits of Earth science research results

NASA information technology and visualization techniques support the integration of Earth science data into decision-support tools. Interoperability standards support use of Earth science products and models by partners and end users.

Table 3.1

NASA Strategic Plan and Earth Science Applications Program		
NASA Mission: To understand and protect our home planet.	Goal 1: To understand Earth's system and apply Earth-system science to improve the prediction of climate, weather, and natural hazards	Objective 1.2: To expand and accelerate the realization of economic and societal benefits from Earth science information and technology
	Goal 2: To enable a safer, more secure, efficient, and environmentally friendly air transportation system	Objective 2.1: To decrease the aircraft fatal accident rate and the vulnerability of the air transportation system to threats and mitigate the consequences of accidents and hostile acts
		Objective 2.2: To protect local and global environmental quality by reducing aircraft noise and emissions
	Goal 3: To create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia	Objective 3.1: To enhance the Nation's security by developing and demonstrating critical access-to-space technologies that benefit NASA, DOD, and other Government agencies

- Support and foster mechanisms for interoperability and information exchange to enable the widest practical use of Earth science in society, including education and training
- Demonstrate the value of NASA's Earth system science approach and research through the application of Earth science results
- Build the broadest network of users and raise expectations for the use of Earth science measurements and predictions in appropriate national policy, business practices, and public and private management decision making
- Support partners' decisionmaking capabilities by enabling their expanded use of Earth science results, information, and technology to serve their management and policy responsibilities

These goals represent the progress the program has been charged to achieve and plans to facilitate and accomplish.

3.3 Program Objectives

The program pursues long-term, near-term, and short-term objectives to support and achieve the program's goals.

Tables 3.2–3.4 present the program's objectives. Table 3.5 presents a brief overview of the 12 applications of national priority.

3.4 Earth Science Applications Roadmaps

The Earth Science Applications Program elements—crosscutting solutions and national applications—establish and pursue activities focused on their areas of responsibility. Each application of national priority employs a roadmap to set its direction, identify key factors, and communicate the evolutionary path toward its objectives.

Pages 36–61 present an overview of the 12 applications of national priority as well as a two-page summary of each application of national priority. Each two-page display presents the application's activities, plans, and direction, the specific roadmap; and an integrated system solutions

Table 3.2

Long-term Objectives (FY12)

As stated in the Integrated Budget and Performance Document (IBPD):

Through 2012, benchmark the assimilation of observations provided from 20 of the 80 remote sensing sensors deployed on the flotilla of 26 NASA Earth observation research satellites.

By 2012, benchmark the assimilation of 5 specific types of predictions resulting from the Earth system modeling framework of 22 NASA Earth system science models.

By 2012, benchmark the assimilation of observations and predictions resulting from NASA Earth Science research in 12 decision-support systems serving the national priorities and missions of Federal agencies.

By 2012, in partnership with the Department of Homeland Security, the Department of Defense, and the Department of State, deliver 15 observations and 5 model predictions for climate change, weather prediction, and natural hazards to 5 national and 5 global organizations and decisionmakers to evaluate 5 scenarios and optimize the use of Earth resources for homeland security, environmental security, and economic security.

Table 3.3

Near-Term Objectives (FY06–08)

Through 2006:

- Complete evaluations on at least 15 decision-support tools for potential Earth science products.
- Assess the potential of CALIPSO, CloudSAT, and GPM to serve decision-support tools associated with the applications of national priority.
- Complete verifications/validations on at least 20 Earth science results for at least 12 decision-support tools.
- Complete benchmark reports on the performance of Earth science products from at least 13 observations and 3 types of predictions into at least 8 separate decision-support tools.

Through 2007:

- Establish agreements or joint development plans with at least 11 Federal partners and at least five nonfederal partners on the application of Earth science to their decision tools and processes.
- Achieve next-generation interoperability standard for Earth science data.
- Publish at least 12 articles on the application of NASA Earth science results to decision-support activities, including at least 3 articles in peer-reviewed journals.
- Assess the potential of OSTM, NPP, and Glory to serve decision-support tools associated with the applications of national priority.

Through 2008:

- Complete evaluations on at least 20 decision-support tools for potential Earth science products.
- Assess the potential of OCO, Aquarius, NPOESS, and HYDROS to serve decision-support tools associated with the applications of national priority.
- Complete verifications/validations of at least 20 observations and 5 types of predictions for at least 15 decision-support tools.
- Complete benchmark reports on performance of Earth science products from at least 16 observations and 4 types of predictions into at least 10 separate decision-support tools.

Table 3.4

Short-Term Objectives (FY04–05)
Through 2004:
• Benchmark measurable enhancements to at least two national decision-support systems using NASA results. *IBPD 4ESA1* • Expand DEVELOP (formerly, Digital Earth Virtual Environment and Learning Outreach Project) workforce development program to at least five additional States. *IBPD 4ESA2* • Competitively select at least five solutions projects for the Research, Education, Applications Solutions Network (REASoN) program to serve national applications. *IBPD 4ESA3* • Verify/validate at least two commercial remote sensing sources/products for Earth science research. *IBPD 4ESA4* • Benchmark improvements to at least two of the target national applications—air quality and agricultural competitiveness. *IBPD 4ESA5*
Through 2005:
• Work within the Joint Agency Committee on Imagery Evaluation (JACIE) and the Commercial Remote Sensing Policy Working Group through partnerships with NGA, USGS, NOAA, and USDA to verify/validate at least two commercial remote sensing sources/products for Earth science research, specifically with respect to land use/land cover observations for carbon cycle and water cycle research. *IBPD 5ESA1* • Benchmark measurable enhancements to at least two national decision-support systems using NASA results, specifically in the disaster management and air quality communities. These projects will benchmark the use of observations from five sensors from NASA research satellites. *IBPD 5ESA2* • Expand the DEVELOP human capital development program to increase the capacity for the Earth science community at a level of 100 program graduates per year and perform significant student-led activities using NASA research results for decision-support with representation in 30 States during the fiscal year. *IBPD 5ESA3* • Benchmark solutions from at least five projects that were selected in the FY03 REASoN program to serve national applications through projects that support decisionmaking in areas such as agriculture, public health, and water quality. These projects will benchmark the use of observations from at least five sensors from NASA research satellites. *IBPD 5ESA4* • The DEVELOP program will advance the capacity of our future workforce with students from at least 20 States working to develop and deliver benchmark results of at least 4 rapid prototype projects using NASA Earth science research results in decision-support tools for State, local, and tribal government applications. *IBPD 5ESA5* • Benchmark solutions associated with at least five decision-support systems that assimilate predictions from Earth system science models (e.g., GISS, GFDL, NCEP, SpoRT, and the Earth science laboratories). *IBPD 5ESA6* • Benchmark enhancements to at least two national decision-support systems using NASA results, specifically in the disaster management, public health, and air quality communities. These projects will benchmark the use of observations from five sensors from NASA research satellites. *IBPD 5ESA7* • Verify and validate solutions for at least five decision-support systems in areas of national priority associated with the FY03-selected REASoN projects. *IBPD 5ESA8* • Benchmark the use of predictions from two NASA Earth system science models for use in national priorities, such as support for CCSP, CCTP, and NOAA/National Weather Service. *IBPD 5ESA9* • Benchmark the use of observations and predictions of Earth science research results in two scenarios-assessment tools, such as tools used by the U.S. EPA and Department of Energy. *IBPD 5ESA10*

diagram (described in section 2.1). Detailed information on each application is contained in the specific application's program plan.

The roadmaps illustrate the evolving, progressive nature of links between the increasing capabilities of NASA-supported research, measurement systems, and technology and their extension to partners' management and policy responsibilities.

The yellow/green bars on the left of the roadmap state the expected developments in Earth science research and technology; the blue bars to the right reflect the contributions of the research to improved management capabilities. Each level shows a steady improvement in the measurements and research along with the associated enhancement in management capabilities and public value. Note: the transition points from yellow bars to blue bars do not necessarily match the time references. The Applications Program roadmaps build on the roadmaps of the six Earth science focus areas.

3.5 Earth Science Gateway

The program has proposed an Earth Science Gateway (figure 3.1), which can serve as a portal to information about Earth and its application to decision-support activities. Users can access observations and predictions of natural phenomena from NASA and other agencies and organizations. Potential users include analysts, scientists, decision-makers, educators, managers, and the public. The gateway serves as a significant resource for the Division and the Applications Program.

Data and visualizations, available through open-standard protocols, are of primary interest within the gateway. Users can identify, discover, and utilize other registered materials, including legacy data and documents. Information providers from organizations worldwide can make their content accessible through the gateway. The gateway provides tools and linkages to search, access, and display data; model outputs; and visualizations using standardized protocols.

Figure 3.1

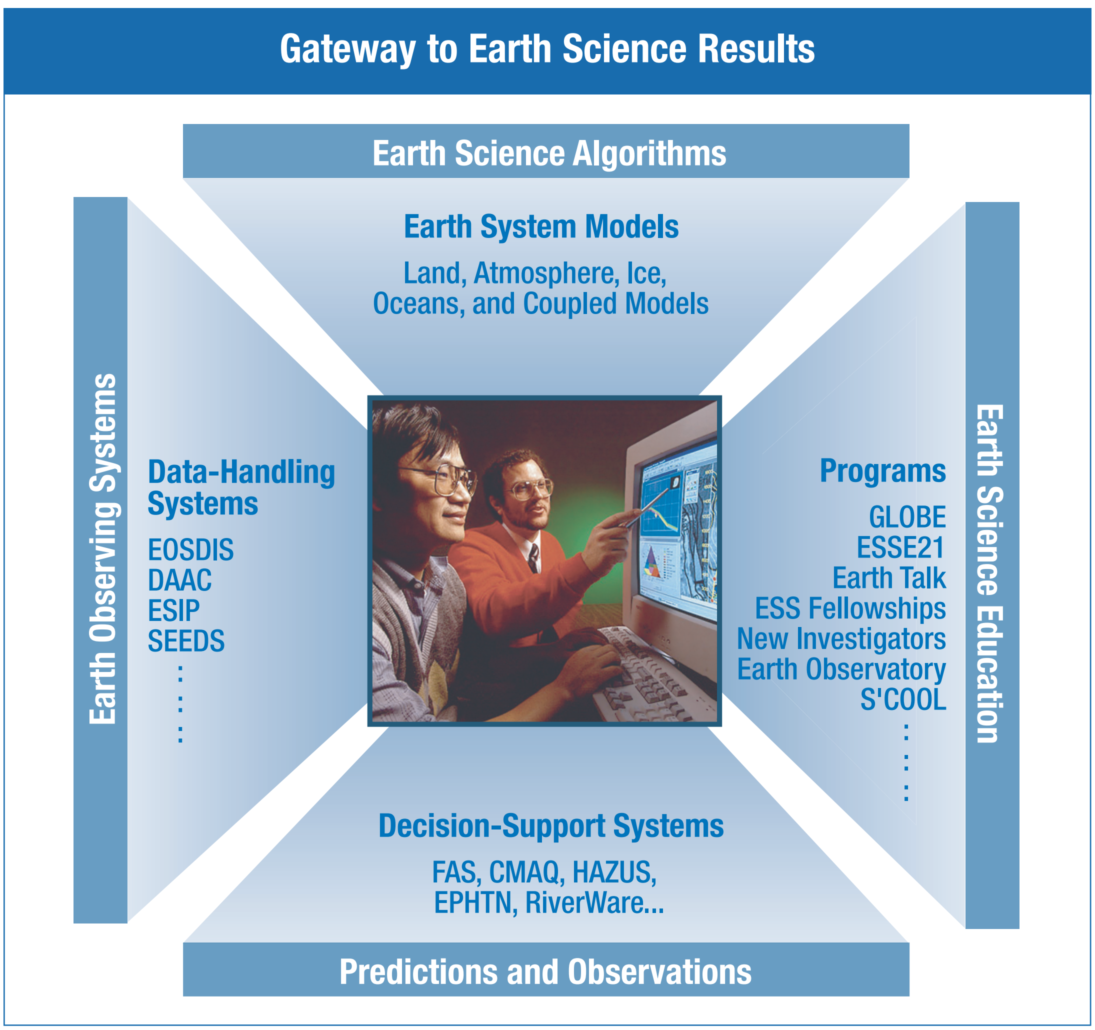
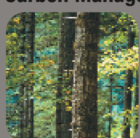
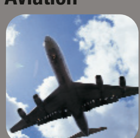
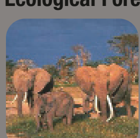
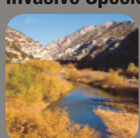
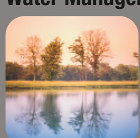


Table 3.5

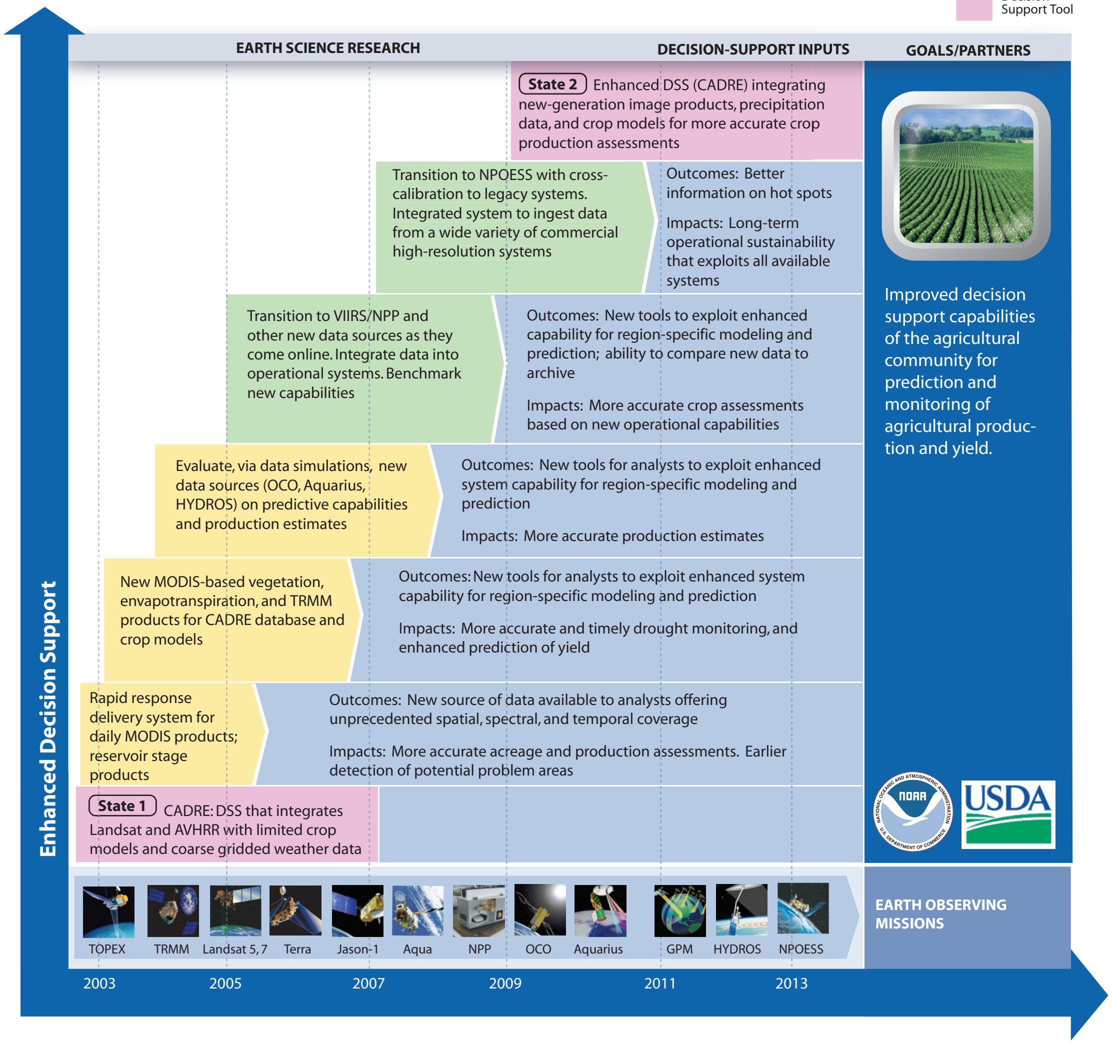
Earth Science Research Results

National Application	Partner Agencies	NASA Contributions	Partner Agencies Decision-Support Tools	Decadal Outcomes of Agencies' Use of NASA Data and Information
Energy Management 	DOE, EPA	Extended weather forecasts, seasonal climate prediction, and distribution of incoming solar radiation via Terra, Aqua, SORCE, CloudSAT, NPP, GPM	• RETScreen • Natural Resources Canada (NRCan)	• Energy management sources and their integration into the power grid through use of RETScreen • Location of energy management facilities • Biomass crop selection and maintenance strategies
Agricultural Efficiency 	USDA, EPA	Seasonal temperature and precipitation, extended weather forecasts, and soil moisture via GPM, Aqua, Terra, NPP, Landsat, Aquarius, suborbital	• Crop Assessment Data Retrieval and Evaluation (CADRE)	• Improved crop production assessments • Increased agricultural productivity and reliability
Carbon Management 	USDA, EPA, DOE, USGS, USAID	Measurement of carbonaceous gases and aerosols, terrestrial biomass and marine productivity via Terra, Aqua, Aura, NPP, OCO, and suborbital	• CQUEST tools developed to implement Section 1605(B) of Energy Act of 1992 (EA92): voluntary sequestration of greenhouse gases	• Operational decision-support system with improved assessment of carbon sources and sinks for a carbon-trading regime
Aviation 	DOT/FAA	Improving weather nowcasting; monitoring of volcanic aerosols via Terra, Aqua, NPP-Bridge, GPM, and suborbital; improving cockpit capabilities via: • Aviation Weather Information Network (AWIN) • Synthetic Vision System (SVS)	National Airspace System (NAS): • Controller/pilot decision aids • Runway incursion prevention	• Enhanced National Airspace System, AWIN, and SVS that reduce the aviation fatal accident rate by a factor of 10 by 2022
Homeland Security 	DHS, NIMA, USDA, USGS, NOAA, DOD	Observations and modeling of atmospheric chemical transport and precipitation via Terra, Aqua, NPP, GPM, and suborbital	• Department of Homeland Security (DHS) situation control	• Improved capabilities of homeland Security officials to prepare, warn, and respond to Homeland security threats, especially air and water exposure
Ecological Forecasting 	USGS, USDA, USAID	Observations of land cover change, vegetation structure, and biomass and use in ecosystem models via Landsat, NPP, and suborbital	• Models of habitat change • Impacts of El Niño and other oceanic oscillations on fisheries • Regional visualization and monitoring system for the Mesoamerican Biological Corridor	• Enhancing ecosystem sustainability as economics and populations shift and grow

and Applications of National Priority

National Application	Partner Agencies	NASA Contributions	Partner Agencies' Decision-Support Tools	Decadal Outcomes of Agencies' Use of NASA Data and Information
Disaster Management 	FEMA, USGS, NOAA, USDA	Observations of topographic change and crustal strain and motion, extended weather forecasts via Aqua, SeaWinds, SRTM, Landsat, GPM, suborbital	• HAZUS risk Prediction • Center for Integration of Natural Disaster Information (CINDI)	• Enhanced risk assessment, warning, and response for hurricanes, tornados, flooding, earthquakes, and landslides
Public Health 	CDC, DOD, NIH, EPA, USGS, NOAA	Observations and modeling of weather, climate, and other environmental factors influencing disease vectors and air quality via Aura, NPP, Jason, GPM	• Environmental Public Health Tracking Network (EPHTN) • Arbovirus Surveillance Network (Arbonet) • Malaria Modeling and Surveillance (MMS)	• Improved surveillance systems (Arbonet) • Integrated environmental factors into EPHTN • Improved accuracy and precision of disease predictions with a corresponding increase in warning time
Coastal Management 	NOAA, EPA	Measurement and modeling of ocean temperatures, winds, color, and salinity associated with harmful algae blooms via Terra, NPP, SeaWinds, Landsat, Jason	• Harmful Algal Bloom Mapping System/Bulletin (HABMap/Bulletin)	• Improved capability of decision-support systems to forecast HAB initiation, transport, toxic severity, landfall, and demise
Invasive Species 	USGS, USDA	Observations and modeling of land cover change, biomass, and climate influencing species proliferation in areas where newly introduced, via Terra, Aqua, NPP, Landsat	• Invasive Species Forecasting System (ISFS)	• Operational, robust, and early detection and monitoring of plant invasions to protect natural and managed ecosystems
Water Management 	USBoR, EPA, USDA, USGS	Improved models of water transport, storage, and quality using observations of snow cover, soil moisture, and topography via Aqua, NPP, GRACE, GPM, Landsat, and suborbital	• RiverWare • Better Assessment Science Integrating Point and Nonpoint Source (BASINS) • Agricultural Water Resources and decision-support (AWARDS)	• Improved water quality and quantity assessments • Forecasts of precipitation and daily crop water use toward reduction of real irrigation • Seasonal predictions for optimum vegetation selection and improved water use efficiency
Air Quality 	EPA, NOAA, USDA, FAA	Measurements of aerosols, ozone, emissions and modeling of aerosol and chemical atmospheric transport via Terra, NPP, Aura, Glory, and suborbital	• Community Multiscale Air Quality (CMAQ) modeling system • AIRNow and Air Quality Index	• Multiple-day air quality forecasts and robust emissions-control planning

Roadmap
Agricultural Efficiency



Where we are now	Where we plan to be
USDA Foreign Agriculture Service (FAS) using data from Landsat, MODIS, AVHRR, Jason-1, and TOPEX/Poseidon in production and yield estimates issued by the World Agricultural Outlook Board for major agricultural commodities. USDA using Earth science data to improve the timeliness and accuracy of FAS reports on disruption in agricultural productivity due to floods, fires and other natural phenomena USDA and NASA have a partnership agreement to integrate Earth science data into agricultural decision-support tools	USDA and FAS using NPP to enhance climate and weather predictions to assess and report on agricultural conditions USDA using observations from HYDROS, GPM, OCO, and Aquarius to drive predictive models that incorporate information on soil moisture, rainfall, carbon fluxes, and sea surface salinity into better estimates of climate impact
2004	2012

Agricultural Efficiency

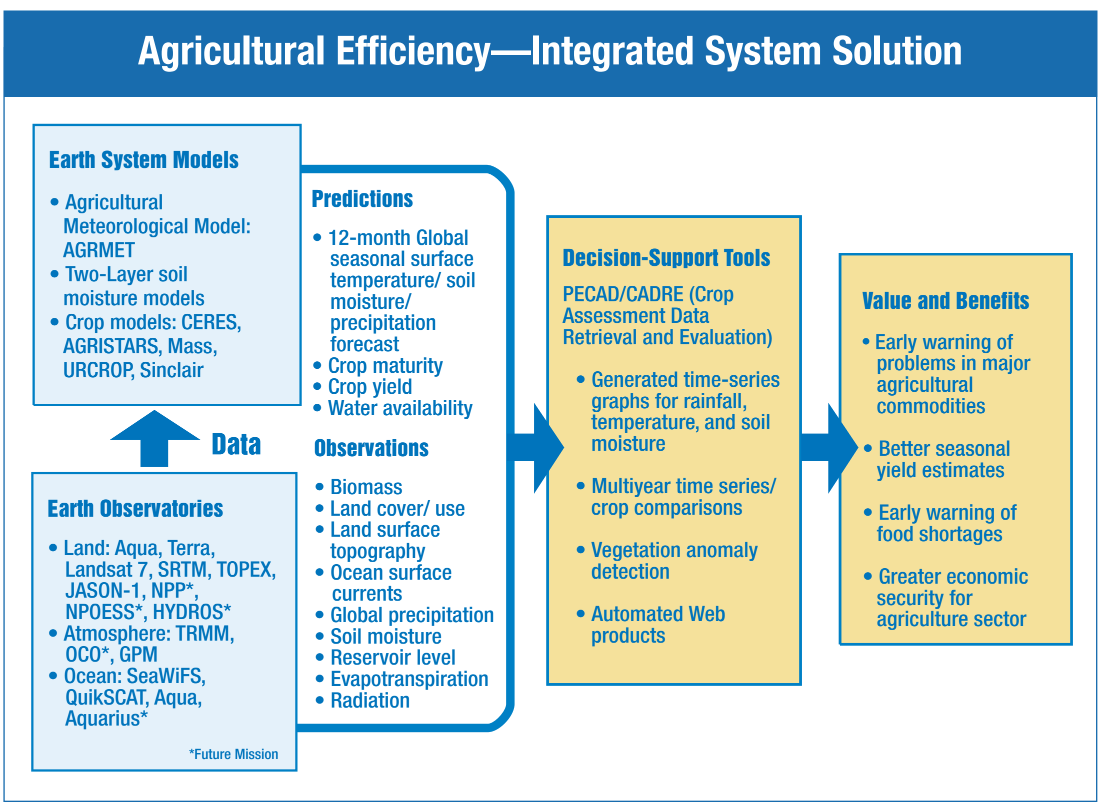
The Agricultural Efficiency national application extends NASA Earth science observations and predictive models to improve decisionmaking capabilities concerning agricultural resource management. The application addresses agricultural issues related to crop production, yield, and condition, drawing on Earth observations such as land cover and land use, precipitation, vegetation condition, and water availability.

In the near term, the program is validating and benchmarking observations from MODIS and TRMM (e.g., vegetation conditions, surface temperature, snow cover, wildfire location and intensity, and precipitation) for incorporation into operational decision-support tools of the FAS, the National Agricultural Statistics Service, and the Forest Service.

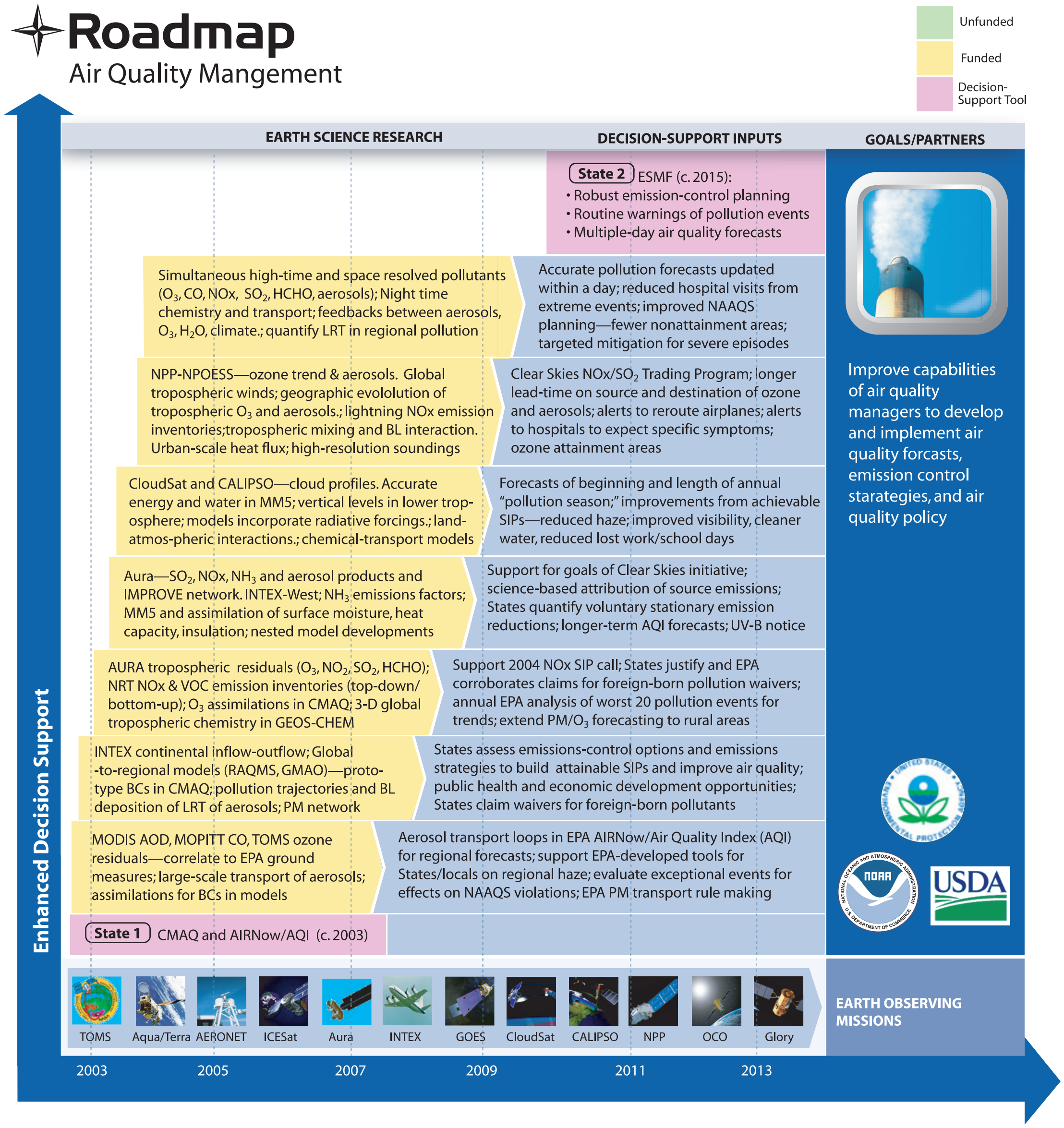
Within the next decade, the program will work to extend products from new systems (e.g., NPP and NPOESS), which advance the operational utility of MODIS-type acquisitions, and products from NASA experimental instruments (e.g., OCO, GPM, HYDROS, Aquarius) that will improve the timeliness and accuracy of predictive models.

NASA partners with Federal agencies and national organizations that have agricultural management responsibilities and mandates to understand variability in weather and climate and their effects on agricultural resource management. Primary partners are USDA and NOAA.

Figure 3.2



Roadmap
Air Quality Mangement



Where we are now	Where we plan to be
Use of Earth science observations on case-by-case project basis	Routine use of Earth science products in decision tools for air quality forecasting, planning, and compliance
Regional and intercontinental transport of air pollutants identified and research on inflow/outflow to regions	Use of Earth science data and model outputs and predictions supporting scenario assessments for policy-making and management
Prototype use of MODIS aerosol depth in air quality forecasts and ozone residuals for air quality planning	At least five separate air quality issues and decisions tools using Earth science products from at least seven sensors and models

2004 ——— 2012

Air Quality Management

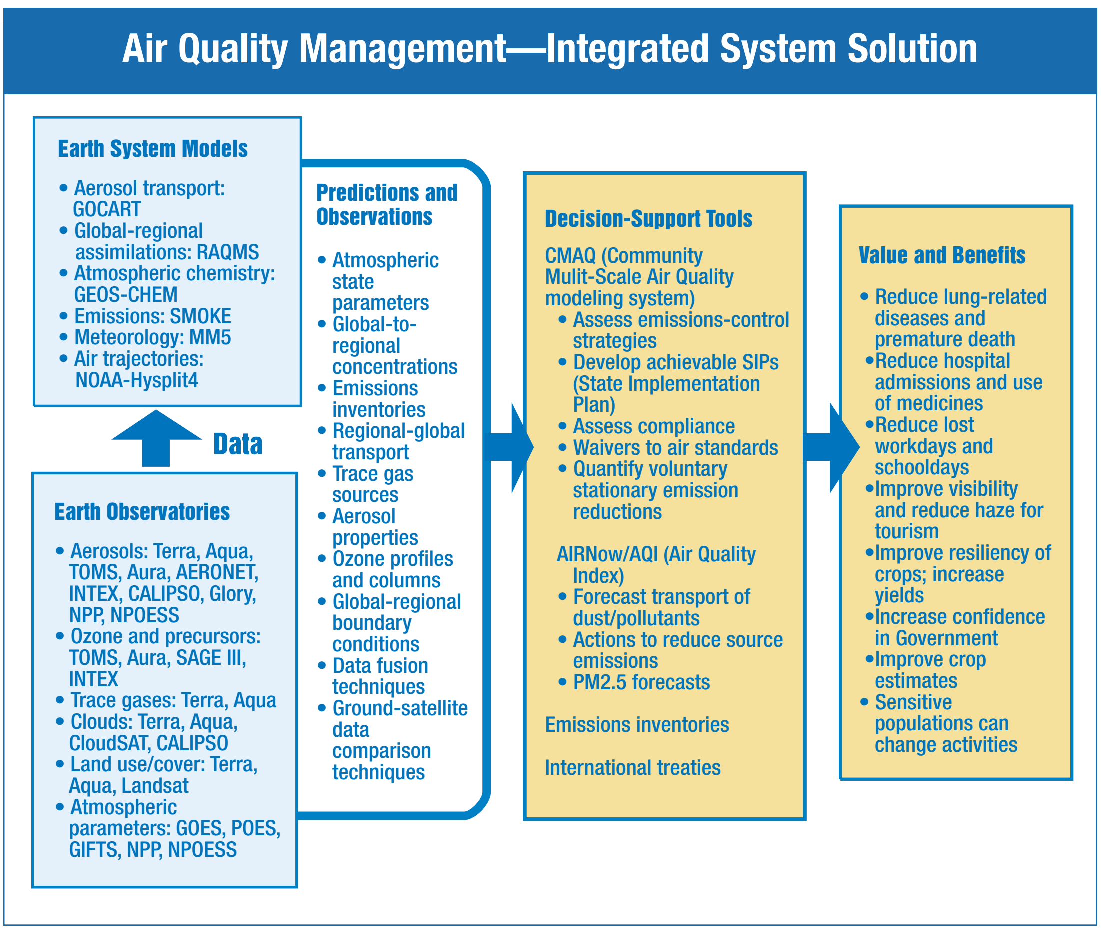
The Air Quality management application extends Earth science results, products derived from Earth science information, models, technology, and other capabilities into partners' decision-support tools for tools for air quality management issues.

The air quality management application addresses issues of concern and decisionmaking related to air quality planning, compliance, and forecasting; the program also addresses the emissions inventory, given the crosscutting benefit to air quality activities.

In the near term, the program is validating and benchmarking products for priority decision tools related to regional aerosol transport, air quality forecasting, and pollution control options—EPA's AIRNow Air Quality Index for forecasting and CMAQ for air quality planning and forecasting. Potential future issues the applications may address include aviation emissions, haze and visibility, ozone forecasting, and long-range pollution transport.

NASA partners with Federal agencies and regional-national organizations that have air quality management responsibilities and mandates to support air quality managers—NASA primary partners are EPA, USDA, and NOAA.

Figure 3.3



Roadmap
Aviation

Unfunded
Funded
Decision-Support Tool

Enhanced Decision Support

EARTH SCIENCE RESEARCH	DECISION-SUPPORT INPUTS
	State 2 WX visualization systems: Fully integrated SVS, WARP and ITWS in-cockpit graphical WX displays featuring real-time weather information with global coverage
	State 2 WX sensors/data sources: AIRS, CrIS and GIFTS fully integrated into NEXRAD and TDWR systems; prepared for seamless integration of ABS (GOES-R)
EOS, NPP, NPOESS and GOES-R	NAS-wide data link WX products provide severe weather location and movement data to controllers and aircrews to promote common situational awareness
GIFTS—Geosynchronous Fourier Transform Spectro-meter Turbulence and Weather Prediction Modeling	Geostationary satellite technology improvements will vastly improve remote measurement of altitude-resolved vector winds and temperatures, allowing for efficient flight planning, operations, and traffic management
Aqua and NPP fly the AIRS and CrIS sensors (Atmospheric Infrared Sounder and Crosstrack Infrared Sounder)	High-spectral (vertical), horizontal, and temporal resolution satellite measurements will render precise numerical weather forecasts and extremely high-resolution wind fields based on the tracking of atmospheric water vapor
NAST (I) Atmospheric Sounder Testbed Infrared (Proteus) Experiments Experiments	Airborne validation of NPOESS instruments provides DSS product development teams with experience in integrating hyperspectral data and information in preparation for subsequent GIFTS and GOES-R missions
Advanced Satellite Applications Products (ASAP) Program	Integration of existing GOES imagery and sounding ?data into AWRP products improve CIP/FIP, terminal convective? WX product, and integrated turbulence forecast
State 1 WX visualization systems: Discrete, stand-alone weather products with little satellite–sounding data or imagery	
State 1 WX sensors/data sources: Ground Doppler radar; twice daily balloon readings yield 6–12-hour forecasts; poor oceanic coverage	

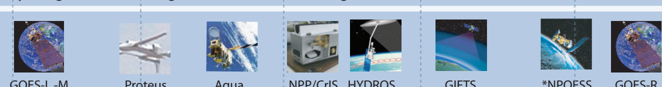
GOALS/PARTNERS

Enhanced Aviation Weather DSS and synthetic vision systems that reduce the aviation fatal accident rate by a factor of 10 by 2022

CURRENT TRAJECTORY

Steady improvement in fielding and integration of hyperspectral LEO and GEO satellite data into NWS aviation weather products and AWRP visualization systems, resulting in fully integrated, real-time global aviation WX coverage

EARTH OBSERVING MISSIONS



*Preformulation

2003 2005 2007 2009 2011 2013

Where we are now

Discrete, stand-alone weather products with limited satellite data and imagery integration. Aircraft icing forecasts of limited usefulness. Poor forecasts of turbulence, convection, ceiling/visibility, and oceanic weather.

Where we plan to be

Fully integrated graphical weather products featuring real-time, global weather information. Precise, continuously updating, short-term (24-hour) aviation weather models that greatly improve aviation safety, increase airline efficiency, and lower operating costs.

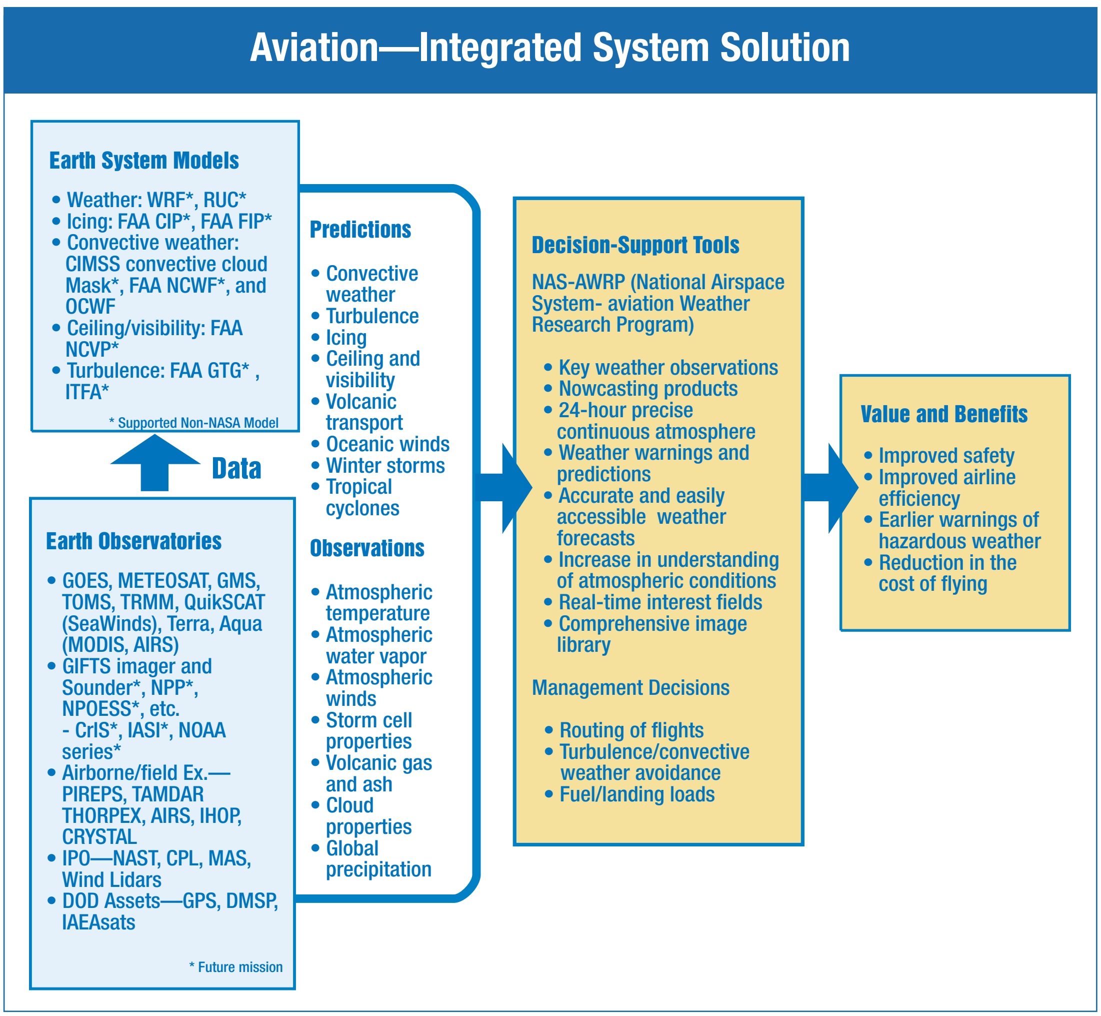
2004 —— 2012

Aviation

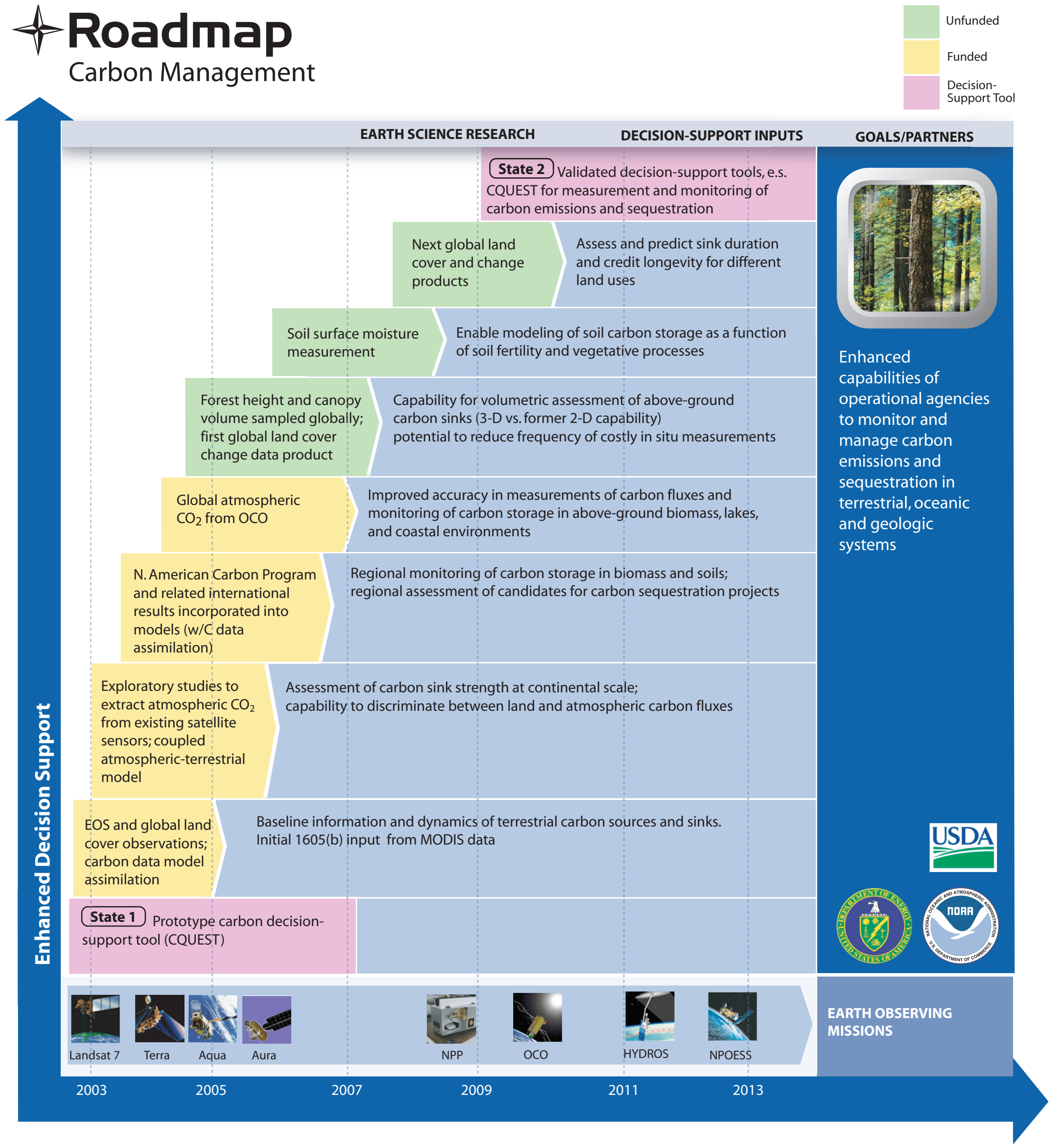
The purpose of the Aviation program element is to extend Earth science satellite data and Earth system science models to support the benchmarking of frequent, densely distributed observations needed to enable a National Airspace System (NAS) that is unfettered by capacity, security, environmental, or safety issues. Data from Earth science satellites such as QuikSCAT, Terra, Aqua, and TRMM are instrumental to this purpose. Data from future Earth Science research missions have the potential to add even more value.

Impacts of weather upon aviation could be substantially mitigated using existing satellite weather information. At present, only a small percentage of the available satellite observations are used in operational weather forecasting. NASA and its partners are also working diligently to bridge the gap between research results and operational solutions that assimilate information obtained by Earth observation satellites. NASA and its partners are working to make sure that information available from instruments on current and future satellite research missions are verified and validated for infusion into operational forecasting techniques in a more timely fashion.

Figure 3.4



Roadmap
Carbon Management



Where we are now

Prototype decision support tool CQUEST incorporates NASA Earth science observations (Terra, Aqua, Aura) and model predictions (CASA) to predict and monitor carbon emissions and storage in vegetation.

Where we plan to be

NASA missions such as OCO and HYDROS enable more accurate monitoring and prediction of carbon sources and sinks.

Applications of improved-accuracy MODIS/VIIRS-based products extended to sequestration modeling.

2004 ——— 2012

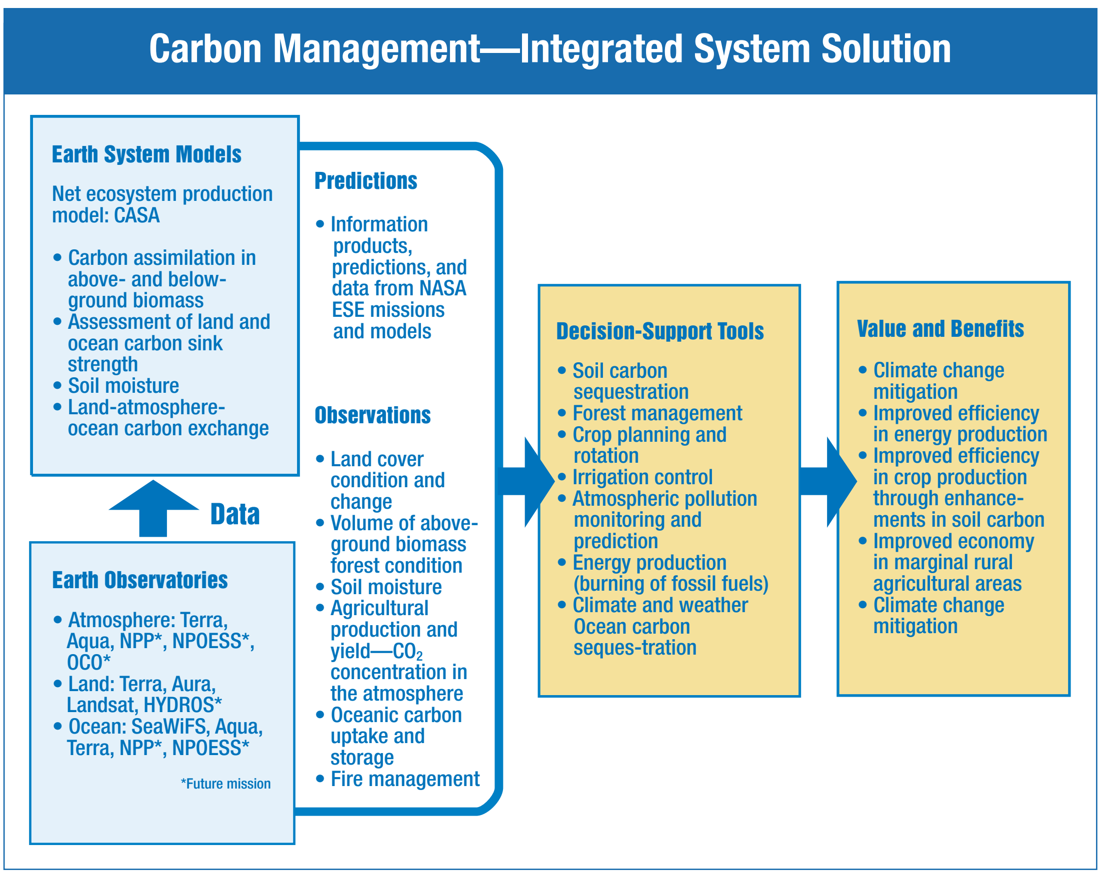
Carbon Management

The Carbon Management application extends the use of current NASA Earth science capabilities and integrates observations from experimental missions as inputs to decision support systems of operation agencies responsible for measurement, monitoring, and validation of carbon emissions and sequestration. The application draws on data related to global climate and climate change, ocean and land cover change, and atmospheric carbon dioxide concentrations in addressing issues related to terrestrial and aquatic carbon sequestration.

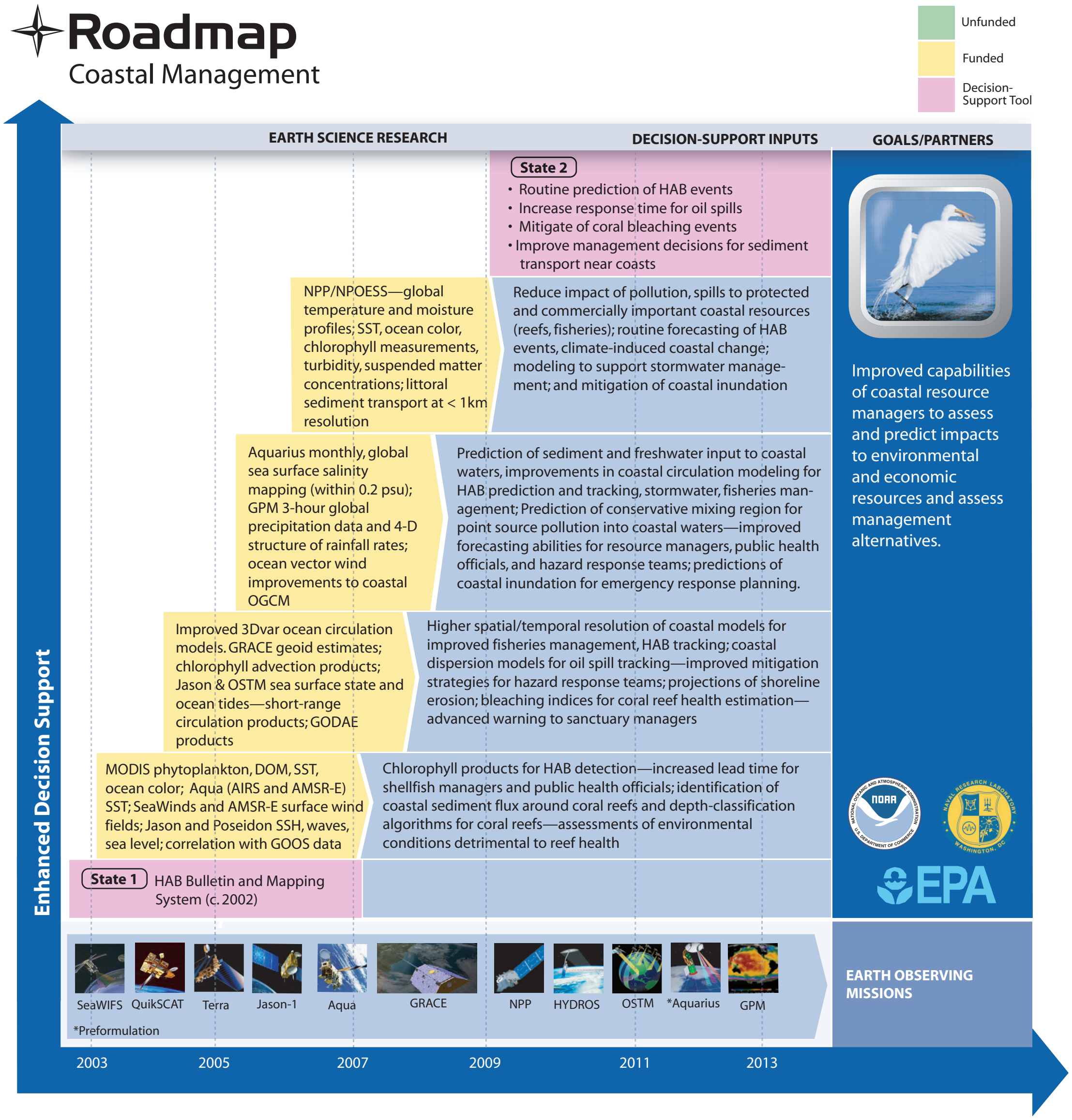
In the near term, the application is validating and benchmarking the use of NASA Earth science data products and model outputs for use in partner-led carbon management decision support tools, such as CQUEST. Future Earth science instruments, such as OCO and HYDROS, have the potential to further improve the predictive power of such tools by providing more precise measurements of carbon fluxes and data that will help assess the impact of global soil moisture on carbon cycling.

NASA partners with federal, state, and local agencies responsible for carbon management. Primary partners include USDA, NOAA, and the Department of Energy (DOE).

Figure 3.5



Roadmap
Coastal Management



Where we are now	Where we plan to be
Use of Earth science observations on case-by-case project basis	Routine use of Earth science products in decision tools by the coastal management community
Sea level change identified as a potential result of climate change with effects on coastal communities and ecosystems	Use of Earth science data and model outputs and predictions supporting sea level scenario assessments for policy making and management
Use of SeaWiFS and QuikSCAT in the HAB Bulletin and Mapping System	At least four separate coastal issues and decision tools using Earth science products from at least seven sensors and models

2004 —— 2012

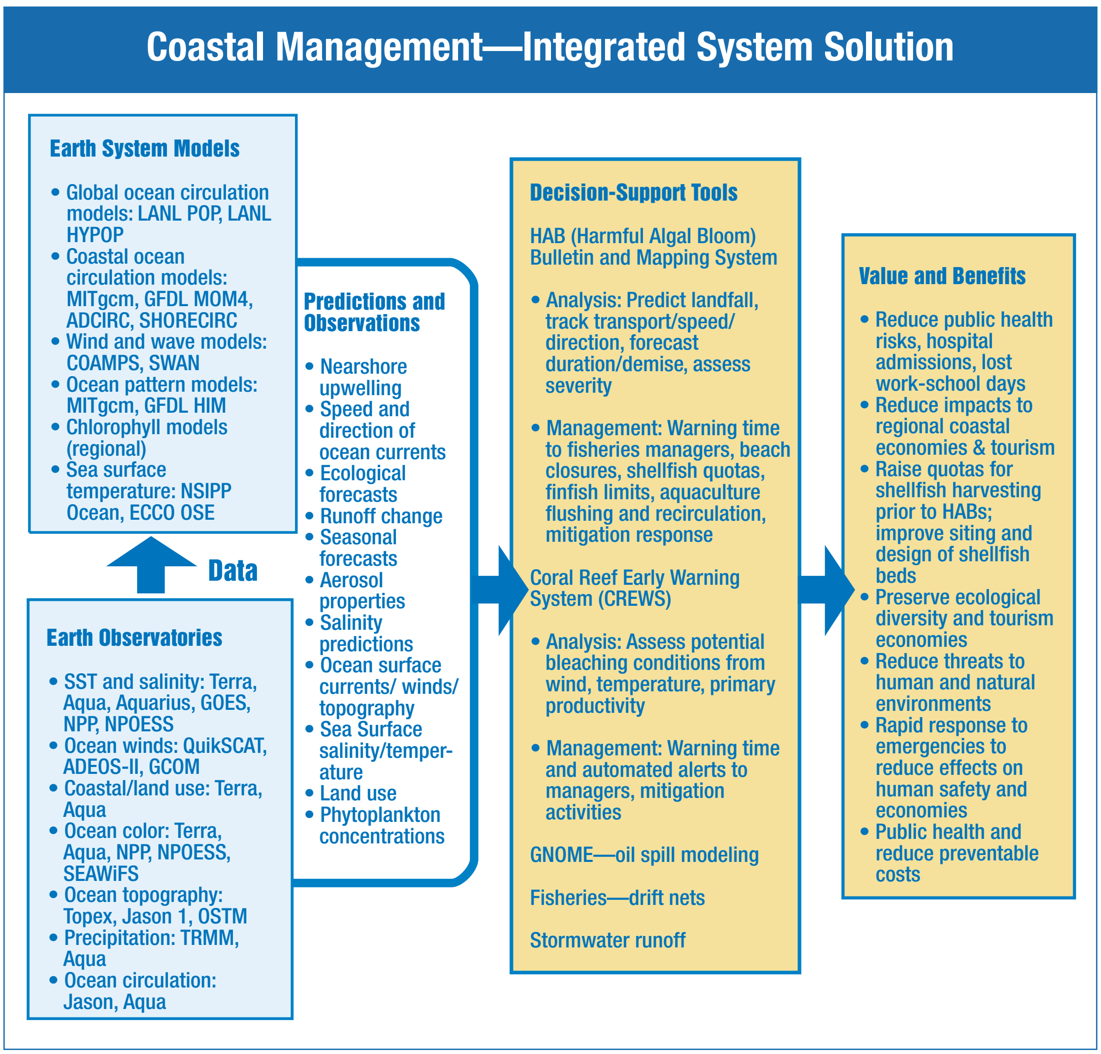
Coastal Management

The Coastal Management application extends Earth science research results, products derived from Earth science information, models, technology, and other capabilities into partners' decision-support tools for coastal management issues. The coastal application focuses on supporting partners' decision tools serving issues related to coastal zones, nearshore environments, marine and open-ocean activities, wetlands, estuaries, reefs, oceanic islands, and coasts of large inland waters.

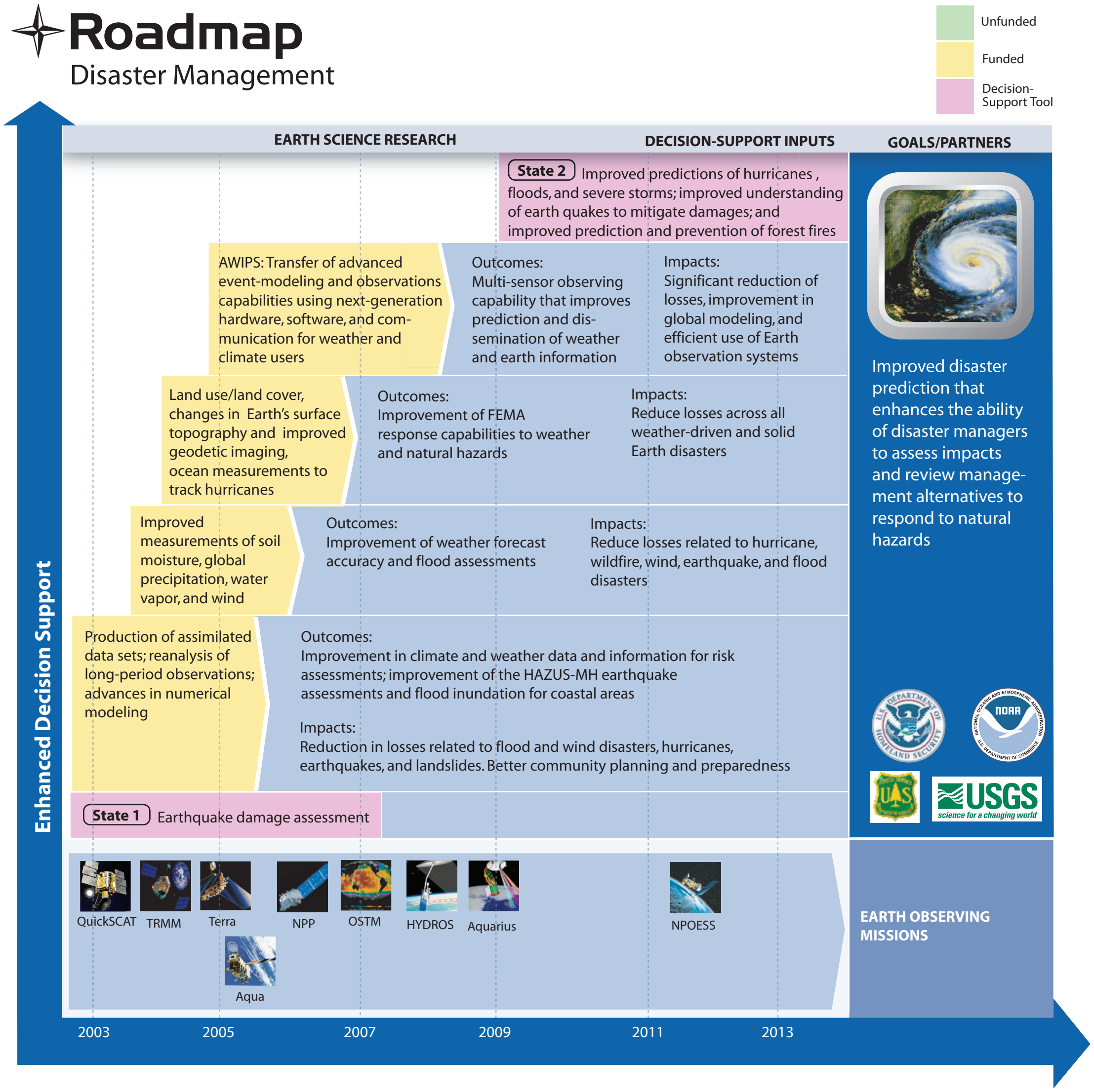
In the near term, the program is validating products for priority decision-support tools related to harmful algal blooms, coral reefs, and oil spill response. Potential future issues including sediment transport, hypoxia, storm-water runoff, sea level change, and wetlands. Coastal Management application works with Ecological Forecasting on marine fisheries and coral reefs, and the application is involved with CCSP on sea level change.

NASA partners with Federal agencies and regional-national organizations that have coastal management responsibilities and mandates to support coastal resource managers—NASA's primary partners are NOAA, EPA, and the Naval Research Laboratory.

Figure 3.6



Roadmap
Disaster Management



Where we are now	Where we plan to be
NOAA incorporates QuikSCAT and TRMM products to enhance hurricane track, landfall, and intensity forecasts	Use of satellite products and improved models to increase tornado warning times to several minutes
USDA Forest Service and land management agencies use MODIS products to create more accurate predictions of probable fire areas and rates of spread	Earth science model and observations seamlessly integrated into all appropriate HAZUS-MH modules
	Disaster management officials and private sector companies using Earth science products to increase warning accuracy and minimize evacuation zones due to natural hazards

2004 — 2012

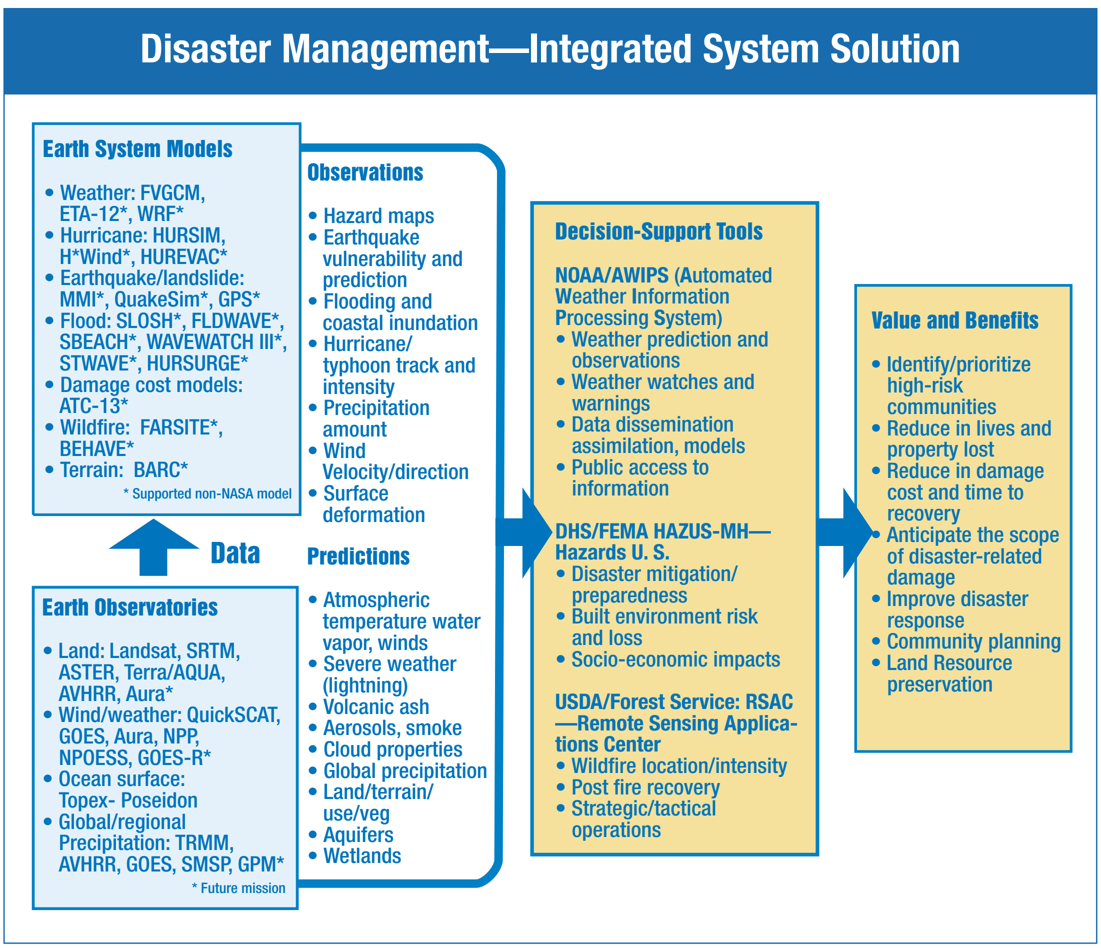
Disaster Management

The Disaster Management application extends Earth science results into partners' decision support tools and centers for activities related to preparation, mitigation, response, and recovery from natural hazards. The application addresses the use of Earth science in support of decision making regarding earthquakes, volcanoes, flood, drought, severe weather, tropical weather, wildfires, and other atmospheric and solid Earth phenomena.

In the near term, the application is validating and benchmarking products for priority decision tools on hazards loss estimation from earthquakes, floods, and wind (HAZUS-MH), tools on wildfires and smoke detection, and tools on severe storms and tornadoes (AWIPS). Potential future focus areas include wildfire emissions, floods, deformation, and landslides.

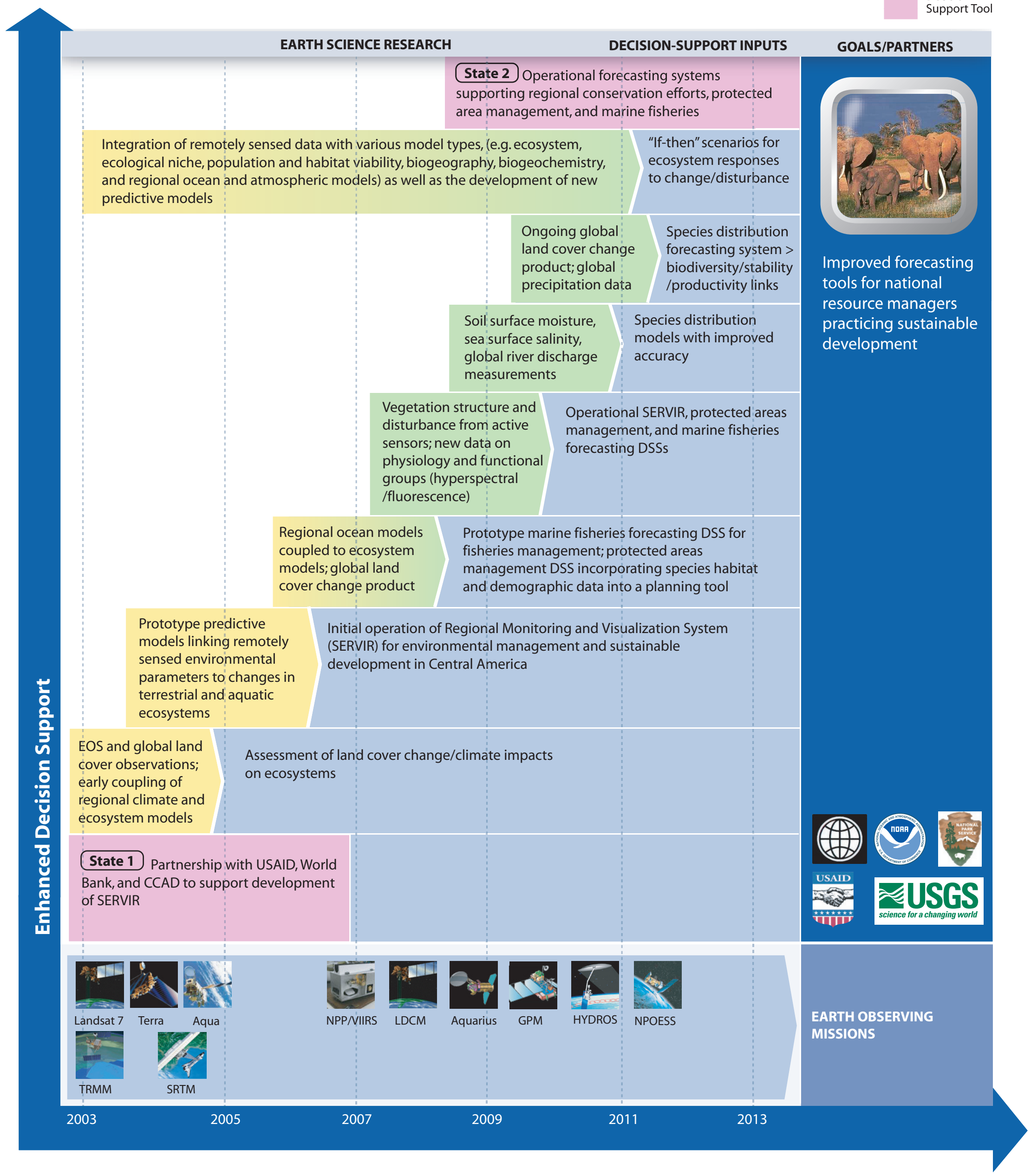
NASA partners with organizations and Federal agencies with disaster management responsibilities in disaster planning and protection of life and property. Primary partners are DHS, NOAA, and USGS. The application is involved with the CENR Subcommittee on Disaster Reduction (SDR) and the Disasters Roundtable of the National Academies, as well as international activities for Earth observation and sustainable development.

Figure 3.7



Roadmap
Ecological Forecasting

Unfunded
Funded
Decision-Support Tool



Where we are now	Where we plan to be
Initial integration of remote sensing observations with environmental models and visualization tools	NASA Earth science observations seamlessly integrated into visualization systems that generate "if-then" scenarios of ecosystem responses to change with estimates of error

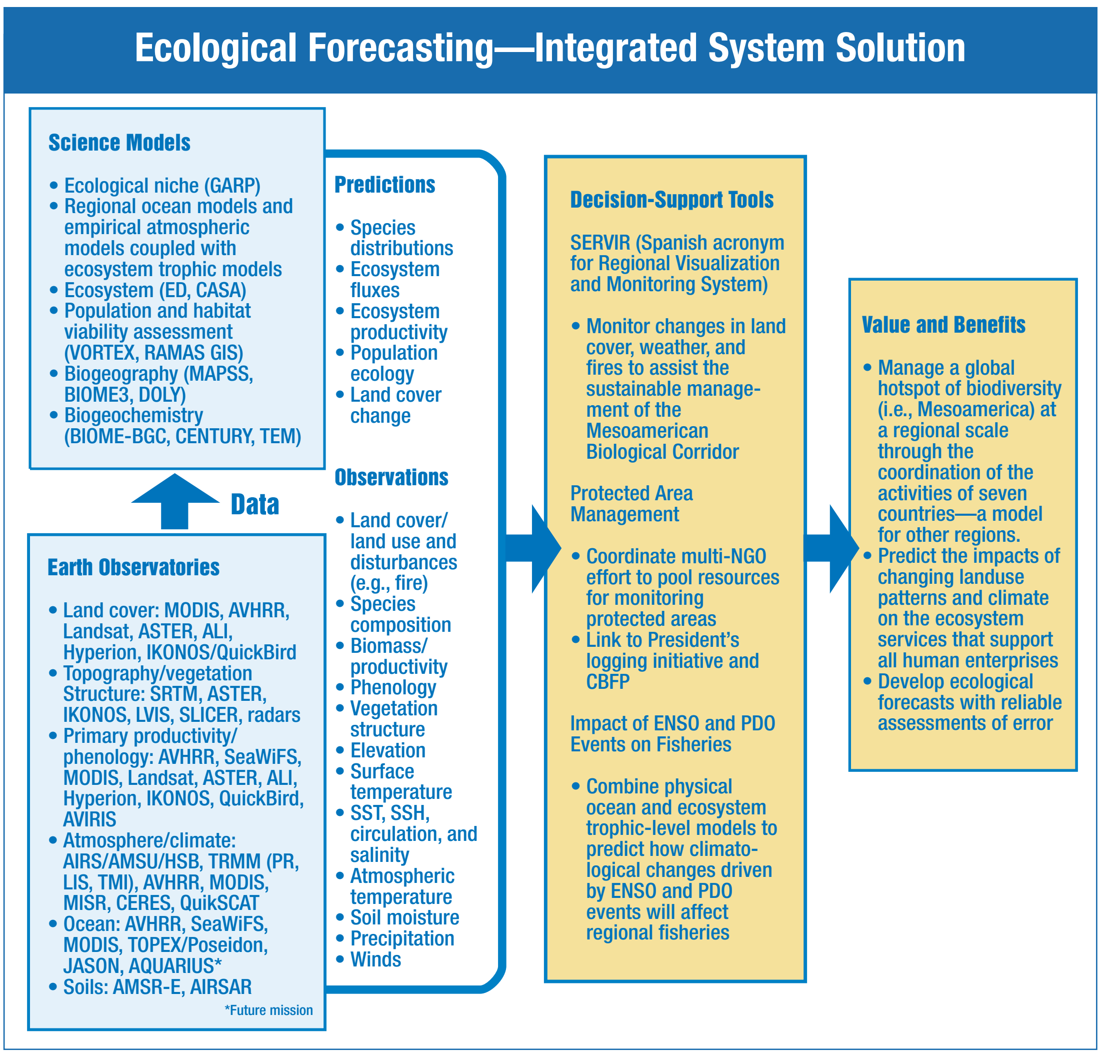
2004 —— 2012

Ecological Forecasting

Ecological Forecasting employs observation data and models to predict the impacts of environmental change on ecosystems. In doing so, it applies information from the physical, biological, and social sciences. Under one partnership, NASA is working with the U.S. Agency for International Development (USAID), the World Bank, and the Central American Commission for Environment and Development (CCAD) to develop a Central American Regional Visualization and Monitoring System (known as SERVIR) for the Mesoamerican Biological Corridor. The Corridor is an unprecedented effort by the countries of that region to integrate their national conservation efforts and promote sustainable development across international boundaries. USAID has made the sustainable development of Central America a priority among its activities.

Ecological forecasting draws on various Earth observation measures, such as land cover/land use, precipitation, and topography, while addressing issues related to transboundary conservation, protected area management, and marine fisheries. Near-term validation and benchmarking efforts include data products derived from the Terra, Landsat, and Aqua satellites. Future missions such as GPM, Aquarius, and HYDROS will provide precipitation, salinity and soil moisture data of relevance to this application.

Figure 3.8



Where we are now

Energy sector policy and energy management decisions are based primarily on the use of historical climatic information and traditional weather data reports, consisting of air temperature, precipitation, humidity, and wind measurements.

There is limited to no use of satellite observations and global model predictions in the energy production and energy efficiency decisions that impact society.

Where we plan to be

NASA-enhanced decision-support tools, such as RETScreen, provide common platforms for evaluating energy management project proposals and reduce the cost and uncertainties of preliminary studies.

Greater use of satellite operations in energy production and efficiency decisions. Better understanding of the roles that clouds and aerosols play in regulating climate. Improved climate models have significant impact on energy forecasting efforts.

2004 —— 2012

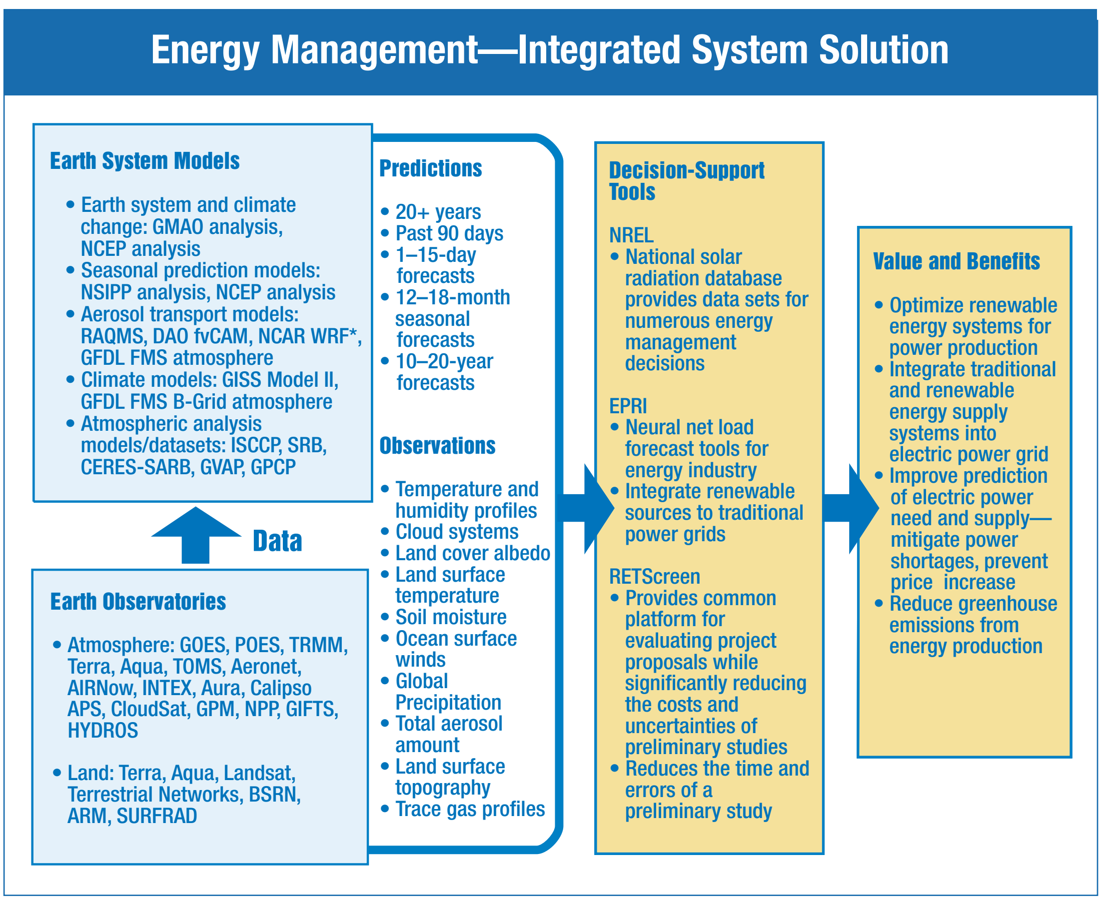
Energy Management

The Energy Management application extends Earth system science by providing data products generated from NASA satellite observations and model predictions as inputs to energy-related decision-support and scenario assessment tools used by partner organizations. The application addresses issues pertinent to energy management—such as production and efficiency, measurement and monitoring of greenhouse gases, and carbon sequestration—by utilizing data on atmospheric composition, carbon cycle, climate change, weather, and water.

In the near term, the application is verifying, validating, and benchmarking products for priority decision support tools related to energy management and forecasting, such as RETScreen (Renewable Energy Technology Screen). Satellite missions that currently provide information related to global-scale energy and hydrological cycles are Aqua (climate change and water), Terra (climate change), and TRMM (global precipitation). Future NASA missions, such as CloudSAT and CALIPSO, will enhance current observations by studying the impact of clouds and aerosols on climate.

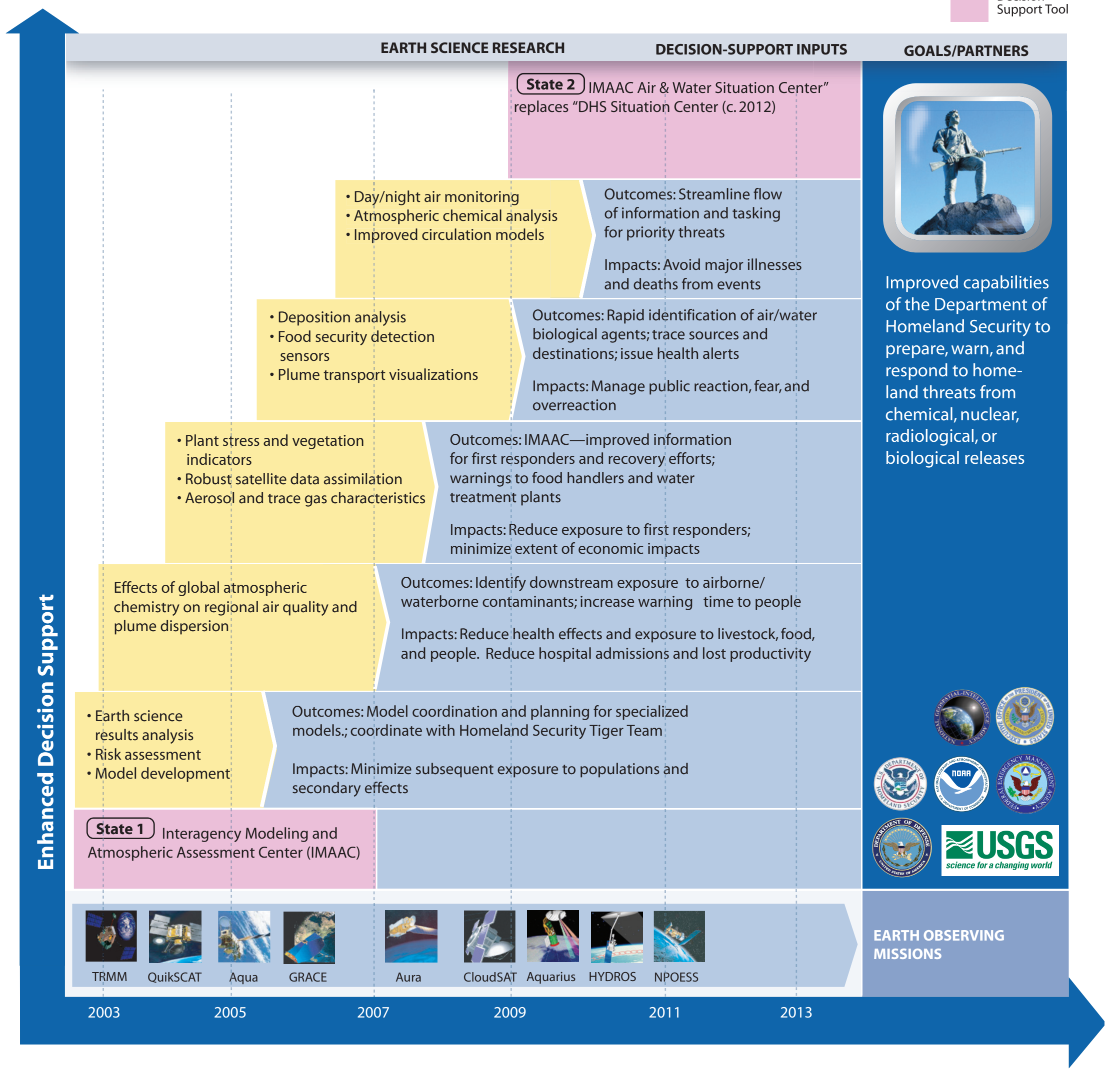
NASA partners with Federal agencies and regional and national organizations that have energy management responsibilities and mandates to support energy managers in improving energy-sector decision support tools. Partners include Department of Energy, NOAA, Natural Resources Canada, and USDA.

Figure 3.9



Roadmap
Homeland Security

Unfunded
Funded
Decision-Support Tool



Where we are now

Investigation of the utility of NASA Earth science data and models to improve the estimation of biological or chemical agent fate

Where we plan to be

Integrated Earth science observations and modeling support more accurate prediction of plume transport and dispersion

Improved satellite and modeling products provide a more comprehensive understanding of chemical changes of releases due to solar radiation

Vegetative stress analysis allows for improved food and plant supply security

2004 — 2012

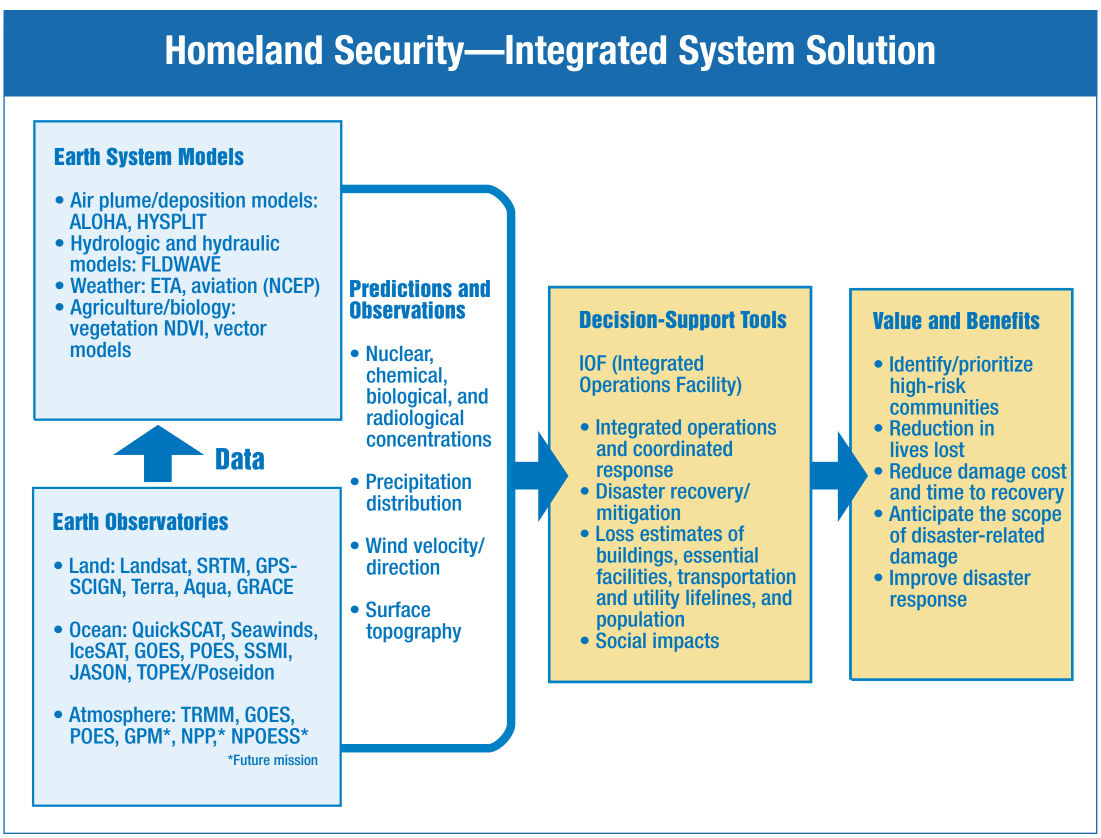
Homeland Security

The Homeland Security application, created in response to the threat of terrorism as a result of September 11th, 2001, has created a number of new and constantly-evolving challenges for NASA's remote sensing technologies, observations, and models. The application extends NASA Earth data products to support and enhance decision making related to the homeland security of the United States. It addresses homeland security issues related to plume modeling, air transport and prediction, border control, monitoring of environmental change, weather monitoring, and prediction of movement of biological contaminants.

Near-term benchmarking activities include the use of NASA Earth science measurements (from satellites such as TRMM, Aura, Aqua, and QuikSCAT) and models for inclusion in national decision support systems such as the Integrated Modeling and Atmospheric Assessment Center (IMAAC). Future missions such as NPOESS and HYDROS have the potential to further improve homeland security plume modeling tools by providing more detailed and accurate soil moisture, evapotransporation, and atmospheric data.

NASA's develops cooperative relationships with federal partners so that the results of NASA science and technology can be incorporated into operational decision-making relevant to homeland security. Primary partners include the Department of Homeland Security (DHS). Primary partners are FAA, NOAA, and USGS.

Figure 3.10



Roadmap
Invasive Species

Where we are now	Where we plan to be
NASA observations and systems engineering integrated into USGS decision support tool, the Invasive Species Forecasting System (ISFS)	Terrestrial plant species capabilities of the ISFS supplemented with capacities for aquatic plant and animal species
ISFS using data from Terra, Aqua, Landsat 7 and SRTM missions to track, assess, and predict probable invasive species introduction points, disease outbreaks, potential rate of organism spread, potential success in alternative management activities, and impacts of mitigation efforts	Observations from additional NASA systems provide access to new geophysical parameters, improving near-term and long-term climate predictions and strengthening invasive species forecasting
2004	2012

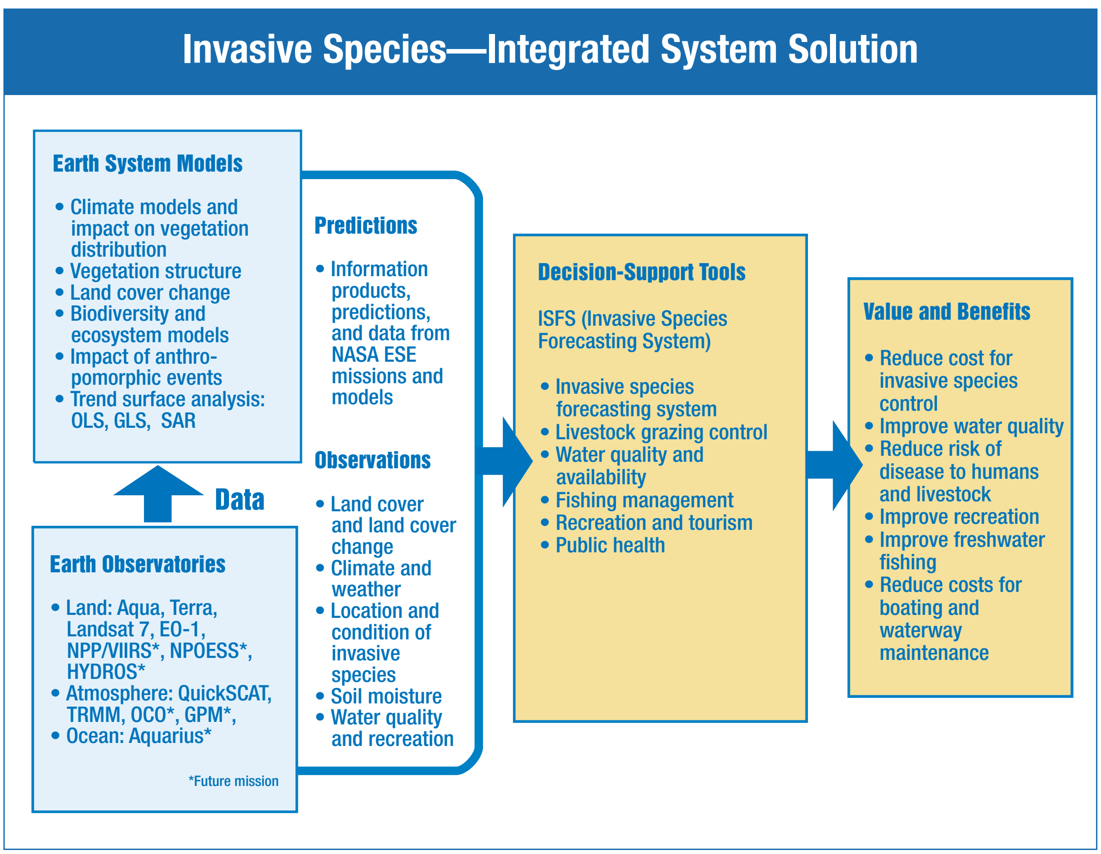
Invasive Species

The Invasive Species application extends NASA Earth science observations and modeling to improve decision-making capabilities for monitoring and control of invasive species. The application draws upon data products that detail climate change, temporal and spatial ocean and land cover change, vegetation characterization, precipitation, soil moisture, topography, hydrologic cycles, and national and global carbon relationships to improve prediction, detection, and monitoring of invasive species in the decision support tools employed by organizations in partnership with NASA.

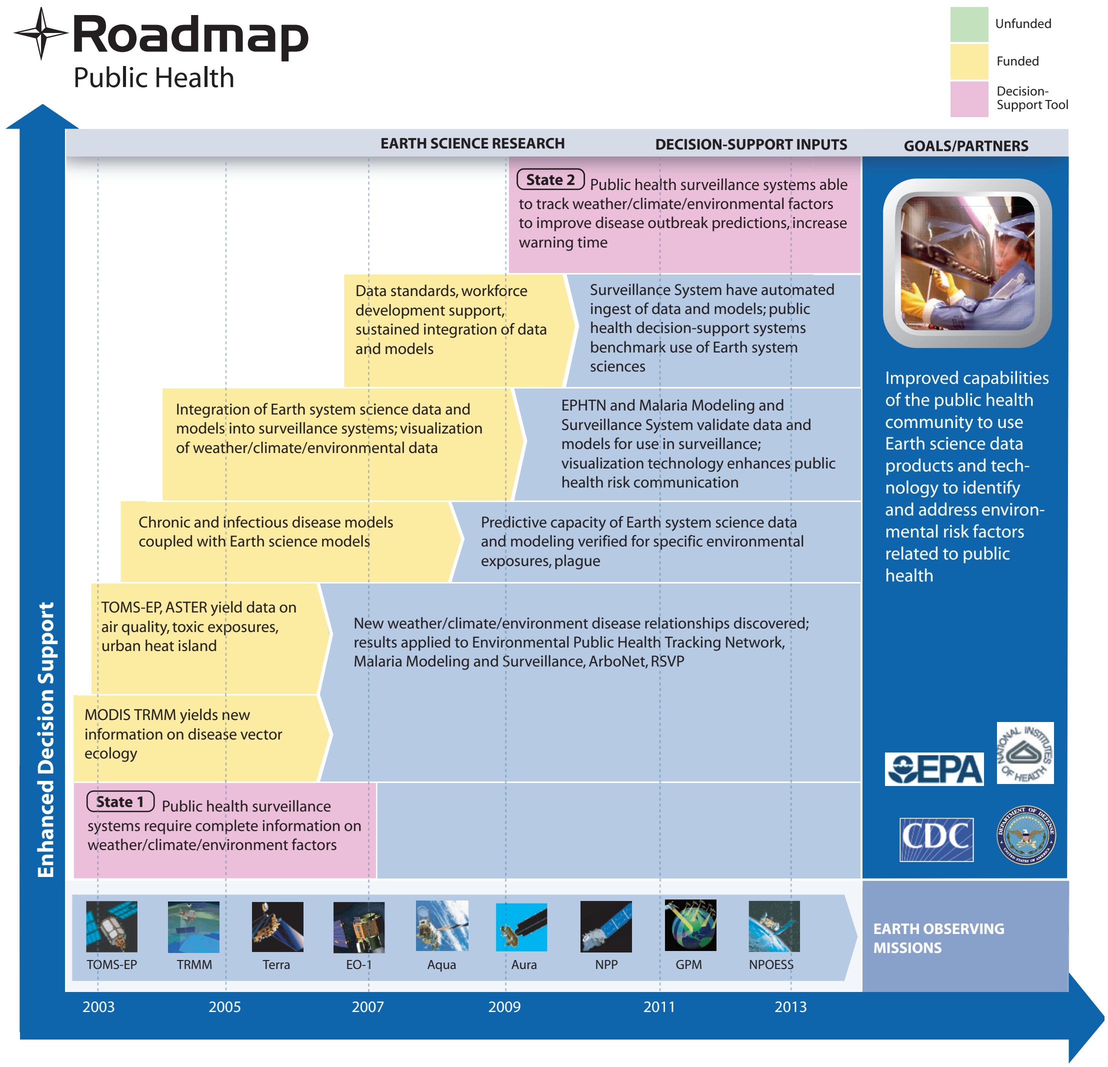
In the near and long term, the application is validating and benchmarking the improvement in predictive capability of the national Invasive Species Forecasting System as a result of the integration of NASA observations, measurements, and systems engineering. Current NASA inputs include evaluation of MODIS data in ISFS statistical models. Within the next decade, the application will work to utilize the data products of NASA experimental systems such as HYDROS and GPM in enhancing climate and weather predictions to significantly impact invasive species forecasts.

NASA partners with Federal agencies and national organizations that have invasive species management responsibilities and mandates to maximize the use of available resources for response to the invasive species threat. Primary partners are USDS, USGA and NOAA.

Figure 3.11



Roadmap
Public Health



Where we are now	Where we plan to be
Earth science missions (Terra, TOMS, TRMM) provide information on environmental features correlated with disease risk factors, such as ecotones, flooding, human settlements, and soil moisture	Weather, climate, natural hazards, and other environmental factors are routinely included in disease forecasting
Earth observing instruments, advanced communication technology, high speed computing capabilities, data products, and predictive models of Earth system phenomena associated with the occurrence of disease assists partners in enhancing epidemiologic surveillance systems	More accurate representation of environmental risk factors enhances the prediction of and response to infectious disease outbreaks, harmful exposures, chronic disease conditions, and bioterrorism
	Verified and validated Earth science enhancements to public health decision support tools

2004 —— 2012

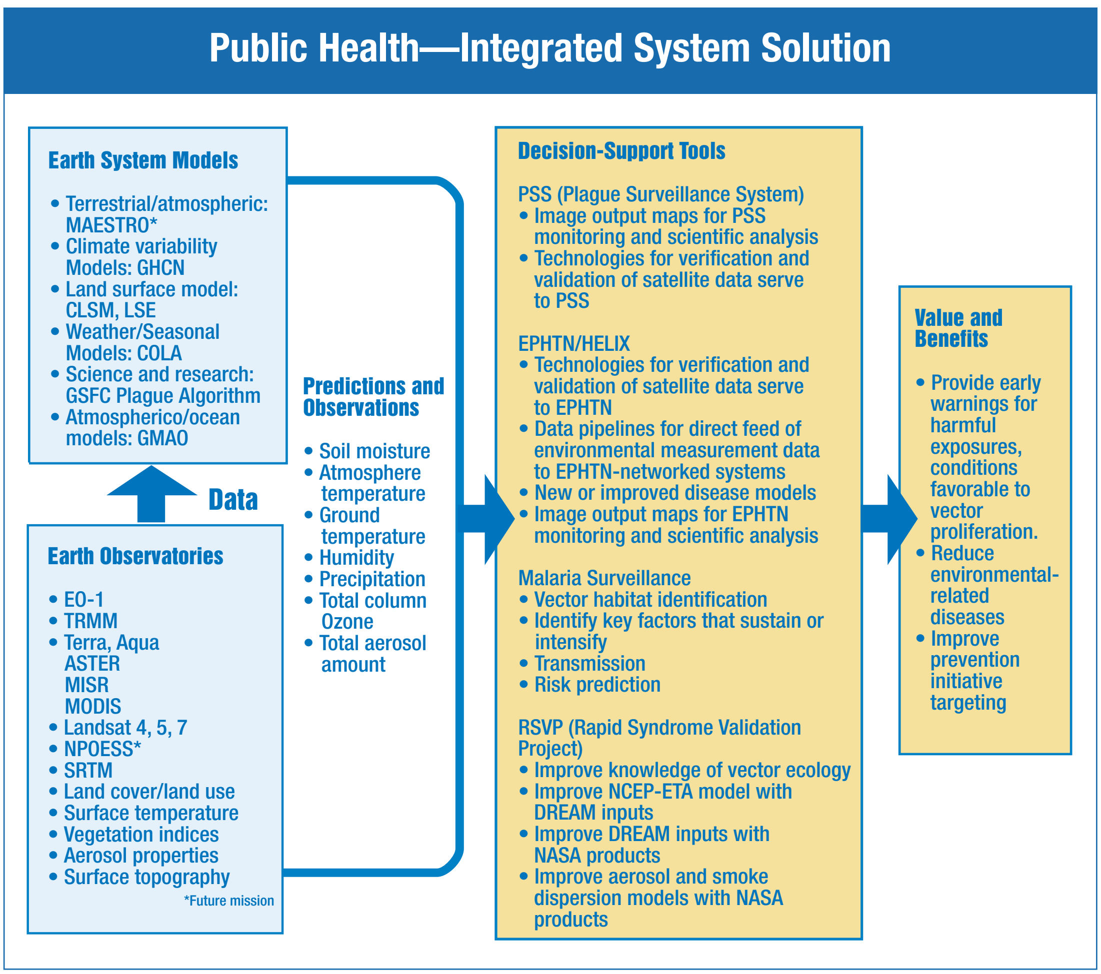
Public Health

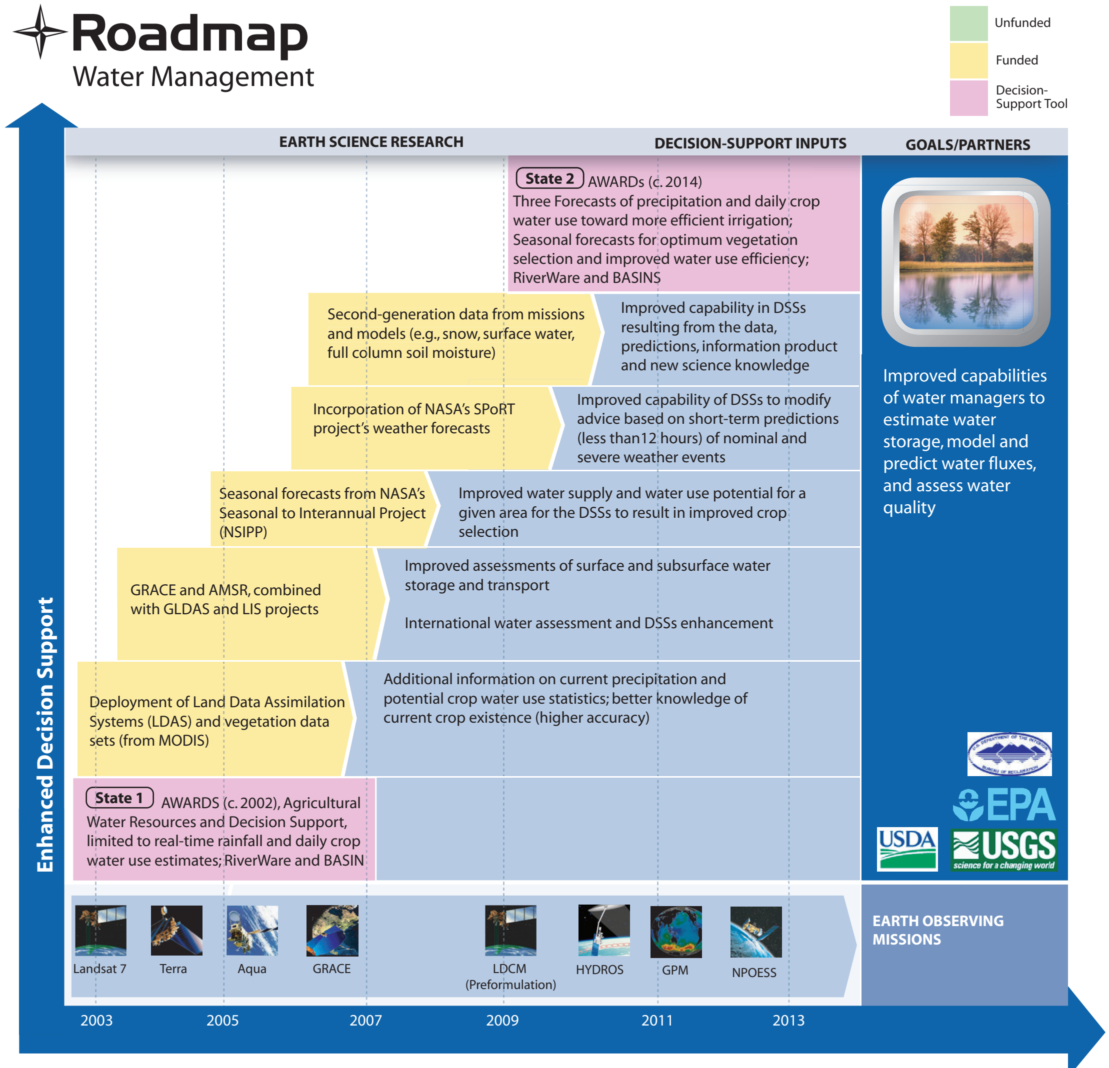
The Public Health application extends products derived from Earth science information, models, technology, and other capabilities into partners' decision support tools for public health, medical, and environmental health issues. The application draws on Earth observations such as weather, climate, natural hazards, and other environmental factors to address public health issues related to infectious disease, environmental health, and bioterrorism.

In the near term, the application is validating and benchmarking observations from missions such as Terra, TOMS, and TRMM for incorporation into partners' operational public health decision support tools and surveillance systems. In the future, observations from Aura, NPP, and NPOESS will be incorporated into these DSTs and surveillance tools.

NASA collaborates with the professional community that is responsible for surveillance to understand and respond to factors in the environment that adversely impact the health of the American public through the Public Health application. Primary partners include the CDC, DOD, DOE, NIH, EPA, USGS, and NOAA.

Figure 3.12





Where we are now

Decision tools for water management sparsely use information on land cover, land cover change, short-wave radiation, and precipitation provided by Earth observing satellites such as Aqua, Terra, and TRMM

NASA missions Landsat 5 & 7 and AVHRR relied upon for assessment of water quality and anomaly detection

NASA data products incorporated into NOAA and Air Force data sets are occasionally picked up by distributed users

Where we plan to be

Earth science missions OCO, HYDROS, and Aquarius provide measurements of atmospheric carbon, soil moisture, and ocean salinity that are seamlessly integrated into all appropriate DST modules, including weather and climate model systems that are coupled to DSTs

Space-based tracking of water storage changes beneath the Earth's surface allow for monitoring of changes in aquifer water storage

NASA resources for augmenting USDA DSTs and its soil moisture model, SWAT, identified and implemented

2004 ——————————————————————— 2012

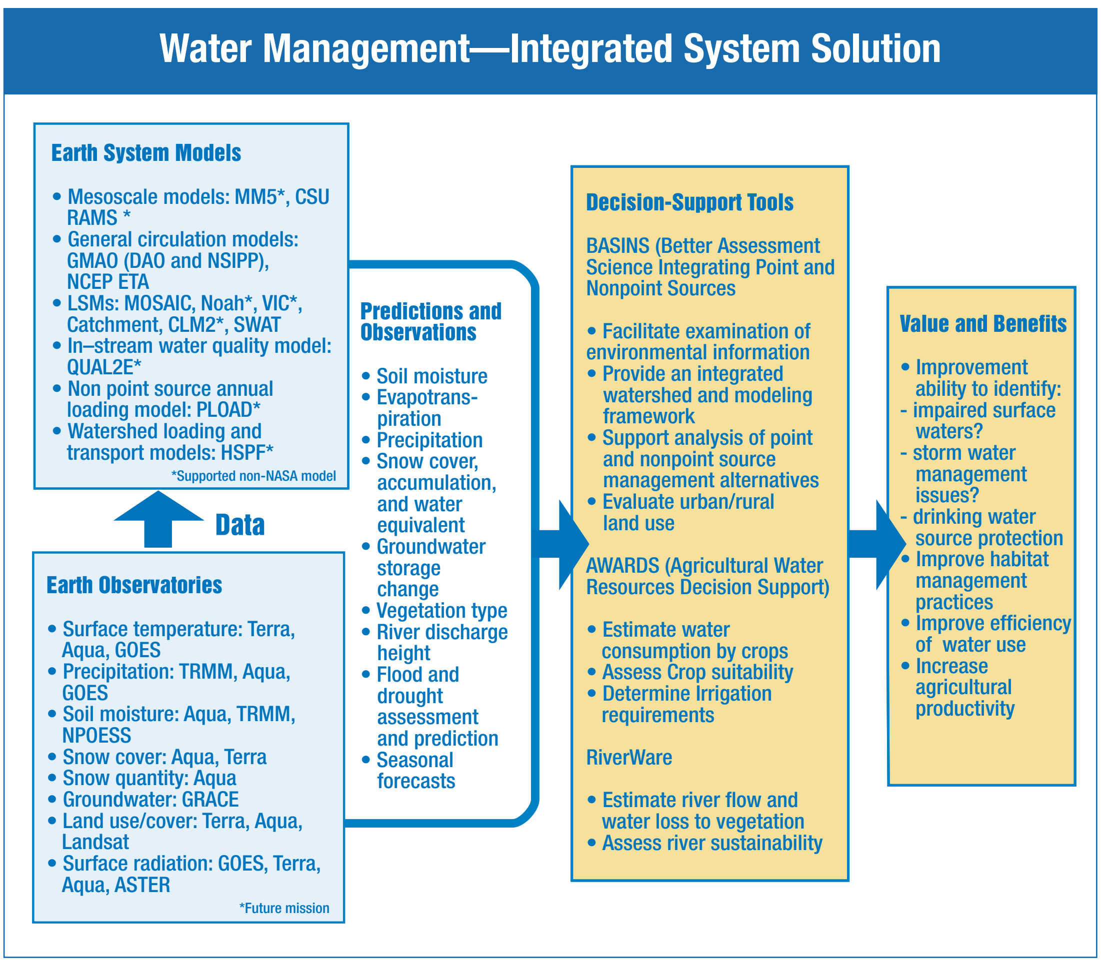
Water Management

The Water Management application extends products derived from Earth science information, models, technology, and other capabilities into partners' decision support tools for water management issues. The Application addresses the use of Earth science in supporting water management decision making through improved information on water quantity and quality.

In the near term, the application is validating and benchmarking products from NASA Earth science instruments such as MODIS and CERES for priority water management decision support systems BASINS, AWARDS, and RiverWare. In the future, data collected by Earth science missions GPM and NPOESS will further enhance water quality assessments by providing enhanced information on global precipitation and water surface temperature.

NASA partners with organizations and Federal agencies that have water management responsibilities and mandates. Primary partners include NOAA, USGS, the EPA, and the BoR (Bureau of Reclamation).

Figure 3.13



4 Program Execution and Performance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4 Program Execution and Performance

The Earth Science Applications Program executes, through a network of organizations, a combination of mechanisms and open and competitive processes that reinforce the strategic goals and objectives stated earlier. NASA, partner agencies, academic institutions, and others carry out a range of activities to achieve the program's goals and objectives. Program managers regularly review the performance of program elements to track progress, set priorities, and maintain a productive portfolio. Table 4.1 presents the key program functions.

4.1 Program Elements

The program consists of the following two elements: national applications and crosscutting solutions. Each program element has sub-elements that target specific activities. The program and its elements work collaboratively with all parts of the Division and the larger community of practice to achieve results.

National Applications

Addressing specific topics of national priority, the national applications element focuses on extending Earth science measurements and predictions for the following:

- Agricultural Efficiency
- Air Quality Management
- Aviation
- Carbon Management
- Coastal Management
- Disaster Management
- Ecological Forecasting
- Energy Management
- Homeland Security
- Invasive Species Management
- Public Health
- Water Management

Table 4.1

Key Program Functions

- Enable and enhance national applications of Earth science observations and predictions in decisionmaking.
- Demonstrate and enable the use of a systems engineering approach to support the adoption of Earth science research in operational environments (see section 2.2).
- Issue competitive solicitations providing the community-of-practice opportunities to contribute to realizing national applications of Earth science measurements and predictions.
- Assist organizations in more effectively using Earth science research results.
- Act as a bridge between the organizations that use Earth science research results and the NASA leadership.
- Participate substantively in relevant Federal and interagency committees to organize plans, priorities, and activities to meet national needs using Earth science and geospatial information
- Conduct outreach (workshops, publications, Internet sites) to provide the community of practice with access to relevant information about opportunities and applications of Earth science research results.
- Sponsor science and technology assessments and contribute to studies on applications of Earth science research, and transition to operations.
- Advance the state of knowledge and practice in measuring the value of applied Earth science research and information.
- Communicate research-to-operations results and collaborative achievements to benefit the partners and the public.

These 12 application topics were selected in 2002 using prioritization criteria described in the ESE Applications Strategy 2002–2012 (Ecological Forecasting was selected in 2003). Program management gathered information from national assessments, Earth science reports, socioeconomic evaluations, and other materials to identify candidate topics. The program also solicited guidance from NASA and Division leadership and stakeholders. These topics were selected partially on their timeless importance in society, allowing the decision-support tools to improve with continuing Earth science research results.

The program periodically reviews the portfolio of application topics; however, adjustments are not considered lightly. The program adjusts the balance and number of application topics depending on progress and performance, partner commitment, budget and resources, Earth science research priorities, and stakeholder guidance. For example, Ecological Forecasting replaced Community Growth based on difficulty finding an appropriate national-level decision-support tool for NASA's community growth efforts.

The manager and team for each application maintains a multiyear plan to articulate its objectives, partners, priority decision-support systems, resource allocation, schedule, etc. In addition to working with partner agencies directly, the national application teams participate in interagency working groups (e.g., CENR sub-committees) to coordinate plans and communicate results.

Crosscutting Solutions

The crosscutting solutions element employs two specific approaches to implement the program objectives. A systems approach is used to systematically identify candidate opportunities and engineering approaches to evaluate, verify, validate, and benchmark the assimilation of NASA Earth science observations and predictions into our partner's decision-support systems. A network approach is used to foster improved data accessibility and develop the knowledge base and human capital to enable networks of organizations to develop integrated solutions for the 12 national applications. Crosscutting solutions has the following four subelements: integrated benchmarked systems, solutions networks, geoscience standards and interoperability, and human capital development.

Integrated Benchmarked Systems

The integrated benchmarked systems (IBS) function is to assure the integrity, quality, and reliability of innovative solutions are delivered by the program. IBS functions include the following:

- Providing systems engineering support and standards for rigorous evaluation, verification, validation, and benchmark-

ing activities for the program
- Maintaining a knowledge base of current and future Earth science measurements, models, predictions, and technologies to support the development of innovative solutions for national applications
- Supporting national and international groups in appropriately using NASA's approach and results in systems for improved decisionmaking
- Verifying and validating commercial sources of data for Earth science research through participation in the Joint Agency Commercial Imagery Evaluation (JACIE) team

Solutions Networks

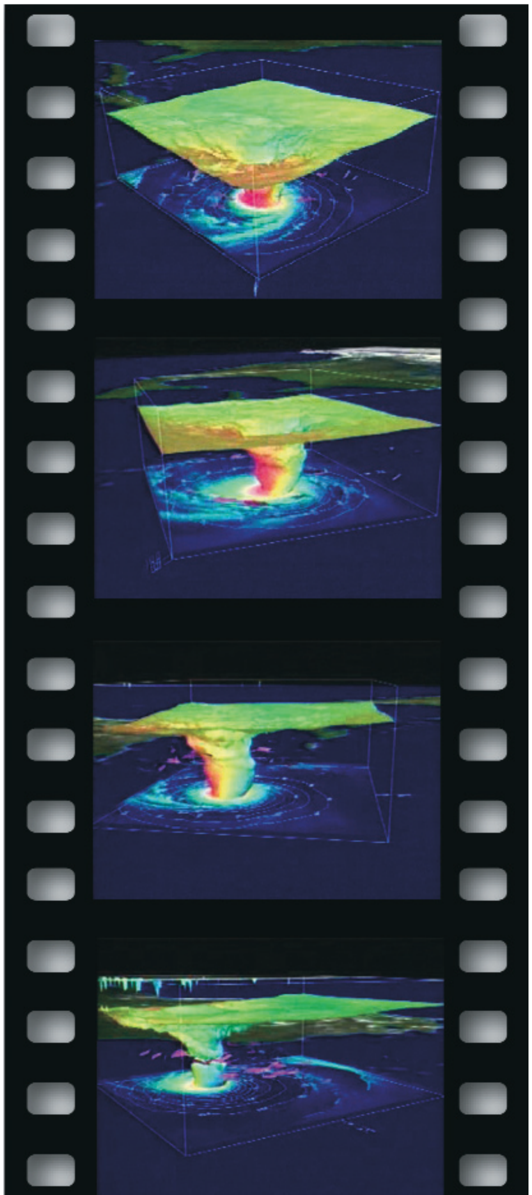
Improving a partner's decision-support system using NASA Earth science research results can only be performed by a network of contributors working in concert to deliver an integrated solution. The solutions networks function is to maintain relationships with Earth science researchers and solutions providers and to maintain a knowledge base of their activities, capabilities, directions, and results in order to facilitate the development of these networks. The networks can include Earth science researchers, laboratories and research centers, academic and international Earth science centers, private-sector and not-for-profit organizations, and interagency and international programs (e.g., U.S. Weather Research Program and GEO). The solutions networks functions are as follows:

- Understanding and maintaining a knowledge base of existing NASA Earth science research products and partnerships to extract relevant and innovative ideas for the program
- Providing the systems and human capital to the national applications teams to efficiently perform evaluations of potential solutions
- Building capacity in the community by engaging and educating contributors in the activities of the program

Eighteen NASA satellites currently provide observations of Earth's oceans, land, atmosphere, and ice.

Each satellite measures specific Earth system processes, and they collectively enable the study of Earth as an integrated system.

Networks of satellites provide opportunities for "sensor webs" of dynamic measurements and on-demand data and analysis.



Three-dimensional visualizations, such as this hurricane sequence, allow researchers to interact dynamically with multiple, integrated data sets, observe Earth science phenomena from numerous perspectives, and gain insights on Earth system processes.

Geoscience Standards and Interoperability

Earth science measurements and model outputs comprise copious amounts of data and information. Crosscutting solutions sponsors program-wide interoperability and visualization activities aimed at enabling the overall integration of Earth science products into decision tools. This subelement ensures that NASA's science data are accessible by our Federal partners and other users in the most efficient manner.

Under the geoscience standards and interoperability function, the Geospatial Interoperability Office (GIO) promotes standards to support interoperability of Earth science data and information, such as standards for Internet data access. The GIO represents the Agency in geospatial standards bodies, ensures that those standards meet NASA's science requirements, and assists individual projects in standards implementations.

Human Capital Development

Crosscutting solutions supports strategic programs aimed at developing long-term capabilities within the workforce to use Earth science results in decisionmaking, such as DEVELOP (formerly, Digital Earth Virtual Environment Learning and Outreach Project). The DEVELOP students (high school to graduate school) demonstrate prototype applications of Earth science measurements and predictions for state, local, and tribal governments. The students respond to issues identified by community decisionmakers, and the DEVELOP projects align with one or more of the national applications topics. The cadre of students participating in the program represents a workforce capable of immediately contributing to the Earth science community.

4.2 Program Scope

The program extends Earth science results to decision-support tools that are primarily national in scope or have the potential to be distributed nationally (albeit used locally). For example, the FEMA develops the Hazards U.S. tool to assess damage from natural hazards. FEMA distributes the tool and enhancements to local governments, which adapt the tool to their specific conditions. The program may work with Federal partners to validate Earth science inputs on a small scale with the intent of the partner distributing the improvements broadly.

In some cases, the decision tools associated with a particular national application are inherently regional in nature (e.g., Gulf of Mexico, Great Lakes), so the program may support Earth science inputs to regionally focused decision tools. Generally, the program pursues decision-support tools that are scalable to overall national needs and priorities that benefit from Federal partners' strong support and contributions.

Internationally, the program works through U.S. partners that have international missions (e.g., U.S. Agency for International Development), international groups the U.S. is a member of (e.g., United Nations Environment Programme), and international initiatives with U.S. involvement (e.g., World Summit on Sustainable Development). The program does not fund individual countries directly, and its activities still focus on extending Earth science results to a partner's decision-support tools.

Decision-Support Tools

Organizations use decision-support tools to synthesize information, assess scenarios, identify risks, and provide insights on potential consequences of possible decisions. Given the computational demands to ingest copious volumes of Earth science data and model products, computer-based decision-support tools provide systematic mechanisms to incorporate data products and assess the value derived from the inputs.

The program does not invest in building decision-support tools for the partners. The partners build, own, and operate the tools for their mandated policy and management responsibilities. The program works with partners to integrate Earth science results to enhance their decision tools.

Each national application identifies partners and candidate decision-support tools associated with the application topic. The applications set priorities on the decision-support tools to pursue based on: technical capabilities, potential value of Earth science products, socioeconomic value of the associated decisionmaking, partner plans for the tools, resource availability, likelihood of success, and partner commitment. Using these factors and results from stages in the systems engineering approach, the applications determine whether to continue or terminate activities on a specific tool.

Earth Science Results

The program extends products that result from the NASA Earth science research activities. Typically, these results include measurements and observations from NASA missions, predictions and outputs from NASA-sponsored models or models that use NASA measurements, products from research efforts, algorithms, aircraft measurements from field campaigns, visualizations, and techniques and other activities supported by NASA or using NASA measurements.

The program sponsors activities to extend and apply Earth science products to partners' decision tools. Applied science or research whose outcomes may have a potential application and the creation of new measurements strictly for a potential application are outside the scope of activities that the program supports.

The program represents all assets of the Sun-Earth Systems Division. To maximize return on limited resources, the program favors measurements that feature routine collection and will continue to be available to the partners for a sinificant time following a successful demonstration, benchmark, and transition. Thus, the program's primary focus is on extending NASA satellite measurements and outputs from models that use satellite measurements. Regarding airborne assets and capabilities, the program supports use of Division aircraft and airborne activities for the verification and validation of solutions that are based on satellite measurements.

4.3 Program Activities

The program uses open, competitive solicitations and peer-reviewed evaluations of proposed concepts and projects to achieve the objectives. Per OMB direction to NASA, the program guideline is to use competitive sourcing for at least 80 percent of its budget to meet its objectives. As described below, the program requires plans or proposals for the activities it supports in order to follow competitive sourcing and program management principles. In addition, in FY04–05 NASA and the program are transitioning to a full-cost budgeting environment.

Solicitations

The program conducts solicitations on a routine basis for activities supporting the national applications and crosscutting solutions. The program solicits proposals for projects from universities, government, not-for-profit organizations, the private-sector, NASA Centers, and others. Furthermore, the program strongly encourages teams of organizations to collaborate on proposals and projects.

The types of solicitations include cooperative agreements, contracts, and grants. Each solicitation describes the specific intent, criteria, and requirements; the period of performance ranges from 1–5 years. Proposals undergo a critical evaluation process using qualified, independent reviewers to judge the technical merit, anticipated results, management approach, and other factors to ensure the highest potential for effective outcomes and relevance to the program's objectives.

For national applications, successful proposals include mechanisms and organizational relationships to extend Earth science results into operational use and decisionmaking by NASA's partners. The program uses the integrated system solutions diagrams (figure 2.1) as notional representations of the application process and follows systems engineering principles (section 2.2). For crosscutting solutions, successful proposals include mechanisms and institutional arrangements to maintain knowledge bases of Earth science results, support systems engineering processes, and enable interoperability standards.

The program collaborates with the Earth Science research program and information management program on solicitations, and it strongly supports cosponsorship of solicitations with partner agencies.

Peer-Reviewed Projects

In working with its partners, each national application team may identify specific research results to transition effectively and efficiently through projects. The program sponsors projects in situations where a strong partnership exists (e.g., agreement, long-term working relationship), the partner is very clear about its objectives, and timing is critical.

Each project has a specific manager and plan, and the program requires periodic peerreview of the projects and results. Projects undergo critical and documented evaluation using objective criteria to examine the technical and business merit, approach, actual or expected outcomes, and other factors to ensure alignment with the program's objectives and peer-review principles. As projects mature and partner relationships develop, the program may choose to include the topics of specific projects in future solicitations.

Program Management Activities

The program supports activities to identify programmatic requirements and address programmatic risks. The program supports cross-Center efforts, and it conducts studies and workshops supporting management and strategic direction of the program. For example, the program directs studies to characterize decision tools used to support international policymaking, and the program runs workshops to identify trends in information technology and decision-support systems.

Each national application and crosscutting solution supports activities, such as interagency working groups and National Academy studies, that are relevant to their respective objectives.

4.4 Agreements and Partnerships

OMB guidance directs Federal agencies to demonstrate cooperation among U.S. agencies, and agreements provide a framework for cooperation between NASA and partnering organizations. Programmatically, agreements facilitate the implementation of solicitations and projects. The agreements enable the program and partners to identify areas of mutual interest, prepare joint development plans, and implement solicitations and projects benefiting both agencies. The program seeks broad agreements at the Agency or Directorate level, with joint development and implementation plans managed at the Division level.

Working together through the systems engineering process, the program and partners may develop prototype products, guidelines, training, transition plans, and procedures to use Earth science results in the decision tools. Following a successful benchmark, the partner agency bears the responsibility of distributing any enhancements, guidelines, and other relevant information to its end users. The program works to make NASA Earth science products available and to notify the partners of any changes to the products.

4.5 Program Management

This section describes guidelines on the management of the program, including responsibilities, resource allocations, and program reviews.

Roles and Responsibilities

NASA Headquarters (HQ) serves as the program coordination and integration office for the program, including the two program elements and their subelements. The HQ program executives (e.g., public health manager, aviation manager) receive reports, suggestions, and advice from their respective teams and partners in order to set priorities and programmatic direction consistent with the Division. In addition, the program executives communicate Division priorities to the application teams, raise issues to Division management, set budgets, and interact with partners on programmatic topics. Overall, the program executives serve as advocates for their elements at NASA HQ and with the interagency community and stakeholders.

The crosscutting plan and the individual national applications plans specify the required capabilities, available resources, and organizations involved for the priority activities. A variety of organizations, such as universities, NASA Centers, not-for-profits, and DAACs, may be involved with implementing the crosscutting and national applications plans and managing the projects.

Coastal decision-support

NOAA operates the Harmful Algal Bloom (HAB) forecast system to identify, track, and monitor the status of harmful algal blooms in the northern and eastern Gulf of Mexico, and NOAA operates the HAB mapping system to give coastal managers and the public access to data and information on HAB conditions. NOAA sends notices about HAB events via e-mail to coastal resource managers, public health officials, and local governments.

Earth science products, such as ocean color, chlorophyll concentrations, and winds, provide insight into location and transport of HABs. The NASA coastal management application works with NOAA and the Naval Research Laboratory (NRL) on the usage of MODIS, SeaWiFS, and QuikSCAT products and data fusion techniques to assist the HAB reporting.
www.csc.noaa.gov/crs/habf/index.html

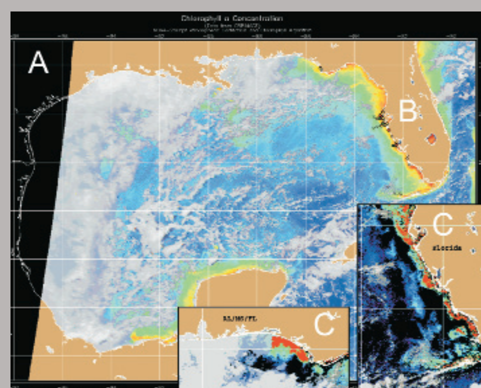
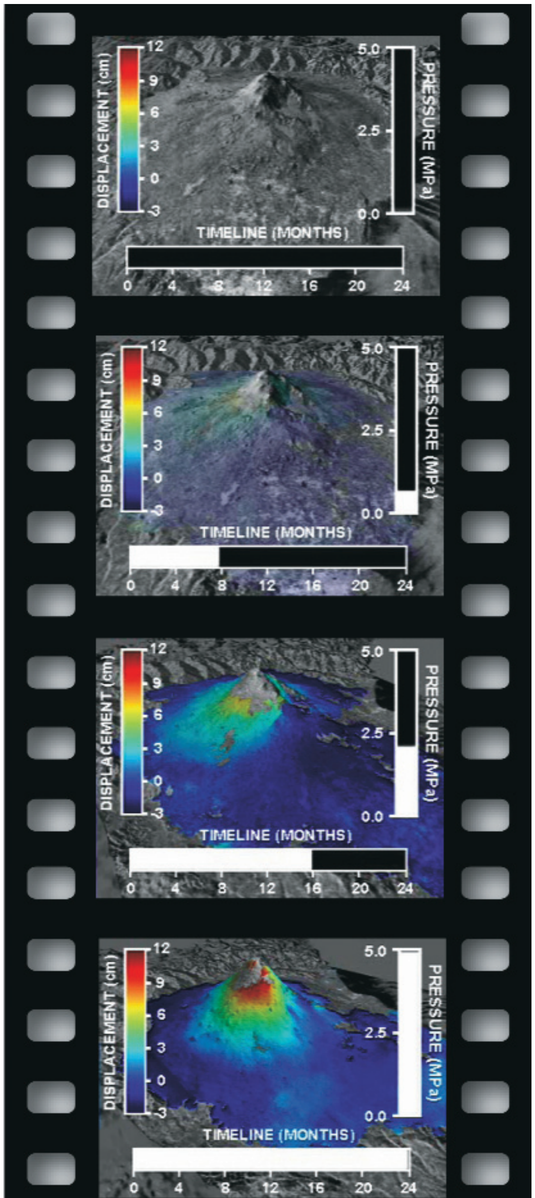


Image shows Chlorophyll-a concentrations in the Gulf of Mexico and possible HAB areas (red=high; blue=low).

NASA Field Centers provide leadership and day-to-day oversight of some projects, including project performance and partnership relationships. The Centers have unique capabilities and expertise related to some or all aspects of Earth science, research, technology, systems engineering, technology transfer, etc. Some Centers have crosscutting roles and expertise, which each of the national applications can utilize. Within the program, the Applications Implementation Working Group (AIWG) provides a forum for the Centers and HQ to resolve issues and identify opportunities to improve the program's ability to accomplish its objectives.



A time series of C-band synthetic aperture radar (SAR) data from the European Space Agency's ERS-1/2 has been used to construct interferograms that show the volcanic deformation of Mount Etna in Italy. SAR interferometry provides a synoptic view of solid Earth deformation at mm scale over large areas and enables scientific advances in our understanding of processes that control potentially catastrophic events such as earthquakes and volcanoes.

For projects involving NASA Centers, the program elements utilize strengths and expertise from the appropriate Centers, and they provide support based on Center performance. The Centers have the responsibility to write or contribute to project plans, manage projects, communicate issues, propose ideas to HQ and respective application teams, maintain knowledge of Earth science results, and report performance. The Centers coordinate and collaborate with each other and work directly with the partners for the overall success of a subelement and the program.

Resources

Budget and resource allocations are made at the program and program element levels. Program management determines allocations between the elements based on program priorities, strategic alignment to Division objectives, and stakeholder direction. Within program elements, the respective managers determine resource allocation based primarily on stated commitments, IBPD objectives, subelement plans and performance, portfolio balance, and cost, timing, and value of expected results. The program requires plans at the program element through project levels to allocate resources.

Reviews

The program conducts routine reviews of the crosscutting activities and 12 national applications. Each subelement presents a quarterly status of issues and accomplishments, and the program conducts a formal semiannual review of results and plans. In September, the program holds a program-wide meeting with all the associated Centers to present plans and priorities for the new fiscal year, present budgets, gather information, and address issues.

The program supports the focus area reviews conducted by the Sun-Earth Systems Division management. In addition, the program periodically requests reviews by the Earth System Science and Applications Advisory Committee (ESSAAC) and external organizations, such as the National Academy of Sciences.

4.6 Performance Measures

The program uses performance measures to track progress, identify issues and trends, evaluate projects, make programmatic adjustments, and establish results. Specific indicators help monitor progress within and across specific activities to ensure that the program meets its objectives.

OMB PART

As 1 of the 18 Agencywide themes, Earth science applications undergoes a triennial review by OMB through the PART. The PART gathers information relative to four areas: purpose, planning, management, and results. The Program develops answers and provides associated evidence to OMB for specific questions in each area.

Program Measures

Program measures fall into two categories: program management measures and performance measures. Program management measures are internally focused to assess activities, inputs, and outputs within direct program control. Performance measures are externally focused to assess if the program's activities serve their intended purposes and provide value to the partners and society. The measures address the following:

- Range in activities and partners it pursues
- Efficiency and effectiveness within the systems engineering approach
- Quality and value of Earth science products
- Cost-benefit variations and value of investments within subelements
- Changes in performance of partners' decision-support tools
- Socioeconomic benefits attributable to Earth science products

Tables 4.2 and 4.3 present the program management measures and the performance measures, respectively. The program uses the information from the measures to determine priorities, form IBPD commitments, and prepare PART responses.

Table 4.2

Program Management Measures (internally focused):	
Inputs *Is the program identifying opportunities to extend Earth science results?*	• Within each application, the potential decision-support tools (DSTs) and issues to support *(number, type, and range)* • Within each application, the possible organizations to partner with *(number, type, and range)* • Within each application, the potential Earth science results to serve the DSTs and issues *(number, type, and range)*
Outputs *Is the program selecting appropriate opportunities? Is the program producing as expected?*	• Evaluation of Earth science results to serve DSTs *(number, type, and range of results; program-wide and within each application)* • Agreements with partners *(presence; program-wide and within each application)* • Reports/Evaluation, Validation, Benchmarking *(number and type; program-wide and within each application)*
Quality and Efficiency *How well is the program performing? How well is the program practicing its systems engineering approach? Is the program maintaining an appropriate level of risk?*	• Earth science results *(results extended per DST number and type; ratio of the results used per DST to the potential results identified)* • Agreements *(ratio of signed agreements to possible partners; program-wide and within each application)* • Program reports *(partner satisfaction, timeliness, time to develop, cost)* • Systems engineering stages *(ratio of validations to evaluations; ratio of benchmarks to validations; program-wide and within each application)*

Table 4.3

Performance and Results Measures (externally focused):	
Outcomes *Are the program products of value to the partners? Are Earth science results being used?*	• Earth science results used/adopted in partner DSTs *(number, type, range of results, partners, and DSTs; frequency and duration of use of results)* • Benchmarks reports *(ratio of Earth science results in use to benchmark reports)* • Partner DSTs *(change in partner's DST performance; value of Earth science results in DST; public recognition of Earth science results in DSTs number and type)*
Impacts *Are Earth science results helping partners provide value and benefits to society?*	• Partner value and metrics *(change in partners' metrics; change in value, ease, speed; uncertainty in partner decisions)*

Program Benchmarks

The program evaluates its approach and performance relative to "program benchmarks," which are national and international organizations with similar purposes and objectives. The program uses the following programs as benchmarks:

- NCAR Research Applications Program
- NCAR Environmental and Societal Impacts Group
- Global Monitoring for Environment and Security in Europe

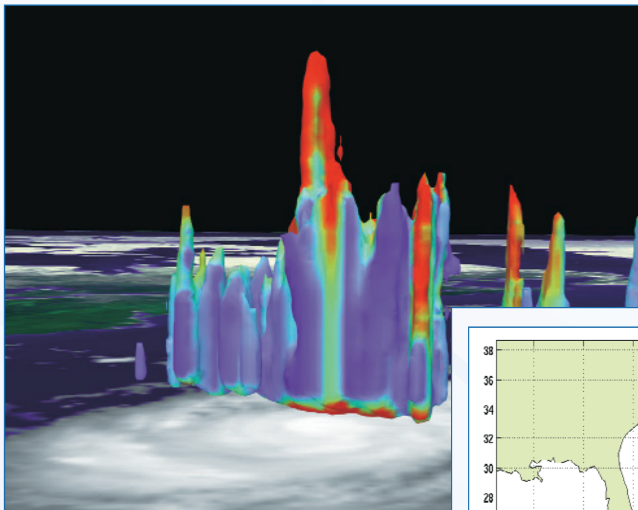
The NCAR Research Applications Program (RAP, *http://www.rap.ucar.edu*) facilitates the transfer of information, knowledge, and technology in the atmospheric sciences to the public and private-sectors. RAP combines scientific knowledge of weather phenomena and cutting-edge technology to create new detection and forecasting capabilities. RAP focuses on agriculture, aviation, fire weather, broadcast and Internet media (i.e., public weather), water resources management, military test range and missile launch support, and surface transportation (road and rail). Unlike the NASA Earth Science Applications Program, RAP conducts significant applied scientific research and contributes to fundamental understanding in atmospheric science.

The NCAR Environmental and Societal Impacts Group (ESIG, *http://www.esig.ucar.edu*) integrates societal needs with knowledge of the environment to better understand and communicate impacts of weather, climate, and global change. Similar to the program, ESIG focuses on the use of Earth science data to support decisionmaking. However, ESIG supports cross-disciplinary research to bridge natural and social sciences, the humanities, and technology. The primary ESIG products are research papers rather than benchmark reports for operational agencies.

The Global Monitoring for Environment and Security (GMES, *http://www.gmes.info*) program is a joint initiative of the European Commission and the European Space Agency. The GMES purpose is to improve the monitoring of the global environment in pursuit of sustainable development, economic stability, and citizen security. Fostering European capacity to monitor the environment, GMES focuses on the use of Earth science observations, especially space-based, and validated science models to support decisionmaking.

Accomplishment:
Hurricane Prediction

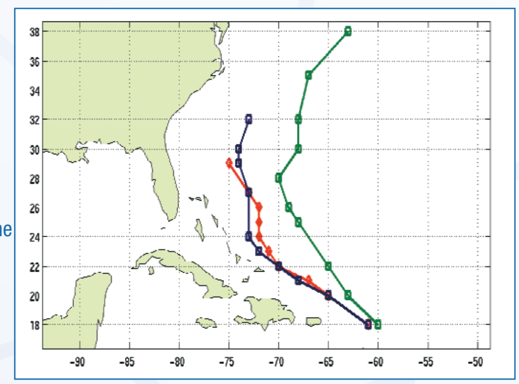
NASA and NOAA use remote sensing observations to enhance hurricane track, landfall, and intensity forecasts. Measurements from NASA's TRMM and QuikSCAT research satellites have been benchmarked for use in weather prediction by domestic and foreign agencies. Both Earth observing satellites help to improve predictions about hurricanes and other tropical systems as they move from the open ocean to coastal regions. Reducing hurricane track error means pinpointing precise regions for evacuation in advance of a predicted landfall. Better forecasts have considerable societal impact, including cost savings.



TRMM-derived rainfall intensity associated with Hurricane Bonnie as it approaches eastern U.S. in 1998

Societal Benefits

The potential socioeconomic benefits of many of these applications are significant. For example, by minimizing unnecessary emergency evacuation measures, improved hurricane predictions could provide as much as $40 million in cost savings for the Nation per event.



Hurricane forecast tracks: actual (red), without TRMM rainfall (green), with TRMM rainfall (blue).

NASA's Unique Capacity and Contributions

The TRMM and QuikSCAT Earth observing research satellites each look at different factors of tropical cyclones to help generate better forecasts. TRMM focuses on the intensity of tropical rainfall, which is indicative of whether a cyclone is weakening or strengthening. It also is valuable in improving hurricane track forecasting through the integration of its rainfall measurements into hurricane forecast computer models.

QuikSCAT measures both the speed and direction of winds near the ocean surface. It is being used by NOAA's ocean and tropical prediction centers to improve the monitoring and forecasting of hurricanes. QuikSCAT observations have been incorporated into operational global weather analysis and forecast systems.

Decision-Support Solutions

NASA, NOAA, and DOD work together in the Joint Center for Satellite Data Assimilation to provide the best hurricane development and landfall track information possible for decision-support purposes. The Tropical Prediction Center (a division of NOAA's National Centers for Environmental Prediction) uses output from several computer models to help forecast and track the path and intensity of tropical cyclones. The assimilation of Earth observing satellite measurements, along with other model enhancements undertaken by NOAA, have led to a vast improvement of model precision in recent years.

5 Challenges and Risks

5 Challenges and Risks

The Earth Science Applications Program faces multiple challenges and risks in pursuing its plan and achieving its goals and objectives. In this section, the program discusses certain identifiable risks and challenges and presents plans to manage these risks or mitigate potential impacts.

In the context of this discussion, challenges are activities that NASA program managers have some control over. Risks are potential impacts that are outside the program's direct control (e.g., satellite failure) and bear significantly on the program.

5.1 Program Challenges

Program challenges include five major areas: partner interest, transition to operational use, continuity of observations, stakeholder directions, and the value of Earth science information.

Partner Interest in Earth Science Data

NASA Earth science research measurements may present types of geospatial information the partners have limited experience using. The measurements may be of a coarser spatial (including vertical) or temporal resolution than the partners are accustomed to using. In addition, some products may have considerable latency in delivery. The program faces a challenge of establishing and maintaining partners if spatial resolution, temporal resolution, or rapid delivery are their primary concerns, or if the partners are reluctant to examine and adopt unfamiliar measurement types (e.g., column ozone profiles). The program faces the challenge of introducing the partners to the range of Earth science data available and helping the partners identify opportunities

Artist's concept of a future decision-support center that maximizes the usage of NASA Sun-Earth Systems Division research and development.

where new types of Earth science data may enhance their systems. The program also faces the challenge of partners needing more timely information for use in operational systems than may be available using data sources developed for research needs. The program addresses these challenges through strong partnerships, the systems engineering approach, and involvement with interagency working groups.

Transition to Operational Use

A key underpinning of the program is the transition of Earth science data sets, model outputs, and other Earth science research results to use in operational environments. While the Division enables the research and the program supports the development of prototype products, a key challenge is the acceptance by the operational agencies. Their acceptance includes technical support in incorporating the data or model products into their standard operating procedures, as well as political and managerial support to accept the product into their decisionmaking process. The partner agencies face potential risks by incorporating new products and costs (e.g., software changes, retraining personnel) into their procedures. Thus, a program challenge is to encourage data integration in the partners' technical and managerial systems to overcome the real and perceived risks.

To manage in the face of this challenge, the program has adopted the approach described in this plan of 1) developing strong partnerships (e.g., agreements), 2) addressing interoperability mechanisms, 3) working with partners to validate products and devise system integration approaches, and 4) benchmarking the performance of the Earth science products in the partner's decision-support tools.

Strong partnerships provide bureaucratic support and trust to encourage familiarity and use of the Earth science data and model products where appropriate. NASA's contributions of a portion of the systems engineering expertise during the benchmarking process also helps mitigate some of the risks. Documenting performance of the Earth science results relative to decision-support system benchmarks also provides an objective evaluation to help communicate the value of the products to managers within the partner agency and to overcome subjective arguments or perceived risks.

The partners may have concerns about investing in measurements from specific satellites that have limited lifetimes. To address these concerns, the program encourages the partners to focus on types of measurements, such as aerosols or sea surface temperatures, rather than data from a specific satellite mission. Satellites have finite lives, and types of measurements are more likely to be collected over time.

As a bridge between the Division's scientific research focus and operationally oriented partners, the program shares in the Division's challenge of developing simple and effective products and results without compromising the objectivity and integrity of the underlying scientific understanding.

Continuity of Observations

The program seeks to encourage partner agencies to utilize Earth science measurements to support their decision tools. The Division satellite missions, measurements, models, and other activities primarily support answering the priority science questions, and the Division cannot support continued operations of the satellites indefinitely.

After Division support for the satellites has reached its programmatic end, a challenge for the community using the measurements is the adoption of the management and operations of the satellite or the development and launch of an equivalent operationally oriented satellite. For example, measurements from MODIS are scheduled to continue on NPP and NPOESS. However, not all operational agencies currently have the budget or expertise to assume operations of the satellites even if the measurements support their mission. Thus, a key challenge the program faces is the long-term availability of the data sets and measurements to the partner agencies that the program seeks to extend to in the short term.

To address this challenge, the program supports interagency efforts to identify requirements for satellites, sponsors studies to advise the Earth science community on policy issues, and supports international efforts, such as the GEO, to provide a long-term framework for critical Earth science measurements and products.

Stakeholder Directions

The program faces a potential challenge when congressionally directed activities do not align with the program's objectives and authorized purpose. If the congressionally directed activities do not align nor contribute to the program, the program faces the risk of the possibility of reduced managerial credibility within the NASA.

Value of Earth Science Information

The program faces a challenge of identifying the value of performance improvements or increased information content from Earth science results in the partners' decision processes. This information is important to help partners determine their commitments to Earth science products in their operations and to establish the credit that NASA Earth science research warrants. To address this challenge, the program uses the benchmarking process to provide an assessment of the value of Earth science products in the partners' decision-support tools.

5.2 Program Risks

Working in space is an inherently risky venture. Several risks manifest themselves as potential impacts to the program. These risks are associated with the successful launch and life cycle for satellites, budget, data products, and complementary assets.

Satellite: Launch and Lifetime

Satellite measurements represent significant resources that NASA extends to its partners. The space environment is hazardous, and satellites sometimes fail with little warning. As satellites near the end of their design life and if follow-on systems do not exist, the partners may be reluctant to invest resources and personnel to adopt data from the aging satellites. In addition, since

Researchers examine Earth science data and visualizations associated with hurricanes on a large multiscreen display.

Weather forecasting can involve distributed computing grids that spread the computation over many diverse systems and use geospatial Web services for data access.

satellites often experience launch delays and require months for check-out, the partners may wait until successful launches before investing significant interest, resources, and personnel to prepare, evaluate, and validate data into their standard operating procedures.

The Earth science community has experienced this risk firsthand with the loss of QuikTOMS and Landsat 6 at launch and the loss of the Midori-II satellite, which failed in October 2003 after only 10 months in orbit. Midori-II carried the NASA SeaWinds scatterometer sensor, so applications relying on ocean winds, such as coastal management and disaster management, face a reliance on data from an older instrument (SeaWinds on QuikSCAT) which uses a different data path.

Satellites nearing their expected end-of-life period include: UARS, TOMS, ERBS, TRMM, Landsat 5, and EO-1. Support for operating QuikSCAT has been extended in response to the loss of Midori-II.

Reduced satellite lifetimes also occur for programmatic reasons. Even when satellites may be operable, NASA may choose to terminate missions for programmatic and budgetary reasons. If NASA's guidelines about the programmatic lifetime of particular missions are unclear, the partners may be reluctant to commit their operations and decisionmaking to measurements from those missions.

Budget

Activities in each fiscal year are predicated on resources to develop and achieve the expected results. A possibility exists that the budgets requested are not appropriated at a level to achieve the results in the timeframes specified. In addition, NASA and Directorate management may re-assess priorities within the Agency and decide to reallocate funds away from all or parts of the Earth Science Applications Program, affecting the ability of the program and its elements to achieve the stated objectives.

Data Product Stream

Many of the partner agencies with operational uses of the Earth science results and products utilize the data in a near-real-time environment. However, there is often considerable latency in the release of Earth science research data. Thus, the application of Earth science products by the partners may depend on NASA's ability to produce and release "quick look" products. Therefore, a risk exists that the end users would not have data in the timeframe needed to support their decisionmaking, and they may decide not to pursue the Earth science data. To manage this risk, the applications program works with the science teams, data centers, DAACs, ESIPs, and other organizations to address issues related to the availability and use of Earth science data in operational environments.

In addition, partner agencies may be hesitant to adopt an Earth science measurement in its decision-support tools if the product is not likely to exist for an appropriate timeframe (e.g., over multiple satellites) to make their investment worthwhile. Some data sets have planned transitions, such as sea surface height (TOPEX-Poseidon to Jason to OSTM) and ocean color (SeaWiFS to Terra/Aqua to NPP to NPOESS).

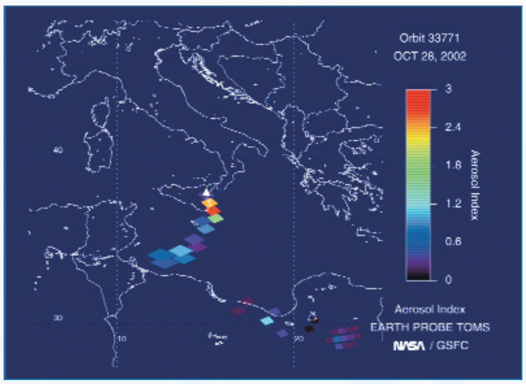
The program and the partners need to ensure that the data products meet appropriate data quality, timeliness, and resolution objectives to serve the end users.

Developments in Complementary Assets (models, software systems)

The application of the Earth science products to partners' decision-support tools depends on technologies and developments beyond the data itself. Developments in related fields of models, data integration, visualization, and software bear on the assimilation of the data products into the decision tools. If these "complementary assets" are not available to support adoption of the Earth science products, then the adoption may proceed slower than expected.

Accomplishment:
Forecast of Volcanic Ash and Icing Hazards to Aviation

Weather and natural hazards can create hazardous conditions for aircraft passengers and the aviation community, challenging Federal agencies to forecast the hazards and reroute plans to reduce exposure. The Federal Aviation Administration (FAA) and NOAA work with NASA on the use of Earth science to improve monitoring of in-flight icing conditions and volcanic ash plumes that contribute to accidents, damage aircraft, and disrupt flight operations.



TOMS aerosol measurements of Mt. Etna, Sicily (2002).

Volcanic Ash

Ash and corrosive gases from volcanoes can cause serious in-flight damage to aircraft engines, posing an immediate safety risk and creating expensive repairs. Since 1980, at least 15 aircraft along northern Pacific routes and at least 80 aircraft worldwide have been damaged by flying through volcanic ash clouds. Airplane radar systems cannot detect volcanic ash because the particles are very small, and pilots have trouble spotting ash plumes in poor visibility and at night.


MODIS image of volcanic plume from Mt. Etna, Sicily.

Measurements from Earth observing satellites can enhance the ability to detect and monitor volcanic ash. NASA's Total Ozone Mapping Spectrometer (TOMS), the MODIS sensor on the Terra and Aqua satellites, and NASA-built sensors on NOAA's GOES and POES operational satellites provide useful observations. An initiative between FAA and NASA includes an effort to develop real-time, automatic detection and monitoring of ash plumes in order to alert aircraft of hazards in their flight paths.

In-Flight Icing

Icing can occur when aircrafts fly through clouds or precipitation containing drops that have cooled below 0°C (but have not yet frozen). Aircraft encountering these supercooled clouds can accumulate ice on surfaces, leading to a rapid loss in performance. Even aircraft equipped with anti-icing capabilities are at risk in extreme conditions. Icing accidents typically result in greater than 25 fatalities per year and direct costs of approximately $100 million.

Weather forecast models generally "over warn" of icing conditions—they identify very large volumes of airspace as having possible icing conditions, while the main hazard areas are usually confined to a few narrow regions. Large-area warnings cause unnecessary re routings, aircraft weight restrictions, and flight cancellations. More precise forecasts can reduce unnecessary delays and disruptions to the public and industry.

NASA is working with FAA and NOAA to use Earth science observations (MODIS, GOES, POES), models, and analytic techniques to retrieve cloud parameters and microphysical properties. Satellite measurements of clouds and Earth science algorithms improve estimates of cloud-top temperatures and cloud height, drop size, and phase to help identify areas of significant icing. As new capabilities are proven, NOAA assumes operational responsibility for the forecast products to give the FAA and the aviation industry.

Appendices

Appendix A

Glossary

Applications—specific use of results of science research, technology, data, information, knowledge, and/or modeling capability that serves an intended purpose or decision.

Applied Research—research aimed at gaining the knowledge or understanding necessary to meet a specific, recognized need. (National Science Foundation)

Applications Demonstration—systematic approach to determine the viability of applying knowledge, data, and technology from research to meet operational requirements; implemented through the design and deployment of prototypes and processes in operational settings.

Assessments—structured and systematic appraisals of the state of science, technology, knowledge, and/or understanding of relevant capabilities, phenomena, or dynamics.

Benchmark—a standard to which a product or system can be compared, measured, or judged; a current practice or reference scenario.

Benchmarking—–the activities to compare the performance of the system (e.g., decision support tool) to a standard, current practice, or reference scenario in order to determine an improvement (and the value of the Earth science product in the decision support tool). Compare its operation, function, and performance to standard version.

Decision-Support System (DSS)—a computer-based information-processing system for scenario optimization through multiparametric analysis. A DSS utilizes a knowledge base of information with a problem-solving strategy that may routinely assimilate measurements and/or model predictions in support of the decisionmaking process. The DSS provides an interface to facilitate human inputs and to convey outputs. Outputs from a DSS would typically be used for making decisions at the local level, and outputs from multiple DSSs may be used in establishing policy.

Decision-Support Tools—a suite of solutions owned by NASA partners that are used in a variety of problem domains for decision-and policy-making. These solutions could include assessments, decision-support systems, decision-support calendars, etc.

Evaluation—the activities to identify decision support tools and examine user-defined requirements relative to Earth science research results that may serve or enhance the tools. Through an evaluation, the program and the partners determine whether to pursue further collaboration on a project.

Geospatial Data—information that identifies the geographic location and characteristics of natural or constructed features and boundaries of the Earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. (USGS)

National Spatial Data Infrastructure—the technologies, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and archive spatial data. (OMB)

Prototype—an initial scaled-down or limited-capacity version of a technique or system that is quickly developed to test the effectiveness of the overall design being used to solve a particular problem. This testing process is sometimes termed “rapid prototyping.”

Roadmap—a system-level diagram depicting the progression of relevant science programs, technology developments and missions, and phases for an application related to a specific set of outputs and outcomes.

Standards—documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes, or services are fit for their purposes. (OMB)

Stakeholders—organizations that have a vested interest in the program, including sources of requirements and beneficiaries of investments, products, processes, and services. Primary stakeholders include representatives of the Executive and Legislative Branches; public sector representatives from Federal, State, local, and tribal organizations; academic and research institutions; and the private-sector.

Standards-Based Data Products—packaged geospatial data and information generated to meet documented performance specifications in compliance with national standards. Data products are independently verified and validated.

Validation—–the activities to determine if a product (technology, observation, model prediction, etc.) serves the functional requirements and its performance can achieve the intended outcomes.

Verification—the activities to measure how the actual performance of a product (technology, observation, model prediction, etc.) meets the user defined requirements within a specified tolerance.

Appendix B

Abbreviations and Acronyms

ADEOS-II	Advanced Earth Observing Satellite II
AERONET	Aerosol Robotic Network
AIRS	Atmospheric Infrared Sounder
AIRSAR	Airborne Synthetic Aperture Radar
ALI	Advanced Land Imager
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AMSU	Advanced Microwave Sounding Unit
APS	Aerosol Polarimetry Sensor (aka, Glory)
AQI	Air Quality Index
ARC	Ames Research Center
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
AWARDS	Agricultural Water Resources and decision-support
AWIN	Aviation Weather Information Network
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BoR	Bureau of Reclamation
CADRE	Crop Assessment Data Retrieval and Evaluation
CALIPSO	Clouds-Aerosol Lidar and Infrared Pathfinder Satellite Observations

CASA	Carnegie Ames Stanford Approach
CBFP	Congo Basin Forest Partnership
CCAD	Central American Commission for Environment and Development
CCRI	Climate Change Research Initiative
CCSP	Climate Change Science Program
CCTP	Climate Change Technology Program
CDC	Centers for Disease Control and Prevention
CENR	Committee on Environment and Natural Resources
CERES	Clouds and the Earth's Radiant Energy System
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CINDI	Center for Integration of Natural Disaster Information
CMAQ	Community Multiscale Air Quality System
COLA	Center for Ocean-Land-Atmosphere Studies
CPL	Cloud Physics Lidar
CREWS	Coral Reef Early Warning System
CrIS	Cross-track Infrared Sounder
DAAC	Distributed Active Archive Center
DAO	Data Assimilation Office

DFRC	Dryden Flight Research Center	ESSAAC	Earth System Science and Applications Advisory Committee
DHS	Department of Homeland Security	ESS	Earth System Science
DMSP	Defense Meteorological Satellite Program	FAA	Federal Aviation Administration
DOD	Department of Defense	FAS	Foreign Agriculture Service
DOE	Department of Energy	FEMA	Federal Emergency Management Agency
DOI	Department of the Interior	FGDC	Federal Geographic Data Committee
DOT	Department of Transportation	FY	Fiscal Year
DSS	decision-support System	GCOM	Global Change Observation Mission
DST	decision-support Tool	GEO	Group on Earth Observations
ENSO	El Niño Southern Oscillation	GFDL	Geophysical Fluid Dynamics Laboratory
EO-1	Earth Observing-1 (new millennium program)	GIFTS	Geosynchronous Imaging Fourier Transform Spectrometer
EOSDIS	Earth Observing System Data and Information System	GIO	Geospatial Interoperability Office
EOS	Earth Observing System	GIS	Geographical Information System
EPA	U.S. Environmental Protection Agency	GISS	Goddard Institute for Space Studies
EPHTN	Environmental Public Health Tracking Network	GMAO	Global Modeling and Assimilation Office
EPRI	Electric Power Research Institute	GMES	Global Monitoring for Environment and Security (ESA)
ERBS	Earth Radiation Budget Satellite	GNOME	General NOAA Oil Modeling Environment
ERS	European Remote Sensing Satellite	GOCART	Global Ozone Chemistry Aerosol Radiation and Transport
ESA	European Space Agency	GOES	Geostationary Operational Environmental Satellite
ESE	Earth Science Enterprise		
ESIG	Environmental and Societal Impacts Group (NCAR)		
ESIP	Earth Science Information Partnership		

GOS	Geospatial One Stop
GPM	Global Precipitation Measurement
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GSFC	Goddard Space Flight Center
HAB	Harmful Algal Bloom
HAZUS-MH	Hazards United States—Multi-Hazard
HELIX	Health and Environment-Linked Information Exchange System
HHS	Department of Health and Human Services
HQ	Headquarters (NASA)
HSB	Humidity Sounder for Brazil
IBPD	Integrated Budget and Performance Document
IBS	Integrated Benchmark Solutions
ICESat	Ice, Cloud, and Land Elevation Satellite
IHOP	International H_2O Project
InSAR	Interferometric Synthetic Aperture Radar
INTEX	Intercontinental Chemical Transport Experiment
IOF	Integrated Operations Facility
IPCC	Intergovernmental Panel on Climate Change
IPO	Integrated Program Office (NPOESS)
ISFS	Invasive Species Forecasting System
IWGEO	Interagency Working Group on Earth Observations
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
LaRC	Langley Research Center
LDCM	Landsat Data Continuity Mission
LIS	Lightning Imaging Sensor
MAS	Millimeterwave Atmospheric Sounder
METEOSAT	Meteorological Satellite (ESA)
MISR	Multi-angle Infrared Scanning Radiometer
MMS	Malaria Monitoring and Surveillance
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NAS-AWRP	National Airspace System—Aviation Weather Research Program
NASS	National Agricultural Statistics Service
NAST	NPOESS Aircraft Sounder Testbed
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction

NDVI	Normalized Difference Vegetation Index	PDO	Pacific Decadal Oscillation
NGA	National GeoSpatial-Intelligence Agency	PECAD	Production Estimates and Crop Assessment Division (FAS)
NGO	Non-Governmental Organization	PMA	President's Management Agenda
NIH	National Institutes of Health	POES	Polar Operational Environmental Satellite
NOAA	National Oceanographic and Atmospheric Administration	PSS	Plague Surveillance System
NPOESS	National Polar-orbiting Operational Environmental Satellite System	QuikSCAT	Quick Scatterometer
NPP	NPOESS Preparatory Project	RAP	Research Applications Program (NCAR)
NPS	National Park Service	REASoN	Research, Education, and Applications Solutions Network
NRC	Nuclear Regulatory Commission	RSVP	Rapid Syndrome Validation Project
NRCan	Natural Resources Canada	SAGE	Stratospheric Aerosol and Gas Experiment
NREL	National Renewable Energy Laboratory	SAR	Synthetic Aperature Radar
NRL	Naval Research Laboratory	SCIGN	Southern California Integrated GPS Network
NSF	National Science Foundation	S'COOL	Students' Cloud Observations On-Line
NSIPP	NASA Seasonal-to-Interannual Predication Project	SDR	Subcommittee on Disaster Reduction
NSTC	National Science and Technology Council	SeaWiFS	Sea-viewing Wide Field-of-view Sensor
OCO	Orbital Carbon Observatory	SEEDS	Strategic Evolution of Earth Science Data Systems
OMB	Office of Management and Budget	SERVIR	Regional Visualization and Monitoring System
OSTM	Ocean Surface Topography Mission	SIP	State Implementation Plan
OSTP	Office of Science and Technology Policy	SN	Solutions Network
PAR	Photosynthetically Active Radiation	SORCE	Solar Radiation and Climate Experiment
PART	Program Assessment Rating Tool		

SRB	Surface Radiation Budget	UNEP	United Nations Environment Programme
SRTM	Shuttle Radar Topography Mission	USAID	United States Agency for International Development
SSC	Stennis Space Center	USDA	United States Department of Agriculture
SSE	Surface Solar Energy	USFS	U.S. Forest Service
SSH	Sea Surface Height	USGCRP	United States Global Change Research Program
SST	Sea Surface Topography	USGS	United States Geological Survey
SURFRAD	Surface Radiation Budget Network	USWRP	United States Weather Research Program
SVS	Synthetic Vision System	VCL	Vegetation Canopy Lidar
THORPEX	The Observing System Research and Predictability Experiment	VIIRS	Visible Infrared Imaging Radiometer Suite
TMI	TRMM Microwave Imager	WMO	World Meteorological Organization
TOMS-EP	Earth Total—Probe Ozone Mapping Spectrometer	WSSD	World Summit on Sustainable Development
TRMM	Tropical Rainfall Measuring Mission		
UARS	Upper Atmosphere Research Satellite		

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