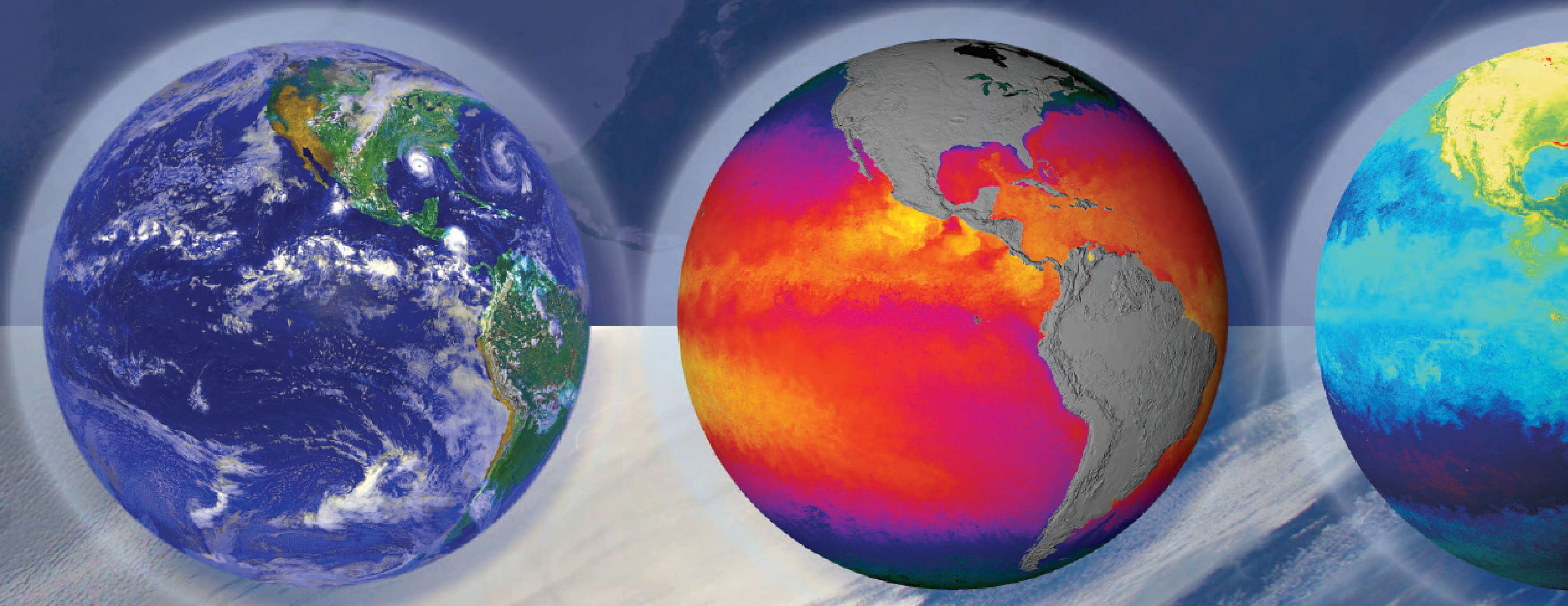
National Aeronautics and Space Administration

NASA Earth Observations
SERVING SOCIETY



Partners

Central American Commission for Environment and Development

THE WORLD BANK

www.nasa.gov

NP-2007-7-840-GSFC

Earth Science Objectives

National Objective

Study the Earth system from space and develop new space-based and related capabilities for this purpose.

NASA Objectives

Advance scientific knowledge of the Earth system through space-based observation, assimilation of new observations, and development and deployment of enabling technologies, systems, and capabilities, including those with potential to improve future operational systems.

Study Earth from space to advance scientific understanding and meet societal needs.

Related Web Sites

NASA: www.nasa.gov

Applied Sciences Directorate: www.esa.ssc.nasa.gov

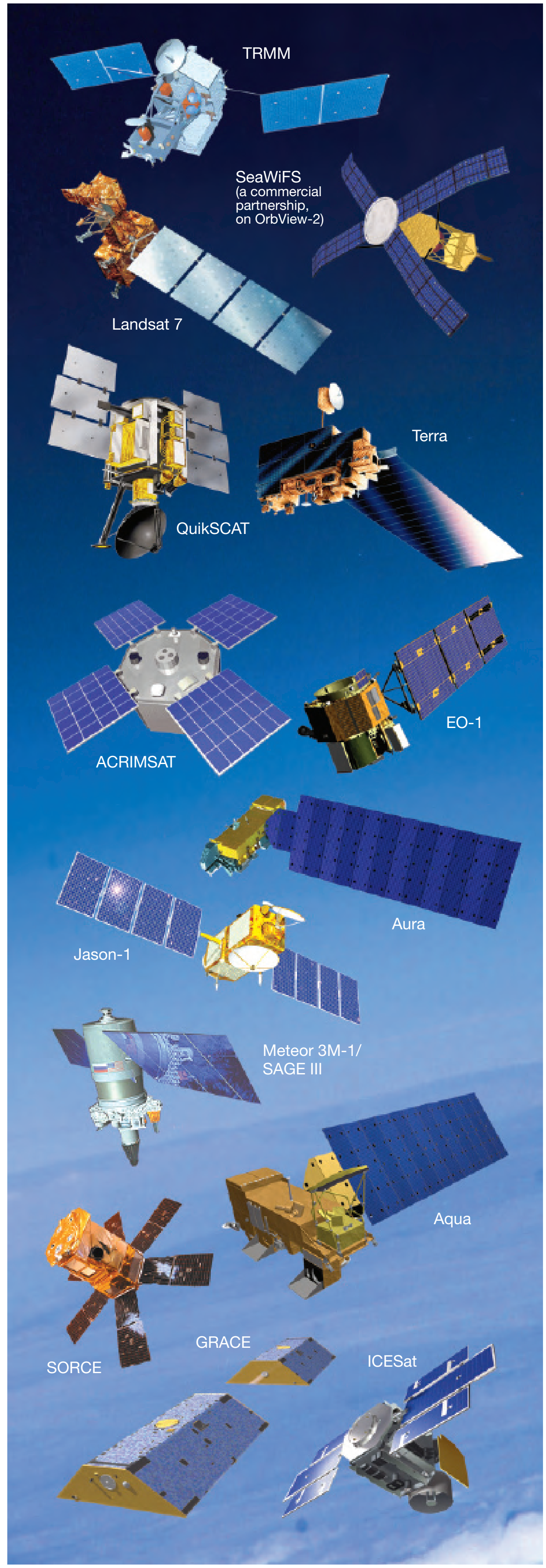
Science@NASA: science.hq.nasa.gov/

The Earth Observatory: earthobservatory.nasa.gov

Visible Earth (images and animations): visibleearth.nasa.gov

Earth Sciences Portal: earthsciencesportal.gsfc.nasa.gov

Earth Science Missions



Earth Science Exploration Serving Society

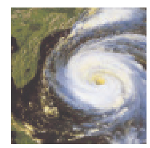
Overview

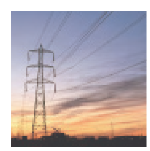
National Aeronautics and Space Administration (NASA) conducts research and development of aerospace science and technology. NASA's Earth Science Division develops Earth observation systems and conducts research to increase our scientific understanding of the Earth's planetary system. NASA collaborates with national and international partners to benchmark the use of Earth science results to improve decision support tools that serve society.

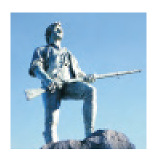
Global measurements of key geophysical parameters provided by NASA Earth observing systems enable Earth system science researchers to develop sophisticated models of land, ocean, and atmospheric processes as well as the interactions among them that make up the Earth's weather, climate, and natural hazards (i.e. storms, volcanoes and earthquakes.) The results of the global measurements and science models that simulate the Earth's behavior are manifestations of the NASA goal to study Earth from space to advance scientific understanding and meet societal needs.

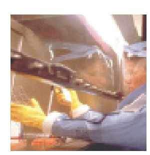
Knowledge resulting from NASA technologies and observations of the Earth's planetary system is harnessed to improve predictive capability for agricultural efficiency, aviation, homeland security, mitigation of invasive species and disasters, the environment and public health, management of carbon resources, water resources, coastal ecosystems, and air quality.

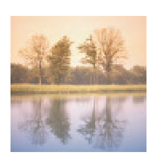
Observations and predictions that result from NASA research and development are assimilated into decision support systems developed and managed by our partner organizations. These systems generate decision support resources that provide key information needed to promote economic vitality and environmental stewardship, and are useful tools for policymakers. NASA contributes systems integration to enable solutions that result in socioeconomic benefits to society.



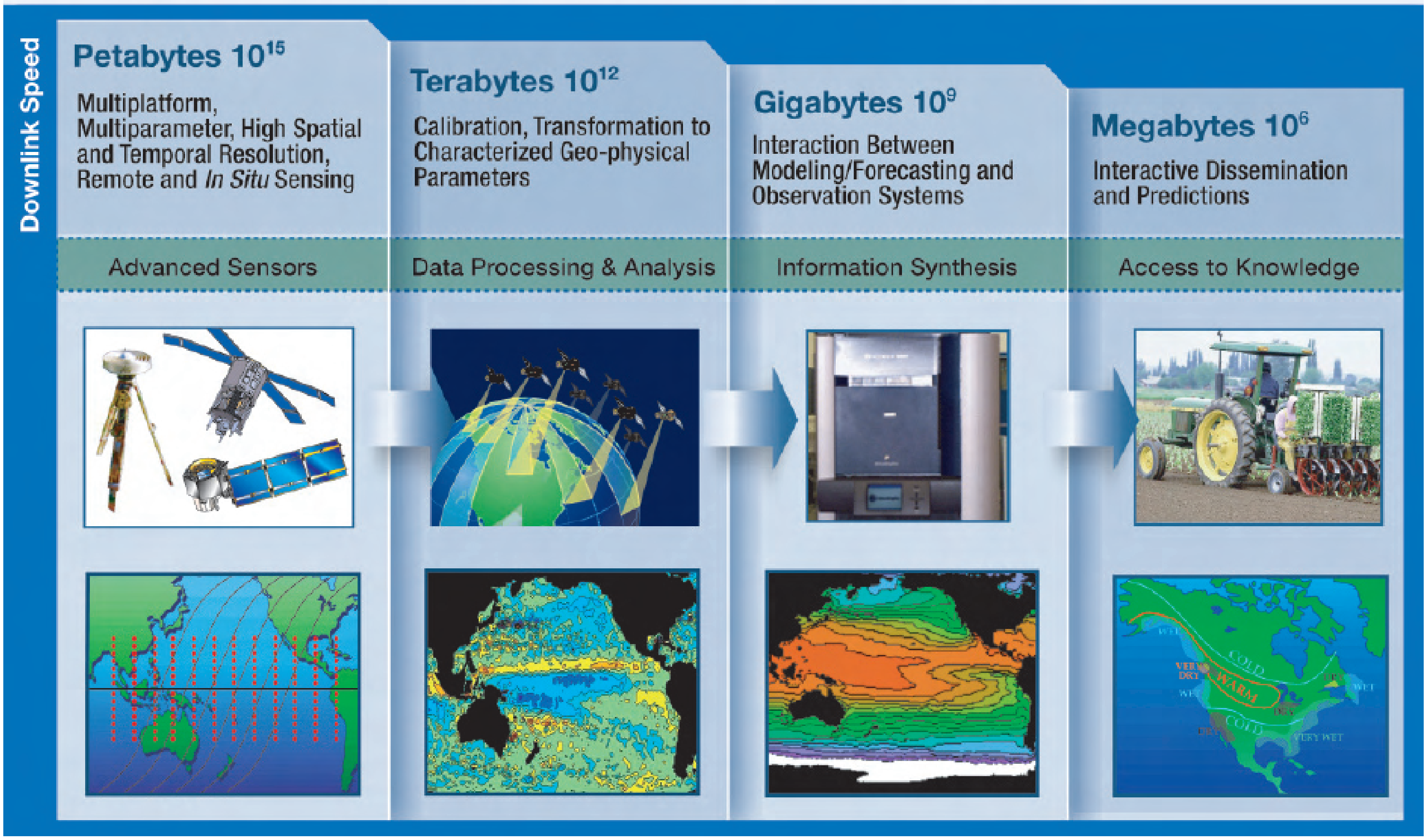




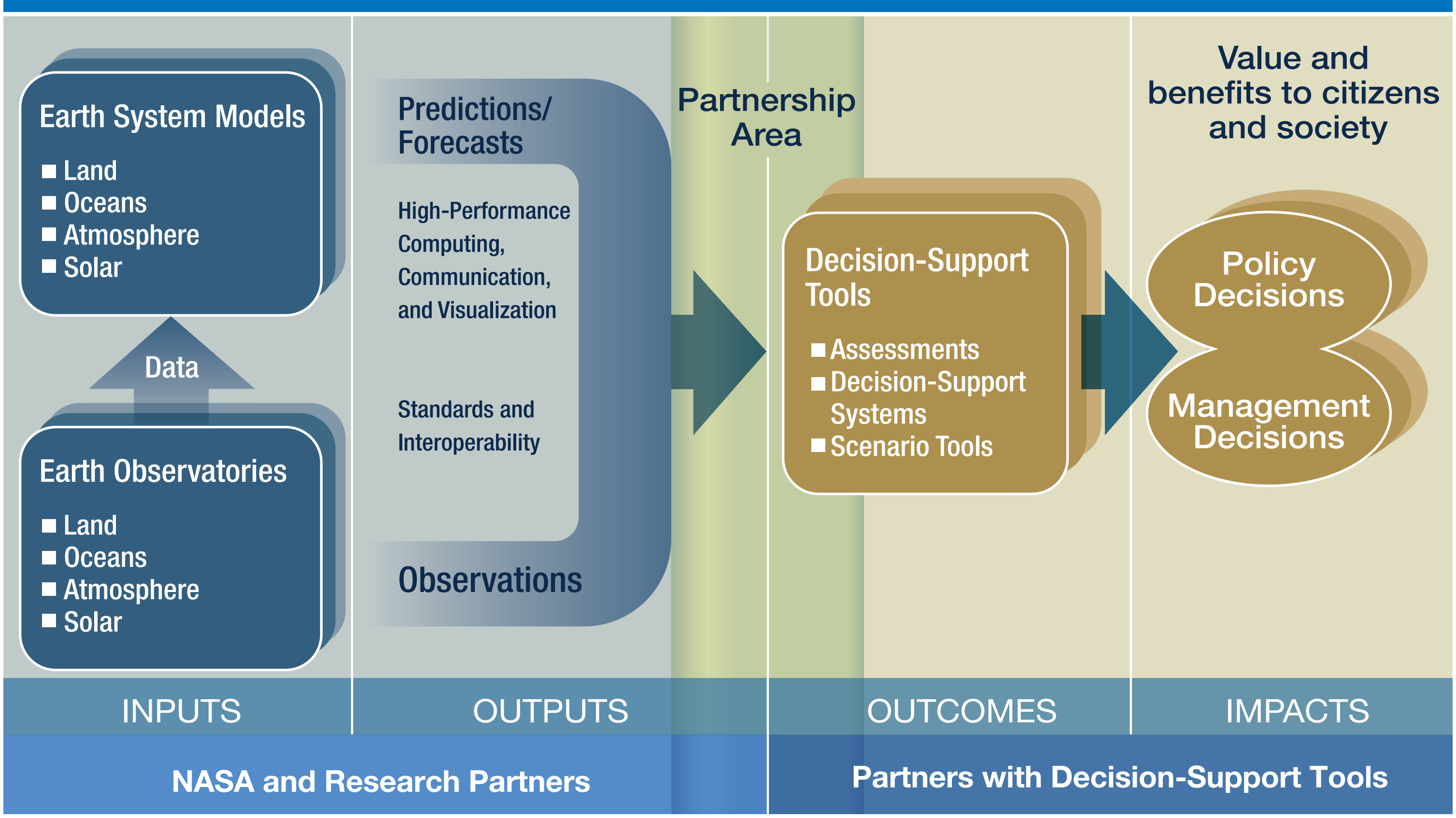




Turning Observations into Knowledge Products



Applied Sciences Program Approach to Integrated System Solutions



Agricultural Efficiency

Overview

One of the nation's and the world's most vital needs is a stable and dependable food and fiber supply. Planet Earth adds roughly 90 million new human inhabitants each year, and agricultural production and its efficiency must increase to meet the resulting demand. In order to improve our agricultural efficiency, an enhanced understanding of the ties between global climate and local weather events is needed so that agricultural production can be optimized for local growing conditions. This understanding leads to providing more accurate and timely information to farmers and organizations responsible for food and fiber production and water resource management decisions.

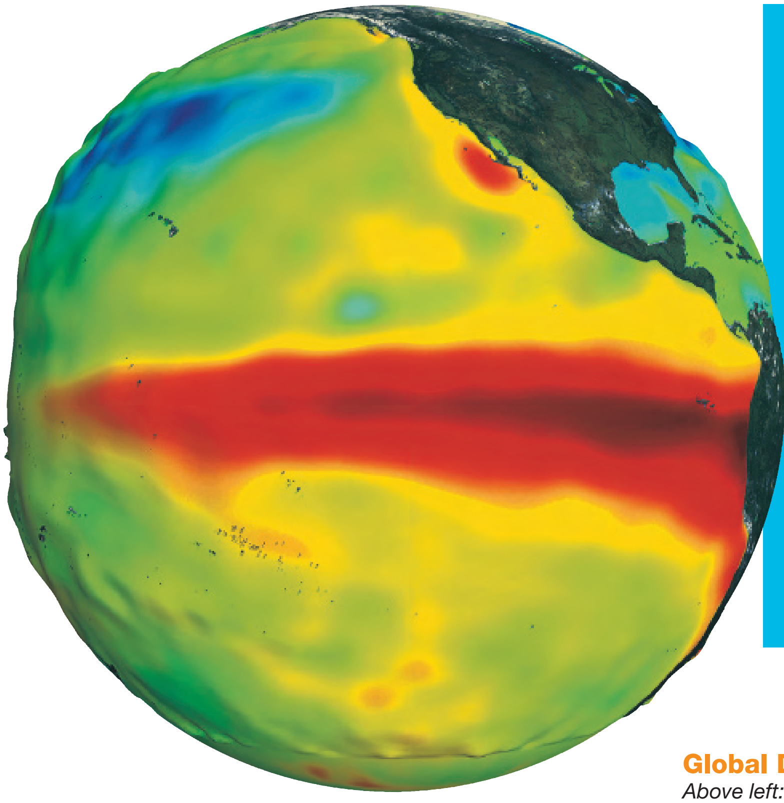
The U.S. is a world leader in agricultural production and export. Agriculture accounts for over 13% of the U.S. gross domestic product. Agricultural exports total more than $50 billion annually and account for over 15% of the U.S. worldwide export totals. Any disruption in the productivity of domestic agriculture can have long-range economic impacts. The 1988 drought in the Midwest U.S., the worst drought since the 1930s, caused an estimated $40 billion in crop damage. Exceptionally wet years, as the one the U.S. experienced in 1993, have similar devastating effects on production. Reliable seasonal forecasts of precipitation and temperature can have an enormous positive economic impact for the global agricultural industry. Likewise, in-season monitoring of global and domestic crop production can provide the information necessary to mitigate the effects of extreme weather events on the agricultural economy and provide resource managers with the information needed for decisions on agricultural production, marketing, and food aid.

NASA scientists are collaborating with the U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA) to better understand daily, monthly, and seasonal variability of weather/climate and apply that understanding to agricultural practices. Space provides an ideal vantage point for the measurement of critical parameters for agricultural production, such as water availability, surface solar radiation, and vegetation health, over large areas. NASA is teaming with the USDA's Foreign Agricultural Service and the National Agricultural Statistics Service to incorporate NASA space-based measurements into models and systems used to monitor and forecast global and domestic agricultural production. The sophisticated Moderate Resolution Imaging Spectroradiometer (MODIS), flown on both the Aqua and Terra satellites, collects daily global data on vegetation condition, surface temperature, snow cover, and evapotranspiration. The Tropical Rainfall Measuring Mission (TRMM) satellite provides comprehensive data on precipitation at tropical and subtropical latitudes. The Landsat 7 satellite provides data on agricultural production at the regional or local scale. NASA research instruments have provided valuable information, and future research and operational satellites, such as the Global Precipitation Measurement (GPM) mission and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will contribute to Earth observation capacity for our nation and the world.

Data from these systems also feed complex climate models developed to improve seasonal and longer-range climate forecasts. Research indicates that many extreme year-to-year changes in local weather conditions are associated with changes in global-scale climatic phenomena. Measurements of ocean surface temperatures and ocean biology are fed into models for predicting the timing, duration, and strength of these climatic events. The ongoing efforts to improve these models lead to more accurate local weather and precipitation forecasts that are being tailored to the needs of agricultural planning.

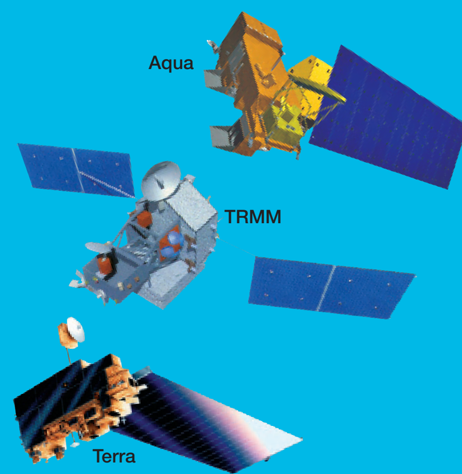
These NASA missions are helping the science community better understand the forces that drive global climate and weather. The results of this NASA research in Earth science and technology are being integrated through the partnership with USDA into local and regional decision support systems for managing agricultural land.

Agricultural Efficiency



Earth Observation Systems

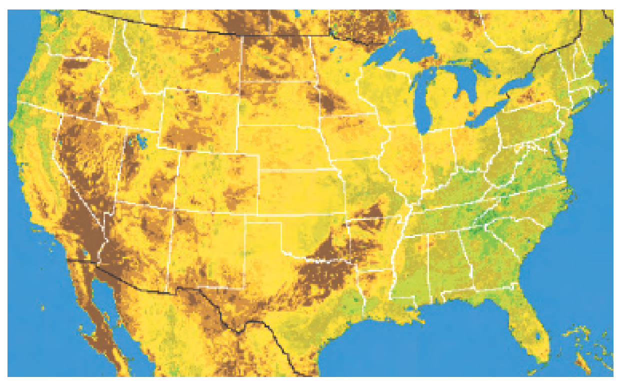
NASA Earth observations provide global measurements of key parameters for use in Agricultural Efficiency.



Global Datasets and Models

Above left: Prediction of large-scale weather events and seasonal climate variations—red indicates elevated sea surface temperatures associated with El Niño.

Below: Farmers can use models and predictions derived from NASA satellite data to effectively plan and maintain their crops and livestock.

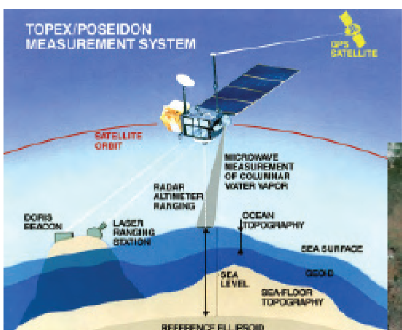


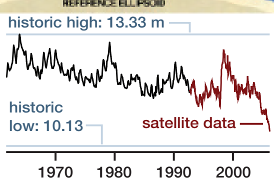
Vegetation Greenness Values

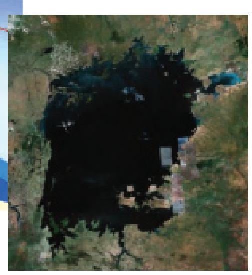
Low Biomass — High Biomass — Water

Decision Support

Enhancements to decision support tools such as those used by the USDA's International Production Assessment group, improve forecasts of global crop production. Below, data from TOPEX/Poseidon used to monitor water level in Lake Victoria, Africa, and the availability of water for crop irrigation in East Africa.







Societal Impacts

NASA-assisted crop yield estimates enable earlier prediction of food shortages and bring added economic security to agribusiness.

Bill Tarpenning/USDA photo

Warren Gretz/NREL photo

Partners

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

United States Department of Agriculture

Overview

Air quality impacts all citizens. A clean, safe air supply is a vital societal need and is mandated by the Clean Air Act. To meet this requirement the Environmental Protection Agency (EPA) needs access to accurate and timely information on air quality. It is important for the EPA to know what the current state of the air is on a global, regional, and local scale. The agency needs to understand how changes that occur on a global scale impact regional air quality and vice versa, and assess how these conditions are likely to change with time.

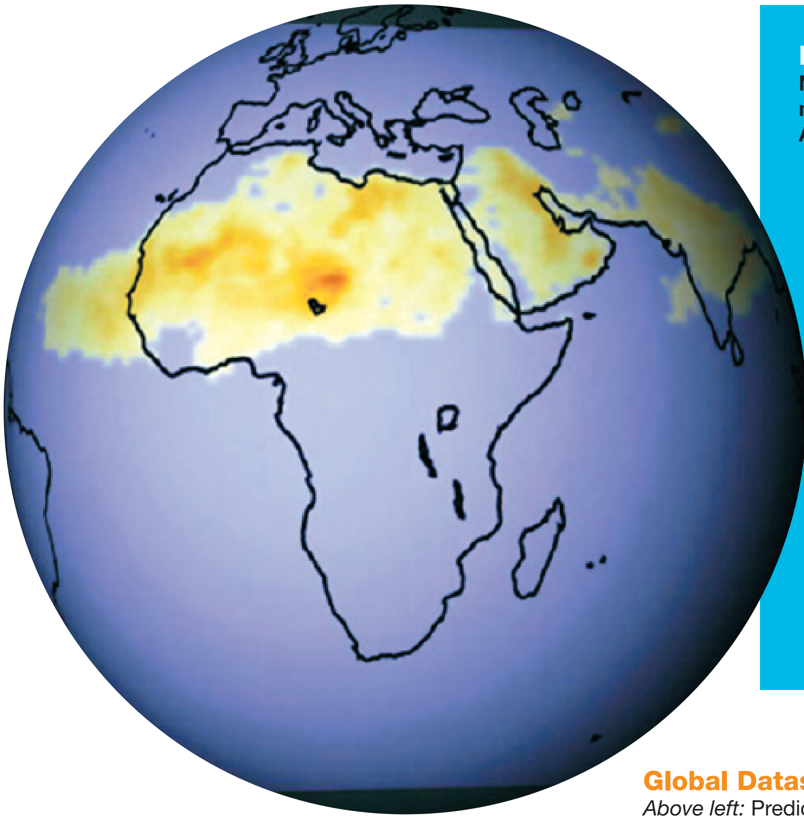
NASA plays an important role in providing global observations and sponsoring research on air quality. NASA-sponsored researchers have developed sophisticated models of the chemistry and dynamics of Earth's atmosphere and are working with the EPA to examine how these models might be used to help the EPA better fulfill its air quality mission. The EPA operates a decision support system used to make air quality forecasts. This decision tool requires measurements and predictions of atmospheric conditions, which NASA observations and models provide.

Current NASA satellite missions provide measurements relevant to air quality both as observations of current conditions and as input to NASA and partner models. For example, the Total Ozone Mapping Spectrometer (TOMS) instrument flying on a series of satellites has been collecting valuable information of relevance to studies of ozone mapping and transport, sulfur dioxide emissions, and particulate matter—also known as aerosols—for the past several decades. More recently, a number of new instruments on the Terra satellite have made significant contributions to air quality studies. For example, the Measurements Of Pollution In The Troposphere (MOPITT) instrument yields global distributions of carbon monoxide. Additionally, MODIS is used for studies of various pollutants and the Multi-angle Infrared Scanning Radiometer (MISR) instrument is used to study particulate matter (aerosols). The Aqua satellite also measures aerosols using a MODIS sensor, as well as measures carbon monoxide (CO) and methane (CH_4) using the Atmospheric Infrared Sounder (AIRS) instrument.

The Aura satellite, scheduled to launch in 2004, is dedicated to studying the chemistry of the Earth's atmosphere. Its entire instrument complement is designed to obtain the most comprehensive measurements of key atmospheric constituents and how the concentrations change with time. It will offer the most detailed information on atmospheric ozone that has ever been obtained, with the ability to track ozone and other pollutants as they are transported around the world. The CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellites, planned for launch in 2005, will collect data on 3-dimensional distribution of clouds and aerosols and enhance our understanding of how the changes in these properties impact air quality.

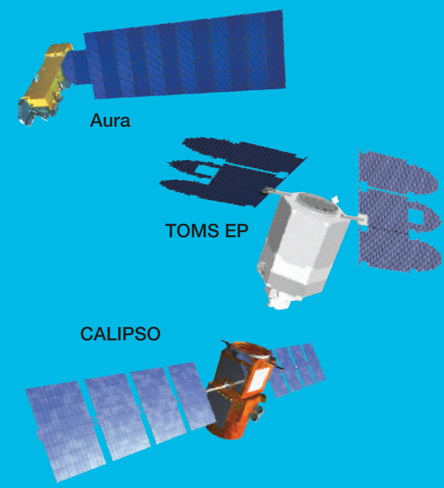
Over the next ten years, atmospheric chemistry models will use this increasingly detailed information from the NASA satellites to produce simulations that are more realistic and useful for prediction. This will lead to more accurate and increased-duration air quality forecasts. Within ten years, three-day atmospheric forecasts will be possible, along with routine warnings of air quality events such as unhealthful levels of ground-level ozone.

Air Quality Management



Earth Observation Systems

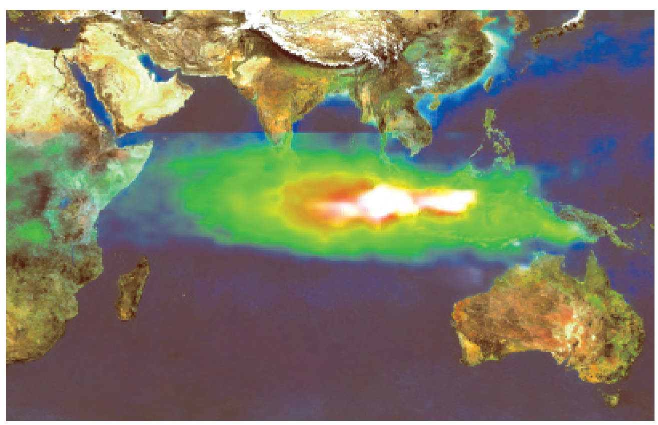
NASA Earth observations provide global measurements of key parameters for use in Air Quality Management.



Global Datasets and Models

Above left: Prediction of atmospheric aerosol movement—brown indicates higher aerosol concentrations, yellow indicates lower levels, and light blue indicates little or no aerosols.

Below: In the second half of 1997, smoke from Indonesian fires remained stagnant over Southeast Asia while smog spread more rapidly across the Indian Ocean toward India. Researchers tracked the transport of pollution using data from NASA's Earth Probe TOMS satellite. White represents the aerosols (smoke) that remained in the vicinity of the fires. Green, yellow, and red represent increasing amounts of low-altitude ozone (smog) being carried to the west by winds.



Decision Support

EPA uses NASA measurements and models through the CMAQ tool to support decisions in its regulatory programs.

Societal Impacts

Accurate air quality forecasts and informed regulation contribute to improved public health, crop health, and tourism.

Partners

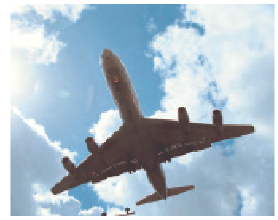
Environmental Protection Agency

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

Overview

To compete in the global economy of the 21st Century, the United States needs a healthy and vibrant aviation industry. Since weather is a contributing factor in about 30% of all aviation accidents, aviation meteorologists need accurate atmospheric data with improved temporal and spatial coverage. They also need timely, accurate data concerning volcanic eruptions and plume dispersion in order to route air traffic around these dangerous natural hazards.



The impact of weather and other natural phenomena upon aviation could be substantially mitigated if existing satellite observations were utilized more effectively. NASA is providing the frequent, densely distributed observations needed by the National Airspace System (NAS) to better mitigate impacts of natural hazards on aviation. NASA and its partners at the Federal Aviation Administration (FAA), the FAA's Aviation Weather Research Program (AWRP), the joint FAA/NASA Aviation Safety Program (AVSP), and the National Weather Service (NWS), are working diligently to make sure that information available from instruments on current and future satellite missions are used in operational forecasting techniques in a more timely fashion. Significant improvements in aviation safety are expected as a result of these cooperative activities over the next decade.

Improved aviation forecasts are critically dependent on accurate upper air observations (atmospheric temperature, humidity and pressure changes). Currently, balloon observations taken twice daily at just over 180 locations in the U.S. are the main source of information for initializing forecasts around the country. New NASA satellites are now dramatically increasing the number and resolution of these observations. The Terra and Aqua satellites both carry MODIS instruments which contribute a wealth of information relevant to aviation. Aqua also carries the AIRS instrument which provides temperature and humidity measurements of the atmosphere from space. The TRMM satellite obtains information on tropical/subtropical precipitation patterns. These measurements, together with improvements in aviation forecasting enabled by the NASA Short-term Prediction Research and Transition (SPoRT) Center and the NASA/NOAA Joint Center for Satellite Data Assimilation, are key to providing needed improvements in aviation weather forecasts.

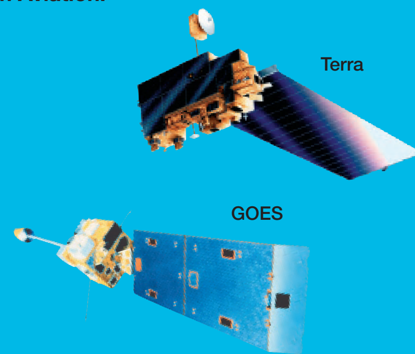
New capabilities are being developed by NASA for the coming decade. The GPM satellite constellation will succeed TRMM and contribute even more detailed information on global precipitation. NPOESS is the next generation of weather satellites, and includes a Visible/Infrared Imager Radiometer Suite (VIIRS) instrument, as a follow-on to MODIS, and the Cross-track Infrared Sounder (CrIS) instrument as a follow-on to AIRS. NASA is creating next generation instrument technologies that will enable continuous, rapid measurements of atmospheric temperature and humidity to enhance regional weather prediction in support of aviation weather forecasts. NASA and NOAA are working together to integrate this technology into the next generation Geostationary Operational Environmental Satellite (GOES-R).

All of this new information will be used in weather forecast models; and because the data used to create the forecasts will be more frequent and more precise, the resulting forecasts will be much more accurate, dependable, and useful for aviation applications.

Aviation

Earth Observation Systems

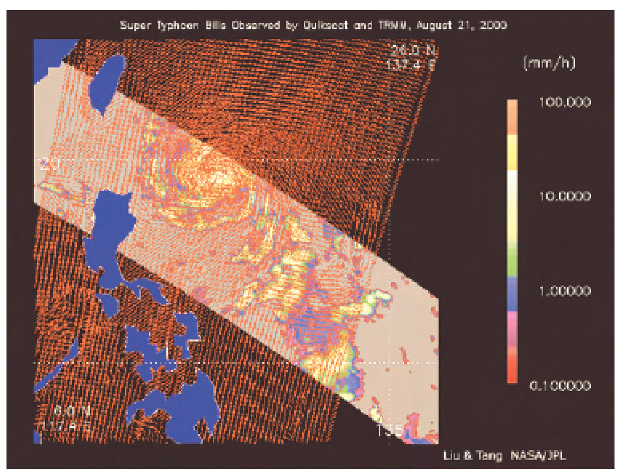
NASA Earth observations provide global measurements of key parameters for use in Aviation.



Global Datasets and Models

Above left: Depiction of severe and hazardous weather conditions globally—see hurricane in the Gulf of Mexico approaching the U.S.

Below: As super Typhoon Bilis, equal in strength to a Category 5 hurricane, bore down on Taiwan, this image from August 21, 2000, shows the massive storm's most devastating components: rain and wind. The image shows the surface winds, measured by the SeaWinds radar scatterometer (that can see through clouds), as red arrows. The wind data are superimposed on rainfall measurements made by the microwave imager on TRMM. The scale shows the amount of rainfall in millimeters per hour.



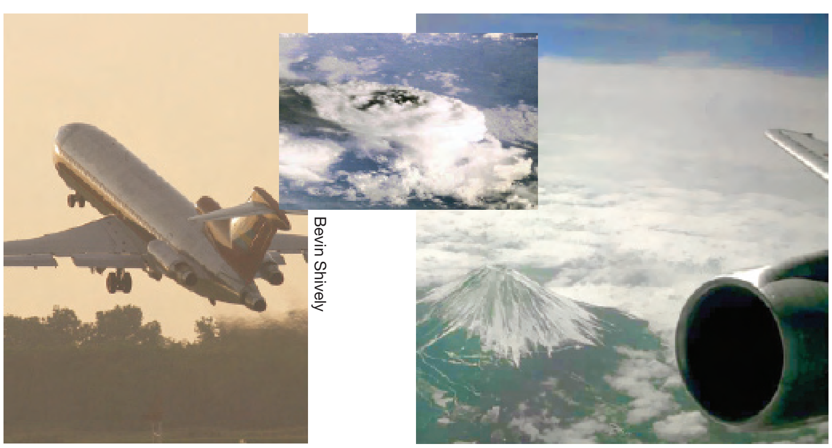
Decision Support

The National Airspace System continuously assimilates observations and predictions to monitor atmosphere characteristics important to aviation.

Joe Hendricks/DoD Photo

Societal Impacts

Augmenting the National Airspace System with NASA science supports improved safety and efficiency through earlier, more precise weather predictions.



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Partners

Federal Aviation Administration

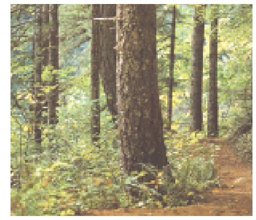
National Aeronautics and Space Administration

National Science Foundation

National Oceanic and Atmospheric Administration

Carbon Management

Overview



Carbon management is a key resource management and policy issue of the 21st Century. The atmospheric concentration of carbon dioxide (CO_2) increased by about 25% during the 20th Century, and it is continuing to increase in part due to the burning of fossil fuels and land cover and land use change practices. Increases in the atmospheric concentration of CO_2 and other greenhouse gases are likely to produce significant changes in global climate, and accompanying changes in the Earth's energy and water cycles. These changes will have profound impacts on the Earth's ecosystems and society.

New technologies for reduction of carbon emissions and storage of carbon deep underground or in the oceans are two principal options to achieve long-term reduction in the concentration of CO_2 in the atmosphere. As these technologies are being developed and applied, a reduction in the rate of increase in atmospheric CO_2 may be possible by increasing storage of carbon in soils, above-ground biomass and aquatic environments. Such carbon sinks currently absorb about 50% of the carbon emitted into the atmosphere annually.

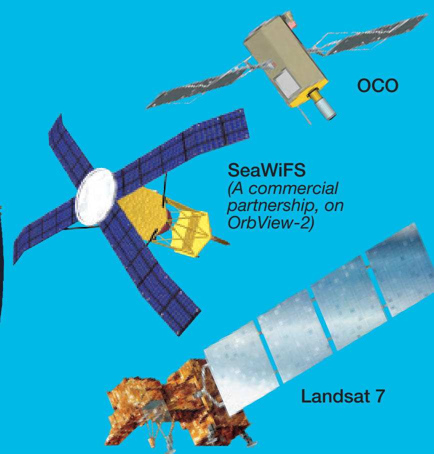
The NASA Earth Science Applications Division, through the carbon management program element, uses data and models to improve knowledge of carbon sources and sinks to help operational agencies fulfill their mandates to manage carbon and to support local, regional, national, and global policy and planning for control of carbon in the environment. NASA also collaborates with academic and government laboratories and operational agencies in the development, testing, and implementation of new technologies for measuring, monitoring, and validation of carbon management practices.

For example, NASA, the USDA, the Department of Energy (DoE), and the EPA cooperate in the development of guidelines for a voluntary program for sequestration of carbon in biomass and soils. The program, created under Section 1605(b) of the Energy Policy Act of 1992 (EPACT), "… affords an opportunity for any company, organization or individual to establish a public record of emissions, reductions, or sequestration achievements in a national database. Reporters can gain recognition for environmental stewardship, demonstrate support for voluntary approaches to achieving environmental policy goals, support information exchange, and inform the public debate over greenhouse gas emissions." Data from the MODIS instrument on the Terra and Aqua satellites are input into a model and an on-line decision support tool that will inform potential participants in the 1605(b) program of the carbon sequestration potential of their land and will allow managers of the 1605(b) program to monitor results.

Carbon Management

Earth Observation Systems

NASA Earth observations provide global measurements of key parameters for use in Carbon Management.



Decision Support

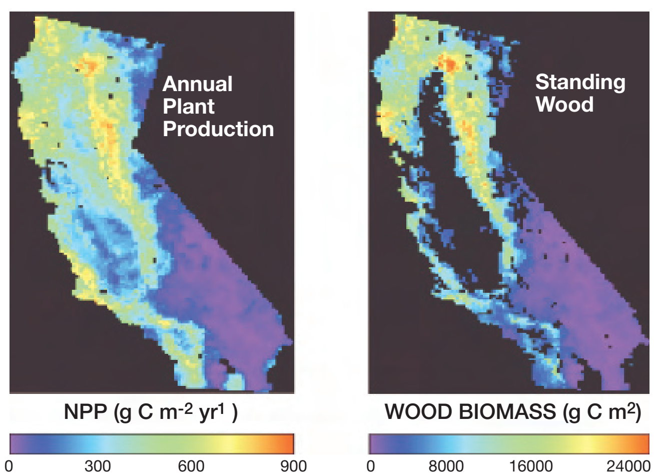
The CQUEST tool provides predictions of carbon sequestration to support carbon trading, forest management, and agricultural planning.

Charlie Rahm/USDA/NRCS photo

Global Datasets and Models

Above left: Global and regional models of surface carbon sources—red indicates fires, a source of carbon dioxide in our atmosphere, and possible changes in land use.

Below: “Baseline” predictions model. Models such as these can provide products for assessing potential for storage of carbon in above-ground vegetation.



C. Potter *et al*., NASA Ames Research Center

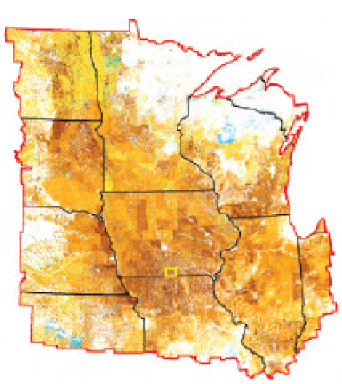
Societal Impacts

Informed carbon management enables more efficient energy production, aids climate change mitigation efforts, and improves agricultural efficiency.

Cumulative change in soil carbon from 1991 – 2000 caused by changes in tillage intensity and crop rotations.

Legend
Change in Soil Carbon (kg C/900m^2)

- MCI region
- State boundary
- -500 – -100
- -99 – 0
- 1 – 10
- 11 – 20
- 21 – 40
- 41 – 60
- 61 – 80
- 81 – 100
- 101 – 500
- 501 – 1,000
- 1,001 – 3,000
- Not cropland



T. West, Oak Ridge National Lab

Partners

Department of Energy

Environmental Protection Agency

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

United States Department of Agriculture

United States Geological Survey

Coastal Management

Overview

The Earth's coastal regions are a precious natural resource—the United States has over 95,000 miles of shoreline. In recent years, there has been a significant increase in the human population in these coastal areas. The coasts are also home for a wide variety of birds, animals, and vegetation. To assure the continued vitality of these coastal regions, we need to understand how human activities along the coast are impacting the natural ecosystems in these areas. In order to accomplish this, it is vitally important that we collect accurate and timely information that can help us understand how our coasts are changing with time and what impact these changes have on the larger global environment.

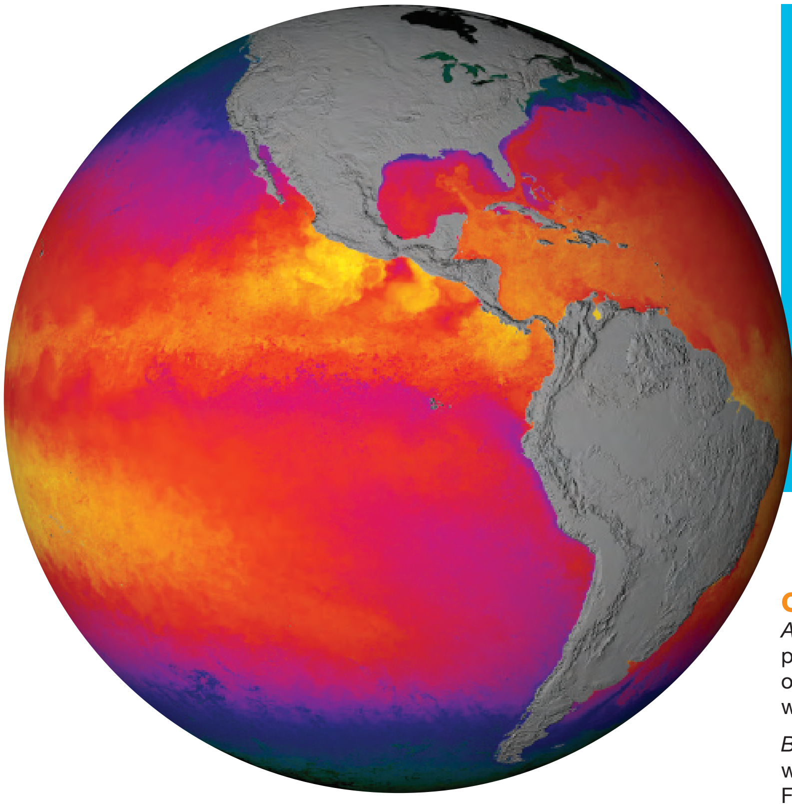
The Earth's coastal regions are affected by a number of natural phenomena. Sea level variability threatens both the natural environment and human activities along the coasts. The incidence of harmful algal blooms (HAB) and hypoxia has also increased probably due to excess nutrient concentrations from coastal runoff and reduced dissolved oxygen, which are affecting marine ecosystems and coastal economies. Over 7,000 square miles of the Gulf of Mexico are hypoxic—the largest swath in the Western Hemisphere.

NASA researchers are making significant contributions to understanding these potentially harmful phenomena and better quantifying how they impact coastal regions. NASA partners with the Naval Research Laboratory (NRL), the EPA and NOAA on these efforts. NOAA has developed models that simulate the oceanic environment and are used to forecast the occurrence of these harmful phenomena. These forecasts require data on environmental conditions such as sea surface temperature, sea surface height, salinity, etc., as input, and NASA's Earth science observatories routinely provide this type of information for NOAA to use in their analysis and advisory announcements.

NASA has a long heritage of providing observations for ocean research with satellites such as Terra and Aqua. Numerous other satellites provide additional important information for coastal management issues, including TOPEX/Poseidon, Jason-1, the Gravity Recovery and Climate Experiment (GRACE), the Ice, Clouds, and land Elevation Satellite (ICESat), and the SeaWinds instrument on QuikSCAT. These observations will continue in the coming decade by the next generation of weather satellites.

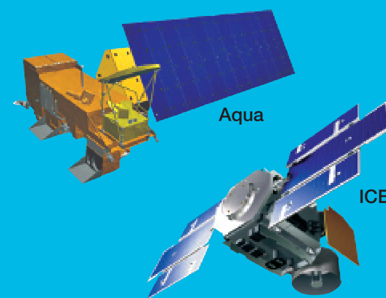
As the decade progresses and more information from NASA satellites are incorporated into coastal and ocean models, their ability to realistically simulate conditions in the Earth's seas will improve. As a result, predictions of sea level change will become increasingly detailed and accurate over the next few years. Similarly, by decade's end, it should also be possible to predict outbreaks of HAB and hypoxia several days in advance of their occurrence and to have much more detailed and accurate information about the severity and the duration of any given outbreak. These improved simulations become the input to decision tools used for coastal management decisions. Armed with this new information, coastal communities will be better prepared to plan for and mitigate the impacts of sea level change and other coastal hazards.

Coastal Management



Earth Observation Systems

NASA Earth observations provide global measurements of key parameters for use in Coastal Management.



Global Datasets and Models

Above left: Model of sea surface temperatures-purple indicates cold water upwelling near the coast of Peru in normal conditions. During an El Niño the waters off Peru are much warmer.

Below: In mid-December of 2002, a mysterious black water overtook the normally bluish green waters of Florida Bay as observed by NASA satellites. Over the course of the winter, the extent of the water grew to encompass an area as big as Lake Okeechobee, Florida. This true-color image was taken by MODIS on the Terra satellite on March 10, 2003, when the black water had started to disperse and drift toward the Florida Keys. Although no one yet knows what caused the discoloration, divers in the area have found dead sponges and coral, which are indicative of a toxic algae bloom.

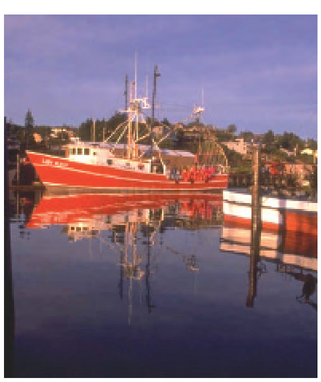
Decision Support

HAB, CREWS, and GNOME support management decisions regarding algal blooms, coral bleaching, and oil spills, respectively.

Scott Bauer/Agricultural Research Service/USDA

Societal Impacts

NASA enhancements to coastal decision support systems will bring added security to coastal fisheries and tourism and enable accelerated disaster mitigation.



Partners

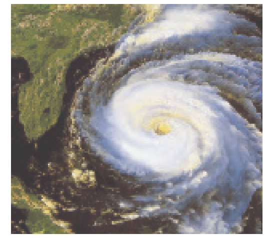
Environmental Protection Agency

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

United States Naval Research Laboratory

Overview



Each year, the U.S. government provides billions of dollars in aid to regions impacted by natural hazards. These may include severe thunderstorms, tornadoes, hurricanes, tsunamis, blizzards, flooding, volcanic ash plumes, wildfires, and earthquakes. Community planners need access to the most accurate and timely environmental information that is available to help them respond to these extreme events. They need to know how vulnerable their jurisdictions are to any of these phenomena in order to plan for proper response. They also need advanced warning to know when extreme weather events will occur, so that they can minimize their impact on society.

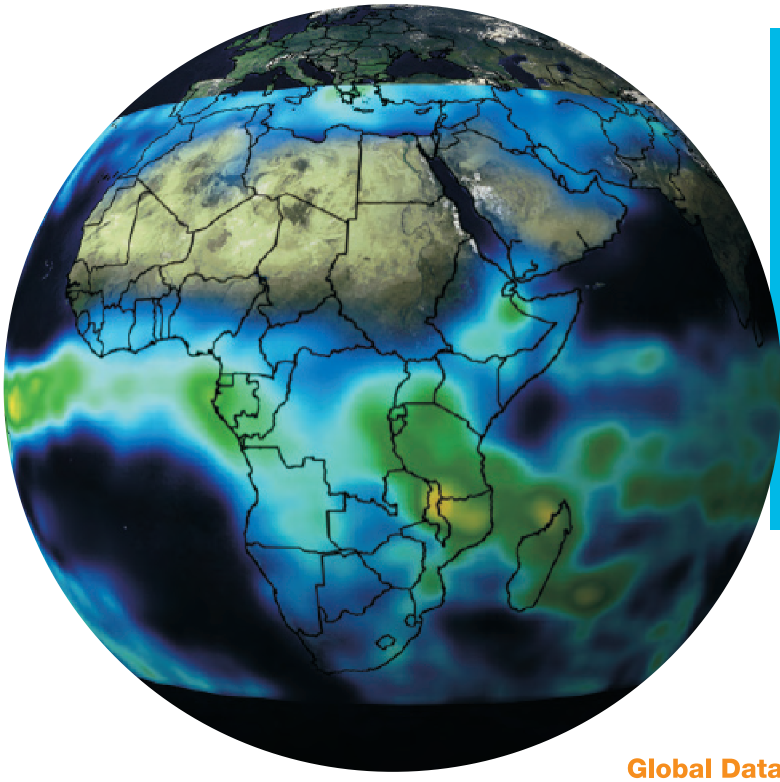
Correct forecasts and predictions of natural phenomena are vitally important to allow for proper evacuation and damage mitigation strategies. NASA works collaboratively with the Federal Emergency Management Agency (FEMA), NOAA, the USDA, and the U.S. Geological Survey (USGS) on this effort. NASA Earth science data are being incorporated into an improved decision support system created by FEMA to meet the requirements of planners, early warning systems and first responders, and to contribute to impact assessments, risk communication, mitigation, and implementation of relief efforts.

The MODIS Land Rapid Response System exemplifies how NASA data are making a difference in planning for and responding to disasters. This system was created to serve the need for quick access to products from the MODIS instrument, onboard the Terra and Aqua satellites, when disaster strikes. NASA collaborates with the University of Maryland, the USDA Forest Service (USFS), and NOAA to provide firefighters with the most up-to-date maps and satellite images from Terra and Aqua, to help them strategically plan their response to forest fires. After the fire is under control, land managers can use the information to assist them in planning for rehabilitating the burned area and for protecting water quality in the affected area.

Data from NASA satellites also make significant contributions in the area of hurricane and flood prediction. NOAA combines satellite-derived estimates of precipitation from the Defense Meteorological Satellite Program with precipitation from the TRMM satellite and wind velocity from the QuikSCAT satellite. Doing so substantially improves the accuracy of forecasts for landfall, track and intensity of hurricanes, and increases the lead time for warnings for both hurricanes and floods. More accurate forecasts, in turn, enable improved decision-making leading to more enhanced community preparedness for these types of events.

As data from additional satellites become available over the next few years, the forecasts mentioned above and others similar to them will be even more accurate and reliable, and increasingly useful for disaster management applications. Provided with such information, decision makers will be better equipped to respond to disasters when they occur. While they will not be able to stop extreme weather events from occurring, these improved forecasts should make it possible to significantly reduce the losses from weather-driven disasters over the course of the next decade.

Disaster Management



Earth Observation Systems

NASA Earth observations provide global measurements of key parameters for use in Disaster Management.

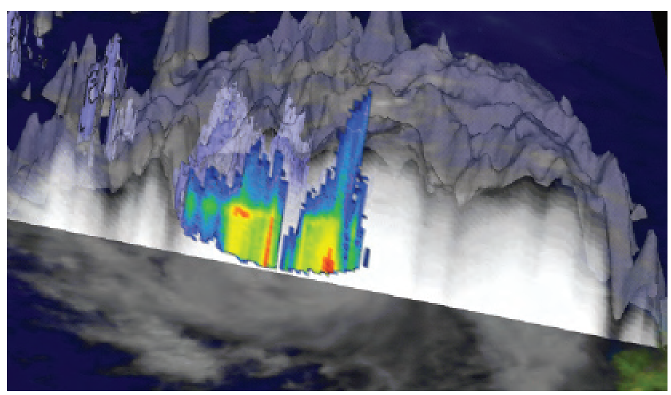
Global Datasets and Models

Above left: Global and regional precipitation and flood prediction—yellow represents more intense levels of precipitation, while green indicates lower levels.

Below: This TRMM overpass from the afternoon of October 23, 2002, shows the rain structure inside the rainbands and inner core of Hurricane Kenna, which was near the western Mexican coast. Red and yellow colors indicate the most intense rain. TRMM shows that the rainfall pattern is highly asymmetric, with most of the rain falling west of the storm center. TRMM also reveals that the tight, compact eye is well formed and is flanked by towering thunderstorm clouds. These towers, which are 16-17 km tall, contain the heaviest rains and act to energize the core of the storm, sustaining winds of nearly 140 mph.

Decision Support

NWS uses AWIPS to formulate prediction of weather and all hazards.



Societal Impacts

Predicting disaster effects helps agencies identify high-risk communities, cope with disasters, and plan new development to better withstand natural hazards.

FEMA News photo

Andrea Booher/ FEMA News photo

Partners

Federal Emergency Management Agency

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

National Weather Service

United States Department of Agriculture

United States Geological Survey

Ecological Forecasting

Overview

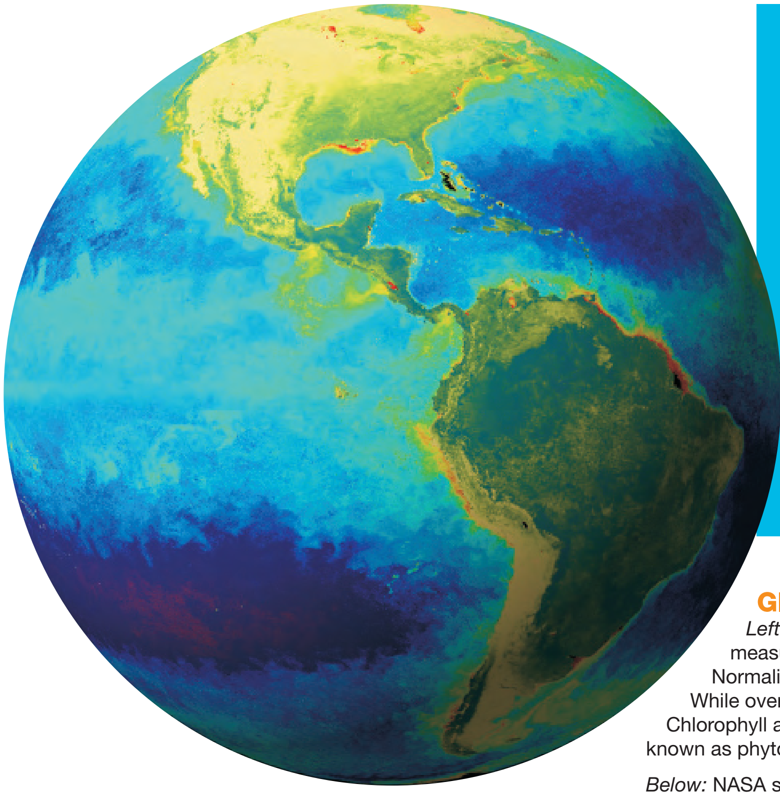
Ecological forecasting involves the use of Earth observations and models to predict the impacts of environmental changes on the ecosystems upon which we depend for our very existence. It links the physical world of climate and geology to the living world of biology and ecology. Our goal is reliable forecast models of changes in living systems with uncertainties and estimates of error explicitly stated. These models must span spatial scales from molecular to global, as well as take advantage of information across time scales to test and refine the accuracy of our predictions. Ecological forecasting requires a grand scientific synthesis across the domains of physics, geology, chemistry, biology, and societal practices. There will no doubt be limits to what we can forecast, but discovering these limits and their causes will only enhance our overall understanding of the ecosystems we select to manage and preserve. The decision support systems partner organizations develop will be vital to efforts to build our economies while at the same time sustaining the natural ecosystems that provide us with the essential services we tend to take for granted, such as: clean air, fresh water, fertile soils, waste removal, and biodiversity. NASA is currently involved in several international and domestic partnerships under the theme of ecological forecasting.

Located at the junction of North and South America and characterized by significant changes in elevation, Central America is a biological crossroads with seven to eight percent of the planet's biodiversity in less than one half of one percent of its land mass. NASA is partnering 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 regional visualization and monitoring system (known as SERVIR). SERVIR is a decision support tool that will assist the seven nations of Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) in developing a Mesoamerican Biological Corridor extending from southern Mexico to the Colombian border. The leaders of these nations established the Corridor in 1997 in an unprecedented effort to integrate their conservation efforts across international boundaries and promote sustainable development throughout the region.

SERVIR will combine satellite imagery with environmental and other data in a geographic information system and generate visualization products for decision makers to aid in ecosystem management. These products will reach users through a series of information nodes located in each of the participating countries. Imagery from the Aqua, Terra, and Landsat 7 satellites will be used to detect wildfires and major changes in land cover. Terra and TRMM data will allow scientists to track rainfall and weather patterns, while Sea-viewing Wide Field of view Sensor (SeaWiFS) and Landsat 7 data will be used to monitor coastal margins and coral reefs throughout Central America.

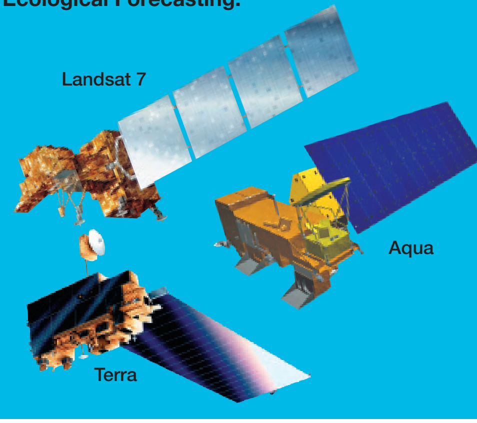
Other NASA activities in the field of ecological forecasting include working with several U.S. agencies and governments in Central Africa and around the world to support the Congo Basin Forest Partnership (CBFP). The CBFP seeks to conserve some of the world's richest tropical ecosystems while meeting the needs of the people of Central Africa for development. NASA also partners with nongovernmental organizations to examine the viability of national parks and other protected areas in this country and overseas. Part of this effort entails supplying Earth observation inputs to a decision support system that shows land managers, city planners, and developers how to minimize the impacts of development on natural ecosystems. With NASA support, NatureServe, a non-profit network connecting science with conservation, is implementing a decision support tool to help planners avoid those lands most important to biodiversity and other ecosystem services. An early prototype of this decision support system will focus on the Greater Yellowstone Ecosystem.

Ecological Forecasting



Earth Observation Systems

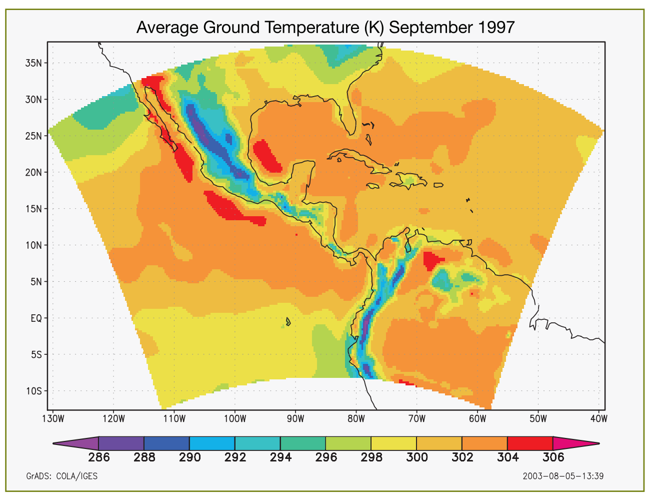
NASA Earth observations provide global measurements of key parameters for use in Ecological Forecasting.



Global Datasets and Models

Left: This image shows the global biosphere from June 2002 measured by SeaWiFS. Over land, SeaWiFS measures the Normalized Difference Vegetation Index, a proxy for plant growth. While over the oceans, SeaWiFS measures the concentration of Chlorophyll a, an important pigment in the microscopic marine plants known as phytoplankton.

Below: NASA scientists are using regional climate models to help understand the relationship between land use changes and past, present, and future climate in Central America. The simulation shown here examines the model's ability to simulate properly Central American surface temperature (depicted in degrees Kelvin for September 1997), as well as to help understand the global climate patterns that control it. NASA scientists are also making improved ecological forecasts by understanding the relationships between human-induced land use change and climate. For example, detailed studies of the land use history of the ancient Maya indicate patterns that may have contributed to the collapse of their civilization in this region over 1,000 years ago—considered to be one of the greatest demographic disasters in human history.



Decision Support

SERVIR monitors land cover, weather, ocean color, and fires in the Mesoamerican Biological Corridor, facilitating protected areas and fisheries management.

Societal Impacts

SERVIR will aid multinational efforts toward preserving ecosystems, halting illegal logging, and predicting impacts of ecosystem change on human activity.

Scott Bauer/Agricultural Research Service/USDA

Partners

Central American Commission for Environment and Development

Federal Emergency Management Agency

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

The World Bank

United States Agency for International Development

United States Department of Agriculture

United States Geological Survey

Overview

The nation depends on stable and reliable sources of energy to meet the demands of its citizens. Traditionally, much of this demand has been met by burning fossil fuels such as oil, coal, and natural gas, but in recent years, concerns have arisen about the environmental impacts of fossil fuel emissions, and alternative sources of fuel have been explored. Nuclear energy has been put forth as a cleaner alternative and used successfully in a few places, but this source is not without its own set of environmental concerns. Other alternatives to fossil fuels are now emerging, including renewable energy technologies (RETs) like solar energy and wind power and biomass fuels such as corn-based ethanol and other species under development. These alternative fuel sources can help reduce our dependence on fossil fuels and, at the same time, will help to improve the quality of air we breathe.

However, for RETs to obtain their fullest potential, planners require very detailed climatic data. A traditional weather data report, consisting of air temperature, precipitation, humidity, and wind, is no longer sufficient. Planners need to know precise details about the makeup of the incoming solar radiation and the actual temperature at the surface. Not only must the information be accurate and timely, it is most helpful if it can be collected on a global scale. To date, the energy sector has based their decisions on where to locate energy producing technology, such as RETs, using historical climatic information only—the idea being that the past conditions give some idea of how the location will fare in the future. However, it is much more desirable to know how the conditions at a chosen location are likely to vary and change with time. NASA and its partners at the Department of Energy (DoE), the DoE's National Renewable Energy Laboratory (NREL), NOAA, and the USDA are working to respond to these needs.

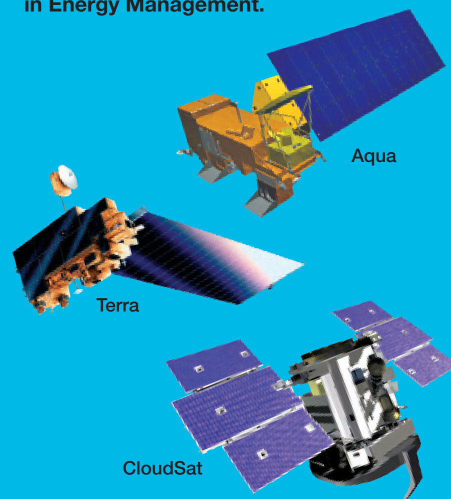
NREL has a decision support tool to help policy makers tackle these difficult questions. The simulation takes all of the environmental parameters provided by models developed by NASA and other partners as input, and outputs energy forecasts that can be used to plan for the optimal location of a new solar energy grid, optimal positioning of a new building to take advantage of incoming solar radiation, or other types of information related to energy resource planning.

NASA makes significant contributions in natural energy management by sponsoring research and developing satellites to understand the Earth's energy and water cycles on a regional and global scale. The primary instrument used for these studies is the Clouds and the Earth's Radiant Energy System (CERES) sensor, which flies on both the Terra and Aqua satellites, and studies major elements of Earth's energy balance, aiding climate change studies. In addition to CERES, the Aqua mission carries an entire sensor package dedicated to studying water in the Earth's system, and the TRMM satellite contributes extensive information on precipitation. The GPM mission, planned for later this decade, will utilize a constellation of satellites to provide even more comprehensive information on global precipitation patterns than TRMM. Two other future satellites will also make important contributions to improved energy forecasting. The CloudSat satellite will collect a comprehensive inventory of clouds and study their impacts on climate in unprecedented detail, and the CALIPSO will study the role that aerosols play in regulating Earth's weather and climate. Better understanding of the role that clouds and aerosols play in regulating climate will have profound implications for energy forecasting efforts. With all of its current and future satellites, NASA is able to collect data on important parameters for energy forecasting over the entire globe. This information especially supplements existing surface measurement networks and data information products, and also provides data where none are available.

Energy Management

Earth Observation Systems

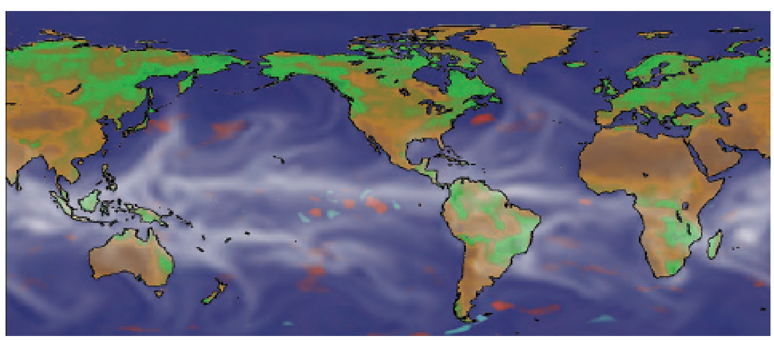
NASA Earth observations provide global measurements of key parameters for use in Energy Management.



Global Datasets and Models

Above left: Prediction of population trends and concentrations, which in turn can aid in prediction of energy use—night lights in North and South America are an indication of population density.

Below: This image represents a recent prediction made by a sophisticated new computer model. Developed by NASA's Seasonal-to-Interannual Prediction Project (NSIPP), this model actually links together three models in one: one each for geophysical dynamics within the atmosphere, oceans, and lands. The colors in the ocean represent a departure from average surface temperature. Red shows where the model predicts there will be warmer-than-average temperatures, light blue shows cooler-than-average temperatures, and dark blue is average. The colors on land represent variation in soil moisture. Orange and brown hues show where the model predicts the soil will be dry; greens show where it will be wet.



Decision Support

EPRI uses a decision support tool to model power grid load, and RETScreen maintains an energy proposal analysis tool that draws on NASA observations.

David Parsons/DOE/NREL photo

Societal Impacts

Energy decision support tools help to optimize renewable energy use, reduce the frequency of power shortfalls, and secure energy prices.

Partners

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

United States Department of Agriculture

Department of Energy

Homeland Security

Overview

Efforts to protect our nation's internal security have redoubled since the September 11, 2001, terrorist attacks. The nation's air and water resources, physical infrastructure, and national borders could be particularly vulnerable to future attacks. Contamination and disruption of these national resources would have profound consequences for society. Thus, it is essential that proactive monitoring and forecasting efforts be implemented to minimize vulnerability in these areas.

For Homeland Security efforts to be most effective, collaboration between Federal agencies is essential. NASA collaborates with a number of Federal partners, including the newly formed Department of Homeland Security (DHS), the National Geospatial-Intelligence Agency (NGA), the Department of Defense (DoD), FEMA, NOAA, and the USGS. NASA's sponsored research, satellites, and computer models can provide data and information to Homeland Security networks run by DHS to support risk, vulnerability, and mitigation assessments. These data and information can support decision making to ensure the adequacy of preparing for, preventing, responding to, and recovering from any threat on our nation's infrastructure.

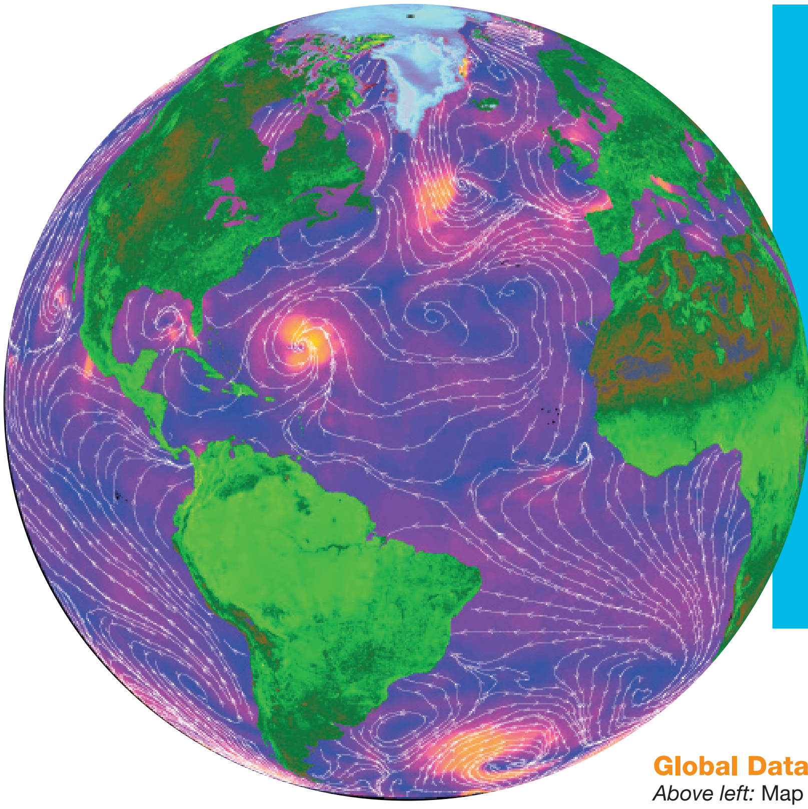
Knowledge of Earth's water cycle is a critical first step in protecting our water supply. Precipitation is the primary source of water on the land surface and thus defines the terrestrial water cycle. Soil moisture is also an important surface boundary condition for weather and climate prediction and in land surface models. Groundwater fluctuations are also extremely important to understand; underground aquifers are vital to maintaining the viability of certain arid or semi-arid locations and they must be protected from contamination. Water flows over the Earth's surface in oceans, lakes, and streams, and is particularly vulnerable to threats.

NASA satellites provide a wealth of information about the Earth's water cycle. The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) on Aqua and the GRACE satellite contribute to improving our ability to monitor water resources and water quality from space. In addition, the GPM satellite planned for later this decade should contribute a wealth of new information on precipitation distribution, amount, and fresh water resources.

We must also protect the quality and safety of the air we breathe. Airborne contaminants can pose danger to human health. Chemical, nuclear, radiological, and biological threats are a potential reality. Although traditional air monitoring efforts have focused on *in situ* sampling and limited airborne monitoring, new technologies such as hyperspectral and ultra-spectral sensors, cloud penetrating radar, and lidar show promise for improved monitoring from space. These technologies will be deployed on upcoming NASA satellites such as Aura, CloudSat, and CALIPSO.

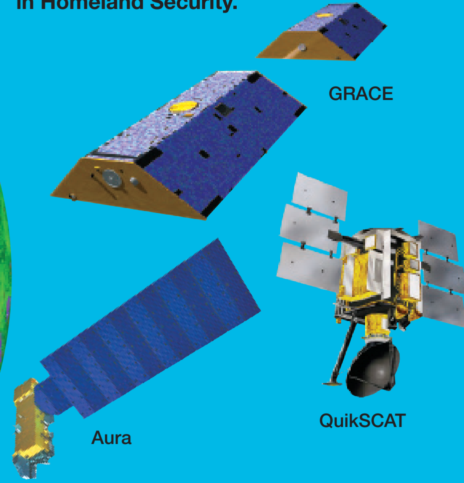
The combination of adequate water resource monitoring from space and global scale air quality measurements will provide enhanced data that will lead to improved decision making for natural resource management and emergency response, thus enabling a better response to future homeland security threats.

Homeland Security



Earth Observation Systems

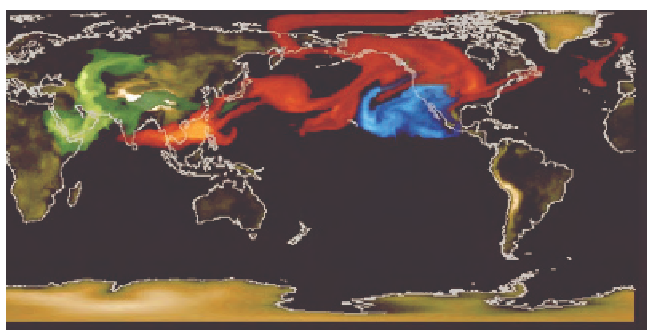
NASA Earth observations provide global measurements of key parameters for use in Homeland Security.



Global Datasets and Models

Above left: Map of ocean winds based on SeaWinds data from the QuikSCAT satellite—the large storm off the Florida coast is Hurricane Gert; Tropical Storm Harvey is in the Gulf of Mexico; and Tropical Storm Hilary is in the Pacific.

Below: Plume dispersion modeling with the computer-generated NASA finite-volume General Circulation Model (fvGCM). This model is a numerical approximation of the fundamental physical, dynamical and chemical processes of the atmosphere that contribute to the transport of gases across the globe.



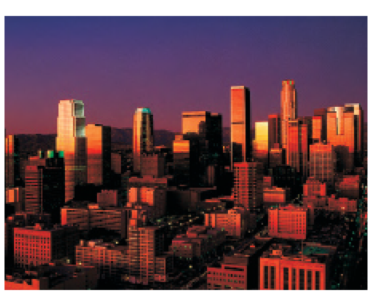
Decision Support

DHS, through its Interagency modeling and atmospheric assessment center (IMAAC), models air plumes to support control of toxic agents, should they enter into the atmosphere.

Societal Impacts

By systematically modeling the effects of numerous natural and human-induced disasters, planners can reduce cost and loss of life in the event of a disaster.

Andrea Booher/FEMA News photo



Partners

Department of Defense

Federal Emergency Management Agency

National Aeronautics and Space Administration

National Geospatial-Intelligence Agency

National Oceanic and Atmospheric Administration

United States Department of Homeland Security

Environmental Protection Agency

Nuclear Regulatory Commission

Overview

The introduction and dissemination of non-indigenous species is a major economic, environmental and health concern in the 21st Century. Such invasive species include; 1) diseases such as malaria and West Nile Virus; 2) agricultural pathogens; and 3) plants and animals that compete with and replace native species, with a resulting degradation of the environment and decline in economic productivity.

The number of species introduced into the United States each year is in the thousands. The cost to the U.S. economy to monitor, contain, and control these species is estimated at $100-200 billion per year—an annual cost greater than that for all natural disasters combined. The rate of introduction of invasive species is increasing through the movement of plant, animal and disease organisms that accompanies globalization.

The response to invasive species is shared by a broad community including local, state, and federal agencies responsible for land management and public health, the agricultural industry, conservation organizations and private landowners. Because the cost of control and eradication of invasive species is prohibitive once a species is well established, a primary focus of response programs is to predict where invasive species are likely to appear next so that control measures can be applied when the cost is low and success probable.

NASA is applying its capabilities in Earth science to assist the USGS, the USDA and the National Invasive Species Council in responding to invasive plants. NASA assistance is focused in three areas:

1) Earth observation data from NASA satellites and model outputs for monitoring land cover and climate are being combined with ground data supplied by the agencies responsible for invasive species control to identify the "corridors" where invasive plants are likely to spread;

2) NASA's computational capabilities are being utilized to develop systems to generate predictive maps for invasive species quickly; and

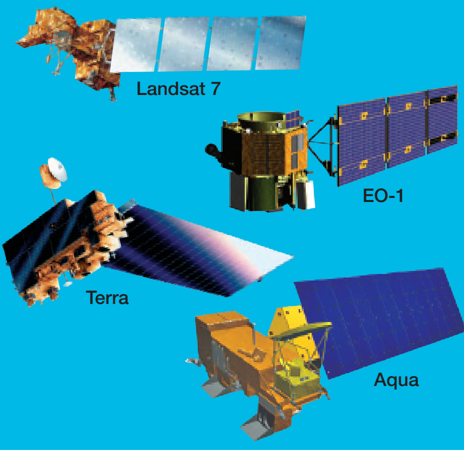
3) NASA scientists are participating in the development of an on-line Invasive Species Forecasting System that will provide the user community ready access to these tools for making maps specific to their geographic area and invasive plant concerns. The Invasive Species Forecasting System will be an interactive and flexible tool to help public and private users respond to the threat of invasive plant species.

NASA's Earth Science Division is the primary source of Earth observation data for the Invasive Species Forecasting System. Observations and measurements from the Terra, Aqua, QuikSCAT, Landsat 7 and other satellites provide key ecosystem parameters for prediction of invasive species distributions. In the next decade, information from NASA satellites will improve the accuracy and timeliness of climate, weather and ecological forecasts and support cost-effective responses to invasive plant species.

Invasive Species

Earth Observation Systems

NASA Earth observations provide global measurements of key parameters for use in the monitoring of Invasive Species.

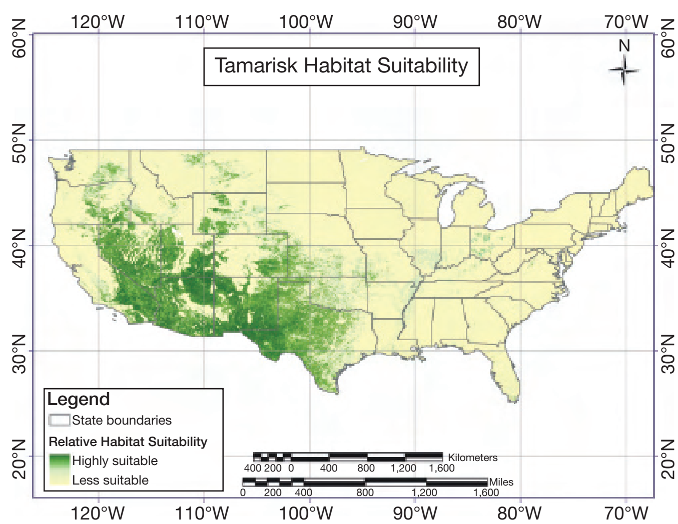


Global Datasets and Models

Left: Map of vegetation—grasslands, woody savannas, savannas, and wetlands are all shown in green. The time series information provided by satellites help model those areas that provide suitable habitat for a given species.

Below: This is an example of a national map of Saltcedar (Tamarisk) habitat. Saltcedars are fire-adapted species that intercept deep water tables and interfere with natural aquatic systems. Saltcedar disrupts the structure and stability of native plant communities and monopolizes limited sources of moisture, increasing the frequency, intensity, and effect of fires and floods.

Lower left: Remote Sensing data are associated with field-based measurements to test and ensure the accuracy of the habitat models.



Decision Support

Decision makers are using the joint USGS/NASA Invasive Species Forecasting System (ISFS) to manage grazing, water sourcing, fishing, and tourism according to probable invasive species outbreaks.

Anthony Sanchez/CDC photo

Societal Impacts

Systematic, NASA-supported species monitoring reduces population control costs and helps mitigate species-induced environmental degradation.

Partners

National Aeronautics and Space Administration

United States Department of Agriculture

United States Department of Interior

Overview

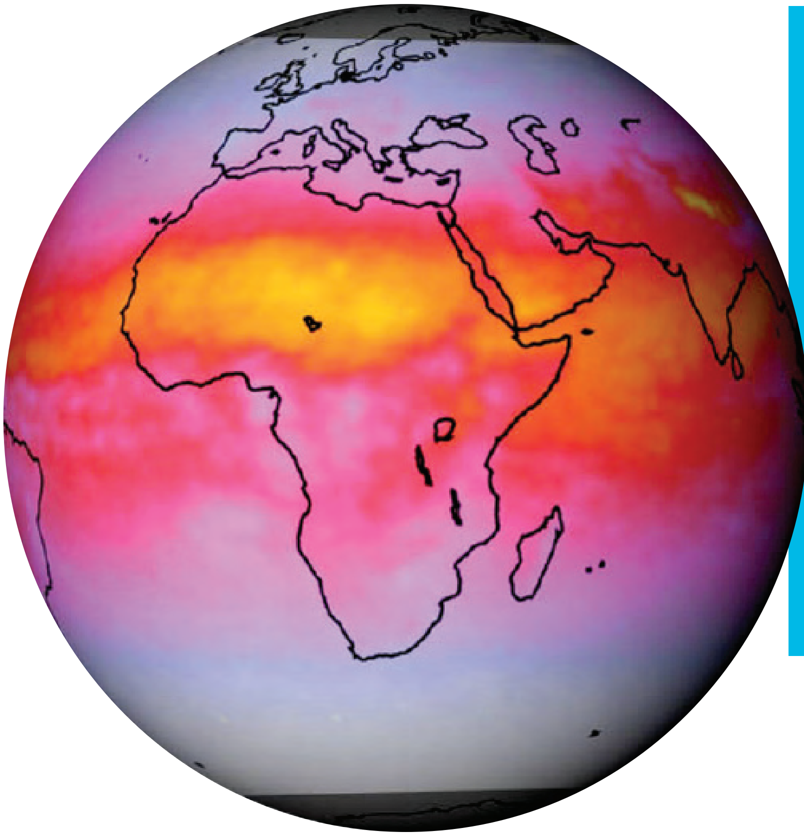
Many chronic and infectious diseases are related to environmental conditions. Recent outbreaks of West Nile Virus and other vector-borne diseases have illustrated the importance of having accurate and timely information to predict and respond to epidemics. Organisms such as ticks and mosquitoes (called vectors) transport these diseases, and variability in rainfall and temperature has a major influence on the distribution and quantity of these pests.

High concentrations of ground level ozone, particulate matter, and/or other atmospheric pollutants can worsen respiratory diseases such as asthma and emphysema. The Center for Disease Control and Prevention (CDC) maintains decision support systems for public health that provide vital information on these conditions and allow for the prediction of disease outbreaks. These systems address the need for surveillance, or “the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding health related events for use in public health action.” NASA provides observations and predictions to help its partners correlate the incidence frequencies of chronic and infectious diseases to weather, climate and other key environmental factors. Once verified, validated and benchmarked, these relationships can be assimilated into surveillance systems such as the Environmental Public Health Tracking Network to track and predict disease. Other partners, such as the National Institutes of Health (NIH), and the EPA are part of this effort.

NASA’s satellites offer a wealth of environmental information for input into the decision support systems used for public health. The Terra, Aqua, and Landsat 7 satellites return information on such factors as vegetation, forests, flooding, wetlands, soil moisture, surface ultraviolet radiation and surface temperatures. For example, both the Terra and Aqua satellites carry the MODIS instrument, which contributes important information on weather and climate contributions favorable to vectors. In addition, the TRMM satellite also provides important data on precipitation, which can be used to study different habitats.

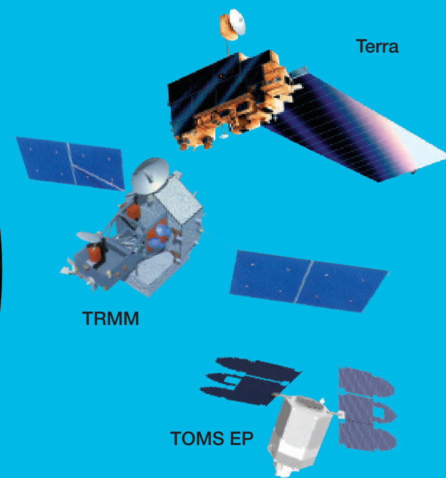
Future satellites are planned that will return environmental information related to public health issues, most notably GPM and future-generation weather satellites.

Public Health



Earth Observation Systems

NASA Earth observations provide global measurements of key parameters for use in the monitoring of Public Health.



Global Datasets and Models

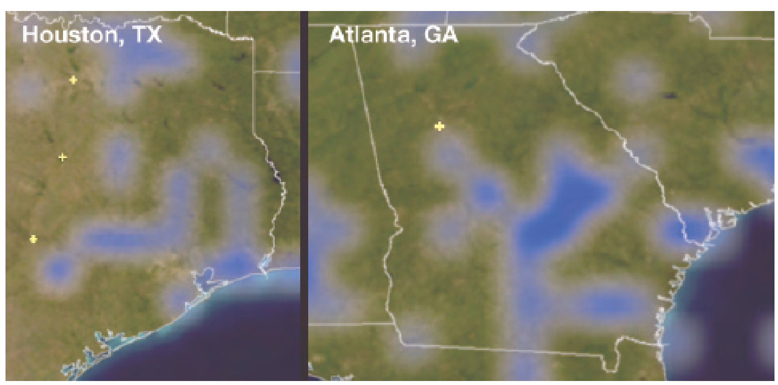
Below left: Map of global ultraviolet radiation levels—yellow indicates high levels of radiation, red and pink indicate intermediate values, and white indicates little or no UV exposure.

Below: Using the world's first space-based rain radar aboard NASA's TRMM satellite, NASA scientists found that mean monthly rainfall rates within 30-60 kilometers (18 to 36 miles) downwind of some cities were, on average, about 28 percent greater than the upwind region due to urban heat islands. In some cities, the downwind area exhibited increases as high as 51 percent. These examples show precipitation to the southeast of Houston, Texas and Atlanta, Georgia.

Decision Support

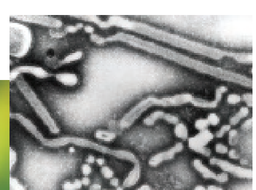
The Rapid Syndrome Validation Project and Malaria Surveillance tools will use NASA observations and disease vector ecology to identify vector habitats.

CDC photo



Societal Impacts

Tracking disease vectors allows public health managers to effectively target prevention efforts and predict conditions that favor vector proliferation.



Partners

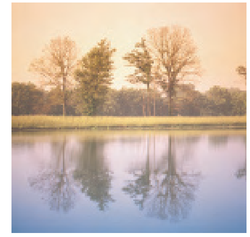
Centers for Disease Control and Prevention

Department of Defense

National Aeronautics and Space Administration

National Institutes of Health

Overview



Viewed from above, our home planet stands out—a "blue marble" set against the vast blackness of outer space, with an abundance of water on its surface. Yet, only a small amount of this water is fresh and suitable for consumption by plants, animals and humans. Monitoring the surface and ground water supply is a vital societal need. Surface water includes both flowing water in streams and rivers, and impounded water in natural lakes, polar ice caps, and human-made reservoirs. Ground water includes the large amounts of water stored beneath the Earth's surface in aquifers—vitally important to the viability of agriculture in drier climates. It is important to determine where supplies of fresh water are located, to quantify how much water is available, and to figure out how fast the water supply is increasing or decreasing. Increased demand threatens to deplete these precious water resources and accurate information on water availability (e.g., from surface reservoirs, snowpack, underground aquifers, etc.) is needed in order to meet the water resource needs of an ever-growing population.

Not only must society concern itself with having water in sufficient quantity, but it also needs to ensure the quality of the available water. Potable water quality issues impact every region of the country and while pollution from point sources has been identified and is relatively well characterized, non-point-source pollution is a much more difficult problem. There are also issues of intermittent flow, and the relation to the variability in stream flow rates that are still not well understood. In addition, underground aquifers must be better characterized in terms of their location, recharge rate, and the potential for having contaminated surface water leech into these underground water reserves. Improvements in water quality monitoring are needed and can benefit from NASA Earth science information.

The MODIS and CERES instruments on the Terra and Aqua satellites are helping to refine our estimates of the Earth's surface energy balance, which helps to improve our understanding of evaporation over the Earth's surface. The AMSR-E instrument on Aqua is enabling measurement of changes in surface soil moisture and proper representation of these processes in atmospheric circulation models. The TRMM satellite monitors tropical/subtropical precipitation patterns. The GRACE satellite tracks changes in water storage beneath the surface layer and should help us track water storage changes over the continents. Supplemented by other information, these data should allow us to monitor aquifer water storage changes from space. The GPM mission, a successor to TRMM, and future-generation weather satellites will lead to steady improvements in water quantity assessments.

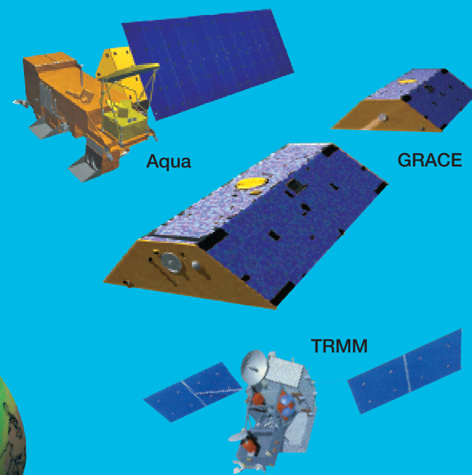
The Landsat 7 satellite and the Hyperion instrument on the Earth Observing-1 (EO-1) satellite obtain visual images of the surface of the Earth that can be analyzed to track changes in water quality over time. The Landsat Data Continuity Mission (LDCM), a joint NASA/USGS mission, will continue the long-term Landsat data record, and enhance our capabilities to remotely sense water quality in the coming years.

Incorporating all of this information into decision support systems will lead to improved capability to predict water availability, protect water quality, and plan for water conservation. Many agencies, including the U.S. Department of Interior's Bureau of Reclamation (BoR), the EPA and the USDA, will benefit from these improvements to decision tools used for water management.

Water Management

Earth Observation Systems

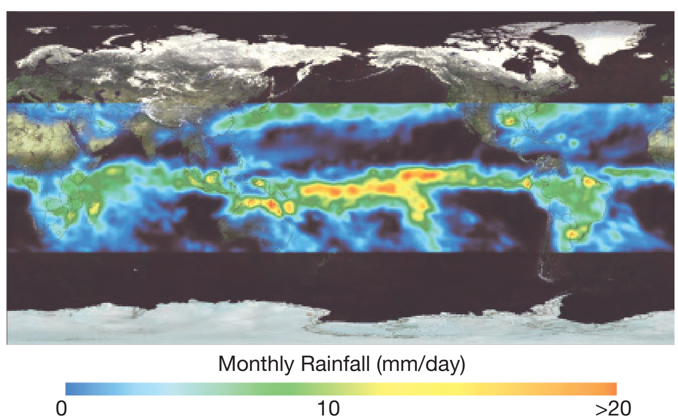
NASA Earth observations provide global measurements of key parameters for use in Water Management.



Global Datasets and Models

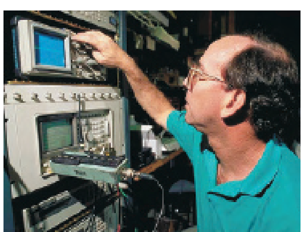
Above left: Monitoring changes in the storage of water on the continents—fluctuations of surface and subsurface waters can affect gravity, which in turn can be measured from space.

Below: This image shows a monthly average of rainfall measurements taken by the TRMM's unique precipitation radar during January 1998. Areas of low rainfall are colored light blue, while regions with heavy rainfall are colored orange and red.



Decision Support

BASINS models watersheds, supporting analysis of management alternatives for point and non-point pollution sources.



Societal Impacts

NASA contributions to BASINS will improve water management efficiency, increase water available for irrigation, and improve wildlife habitat management.

Scott Bauer/USDA photo

Partners

Environmental Protection Agency

National Aeronautics and Space Administration

United States Department of the Interior

United States Department of Agriculture

Acronyms & Abbreviations

AIRS	Atmospheric Infrared Sounder
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AVSP	Aviation Safety Program
AWRP	Aviation Weather Research Program
BASINS	Better Assessment Science Integrating point and Nonpoint Source
CADRE	Crop Assessment Data Retrieval and Evaluation
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CBFP	Congo Basin Forest Partnership
CCAD	Central American Commission for Environment and Development
CDC	Center for Disease Control and Prevention
CERES	Clouds and the Earth's Radiant Energy System
CMAQ	Community Multiscale Air Quality Modeling System
CQUEST	Part of the Energy Policy Act of 1992, Section 1605(b)
CREWS	Coral Reef Early Warning System
CrIS	Cross-track Infrared Sounder
DHS	Department of Homeland Security
DoD	Department of Defense
DoE	Department of Energy
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
fvGCM	finite-volume General Circulation Model
GNOME	General NOAA Oil Modeling Environment
GOES-R	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement satellite
GRACE	Gravity Recovery and Climate Experiment
HAB	Harmful Algal Bloom bulletin/mapping system
HAZUS-MH	Hazards U.S. - MultiHazards
ICESat	Ice, Clouds, and land Elevation Satellite
ISFS	Invasive Species Forecasting System
MISR	Multi-angle Infrared Scanning Radiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements Of Pollution In The Troposphere
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRL	Naval Research Laboratory
NREL	National Renewable Energy Laboratory
NSIPP	NASA's Seasonal-to-Interannual Prediction Project
NWS	National Weather Service
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SPoRT	Short-term Prediction Research and Transition center
RETs	renewable energy technologies
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measuring Mission
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USFS	USDA Forest Service
USGS	U.S. Geological Survey
VIIRS	Visible/Infrared Imager Radiometer Suite