



2011 | ANNUAL REPORT

NASA Earth Science
Applied Sciences Program





Lawrence Friedl, Director, Applied Sciences Program

Welcome to the NASA Applied Sciences Program's 2011 Annual Report. The year was a productive, successful one for Applied Sciences. We invite you to read and learn about ways we advanced the use of Earth observations in innovative and practical applications. This report captures some of our achievements, summarizes progress on our programmatic changes, and describes new initiatives.

Looking back at 2011, our projects provided societal benefits in addressing newsworthy events and enhanced routine decision making. For example, a project delivered NASA data products to help the response to the 2011 Tohoku earthquake and resulting tsunami. The National Marine Fisheries Service in NOAA used data from the *Jason*, *Aqua*, and *Terra* satellites to classify spawning areas for Atlantic bluefin tuna and to support its recommendations on stock assessment and management. The U.S. Coast Guard applied ocean models and data from *OSTM/Jason-2* and *Aqua* to aid its search and rescue activities on the U.S. West Coast.

This past year was significant for the Water Resources Applications area and for DEVELOP, our program for young professionals. The Water program integrated *GRACE* data products into the U.S. Drought Monitor. Under American Recovery and Reinvestment Act funds, it delivered results on a project using *Terra*, *Landsat*, and *Aqua* data to assess crop water needs and optimize irrigation management. It also ran numerous workshops. DEVELOP had record numbers of applicants, interns, and projects: 259 young professionals participated across the three terms. DEVELOP received a NASA Group Achievement Award, and three DEVELOP interns won prestigious invitations to speak at the International Astronautical Congress' youth plenary in Cape Town. DEVELOP also opened new centers in Missouri and Colorado to expand its national scope.

In 2011, Applied Sciences implemented changes we initiated in recent years. Inside, you can learn about progress in engaging users in satellite mission planning, use of the new Applications Readiness Level as our performance measure, creation of new Applied Sciences teams, support to climate risk assessment and adaptation strategies, and pursuit of socioeconomic impact analyses of our projects.

We also tried some new things in 2011. Applied Sciences sponsored the inaugural Global Humanitarian Technology Conference. DEVELOP initiated a new online, virtual poster session for its projects as well as a video contest for project results. We organized a solicitation across five federal agencies. Applied Sciences also sponsored an Ignite-style event at the American Geophysical Union's annual conference.

I'm proud of the work and leadership of the Applied Sciences staff at NASA Headquarters and Centers in 2011 and during the programmatic changes of the past few years. On behalf of NASA, we appreciate the project teams and our partners for their creativity, energy, and dedication to apply Earth observations to benefit society.

We want to highlight Sarah Burgess-Herbert, who was a AAAS Science & Technology Policy Fellow with Applied Sciences in 2010–2011. We are extremely grateful for her hard work and the contributions she made during her time with us. We wish her all the best in her future endeavors.

As we look to future projects and opportunities, we're excited about the many possibilities we see to enable the use of Earth observations in benefiting our nation and the world.

To learn more about the Applied Sciences Program, visit <http://AppliedSciences.NASA.gov>.

The Applied Sciences Program is part of the Earth Science Division of the NASA Science Mission Directorate.



FEATURED PROJECTS AND EVENTS	5
Enhancing Drought Monitoring in North America	6
Improving Management of Atlantic Bluefin Tuna	8
Supporting Effective Search and Rescue Missions	10
Aiding Irrigation Management in California	12
Assisting in Earthquake Response and Disaster Management	14
Building Capabilities in Applying Earth Observations	16
Developing Future Voices in Space and Earth Science	17
Assessing the Utility of NASA Earth Science Satellites	18
Igniting Audiences on Earth Science Applications	19
Launching New Satellites and Potential Applications	20
Tracking Air Quality for Better Public Health	22
Increasing Emergency Management Capacity for Decision Making	24
APPLICATIONS AREAS AND CAPACITY BUILDING ACTIVITIES	27
Applications Areas	28
Serving Air Quality Managers and Decision Makers	32
Improving Natural Resource Management in Response to Climate Change	33
Water Resources Workshops	34
Capacity Building Activities	36
Supporting Climate Assessment and Adaptation Planning	40
APPLIED SCIENCES PROGRAM MANAGEMENT	43
Achieving Program Goals	44
Quantifying the Benefits of Earth Observations	45
Exploring Science and Policy Connections	47
Engaging Users in Satellite Mission Planning	48
Collaborating across NASA's Earth Science Division	52
Looking Ahead	56
Acronyms	59

Definitions of some acronyms appear in the text; others appear in the acronym list on page 59.





Featured Projects and Events

The Applied Sciences Program supports efforts to discover and demonstrate innovative and practical uses of NASA Earth science and satellite observations. The following projects and events showcase the use of Earth observations in ways that provide societal and economic benefits.





Enhancing Drought Monitoring in North America

An Applied Sciences project integrated data from the *Gravity Recovery and Climate Experiment (GRACE)* satellite mission to improve the U.S. Drought Monitor. Managers and government officials use maps from this premier drought monitoring tool to better manage limited water supplies and distribute drought aid where it is needed most.

Applying Data from Satellites

The National Drought Mitigation Center (NDMC) produces official drought maps and products on a weekly basis. The NASA-funded project, led by NASA hydrologist Matt Rodell, developed new drought indicators using Earth observations from *GRACE*, ground data, and other satellites; these indicators are now part of the NDMC's routine production.



GRACE—a pair of satellites that orbit in tandem about 285 miles above the ground—detects very small variations in the Earth's gravitational field. The variations are used to determine changes in the total amount of water stored both on top of and below the land surface, including snow, surface waters, soil moisture, and groundwater. Having a complete picture of these water types enables better classification of drought severity.

Rodell's team combined *GRACE* data with other observations—including precipitation, temperature, and

An innovative application of Earth observations improved the U.S. Drought Monitor and the classification of drought severity.

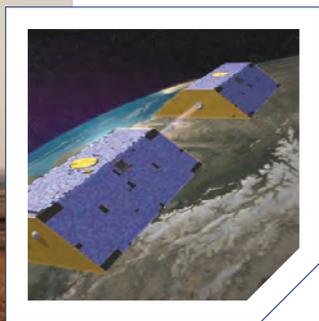
solar radiation data—and high-resolution numerical modeling to develop a continuous record of soil moisture and groundwater dating back to 1948. The team then used the soil and groundwater record to produce weekly maps of wetness conditions in the soil and aquifers.

This project generated an independent and reliable data set, which augmented the existing data available to assess droughts. Prior to the addition of the new *GRACE*-based drought indicators, the U.S. Drought Monitor lacked information on deep soil moisture and groundwater storage. The officials who produce the Drought Monitor's weekly maps can use this valuable information to gauge the impact of long episodes of wet or dry weather.

The NDMC is located at the University of Nebraska, Lincoln. The U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA) are the primary federal agencies sponsoring the Drought Monitor.

Facilitating Decisions

The U.S. Drought Monitor authors make routine use of the soil moisture and groundwater data from the project team. "For us, it is another voice in the room to answer questions about soil moisture. It does help greatly to



“These [GRACE] maps provide regional to national-level water resource information that was previously unavailable to policy and decision makers. The novel use of satellite-based gravity data in combination with advanced modeling techniques has given us a unique perspective on groundwater that was not resolvable through just ground-based observations.”

Brian Wardlow
National Drought Mitigation Center

define the long-term and short-term drought situation, as well as provide details for inclusion in the weekly narrative, where the author explains if impacts are hydrologically and/or ecologically devastating, or having more of an impact on agriculture and society,” said Matt Rosencrans, a meteorologist at the NOAA Climate Prediction Center.

Drought planning entails drought monitoring, understanding drought impacts, and mitigating the associated risks. Enhanced drought monitoring through additional data could improve drought planning on the national, state, local, and tribal level.

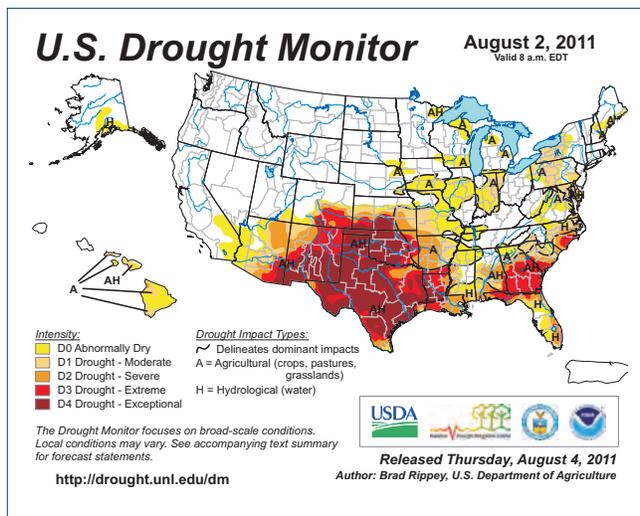
Droughts are significant economically. For example, the USDA Livestock Forage Disaster Program disbursed \$479 million for drought-related grazing losses of livestock from 2008 through 2011. The program uses U.S. Drought Monitor ratings of severe and extreme drought by county to determine eligibility for compensation. In 2011, the cost of the Texas drought in livestock and crop losses exceeded \$7.6 billion plus more in damages from drought-related wildfires.

Expanding Potential Applications

The project’s data products not only benefit official drought monitoring. The team posts its weekly groundwater and soil moisture maps online, allowing people to tap the data for their own assessments and decisions. The maps are especially useful in helping water resources managers differentiate between short-term and long-term drought.

The GRACE-based data products may ultimately support long-term planning, as decisions on issues such as disaster aid, construction of dams, and water allocation rely on accurate assessments of drought. Rodell’s

project team included people from the NDMC, NOAA, and the University of California, Irvine. In 2012, the team plans to expand the techniques globally.



U.S. Drought Monitor map, August 2, 2011.

GRACE is a U.S.-German satellite mission. NASA and the German government have agreed on a GRACE Follow-On mission (GRACE-FO) for 2017 to continue these important measurements and the long-term record. There are discussions for a GRACE-II mission to improve the accuracy and resolution of the measurements.

The U.S. Drought Monitor is available on the NDMC website: <http://www.drought.unl.edu>.

To view the weekly groundwater and soil moisture condition maps, visit <http://www.drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx>.



Improving Management of Atlantic Bluefin Tuna

An Applied Sciences project used NASA Earth observations in an application to improve assessments of the Atlantic bluefin tuna population. Fisheries authorities now use techniques developed by the project team to support stock assessment and management.

The Atlantic bluefin tuna is one of the largest and most valuable fish in the sea. The species is important to commercial and recreational fisheries in the United States and abroad. The species is slow growing with a long life expectancy, making it susceptible to overfishing. Populations of Atlantic bluefin tuna have been declining since the 1970s, necessitating annual fishing quotas.

The project team applied data from the *Aqua*, *Terra*, and *Jason* satellites to a population assessment technique and coordinated the transfer of the technique to NOAA's National Marine Fisheries Service (NMFS). The NMFS Southeast Fisheries Science Center is responsible for Atlantic bluefin tuna assessments and makes recommendations to the International Commission for the Conservation of Atlantic Tunas (ICCAT), the governing body for stock management.



An Applied Sciences project delivered a new method using satellite data to support fisheries stock assessment and management of Atlantic bluefin tuna.

Developing Applied Techniques

The U.S. Sustainable Fisheries Act stipulates that fish populations be managed to produce maximum sustainable yield. Accurate population assessments are critical to fisheries management decisions, and an understanding of Atlantic bluefin tuna spawning supports the population assessments. Bluefin tuna larvae are a primary indicator of the spawning and show apparent fluctuations in population.

Applying a combination of larvae catch information, satellite observations, and *in situ* data, the project team developed a habitat classification model of larval occurrence to predict where larvae could be captured. The team used sea surface temperature and ocean color data (i.e., chlorophyll) from *Terra* and *Aqua*, sea surface height from *Jason*, and *in situ* measurements of salinity, bottom depth, and other factors.

“Satellite-derived data provides an overview of ocean conditions that are not available from traditional shipboard measurements. By applying daily satellite sea surface temperature and chlorophyll, we have been able to construct real-time models of larval bluefin tuna abundance in the Gulf of Mexico,” said John Lamkin, a fisheries oceanographer at the NMFS Southeast Fisheries Science Center.

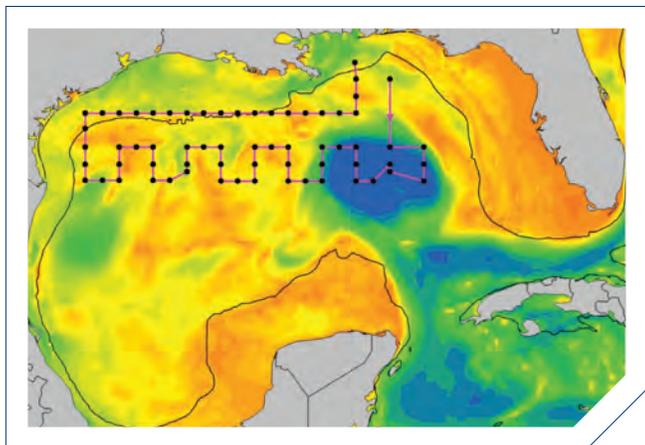


“By applying daily satellite sea surface temperature and chlorophyll, we have been able to construct real-time models of larval bluefin tuna abundance.... This capability greatly expands our understanding of larval bluefin ecology, and has allowed us to target specific areas resulting in the development of an improved larval index.”

John Lamkin
NOAA National Marine Fisheries Service

Improving Efficiency of Larval Surveys

Variance in estimates of larvae and “larval abundance” (i.e., individuals per area) are key measures of larval surveys. The project team used the model and satellite observations to forecast larval occurrences, and the new method to classify spawning habitats proved successful. The team caught over 13 percent more larvae in 2011 than in 2009. Additionally, the team used the technique to capture larvae from an area off the Yucatan Peninsula, where larvae had not previously been documented. In combination with NMFS’ long-term *in situ* data records, the team reduced the variance in estimates of larval abundance by approximately 14 percent, which is considered to be a substantial reduction.



The project team applied satellite infrared and ocean color data (May 1–7, 2011) to derive a larvae habitat model. The model helped explain the variation in catches of the fixed sampling sites (black dots) in the Gulf of Mexico. Warm (orange-red) colors depict higher probability areas; cool colors (blue and green) depict lower probability areas. Credit: Mitchell Roffer

Transferring the Application

Led by Mitchell A. Roffer of Roffer’s Ocean Fishing Forecasting Service, Inc., the project team involved a group of academic researchers, NMFS scientists and managers, and commercial scientists.

The collaborators worked with the NMFS Southeast Fisheries Science Center to transfer the techniques and habitat classification models for their adoption. They worked with and trained fisheries management and research personnel at NMFS on the techniques, which have been adopted as standard practice in deriving the U.S. national stock assessment used by the ICCAT. The techniques are also being used for other fisheries management applications.

“This capability greatly expands our understanding of larval bluefin ecology, and has allowed us to target specific areas resulting in the development of an improved larval index. This index is used by the ICCAT as part of the stock assessment process and is the only fisheries independent survey for Atlantic bluefin tuna,” Lamkin said.

NMFS now routinely uses satellite observations in its surveys and stock assessment process for Atlantic bluefin tuna. NMFS representatives have presented their Atlantic bluefin Tuna assessments to the ICATT using the techniques adopted from this project.



Supporting Effective Search and Rescue Missions

Every year, the U.S. Coast Guard performs thousands of search and rescue missions, saving more than 5,000 lives. The Coast Guard uses its Search and Rescue Operations (SAROPS) tool in its execution of searches to minimize response times.

An Applied Sciences project worked with the Coast Guard to apply data from *Aqua*, *OSTM/Jason-2*, and other satellites along with Earth science models into SAROPS. The project enhanced forecasts of currents and winds used in targeting search areas, reducing the areas and response times. Following tests of the application in the northeastern Pacific Ocean, the Coast Guard incorporated the NASA data and models into its operations off the coast of California in 2011.



Reducing Search Areas

Once alerted to a new case, the Coast Guard, aided by SAROPS, develops a search action plan based on the search area and available resources. SAROPS is a Monte Carlo simulation-based system that uses thousands of simulated particles to estimate ocean currents and likely locations of persons and property in distress. By enhancing predictions available in its SAROPS tool, the Coast Guard can narrow down the area of deployment and increase efficiency to locate possible survivors.

“I’ve been very impressed with the Coast Guard’s commitment to bring NASA satellite data and model forecasts into their decision-making process in order

to improve their search and rescue operations,” said Yi Chao, who led the project.

The project team used Earth observations and Earth science models to enhance SAROPS forecasts of ocean surface current speed and direction as well as ocean surface wind speed and direction. It also used the models and observations to create the range of estimates of predicted current and winds. Characterizing the range can be crucial when deciding on how broad or narrow a search area to target.

The Coast Guard used NASA Earth observations and models to enhance its search area estimates, narrowing the area of deployment and increasing efficiency in locating possible survivors.

The project applied forecast capabilities from the Weather Research & Forecasting atmospheric model and the Regional Ocean Modeling Systems oceanographic model. For search and rescue activities, the project enhanced these models through the integration of data from NASA’s Earth observing environmental satellites, which collect information on all parts of the Earth.

The team applied ocean height data from the *Jason* and *OSTM/Jason-2* satellites as well as sea surface temperatures from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on *Terra* and *Aqua*. For example, measurements of sea surface temperatures, which are associated with thermal gradients, provided changes in surface patterns used to derive surface currents.



“[This application is an] extraordinarily powerful technique that we will continue to use and incorporate.”

Arthur Allen
U.S. Coast Guard Office of Search and Rescue

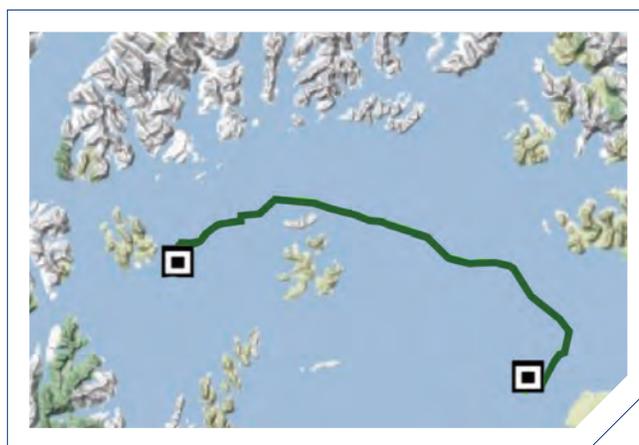
The project combined the satellite observations with surface current information from partners' high frequency radar, ship surveys, moorings, and drifters. The team completed field tests in Prince William Sound, Alaska, comparing the satellite data with known variables such as wind speed, wave height, and current direction gathered by equipment on-site. The team used these comparisons to refine the models.

Saving Lives, Time, and Money

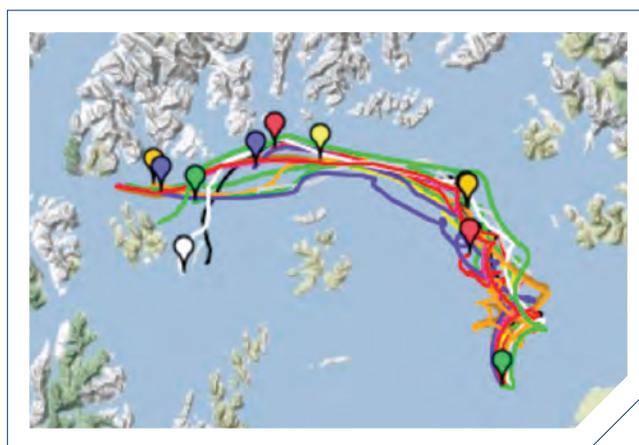
Time is critical when deploying search and rescue operations over oceans and other large bodies of water. By enhancing predictions available in SAROPS, the Coast Guard can narrow down the area of deployment and increase efficiency to locate possible survivors. A Coast Guard rotary-wing aircraft costs \$8,500–14,500 per hour to operate, and a Coast Guard cutter costs \$2,300–13,000 per hour to operate. Improved reliability of predictions can also significantly reduce costs and time and increase success of search and rescue deployments.

Effective search and rescue missions depend on having the right data at the right time and in the correct format. Of the application of NASA data and models, Arthur Allen, a physical geographer with the Coast Guard's Office of Search and Rescue, said that it was an “extraordinarily powerful technique that we will continue to use and incorporate. We, the Coast Guard, will continue to bring it to fruition.”

In 2012, the NASA-sponsored project will make further refinements with the Coast Guard to improve the use of the satellite data and Earth science models in SAROPS, with possible uses in other regions. In addition, Applied Sciences will work with the Coast Guard to incorporate data from the *Suomi NPP* satellite launched in late 2011.



The project team conducted field tests in Prince William Sound, Alaska, to evaluate the application. The tests compared modeled drift trajectories with observed ones. This image shows the actual, observed drift trajectory in one test.



This image shows the forecasted drift trajectories based on the model including NASA data. Note points of correlation with observed trajectory.



Aiding Irrigation Management in California

In the arid western United States, irrigation decisions are increasingly important for farmers and water managers. An Applied Sciences project collaborated with the California Department of Water Resources to apply satellite data in a key system used by California growers to optimize irrigation management.

Limited water supplies must meet the needs of agriculture, industry, environmental uses, and growing urban and suburban populations. Agriculture accounts for more than 80 percent of total water consumption in many western states, and maintaining the sustainability of water supplies for irrigation (and other uses) is important to U.S. agricultural production.

Bridging Research and Applications

Research had shown that incorporating information on weather conditions and crop growth stage into irrigation scheduling practices could improve yields while reducing the total applied irrigation on average. Agricultural weather information is available to growers in many western states, though the calculations required to convert this information to a field-specific crop water requirement are often a barrier to more widespread use.



To map and forecast irrigation demand, the California Department of Water Resources and NASA partnered to apply *Terra*, *Landsat*, and *Aqua* data to extend the capabilities of the California Irrigation Management

A novel application of NASA satellite data supports irrigation management in California’s Central Valley, which is one of the most productive agricultural regions in the world.

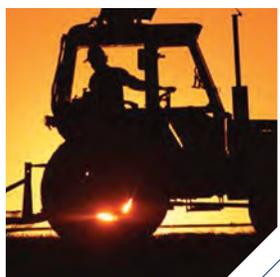
Information System (CIMIS). CIMIS provides publicly available information useful in estimating crop water use for irrigation scheduling. Agricultural growers, landscape managers, and water managers use CIMIS for assessing crop water needs, allowing for ways to improve irrigation management.

The American Recovery and Reinvestment Act provided funds for this project. As part of the funding, the project used NASA’s Earth Exchange collaboration platform and implemented an automated data processing system at NASA’s Advanced Supercomputing Facility at Moffett Field, California.

Improving Water Management

The new system produces observations of crop canopy conditions from the Earth-observing satellites in near real-time. This data is then combined with data on agricultural weather conditions from CIMIS to estimate crop water needs for each field, providing a new source of information that can be used by growers to account for optimal irrigation rates when scheduling irrigation.

The new information products were designed for ease of use, with the goal of supporting growers in optimizing on-farm water management. “The idea is efficiency, getting the most you can from every drop of water,” said



“This effort is of substantial value to the California Department of Water Resources’ efforts to support ongoing improvements in agricultural water use efficiency and strategic planning for mitigation of drought impacts.”

Bekele Temesgen
California Department of Water Resources

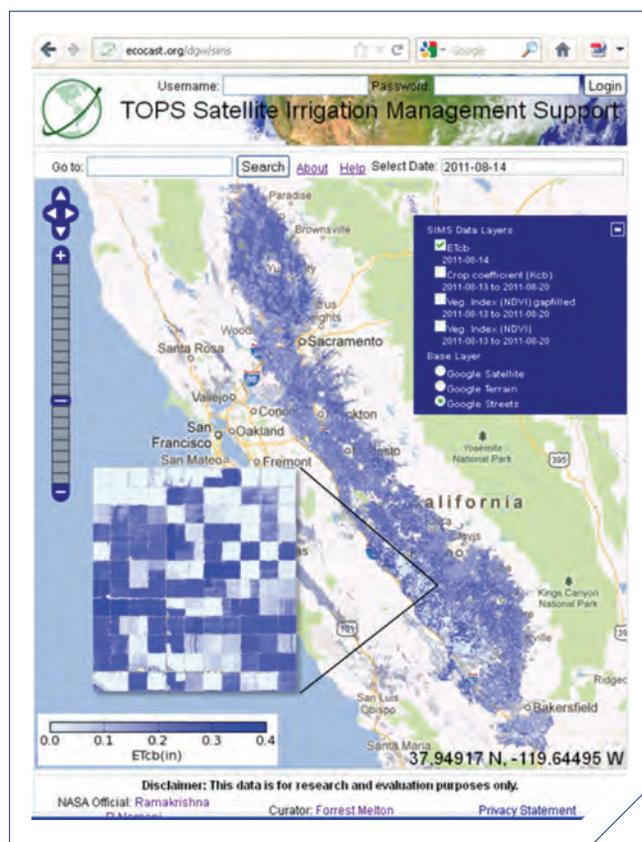
Sonia Salas of Western Growers, an agricultural trade association with members in California and Arizona.

By integrating the satellite-derived observations with the information from CIMIS, the enhanced information products can accurately measure crop canopy cover and map crop water requirements over 15 million acres of farmland in California’s Central Valley. The project delivered ways to map key indicators of crop water requirements and agricultural irrigation demand across the entire Central Valley at the scale of individual fields daily.

Grower associations and individual growers participated to evaluate the utility of the new information products to maximize the benefits for agricultural production. As part of the validation of the new information products, the project team installed sensor networks that measured applied irrigation, soil moisture, and evapotranspiration at pilot sites in partnership with growers.

Bekele Temesgen of the California Department of Water Resources noted, “This effort is of substantial value to [the department’s] efforts to support ongoing improvements in agricultural water use efficiency and strategic planning for mitigation of drought impacts.”

By the end of 2011, the project team, in cooperation with several commercial farms, piloted a beta version of the Satellite Irrigation Management Support web interface for growers and water use managers. To view the interface, visit <http://ecocast.arc.nasa.gov/sims>.



The Satellite Irrigation Management Support web interface provides access to daily, field-scale maps and seasonal profiles of crop canopy conditions and indicators of crop irrigation demand, including profiles of daily crop water requirements. Data for individual fields can be obtained by querying the maps using a web browser, and soon from mobile phone applications as well.



Assisting in Earthquake Response and Disaster Management

Long before the March 2011 earthquake off the coast of Japan, an Applied Sciences project was working to integrate Earth observations in earthquake management and response. In the aftermath of the tragic Tohoku earthquake and resulting tsunami, the project team was able to provide data products to support Japan's disaster response.

Maggi Glasscoe of NASA's Jet Propulsion Laboratory leads a project applying remote sensing data and geophysical modeling tools for hazard risk evaluation. Her project—Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response, or E-DECIDER—supports long-term disaster management planning and short-term response following earthquakes, such as identifying areas where the greatest changes and damage occurred.



Supporting Japan's Response

Japan has extensive experience with Earth observing satellites and applications of remote sensing data. Under the provisions of the International Charter on Space and Major Disasters, the Japanese government requested satellite observations and data to help its response to the Tohoku earthquake and tsunami. U.S. and global efforts supported the request and made imagery and data available through the charter.

A NASA project applied Earth observations to support disaster management and response, providing assistance to Japan after its tragic 2011 earthquake and tsunami.

The E-DECIDER team was part of a U.S. group that quickly provided a response. Based on a list of cities provided by the Japanese government, the E-DECIDER team delivered various map products of the affected areas in the Fukushima prefecture. Beyond satellite images of damaged areas, the project team focused on products that showed changes from before the earthquake and tsunami.

The team provided analysis of damage extent in the inundated parts of the Fukushima prefecture. Using MODIS data from the *Aqua* satellite, the team produced preliminary inundation assessments. The E-DECIDER team generated change-detection products based on MODIS and *Landsat* data to indicate the effect the earthquake and tsunami had on land and structures. The team also developed methods to better access data from the USGS Hazards Data Distribution System, the service that hosts International Charter data. USGS has national responsibilities for earthquake monitoring, notification, and impact and hazard assessments.

"We were grateful we could contribute our work toward the global response to the Tohoku-oki disaster. It was a huge eye-opener to us on ways to further improve E-DECIDER to help public safety officials plan for and respond to events," said Gerald Bawden, a USGS member of the project team.

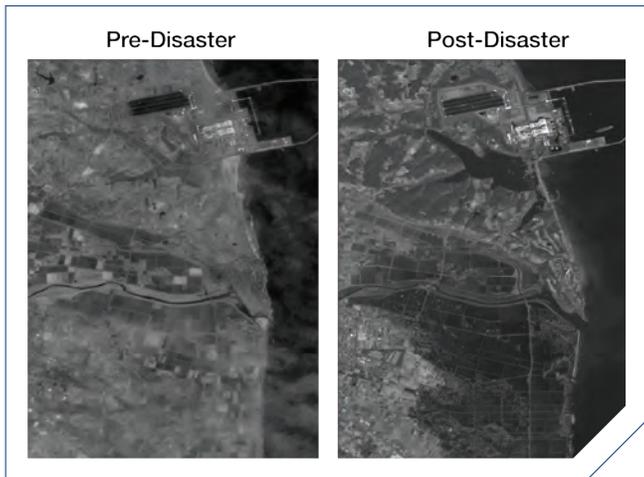


“We supported a number of actual disasters and disaster scenarios in 2011. These events helped us test and develop our capabilities for hazard and risk assessment as well as ways for visualizing the results.”

Maggi Glasscoe
 NASA Jet Propulsion Laboratory

Modeling Disasters to Save Lives

Beyond earthquake response improvements, the E-DECIDER project supports applications of Earth observations for risk evaluation and long-term disaster management planning. E-DECIDER utilizes remote sensing data from optical and radar sources and from satellite and airborne sensors, such as the NASA Unmanned Air Vehicle Synthetic Aperture Radar. The project team supports uses of Earth observations in pre-event scenario catalogs, deformation modeling, and earthquake forecasting.



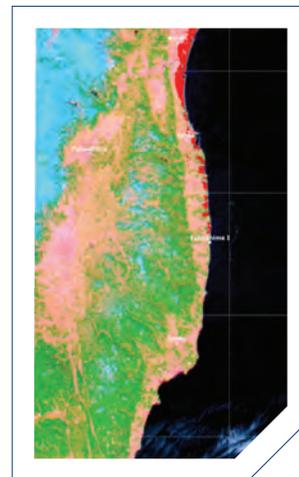
Images pre- and post-disaster indicating tsunami-affected areas in Minamisoma, Fukushima, Japan. Visible damages include flooding (darker areas) and destroyed bridges and homes. E-DECIDER used commercial satellite imagery from DigitalGlobe for this image analysis. Credit: E-DECIDER

In 2011, the project team worked to deliver NASA Earth observation data and modeling results for use with the Federal Emergency Management Agency’s Hazards U.S. Multi-Hazard (HAZUS-MH) tool for estimating potential losses from natural disasters. The team delivered

methods for HAZUS-MH users to generate scenarios and earthquake hazard maps and to export results to Google Earth.

The team also prototyped techniques to add tilt maps, interferograms, and deformation gradient maps in Google Earth. These capabilities allow for richer simulations of what could happen to a region during earthquakes of different levels and locations.

“We supported a number of actual disasters and disaster scenarios in 2011. These events helped us test and develop our capabilities for hazard and risk assessment as well as ways for visualizing the results,” said Glasscoe.



Map shows the overview of tsunami inundation extent (inundated areas are red), which was derived from Aqua/MODIS images (250 m spatial resolution) acquired on February 23, 2011 and March 13, 2011. The image from March 13 also serves as backdrop. Credit: E-DECIDER

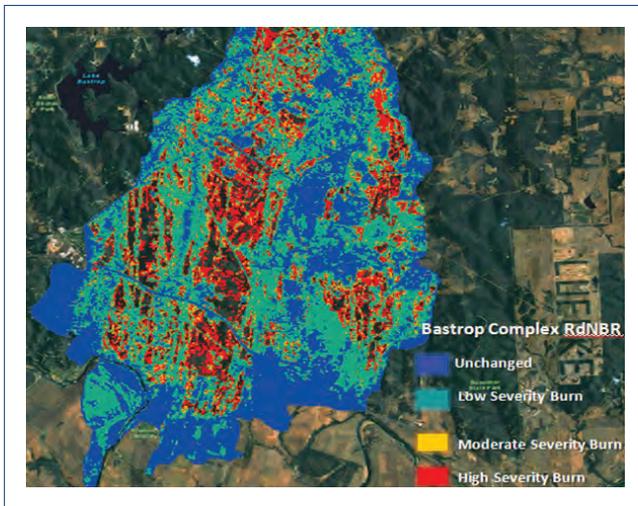
The team expects to deploy some of these prototype techniques in 2012. Disaster managers can use the tools to assess risks associated with earthquakes, including landslides and subsidence, and threats to vulnerable systems, including levees and rapid transit systems. Examining possible scenarios based on accurate models and sound data can support response planning and allocation of appropriate resources and first responders to areas of high risk when an earthquake occurs.



Building Capabilities in Applying Earth Observations

DEVELOP is an Applied Sciences development program in which young professionals gain experience with satellite remote sensing and apply Earth observations to issues facing state and local governments. In 2011, DEVELOP sponsored 259 people across 54 hands-on applications projects in its three terms, including a record 137 interns in the summer term. Below are descriptions of two projects from 2011.

DEVELOP had a record year in the number of participants and projects supporting state and local governments' uses of Earth observations.



Using *Landsat* imagery, this map displays four levels of burn severity in the Bastrop Complex fire, Bastrop County, east Texas. DEVELOP used a Relative difference Normalized Burn Ratio technique to produce the map.

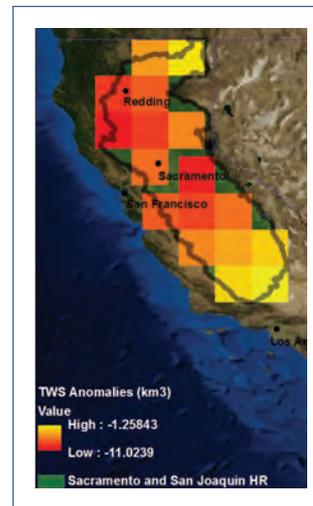
Performing Risk Mapping of Wildfires

In 2011, fires burned nearly 4 million acres of land across Texas. The Texas Forest Service is responsible for directing matters pertaining to forestry within the state, and it was interested in the capabilities of NASA Earth observations to enhance and assist in fire monitoring during and after wildfires. A four-person DEVELOP team worked with the Texas Forest Service to apply data from the *Terra*, *Aqua*, and *Landsat* satellites to assess the impacts of the fires.

The DEVELOP team used burn-scar imagery and calculated various spectral indices to assess the surface vegetation, impact of drought, and the magnitude of ecological change caused by the fires. The team combined these separate analytical techniques to generate a composite fire-risk map and a time-lapse representation of the changing conditions of surface water resources during the fires. This information provided the Texas Forest Service with a method for timely and cost-effective assistance in fire management.

Improving Groundwater Storage Estimates

The California Department of Water Resources conducts extensive modeling and field-based activities to estimate groundwater storage within the Central Valley aquifer, the second most heavily pumped aquifer in the United States. A five-person DEVELOP team worked with the department to examine the use of satellite observations for aiding estimates of groundwater storage and change in the aquifer.



GRACE total water storage anomalies for the hydrologic regions of the Central Valley, September 2011.

The DEVELOP team used data from *GRACE*, which can measure changes in total water storage. The team combined the total water storage for each hydrologic region with data on soil moisture, surface water storage, and snowpack to provide estimates of groundwater storage and its change. The results proved comparable to current methods, suggesting that remote sensing technology might provide the department an additional method for estimating groundwater storage.

Overall, the team found that *GRACE*-based products provided a tool for characterization of groundwater storage change in large aquifer systems, such as the three hydrological regions of the Central Valley aquifer, yet the products were not suitable for smaller basins and sub-basins.

Virtual poster sessions, including videos of DEVELOP projects, are on the *Earthzine* website: <http://www.earthzine.org>.

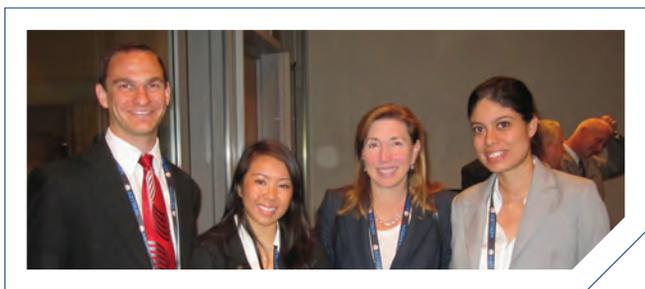


Developing Future Voices in Space and Earth Science

Three DEVELOP representatives—Jason Jones, Katrina Laygo, and Vanessa Villa—won selections to speak at the 62nd International Astronautical Congress (IAC) in Cape Town, South Africa, and its special plenary event on younger generations’ views on space. This remarkable achievement followed a rigorous, two-round video competition that the International Astronautical Federation (IAF) organized to select the IAC youth plenary speakers.

The IAF is a worldwide federation of organizations active in space, advancing knowledge about space and the application of space assets for the benefit of humanity. The IAF’s annual congress is the premier global space conference.

The DEVELOP representatives spoke at the IAC plenary, “Next Generation Visions for Earth Observations in the 21st Century.” This plenary allowed young professionals to share their ideas and experiences on how Earth observations can be improved, sustained, and utilized for decision making. The IAC youth plenary had six speakers, and there were more than 150 people in the audience.



Jason Jones, Katrina Laygo, NASA Deputy Administrator Lori Garver, and Vanessa Villa at the 2011 International Astronautical Congress.

“The future of Earth observation depends on us and our willingness to invest in the next generation of explorers. Countries around the world can rise to the occasion by establishing hands-on training opportunities for students today, who are the leaders of tomorrow,” said Jones.

Three DEVELOP participants spoke about younger generations’ views on Earth observations at the 2011 International Astronautical Congress.

“Gaining a panelist place at the IAC opened a networking opportunity, allowing me to meet and interact with the



Jason Jones speaking at the IAC plenary, “Next Generation Visions for Earth Observations in the 21st Century.”

people involved in one of the most important scientific fields,” said Villa. “It allowed me the experience of sharing what I have learned by working at DEVELOP to enhance the quality of life for local communities in Mexico.” Villa was the only attendee at the conference from Mexico.

The three DEVELOP representatives competed in a two-stage competition based on video submissions through YouTube. The competition had 28 video submissions, and IAC accepted all three DEVELOP submissions.

Laygo, Villa, and Jones also participated in other IAC events. Laygo presented a DEVELOP project at an IAC session, “Earth Observations for Economic Applications and Benefits.” Villa spoke on a panel focused on building successful careers. Jones did an interview with a local Cape Town radio station. All three met with Berndt Feuerbacher, IAF president.

“Participating in the IAF congress helped me further realize opportunities for positively impacting our communities at home and abroad, especially within the realms of disaster management and public health,” Laygo said.

To view the youth plenary event and speakers, visit http://www.iafastro.org/index.html?title=IAC2011_Plenary_6.



Assessing the Utility of NASA Earth Science Satellites

In 2011, NASA conducted its biennial review of all of its Earth-observing satellites past their planned design lifetimes. This so-called Senior Review determined whether to continue funding for operating the satellites and producing their respective data products. The review considered the scientific value, national utility, technical performance, and proposed cost of extending each mission in relation to NASA Earth science objectives.

The 2011 Senior Review evaluated 12 NASA Earth science satellite missions past their design lifetimes: *Aqua*, *Aura*, *CALIPSO*, *CloudSat*, *EO-1*, *GRACE*, *Jason-1*, *OSTM*, *QuikSCAT*, *SORCE*, *Terra*, and *TRMM*.

The Applied Sciences Program organized the National Interests Panel in the review. This panel represented users of the data for primarily non-research purposes. The National Interests Panel included public and private sector representatives from 12 organizations: six civil agencies, two military branches, two nongovernmental organizations, one state association, and one trade association. John Haynes, a program manager in Applied Sciences, chaired the National Interests Panel.

The National Interests Panel reviewed the satellite missions and rated the utility of the data products. It assessed the utility of the satellites' data sets for applied and operational purposes in the public and private sector, such as weather services, military operations, state government services, policy making, business services,

and nongovernmental organizations' uses. The panel assessed the utility on three criteria—value, frequency of use, and latency—and assigned an overall utility rating.

Applied Sciences led a review that assessed the utility of 12 NASA Earth science satellites in serving U.S. national interests.

The National Interests Panel determined that three satellites have very high utility: they produce highly valued data products routinely used for important activities and loss of the data products would have a significant impact. The panel determined that nine satellites have high utility. The panel did not rate any satellites below high utility.

The Senior Review combined these ratings with other panels' assessments of scientific value, technical performance, and proposed cost. Overall, the Senior Review found that the continuation of all 12 missions would make critical contributions to enabling NASA to continue to meet its Earth science objectives.

To view the 2011 Senior Review report, with findings for each satellite mission, visit <http://science.nasa.gov/earth-science/missions/operating>.



A map of sea surface temperature, December 2011, based on data from *Aqua*/MODIS. Lighter colors depict warmer temperatures.



Igniting Audiences on Earth Science Applications

Ever tried to give a presentation in five minutes? And also in a format that automatically advances your slides every 15 seconds?

Seventeen people did both in December 2011 at a first-time-ever event that Applied Sciences sponsored at the American Geophysical Union (AGU) Fall Meeting, in San Francisco. They rose to the challenge of the event, Ignite@AGU. It was a rousing, invigorating evening. The presenters represented government, industry, and academia and covered a wide range of Earth science applications topics such as agriculture, air quality, disasters, and water quality.

Ignite, a concept publicized by O'Reilly Media, isn't your typical conference presentation. The talks are fast-paced, innovative, and boundary pushing; presenters are challenged with an unconventional format to convey their messages. The 20-slide presentations are meant to "ignite" the audience on a subject—to generate awareness and stimulate thought and action.



The Ignite@AGU speakers energetically and creatively covered a variety of topics. For example, Sean Raffuse, Sonoma Technology, presented "Finding a Fire: A Story of NASA Data in Application (in 3D)." Hook Hua, NASA JPL, spoke on "Earth Science Data: What We Can Learn from Food." Sky Bristol, USGS, asked the audience to "Think Big, Act Small, Fail Fast, Learn Rapidly." Deborah McGuinness, Rensselaer Polytechnic Institute, addressed "Next Generation Monitoring of Environmental and Ecological Data."

More than 200 people heard inventive, fast-paced talks on Earth science applications at a first-time-ever Ignite@AGU event.

In an incredibly full week of activities at the AGU Fall Meeting, more than 200 people attended this event. The multidisciplinary nature of Ignite@AGU allowed people from quite varied fields to make connections they might normally not have made at the AGU meeting. Comments and feedback on the event were very positive, and there are plans for another Ignite event at AGU 2012.

Tim Dye of Sonoma Technology conceived of Ignite@AGU. Erin Robinson of the Federation of Earth Science Information Partners organized the event in collaboration with Sonoma Technology and the AGU Earth and Space Science Informatics focus group. Francis Lindsay of NASA Earth Science served as the emcee.

The Ignite@AGU presentations are online, where visitors have viewed them hundreds of times since the event, increasing the reach of Applied Sciences.

To view the presentations, visit <http://igniteshow.com/events/igniteagu-2011>.

Ignite@AGU Sponsors





Launching New Satellites and Potential Applications

Two new satellites joined NASA's constellation of Earth-observing satellites in 2011: *Aquarius* and *Suomi National Polar-orbiting Partnership (Suomi NPP)*. *Aquarius* introduces a new type of measurement from a space-based platform, and *Suomi NPP* continues measurements from current, aging satellites.

Age of *Aquarius*

NASA launched the *Aquarius* satellite mission from Vandenberg Air Force Base, California, on June 10, 2011. This mission is an international effort planned to spend at least three years measuring and mapping ocean surface salinity.

Aquarius provides the first space-based global observations of salinity (the concentration of dissolved salt) at the ocean surface. Global ocean salinity is a key missing variable in satellite observations of Earth that influences ocean circulation, traces the path of freshwater around the planet, and helps drive Earth's climate. Information on salinity helps scientists better understand the global water cycle and ocean circulation, which are major components of the climate system.



Aquarius is the primary instrument on the international *SAC-D* spacecraft developed by NASA and Argentina's space agency, Comisión Nacional de Actividades Espaciales. Brazil, Canada, France, and Italy were also involved in the mission development.

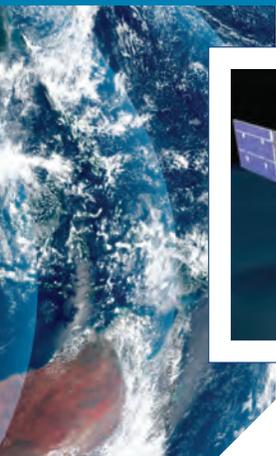
NASA launched *Suomi NPP* to extend key measurements and applications and *Aquarius* to pioneer new space-based observations important in climate models and weather forecasts.

In 2011, *Aquarius* began to generate maps of ocean salinity, which can improve abilities to predict Earth's climate. The satellite mission will provide monthly, global maps of changes in salinity. The first few months of the mission collected more ocean salinity data than had been collected with ships and in-water sensors during the preceding 125 years.

Additionally, the mission will collect information on ocean winds and other environmental data. The set of information will help scientists improve computer models on climate change and weather forecasting. Improved data and forecasting can help identify and mitigate impacts of disasters, such as flooding, droughts, and extremely strong winds, and aid appropriate disaster planning.

Aquarius is composed of three radiometers that are sensitive to salinity (measured in L-band at 1.413 GHz) and a scatterometer measuring surface winds to correct for the ocean's surface roughness.

NASA released an *Aquarius* iPhone app in 2011, providing information on the science and purpose of the mission, news updates, videos, and animations. A data-view feature shows many of the factors that affect Earth's oceans and the water cycle.



“*Suomi NPP* data will improve our forecast skills out to five to seven days in advance of extreme weather events, including hurricanes and severe weather outbreaks. With *Suomi NPP*, our goal is to make the accurate forecasts achieved for this year’s events even better in the future.”

Louis Uccellini
NOAA National Centers for Environmental Prediction

Suomi NPP

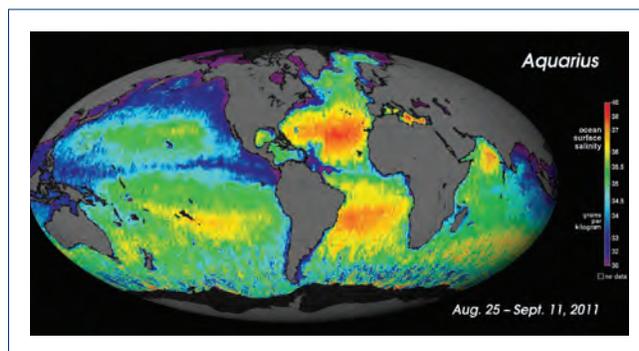
NASA launched *Suomi NPP* from Vandenberg Air Force Base on October 28, 2011. *Suomi NPP* is an interagency mission with a five-year design life to collect measurements of sea and land surface temperatures, clouds, vegetation, ocean color, ice cover, ozone and aerosols, solar incidence, and many other environmental parameters.

With a suite of five sensors, *Suomi NPP* orbits about 500 miles above Earth every 102 minutes. The mission continues key measurements from the *Terra*, *Aqua*, and *Aura* satellites. For example, *Suomi NPP*’s VIIRS sensor continues measurements from MODIS on *Terra* and *Aqua*, and *Suomi NPP*’s OMPS sensor continues observations from *Aura*’s OMI instrument.

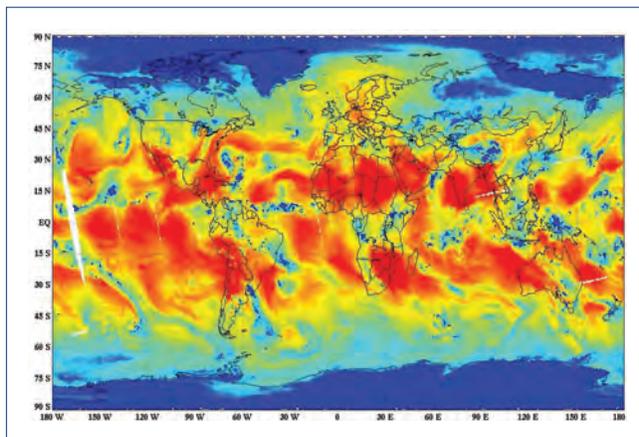
The *Suomi NPP* mission will extend applications discovered and made possible from those satellites. For example, *Suomi NPP* data can track volcanic ash plumes, detect forest fires, and monitor water quality and changes in Arctic sea ice and the Antarctic ozone hole.

With a core mission focused on weather and climate, *Suomi NPP* will help with understanding and predicting short-term weather conditions as well as long-term climate change. The mission serves as a bridge between today’s research satellites and the next generation of operational, polar-orbiting satellites.

NASA Applied Sciences, in cooperation with NOAA, USDA, and USGS, will hold a *Suomi NPP* applications workshop in 2012 to inform users on *Suomi NPP* instruments, data products, and access to data (http://geo.arc.nasa.gov/npp/npp_conf_index.html).



The first global map of the salinity of Earth’s ocean surface produced by *Aquarius*. The map is a composite of the first two and a half weeks of data since *Aquarius* became operational on August 25, 2011. The numerical values represent salt concentration in practical salinity units (PSU: grams of salt per kilogram of sea water). Yellow and red colors represent areas of higher salinity, with blues and purples indicating areas of lower salinity. Areas colored black are gaps in the data. The average salinity on the map is about 35 PSU.



The image based on the first measurements from the Advanced Technology Microwave Sounder (ATMS) on *Suomi NPP*, November 8, 2011. The image shows the ATMS measurements of atmospheric water vapor. Tropical Storm Sean is visible as the patch of blue in the Atlantic Ocean off the southeastern coast of North America.



Tracking Air Quality for Better Public Health

Environmental conditions and hazards have substantial effects on public health. The Centers for Disease Control and Prevention (CDC) formed the National Environmental Public Health Tracking Network (EPHTN) to catalog and better understand environmentally related health problems. The network is a system of integrated health, exposure, and hazard information from multiple sources, including data from tracking networks in 23 states.

An Applied Sciences project worked with the New Mexico Department of Health to explore the application of Earth observations in the state's health tracking system, a part of the national network. The system identifies links between exposure and associated health effects, improving surveillance to enable quicker responses by New Mexico officials and health workers to environmental public health issues. The NASA project focused on air quality issues, such as dust and particulates.



Linking and Applying Earth Science Models

Public health in a region is connected to local air quality. Certain illnesses, including asthma and myocardial infarction, seem specifically tied to ground-level ozone, fine particulate matter (PM_{2.5}), and other pollutants such as persistent organic pollutants. The U.S. Environmental Protection Agency (EPA) and states routinely collect accurate measurements of air pollutants from ground monitors at specific locations. The NASA project used satellite observations and atmospheric models to support the New Mexico Environmental Public Health Tracking System in providing dust estimates across the state.

Applications of Earth science models demonstrated new ways to estimate dust and air quality in New Mexico and enhance a public health tracking system.

Both the New Mexico tracking system and the national EPHTN use a regional dust entrainment model called DREAM, which predicts concentrations of windblown dust in time and space and is a component of the NOAA model named NCEP Eta. This set of models (DREAM/ Eta) can produce regional dust forecasts on a 24- and 48-hour basis.

Furthermore, by combining this set of models together with EPA's CMAQ model for air quality, it is possible to link atmospheric dust with anthropogenic dust and aerosol concentration to produce a more complete forecast of air quality. One of the critical data needs for linking these models is atmospheric dust loading. The NASA project addressed both atmospheric and anthropogenic dust data needs.

Identifying Sources of Dust

The project team applied *Terra*/MODIS land cover data products, Normalized Difference Vegetation Index products, and a land cover classification algorithm to catalog land patterns that alternate between cropped or barren land. Using data to update distributions of barren land, the team identified PM_{2.5} sources. When the team added land change patterns to the model, it produced refined hourly forecasts of PM_{2.5}. The dust loadings were used, prototypically, to improve depiction of ozone and aerosol concentrations.



The system identifies links between environmental exposure and health effects, improving surveillance to enable quicker responses by New Mexico health officials. Additionally, the CDC obtains more complete information to catalog and better understand, at a national level, environmentally related health problems.

The project demonstrated uses of the Earth observations in the model and set the stage for future forecasts of ozone, fine particulates, and aerosols. The project team provides daily model outputs and forecasts of fine particulates to the New Mexico Environmental Public Health Tracking System, which makes environmental data sets available on a convenient, interactive portal. Opportunities exist to provide more routine uploads of aerosol species data to the system.

Making Informed Decisions

Armed with a more comprehensive picture of atmospheric dust and other contaminants, New Mexico public health officials can advise schools to keep children indoors during recess, parents can more accurately manage their children’s asthma, and hospitals can be better prepared with more staff and resources during forecasted air quality events.

These preparations should allow decision makers and citizens to better react to poor air quality events. Being prepared with advance forecasts has a substantial impact on quality of life, prevention of illness, and reduced health care costs.

Public health officials use the state’s Environmental Public Health Tracking System to monitor air quality and protect residents from environmental threats to their well-being. The long-term intention is to present a more complete picture of the region’s air quality and associated risks. Additionally, the CDC obtains more complete information to help improve, at a national level, the clinical understanding of the relationship between illness and air quality.

To see dust forecasts across New Mexico, visit <https://nmtracking.unm.edu>.





Increasing Emergency Management Capacity for Decision Making

Hurricane Irene and Mississippi River flooding were two major U.S. disasters in 2011. An Applied Sciences project supported the disaster preparations and response with an innovative tool for real-time collaboration. The tool allowed emergency management agencies to combine Earth observations data, visualize impacts and threats, discuss priorities and alternatives, and make coordinated decisions.

Led by StormCenter Communications, Inc., the project developed ways of sharing data among state and federal agencies involved in emergency management. Applied Sciences invested in the project to improve decision making through real-time collaboration using Earth observations. The project enhanced the Envirocast Vision Collaboration Module (EVCM) technology, a cloud-based system that allows rapid overlaying of multiple images and distributed data sets.



This technology connects users—such as emergency managers, emergency responders, and government officials—to share data and information from both real-time—and archived sources. For example, users can share location-based data, environmental data from satellites, weather forecast models, storm surge predictions, and other data sets for situational awareness and collaborative analyses. No single data source needs to reside in the same place. EVCM allows the users to see and discuss the same information and maps whether they are in the same room or separate time zones.

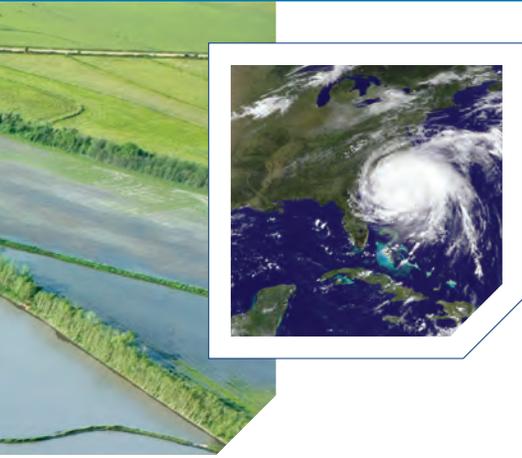
An innovative technology enabled real-time collaboration, data sharing, and decision making across emergency management agencies during natural disasters in 2011.

Hurricane Irene

In August 2011, Hurricane Irene developed over the Atlantic Ocean, and the National Weather Service (NWS) began to alert residents and state emergency management agencies along the U.S. East Coast. Requested by the Maryland Emergency Management Agency (MEMA), StormCenter deployed personnel and equipment to the State Emergency Operations Center.

The project team, distributed across Maryland, used EVCM to access and share data on storm conditions and possible impacts with Maryland Governor Martin O'Malley, MEMA Director Richard Muth, and the governor's cabinet. For example, the team showed *Aqua* and *Terra* land-cover data for coastal vulnerabilities, *TRMM* data on rainfall intensity, *GOES* data for storm positioning and movement, and infrastructure data from MEMA's geographic information system to illustrate potential impacts. These products blended in EVCM with weather data and information from other federal agencies. Many of the satellite data products the users accessed through EVCM were not ones typically used by MEMA in hurricane preparations.

Hurricane Irene caused scores of deaths and billions of dollars in damage. However, the disaster proved a successful test for the project and EVCM, which can help further protect lives and property in future storms.



“StormCenter’s technology allowed us to access data that we had not been able to access in the past. By combining NASA, NOAA and our own GIS information, we were able to improve our situational awareness in real time so we could better serve the citizens of Maryland.”

Martin O’Malley
Governor of Maryland

Mississippi River Flooding

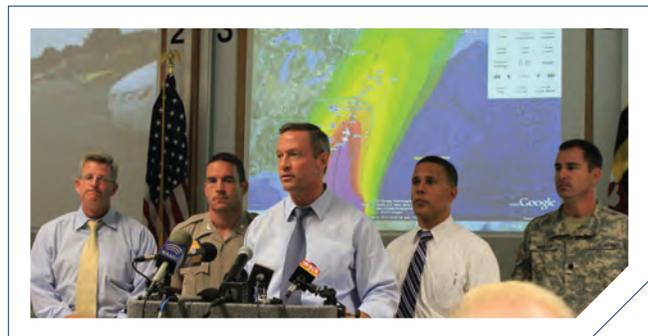
The project team also provided its collaboration capabilities during the 2011 Mississippi River flooding. In mid-May, the U.S. Army Corps of Engineers (USACE) opened the Morganza Spillway, deliberately flooding an area of Louisiana to protect people and infrastructure around the ports of Baton Rouge and New Orleans. The decision was not without cost, as people lost homes and farms within the flood plain.

StormCenter set up collaborative sessions for government agencies to better understand the implication of the USACE decision to open the spillway. For example, FEMA Region VI, NWS Southern Region, and state agencies used the EVCM tool to discuss the estimated flooding. Participants in separate locations examined and discussed output from the USACE Inundation Depth Grid model to better understand the implications of opening flood-control gates. The sessions used satellite observations from *Landsat*, *EO-1*, *Terra*, and *Aqua*. Emergency management and NWS officials issued timely warnings to the general public.

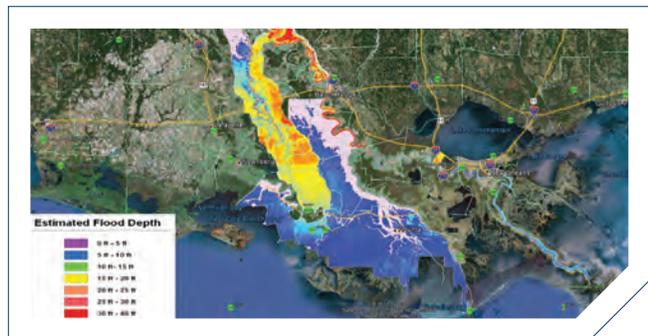
Development to Application to Licensing

Later in 2011, the NWS licensed EVCM for use in its new Operations Proving Ground in Kansas City, Missouri. The Operations Proving Ground executes formal evaluation sessions to test the performance, utility, and other aspects of new capabilities, and it builds impact-based decision support capacity. EVCM will thus support NWS efforts to provide decision support services to all agencies that need weather and hazard support for the protection of life and property.

In 2012, the project expects to expand EVCM to support broader state and federal collaboration for disasters and other applications. The team is also looking to the upcoming *SMAP* and *HyspIRI* satellite missions for potential applications.



Maryland Governor Martin O’Malley holds a press conference on Hurricane Irene during a state of emergency. The EVCM technology is displayed directly behind the governor. Credit: StormCenter



Screen image from a collaborative session detailing the impact of opening the gates of the Morganza Spillway during the 2011 Mississippi River flooding.





Applications Areas and Capacity Building Activities

The Applied Sciences Program promotes applications of Earth observations and Earth science models to improve decision making in the public and private sectors. In 2011, the Program focused on four applications areas: Disasters, Ecological Forecasting, Health & Air Quality, and Water Resources.

Applied Sciences supports efforts to build capabilities and expand the number and type of users applying Earth observations for societal benefit. The Program supported four capacity building activities: DEVELOP, SERVIR, the Gulf of Mexico Initiative, and Applied Remote Sensing Education and Training.

Applied Sciences also supports several activities related to climate assessments and adaptation.





Applications Areas

Applied Sciences supports both applied research and decision support projects on topics of national priority. In 2011, the Program supported four applications areas: Disasters, Ecological Forecasting, Health & Air Quality, and Water Resources. Applied Sciences supports ad hoc activities in other topics, seeking opportunities to expand and develop formal applications areas in the future.

Disasters

The Disasters Applications area promotes the use of Earth observations in forecasting, mitigating, and responding to natural and technological disasters. In 2011, the Disasters area had eight projects in its portfolio. Projects included predictions of hurricane landfall risk, models for forecasting the dispersion of airborne toxins in the atmosphere, automated flood monitoring tools, a GPS-aided earthquake and tsunami alert system, and more.



One project focused on enhancing dispersion pattern forecasts of harmful toxic materials into the atmosphere. The project team integrated data from GPS instruments aboard satellites with surface-based measurements to develop a product that is now a part of the National Weather Service's nationwide atmospheric boundary layer analysis. This parameter is critical for contaminant dispersion models used by emergency response managers. The project's real-time planetary boundary layer height analysis also improved the operational

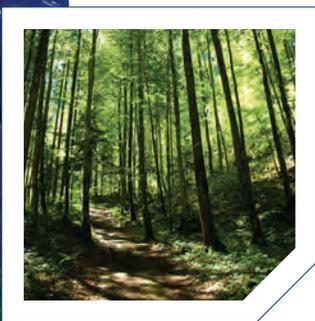
NOAA-EPA ozone forecasts in the National Air Quality Forecast Capability.

The Applied Sciences Program focused on four areas that used Earth science to enhance disaster management, improve air quality forecasting, support drought monitoring, and assist in conservation efforts.

Working in collaboration with the California Department of Water Resources in the San Joaquin Valley of California, another project developed and validated a new method for rapidly detecting seeps or structural damage in levees. This novel use of radar remote sensing for identifying subtle changes in levee condition before catastrophic failure garnered the interest of the Department of Homeland Security, FEMA, and USACE, which are considering its application to areas such as New Orleans, Houston, St. Louis, and the Green River Valley in Washington state.

In addition to ongoing applications development, several project teams supported the response to disasters that occurred in 2011. One project team supplied satellite images and analyses of damaged areas following the Tohoku earthquake and tsunami (see pages 14–15). Another project team aided the preparations for and response to Hurricane Irene and Mississippi River flooding (see pages 24–25).

In 2011, the Disasters Applications area solicited proposals for feasibility studies and projects that apply Earth observations. The Disasters program will select



“From the theoretical underpinnings to the model algorithms, this [Applied Sciences] project helped ensure that EPA’s regulatory modeling system included the science critical for air quality management and better environmental decision making.”

Rob Pinder
U.S. Environmental Protection Agency

projects in 2012 that improve disaster management and decision making related to topics such as floods, landslides, earthquakes, volcanic effluent, and post-disaster assessment.



Another project developed an Internet-based decision support system with the organizations managing the Appalachian Trail, including the National Park Service, USFS, and Appalachian Trail Conservancy. The system brings together MODIS and *Landsat* satellite products and climate, carbon, and hydrological model outputs within NASA’s TOPS framework. The system predicts the impact of climate and land-use change on the Appalachian Trail, and it has monitoring and predictive modeling capabilities and tools for data visualization. The partners will evaluate the system in 2012.

Ecological Forecasting

The Ecological Forecasting Applications area promotes the use of Earth observations and models to analyze environmental changes that affect ecosystems and to plan effective resource management strategies. In 2011, the Ecological Forecasting portfolio had 20 active projects. Eight of these were new projects beginning in 2011, selected under a five-agency solicitation on climate and natural resources (see page 33).

A feasibility study produced decision tree models predicting the presence and absence of economically important conifer species in the Pacific Northwest. With the U.S. Forest Service (USFS), the project team used USFS Forest Inventory and Analysis program tree species information, satellite imagery, and Terrestrial Observation and Prediction System (TOPS) model outputs. As a proof of concept, the project assembled a tool for predicting where regionally important tree species are likely to grow under future climate conditions. To test the accuracy of its decision tree models, the project turned back to the 1950–1975 period to say which of 15 native conifer species should appear on which USFS and Canadian Forest Service plots. The models achieved an average accuracy of more than 80 percent.

At the NASA Carbon Cycle and Ecosystems Joint Science Workshop in October, the Ecological Forecasting Applications area organized a panel of international conservation organizations to discuss their needs for satellite imagery and associated products. The participants decided to create a regular forum between NASA and conservation organizations, and they plan a kickoff event in 2012. NASA continues to be the U.S. lead for the international Group on Earth Observations Biodiversity Observation Network (GEO BON). In 2011, GEO BON originated the concept of Essential Biodiversity Variables to focus on the key set of observations necessary to document how biodiversity is changing over time.

Several decision support projects, initiated in 2008 and 2009, will conclude in 2012, and the program will focus on transferring the applications for sustained use. In 2012, Ecological Forecasting plans to issue a call for proposals for feasibility studies of innovative applications.

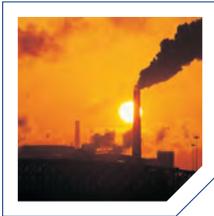


Applications Areas

Health & Air Quality

The Health & Air Quality Applications area promotes the use of Earth observations in air quality management and public health, particularly regarding infectious disease and environmental health issues. The area also addresses effects of climate change on public health and air quality to support managers and policy makers in their planning and preparations. In 2011, the Health & Air Quality Applications area had 36 projects, including ACAST member projects and nine new feasibility studies.

The program supports a project to improve air quality index maps in EPA's AIRNow system by fusing NASA satellite-estimated PM_{2.5} data from MODIS with ground observations. In 2011, the project launched the AIRNow Satellite Data Processor website, including a system overview and experimental maps for air quality forecasters to assess. For information, visit <http://asdp.airnowtech.org> and <http://airnow.gov>.



Also in 2011, the integration of NASA satellite-driven daily air temperature and heat indices for the CDC's Wide-ranging Online Data for Epidemiologic Research (WONDER) system—an online system for data acquisition available for public health end users internationally—was one of several stakeholder successes. The CDC WONDER project lead, Sigrid A. Economou, stated, “These data provide a useful addition to CDC WONDER, allowing public health researchers and policy makers to better include environmental exposure data in the context of other health data available in the system.”

Another project applied NASA research on nitrogen oxides in air quality management. Nitrogen oxides are a primary component to smog formation, and nitrogen dioxide (NO₂) is known to cause respiratory illnesses and lung disease. Lightning is a natural source that can produce significant amounts of nitrogen oxides, especially during the summer. The project team developed a

lightning–nitrogen oxide algorithm and worked with EPA to implement the algorithm in the CMAQ air quality model that states use in their planning to meet air quality standards. The project team and EPA evaluated the model using NO₂ data from the *Aura* OMI instrument. Tests showed that, without the algorithm, CMAQ underestimated NO₂ columns by 15 to 30 percent. In October 2011, EPA released version 5.0 of CMAQ, which included the project's algorithm.

In the summer of 2011, the program supported an Earth Science Division airborne campaign in the Washington–Baltimore region focused on air quality. This campaign was part of the division's Earth Venture class of missions. In 2012, the program plans to solicit applications projects on infectious disease, environmental health, and air quality forecasting and planning. The program also expects to hold its annual review with the Naval War College, a program partner on the effects of dust on the health of U.S. military personnel.

Water Resources

The Water Resources Applications area promotes the integration of Earth observations into water resources management tools for the sustainable use of water. In 2011, Water Resources had 15 projects in its portfolio. Projects addressed snow water runoff, groundwater change, soil moisture, reservoir levels, water quality, and climatic and ecological impacts on water resources. Other critical topics included water demand from agriculture and agricultural impacts from water resource changes.

One project integrated *GRACE* satellite gravimetric measurements with land surface models, and substantially improved soil and groundwater change assessments. The U.S. Drought Monitor now uses the new soil and groundwater data to inform its drought declarations (see pages 6–7).

Another project reached a significant milestone. The USAID Famine Early Warning System Network received final implementation and testing of NASA's Land Information System. Inclusion of the system will facilitate more effective use of sparse hydroclimatic information from diverse sources, which is common in regions of the world that lack food security.

“We commit to improve market information and transparency in order to make international markets for agricultural commodities more effective. . . . [The Global Agricultural Geo-monitoring Initiative] will coordinate satellite monitoring observation systems in different regions of the world in order to enhance crop production projections and weather forecasting data.”

G20 Cannes Summit Final Declaration

A project worked with the University of Maryland, which published levels of more than 600 reservoirs and lakes from the European Space Agency’s *Envisat* to add to its 800 reservoir and lake levels derived from U.S. and international satellites. A diverse audience, ranging from water security experts to fish production forecasters, use this multi-satellite, global information source.



The Water Resources Applications area solicited proposals in 2011 for projects that target water management challenges related to drought, such as snow water estimates, agricultural water demand, national drought estimates, and climate impacts on water resources. The program will select and initiate projects in 2012. In addition, the program will convene water resources managers and scientists to review future satellite missions and address how to improve snow melt and evapotranspiration information, products, and collaboration for use in decision making.

Other Applications

In addition to the four applications areas discussed previously, the Applied Sciences Program supports some ad hoc activities in five others: Agriculture, Climate, Energy, Oceans, and Weather.

Applied Sciences has sponsored for several years a project using Earth observations for global agricultural monitoring, GEO-GLAM. This multinational project is part of an initiative under the intergovernmental Group on Earth Observations. By providing reliable information on crop production, global agricultural monitoring can make agricultural markets more effective, reduce price volatility, and promote food security. In 2011, the G20 Cannes declaration endorsed this initiative to coordinate satellite monitoring to enhance crop production projections.

A study assessing the application of Earth science data in the production of building climate zone maps concluded in 2011. The project was a collaboration with ASHRAE, the building technology society that produces climate zone maps. These maps are used to set building codes by counties and states nationwide. The project successfully produced maps using outputs from NASA’s MERRA, a long-term synthesis of meteorological variables used for investigating climate variability. The project used MERRA surface temperature, relative humidity, and precipitation in determining climate zones.

In 2011, NASA’s web portal, Surface Meteorology and Solar Energy, hit a milestone. This web application delivered its 5 millionth specific user request for data. The portal supports the solar and renewable energy industries, and users from other areas, such as health and agriculture, have also ordered data. There are registered users from more than 120 countries. For information, visit <http://eosweb.larc.nasa.gov/sse>.

A project with the National Renewable Energy Laboratory (NREL) made progress in developing a satellite-based mapping tool to depict solar radiation levels globally. The project team expects to enhance several NREL tools, including the National Solar Radiation Database. In 2011, the team tested its algorithm for multiple surface sites and evaluated performance across data from multiple satellites in the nearly 30-year record. In 2012, the team will conduct its first end-to-end global production test and begin the application transition to NREL.



Chile’s Puyehue-Cordón Caulle Volcanic Complex erupted on June 4, 2011 and continued releasing ash and steam for months, affecting air traffic. *Aqua*/MODIS observed the plume blowing to the northwest. In this image from July 2, 2011.



Serving Air Quality Managers and Decision Makers

Applied Sciences continually looks for innovative ways to make Earth science research, data, and techniques accessible to organizations for application. In 2011, the Program introduced new Applied Sciences Teams. These teams are a group of funded scientists charged with reaching out to federal, state, and local organizations and responding to their inquiries about the latest scientific knowledge and ways to apply it. The teams perform a synthesis function across the research, serving as a way to support users and managers with information from the latest scientific papers.

The Applied Sciences Program initiated the Air Quality Applied Sciences Team (AQAST) in 2011 to serve needs of U.S. air quality managers and decision makers through the use of Earth science knowledge, models, and data.

AQAST has 19 members, including scientists and applied researchers with experience in atmospheric chemistry, ozone, emissions, aerosols, trace gases, modeling, transport, and climate as well as air quality planning, forecasting, and public health. The members engage and partner with local, state, interstate, and federal air quality agencies, such as the Bay Area Air Quality District, Wisconsin Department of Natural Resources, Western Regional Air Partnership, Lake Michigan Air Directors Consortium, NOAA, and EPA.



A new 19-member Air Quality Applied Sciences Team helps user organizations learn about and apply the latest scientific knowledge and research results.

“AQAST offers a unique opportunity to provide additional technical analysis services for the air quality management community that complements air quality planning tools already in use,” said Tom Moore, air quality program manager, Western Governors’ Association. “The team’s expertise and ability to evaluate air quality issues using NASA data and tools, provides decision makers with results to improve air quality analysis and planning, and identifies new applications to help them better do their work.”

Daniel Jacob of Harvard University leads the team. AQAST members work on short-term projects that usually involve one member and an air quality management partner. Members also form “tiger teams,” which allow for quick turnaround on projects that require cross-team collaboration to address the urgent needs of one or more partner organizations. To learn more about AQAST, visit <http://acmg.seas.harvard.edu/aqast/index.html>.

“AQAST offers a unique opportunity to provide additional technical analysis services for the air quality management community that complements air quality planning tools already in use.”

Tom Moore
Western Governors’ Association



Improving Natural Resource Management in Response to Climate Change

NASA's Earth Science Division led a five-agency request for proposals in 2010 entitled "Climate and Biological Response: Research and Applications." The solicitation focused on innovative projects to bring the global view of climate from space down to Earth to benefit the management of wildlife and key ecosystems.

NASA partnered with USGS, the National Park Service, U.S. Fish and Wildlife Service, and Smithsonian Institution. This solicitation marked the first time Applied Sciences targeted research investigating the intersection of climate and biological studies. The partners received 151 proposals and, in 2011, they selected 17 projects for awards, investing \$18 million over four years.



Eight of the awarded projects are Applied Sciences projects to apply Earth observations and models for management of natural resources and ecosystems. The projects develop and improve forecasting tools that resource managers apply to incorporate the impacts of climate change on the populations, species, communities, and ecosystems they manage.

Projects will address land use and climate adaptation challenges in national parks, national wildlife refuges, national forests, and off the U.S. coasts. Projects will also examine groups of managed wildlife species including forest birds, waterfowl, and whales. One focuses on habitat modeling tools and climate impacts for management of invasive species.

NASA leads a five-agency effort to enhance natural resource management in a changing climate.

"The response to this solicitation was much greater than we expected, and the overall quality of the proposals was quite high. Working with the other agencies was a great experience," said Woody Turner, program manager of Applied Sciences' Ecological Forecasting Applications area. "These projects bring together global satellite data of the physical environment with ground-based data and computer modeling to assess how specific species and ecosystems will respond to climate change. As a result, agencies and resource managers can improve management strategies for ecosystems and natural resources."



Cover of the brochure on the interagency solicitation that NASA's Earth Science Division led.

For a summary of the solicitation, visit http://www.nasa.gov/topics/earth/features/climate_partners.html.

To learn more about the projects, visit the Ecological Forecasting Applications page on Applied Sciences' website: <http://appliedsciences.nasa.gov/eco-forecasting.html>.





Water Resources Workshops

Applied Sciences' Water Resources Applications area had a busy and productive year with several events and workshops.

NASA–USDA Evapotranspiration Workshop

NASA and the USDA co-sponsored an Evapotranspiration (ET) Workshop in Silver Spring, Maryland, on April 5–7, 2011. The workshop's goal was to help ensure sufficient and accurate ET information for U.S. and international water resources agencies. Seventy-six attendees discussed ways ET information could be used for sound decision making regarding water availability for competing needs, such as crop production, human consumption, energy production, and ecosystem services.



Attendees discussed the applications, observations, and model needs for the community, and completed a white paper by the fall of 2011 to support the need for ET as an Essential Climate Variable (ECV) within the Global Climate Observing System and steps to improve the use of ET measurements. In addition, the workshop led to the creation of a multi-agency working group comprised of private sector organizations and local, state, and federal agencies to promote the development and practical use of satellite-based ET data. This group is planning a series of educational workshops where users of satellite-based ET data can share their experiences with fellow water resources managers and scientists.

The Applied Sciences Program organized as well as co-sponsored a variety of group discussions to better inform decision making in water management.

To learn more about the ET workshop, visit http://wmp.gsfc.nasa.gov/workshops/ET_workshop.php.

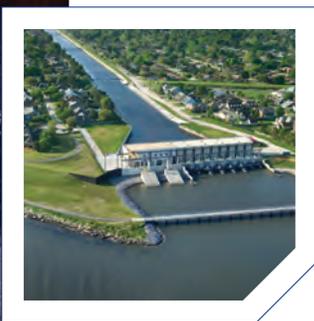
NASA Global Drought Monitoring Workshop

NASA hosted the Global Drought Monitoring Workshop in Silver Spring, Maryland, on April 11–12, 2011. The workshop attracted 74 attendees who discussed the information requirements for drought monitoring products. Breakout groups focused on monitoring strategies, scientific and technical issues, and developments in a global drought monitoring service.

Attendees evaluated and explored ways that NASA's drought monitoring capabilities could be used more effectively, both regionally and globally. Attendees developed a set of actions that NASA, alone or in cooperation with other federal agencies, could use to influence drought information for decision-making purposes. The workshop provided the set of actions to the Water Resources applications area to offer direction on program priorities and opportunities related to drought.

Border Water Management Workshop

NASA held a workshop, Remote Sensing Applications for U.S.–Mexico Border Water Management, in San Diego, California, on June 8–9, 2011. Co-sponsored by the California Department of Water Resources, the

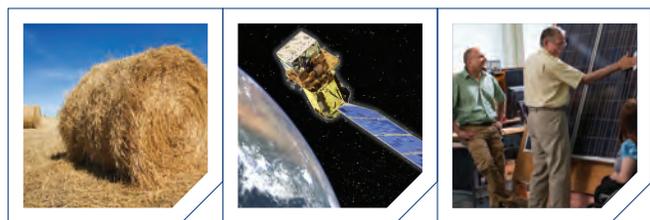


“We made a big push in 2011 to convene water resources managers and scientists, look at needs for information, and discuss applications of remote sensing to help with water resources management. The people were really enthusiastic and insightful, and the workshops were incredibly productive. They helped guide where we’re going next with the Water Resources Applications area.”

Brad Doorn
Applied Sciences Program

educational workshop provided water managers on both sides of the border with an overview of remote sensing data and tools that could be applied to binational water management issues. The workshop also built on experience gained from recent NASA projects demonstrating the potential use of existing remote sensing data sets for water resources applications in the California–Mexico border region.

Thirty attendees—representing a binational cross section of academia, federal and local agencies—heard talks on remote sensing basics, examples of remote sensing applications for water resources management, and a case study involving the Cienega de Santa Clara wetlands at the Colorado River Delta in Baja California, Mexico.



Water managers who attended the workshop discussed the need to improve groundwater monitoring, better prepare for droughts and floods, and characterize vegetation in sensitive wetlands through the use of remote sensing data collection and monitoring for decision making. The paucity of available ground-based observations presents a significant challenge to Mexican water agencies, as well as U.S. agencies involved with Mexico in managing trans-boundary water resources.

To overcome some of the difficulties in implementing trans-boundary projects, some attendees concluded

that it might be best to develop more case studies and work with local universities and nongovernmental organizations, some of which were represented at the workshop. The workshop helped facilitate discussions about possible projects prior to proposal submission to Applied Sciences’ Water Resources Applications area.

Western States Evapotranspiration Workshop

NASA, in partnership with NOAA, USDA, USGS and WestFAST (Western States Federal Agency Support Team), held a Western States Evapotranspiration Workshop in Boise, Idaho, on October 12–13, 2011, for 85 people. This workshop demonstrated ET remote sensing capabilities in the western United States, helping western states’ resource managers to improve their efficiency and the costs associated with water resources management.

The amount of ET to the atmosphere for many western states can be more than 90 percent of the water loss and can critically affect local economies in terms of agriculture, recreation, hydroelectric power, and more. The workshop included several presentations that highlighted the role remote sensing could play in better understanding ET. As a result, the workshop identified specific requirements and limitations of existing ET data for western states application users, as well as educational and information needs of both ET data users and developers.



Capacity Building Activities

The Applied Sciences Program supports four interdisciplinary, capacity building activities: DEVELOP, SERVIR, Gulf of Mexico Initiative, and Applied Remote Sensing Education and Training. These programs help extend the application of Earth science to benefit people around the world. In 2011, Nancy Searby became the inaugural manager of the Capacity Building program.

DEVELOP

DEVELOP is a national training and development program. Young professionals gain hands-on experience with satellite remote sensing and apply Earth observations to real-world issues facing state and local governments. Participants work on specific projects and communicate their results to broad audiences and leaders in government, academia, and industry. The program fosters a high-quality corps of early-career professionals, cultivating advanced skills in Earth science applications and an understanding of science in decision making.



The past year was very successful for DEVELOP, with 259 interns—a program record—working on 54 applications projects at 12 locations. These activities involved 42 states and territories, greatly extending the benefits of NASA's investment in Earth observing satellites and applications. In addition, NASA gave DEVELOP a Group Achievement Award in recognition of outstanding accomplishments in the training and development of students and early career professionals to extend NASA Earth science.

Four programs sponsored activities to apply NASA Earth observations to improve the capabilities of decision makers, community leaders, and resource managers in the United States and abroad.

DEVELOP expanded with three new centers in 2011—Saint Louis University in Missouri, Fort Collins Science Center in Colorado, and Tecnológico de Monterrey in Mexico—setting the stage for new opportunities for interns, projects, and partnerships in the respective regions. The Monterrey office represents the inaugural international center for the program, and the Fort Collins office represents the first collaboration with a fellow federal agency (USGS). With these new locations, the total number of DEVELOP centers increased to 12. The DEVELOP website has the complete list of centers.

During 2011, DEVELOP participants gave presentations at more than 30 science and policy conferences, such as the American Meteorological Society Annual Meeting, AGU Fall Meeting, Council of State Governments' National Conference, and IAC. DEVELOP also issued 10 articles in publications such as *Earth Observer*, *Researcher News*, and *Earthzine*.

Through a partnership with *Earthzine*, DEVELOP began a series of virtual poster sessions as part of each 10-week term. These sessions provided an opportunity for DEVELOP teams to present their work to global audiences through short videos that the students filmed and edited to highlight their work. The 2011 fall term's virtual poster session attracted viewers from more than 89 countries, who made comments and discussed with the DEVELOP interns their application projects.



NASA gave DEVELOP the Group Achievement Award in recognition of outstanding accomplishments in the training and development of students and early career professionals to extend NASA Earth science.

Looking to 2012, DEVELOP will continue to expand its reach with new locations in North America. It will investigate efforts to conduct international projects in Asia and South America. DEVELOP will pursue a collaboration with the Embassy of Rwanda, exploring opportunities for projects in Africa and possibilities for Rwandan students studying in the United States to participate in the program. DEVELOP expects a new record number of internship applicants and projects in 2012, and the program will continue to support professional development in applying Earth observations. To learn more about DEVELOP, visit <http://develop.larc.nasa.gov>.

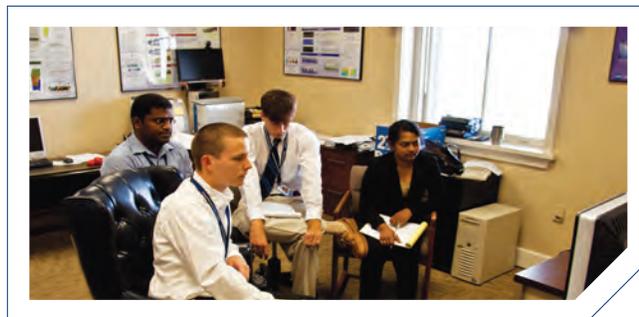
SERVIR

SERVIR is a joint venture between NASA and the U.S. Agency for International Development (USAID). SERVIR integrates satellite observations, ground-based data, and forecast models to help developing nations monitor, manage, and respond to environmental changes. SERVIR enables managers, scientists, media outlets, and government officials in developing countries to improve their decisions and actions. Using Earth observations, SERVIR helps nations in areas of water resources management, disaster assessment, public health, biodiversity conservation, climate change, agricultural development, and more.

SERVIR has three regional hubs—SERVIR-Mesoamerica, SERVIR-East Africa, and SERVIR-Himalaya—and more are expected.

SERVIR's first hub opened in Panama at the Water Center for the Humid Tropics of Latin America and the Caribbean, or CATHALAC. This hub, SERVIR-Mesoamerica, serves Central America and the Dominican Republic. CATHALAC completed its NASA funding

contract in 2011 and began self-sustaining operations. CATHALAC continues as a SERVIR network affiliate, using Earth observations and models in providing maps and information products to the region.



DEVELOP's team in Mobile, Alabama, sharing project results via webinar. Left to right: Naresh Aligeti, Josh Stodghill, Hunter Winstanley, and Tharini Jeyaprakash.



DEVELOP participants and managers at Langley Research Center (Hampton, Virginia) accept the 2011 NASA Group Achievement Award, in recognition of the program's outstanding accomplishments in the training and development of students and early career professionals to extend NASA Earth science.



Capacity Building Activities

SERVIR-Mesoamerica assisted in the response to Tropical Storm Emily in July and August 2011. SERVIR used *TRMM* data to characterize rainfall accumulation for the island of Hispaniola along with MODIS data to assess flooding. The Dominican Republic government and USAID used the information and products before, during, and after the storm, which passed over the country on August 3. This response marked the 50th extreme event to which SERVIR had provided support in Latin America and the Caribbean. In 2011, SERVIR conducted additional post-disaster assessments including floods, severe precipitation deficit, earthquakes, and others in the region.

SERVIR conducted training to help build the capacity of local decision makers in using geospatial data and applications to make informed environmental choices. SERVIR trained 115 people during the year at the Mesoamerica hub. SERVIR-East Africa trained 330 people, and 437 people attended training at the SERVIR-Himalaya hub.

SERVIR-Himalaya supported the international symposium, “Connecting from Space to Village: Enabling Climate Change Policy and Actions in the Himalayas,” in November 2011. Held in Bhutan, the event emphasized uses of space technologies for addressing climate change in the Hindu Kush–Himalaya region. The symposium introduced scientists, researchers, government officials, development practitioners, youth, and media to Earth science applications, remote sensing, and GIS technologies. For example, applications demonstrated at the event helped the Ministry of Water Resources in Bhutan quantify impacts of climate change on water resources and energy needs in the region.



Participants at the Third Crop and Rangeland Monitoring Workshop, Nairobi, Kenya, September 26–30, 2011.

At SERVIR-East Africa, there was a crop and rangeland monitoring workshop in September. SERVIR staff demonstrated a streamflow model for an eight-country domain in East Africa. Streamflow information supports farming practices and gives early warnings of agricultural production deficits, helping officials plan for and respond to food emergencies. In December, SERVIR-East Africa hosted, in cooperation with USGS, a workshop in Kenya to develop an ecosystem map that encompasses Africa’s Saharan and Mediterranean areas. This ecosystem map supports biodiversity conservation planning, resource management, and assessments of climate change on ecosystems in the region. To learn more about SERVIR, visit <http://www.servirglobal.net>.

Gulf of Mexico Initiative

The Gulf of Mexico Initiative (GOMI) supports the Gulf region in applying Earth observations to address coastal management issues. Formed after the devastating Hurricanes Katrina and Rita, GOMI focuses on regional priorities defined by the Gulf of Mexico Alliance, a collaboration of Alabama, Florida, Louisiana, Mississippi, Texas, and 13 federal agencies, to enhance the ecological and economic health of the Gulf region.

GOMI identifies user needs in the region that can be addressed by Earth observations. GOMI creates tools and supplies information that helps state, local, and other users in the region make informed decisions, establish policies, and respond to crises. GOMI oversees applications projects, gives students hands-on experience, and participates in regional events. Overall, GOMI is building capacity of users in the Gulf Coast region—managers, scientists, students, government officials, and others—to apply NASA Earth science in their own communities.

SERVIR's support during Tropical Storm Emily was the 50th extreme event it has aided in Latin America and the Caribbean.

In 2011, GOMI applied Earth observations to respond to major disasters, such as flooding along the Mississippi River and tornadoes that struck the southeastern United States. The ongoing response to the Deepwater Horizon oil spill highlighted GOMI's disaster assistance and an operational tool for oil slick detection. The project utilized NASA observations, including synthetic aperture radar data. Accurate information about the slick facilitates optimal deployment of resources to minimize the ecological and economic impact of the spill.



GOMI transferred several research products to end users in 2011 for sustained use. To enhance disaster management response capabilities, Lawrence Livermore National Laboratory in California began using surface roughness data. The Mobile Bay National Estuarine Program began using GOMI land-use and land-cover products for conservation and restoration decision making on critical habitats around Mobile Bay, Alabama. In the Suwannee River Basin, organizations in Florida began using a GOMI tool to help farmers choose management practices to minimize impacts on water quality.

In 2012, GOMI will continue to work with the Gulf of Mexico Alliance and the Gulf Coast Ecosystem Restoration Task Force to assist them in applying Earth observations. Dozens of projects are expected to complete in 2012, and GOMI will begin preparations for the close-out workshop in early 2013. To learn more about GOMI, visit <http://www.coastal.ssc.nasa.gov>.

Applied Remote Sensing Education and Training

The Applied Sciences Program conducts professional-level training focused on building skills to access and use Earth observation data. Applied Remote Sensing Education and Training, or ARSET, includes hands-on, computer-based sessions to support users' application of NASA Earth observations to environmental management and decision support.

The ARSET program conducted eight in-person and online training sessions in the United States and abroad, reaching 166 end users in 2011. The program expanded beyond air quality to begin courses for water resources management. For example, ARSET staff participated in a GEO Latin America and Caribbean Water Capacity Building Workshop in Cartagena, Colombia. At this event, ARSET taught participants how to access and apply NASA data for water topics; training modules used NASA precipitation and snow products, with case studies tailored to South America. To view the water modules (in English and Spanish), visit <http://water.gsfc.nasa.gov>.

ARSET conducted its first training for health professionals at the annual conference of the International Society of Exposure Science in Baltimore, Maryland. For this training, ARSET staff developed modules specific to health applications of NASA air quality data. In addition, ARSET held training in Montreal for industry professionals and air quality managers from Environment Canada, the Canadian environmental agency. To view the air quality training modules, visit <http://airquality.gsfc.nasa.gov>.

To increase the number of end users reached, the ARSET program also developed its first online course, held over a five-week period in the fall of 2011. Sixty attendees, including DEVELOP interns, participated in the weekly online learning sessions that also included live question and answer capabilities.

To learn more about the *Earthzine* site for the DEVELOP 2011 video contest, visit <http://www.earthzine.org>.





Supporting Climate Assessment and Adaptation Planning

NASA's Earth Science Division (ESD) is actively involved in initiatives to apply scientific knowledge and modeling capabilities regarding climate change and its risks. In partnership with ESD's Research Program, Applied Sciences sponsored workshops and initiated projects to support the National Climate Assessment. The two programs also supported broader NASA efforts on climate risk resiliency and planning at NASA Centers.

Contributing to the National Climate Assessment

The Global Change Research Act of 1990 requires the United States to conduct periodic assessments of climate change. Each National Climate Assessment (NCA) analyzes and projects major trends for the subsequent 25 to 100 years in terms of changes to U.S. regions and economic sectors.

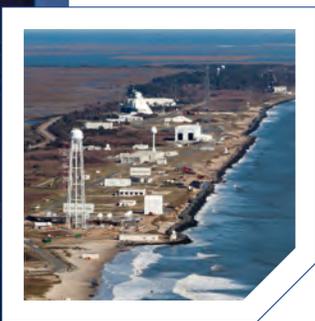


In 2011, Applied Sciences gave the kickoff address at an NCA Societal Indicators Workshop. The event focused on indicators that can provide understandable trends in climate changes, variations in vulnerabilities, and success of response strategies. The workshop addressed socioeconomic indicators such as demographic, behavioral, and economic aspects. The workshop produced key information and principles for the Federal Advisory Committee writing the official 2013 Assessment.

Applied Sciences supported NASA Centers' climate adaptation planning and NASA's contributions to the National Climate Assessment due in 2013.

Applied Sciences sponsored NASA's Goddard Institute for Space Studies (GISS) in New York to lead the Northeast regional assessment. GISS brought together more than 60 regional leaders to plan and develop the technical input on the Northeast for the 2013 Assessment. Applied Sciences personnel also participated in regional assessment for the Southeast, where many NASA Centers are located.

In 2011, ESD's Applied Sciences and Research Programs requested project proposals from NASA Centers to support the NCA and climate assessment work. Of the 34 proposals from seven Centers and GISS, ESD selected 14. Some of the projects provide tools for conducting assessments, such as key data sets, climate model runs, scenarios, and visualizations to communicate findings. Other projects will produce specific assessments of climate trends for sectors, regions, and interdisciplinary topics. These projects commenced in 2011 and support NASA contributions to the 2013 NCA and future ones. To learn more about the NCA, visit <http://www.globalchange.gov/what-we-do/assessment>.



“[Each federal agency shall] evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency’s operations and mission in both the short and long term.”

Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance



Applying NASA Earth Science at NASA Centers

NASA formed a Climate Adaptation Science Investigators (CASI) workgroup to investigate climate risks at NASA Centers and their environs. NASA Earth scientists partner with Centers’ facility managers regarding areas such as infrastructure, environmental management, and master planning. CASI is part of an ESD collaboration with the NASA Office of Strategic Infrastructure (OSI).

The CASI team applies NASA’s scientific knowledge and climate models to determine Center-specific climate hazards, so the Centers can assess risks and vulnerabilities and design appropriate actions. In 2012, CASI will likely expand to include additional Centers and facilities. Cynthia Rosenzweig and Radley Horton of GISS lead the workgroup.

In 2011, CASI developed downscaled climate projections for each NASA Center using regional climate models from the North American Regional Climate Change Assessment Program. Using the projections, CASI worked with Centers’ master planners on energy modeling for Center buildings.

Building Climate Resiliency at NASA Centers

In February 2011, NASA held a workshop in Mountain View, California, to examine climate risks and adaptation strategies for Ames Research Center and Silicon Valley. More than 90 people participated, including facilities, master, and environmental planners. Attendees included regional and county officials from the Bay Conservation and Development Commission, USACE, and San Francisco Public Utilities Commission. The key climate hazards in the region involve sea level rise, rising temperatures, and increases in drought and flood occurrences.

In September, NASA hosted a workshop in Virginia to examine climate risks and resiliency at NASA Langley Research Center and in the Hampton Roads region. Participants included representatives from the local planning districts, Wetlands Watch, local universities, and the U.S. Air Force. In developing strategies, participants discussed the likelihood and consequences of climate impacts to infrastructure, natural resources, and communities.

These workshops are part of the ESD–OSI collaboration and are hosted by each Center. In 2012, NASA plans to hold climate resiliency workshops for Johnson Space Center in Texas and Stennis Space Center in Mississippi.

A 2011 article in *Livebetter* magazine describes NASA’s Climate Adaptation Science Investigators workgroup and how NASA science can support climate resiliency and adaptation:
http://livebettermagazine.com/eng/magazine/article_detail.lasso?id=244.







Applied Sciences Program Management

This section provides information on Applied Sciences' programmatic activities and performance in 2011, including work to estimate the socioeconomic benefits from the use of Earth observations in decision making.

In addition, this section describes activities that Applied Sciences did with other programs of NASA's Earth Science Division. In particular, this section reviews significant work to increase the involvement of the applications community in early-stage planning activities for future Earth-observing satellite missions.





Achieving Program Goals

The Applied Sciences Program achieved its 2011 Annual Performance Goal to assess socioeconomic benefits from the use of Earth observations by delivering socioeconomic impact analyses of two projects. These analyses were part of the Program's broader efforts to quantify socioeconomic benefits of Earth science applications.

The impact analyses concerned the use of Earth observations for aviation volcanic ash advisories and malaria early warnings (see pages 45–46 for summaries). The full reports and additional analyses are available on the Program's website.

Tracking Progress of Applications Projects

In 2010–2011, the Program introduced a nine-stage Applications Readiness Level (ARL) index to track the maturity of applications projects—from the initial idea, through its stages of development, to its transition to operational use. The Program assesses the projects' ARLs throughout the year. In the index, ARL 1 represents basic research and ARL 9 represents operational deployment and use in decision making.

Next year will be the first that the Program uses the ARLs in its Annual Performance Goals. Applied Sciences will include ARL assessment requirements in solicitations for decision support projects.

In 2011, Applied Sciences gathered the ARLs of projects to serve as the baseline for comparison in 2012. The Program gathered data from 122 active projects across the applications areas and the Gulf of Mexico Initiative, including the projects' starting, current, and goal ARL at project completion. The baseline ARL assessment established that 67 percent of the projects were at ARL 4 or lower.

Applied Sciences met its 2011 performance goal and gathered baseline data on its new performance metric.

Looking to Future Goals

The Program's 2012 Annual Performance Goal calls for at least 25 percent of the decision support projects to advance at least one ARL. The Program will compare the projects' 2012 ARLs with the baseline ARLs of 2011. The 2013 Annual Performance Goal is also for at least 25 percent of the decision support projects to advance at least one ARL.

ARL Levels 7-9

Complete the integration and transition of use of Earth science products for sustained use.

ARL 9
—
ARL 8
—
ARL 7

ARL Levels 4-6

Develop and prototype capability of Earth science product to enhance decision making.

ARL 6
—
ARL 5
—
ARL 4

ARL Levels 1-3

Establish the information content, characterize decision support need, and assess proof of concept of application idea.

ARL 3
—
ARL 2
—
ARL 1

Depiction of the Applications Readiness Levels.



Quantifying the Benefits of Earth Observations

In 2011, Applied Sciences performed two analyses of the social and economic impacts associated with the use of Earth observations.

Volcanic Ash Advisories and Aviation Safety

Large volcanic eruptions can eject ash to heights at which commercial aircraft normally fly. Volcanic ash can cause damage to engines and fuselages, making it necessary to reroute, delay, or cancel flights to protect aircraft and maintain passenger safety. The international aviation community uses information and warnings from nine Volcanic Ash Advisory Centers (VAACs) on the location of volcanic ash.

Designed for atmospheric and climate research, the *Aura* satellite measures ash aerosols and sulfur dioxide, which serve as reliable markers for volcanic ash clouds. Applied Sciences funded a project beginning in 2006 that worked with NOAA and the Federal Aviation Administration to integrate *Aura* data into the two U.S.-based VAACs and enhance their warnings.



In 2010, Iceland's Eyjafjallajökull volcano erupted, sending volcanic ash into European airspace that cancelled flights. The London VAAC had not previously used *Aura* data, and the project team developed and delivered requested data products within days of the eruption to support the London VAAC's warnings. European officials used the *Aura* products in their determinations of which airspace to open.

In 2011, Applied Sciences analyzed the benefits of the project and VAACs' use of the *Aura* data. One part focused on the benefits from use following the Eyjafjallajökull eruption, and one part focused on a global estimate of average annual benefits.

Use of the Earth observations following the 2010 volcanic eruption in Iceland saved the aviation industry an estimated \$25 million to \$75 million.

The analysis team used data on flight cancellations and revenue losses due to Eyjafjallajökull, historical frequencies of aircraft damage from volcanic ash, and aircraft repair costs. The team estimated how much the *Aura* data would reduce the uncertainty about the level of ash threat, determining a risk-adjusted value of the observations. Overall, the analysis found that the satellite data reduced the probability of an aircraft experiencing a volcanic ash incident by approximately 12 percent.

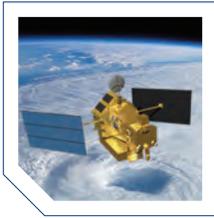
The team estimated that use of the data following the Eyjafjallajökull eruption saved \$25 million to \$72 million in avoided revenue losses due to unnecessary delays and avoided aircraft damage costs. If the data had been used from the beginning of the incident, an estimated additional \$132 million in losses and costs might have been avoided.

The team extrapolated the risk-adjusted results globally to estimate the potential annual impact from the use of Earth observations by the VAACs. Accounting for frequency and magnitude of volcanic eruptions, the team estimated an expected value of up to \$10 million annually.

Applied Sciences' total investment in the project was \$1.4 million.

Malaria Early Warning

Malaria infects hundreds of millions of people every year and claims countless lives. In areas where malaria is endemic, health officials often have limited resources to direct preventative measures and protect vulnerable populations. Applied Sciences funded a project with USAID and USGS for a prototype Malaria Early Warning System (MEWS) to provide precipitation estimates to help malaria control planners assess candidate areas for malarial outbreaks and target the allocation of resources for prevention.



Quantifying the Benefits of Earth Observations

The project applied *TRMM*, *Aqua*, *Landsat*, and other observations into models of mosquito activity and developed estimates of malaria transmission efficiency and predictive capabilities. It applied satellite-based rainfall, temperature, vegetation cover, and other environmental data to identify specific regions where outbreaks were likely to occur. MEWS began using the data in 2007.

In 2011, Applied Sciences used two approaches to analyze the benefits of the project and value of the Earth observations. The analysis focused on estimating the reduced mortality, reduced morbidity, and improved cost efficiency. The team focused on Botswana, which had malaria statistics for 1997–2009.



The team used an expert opinion approach. Experts provided a consensus estimate that as much as 10 percent of the observed reductions in malaria cases might reasonably be attributable to the NASA project, representing an upper limit of 105 fewer cases per year in Botswana.

The team extrapolated the results to 28 countries in sub-Saharan Africa to obtain a first-order estimate of the potential regional impact. Estimates in reduction of malaria cases ranged from 665,000 to 6.9 million cases per year, suggesting an impact of at least a half million avoided cases.

The team also used a comparative impact approach. The team compared malaria cases and deaths after inclusion of the satellite data with projections based on historical trends prior to 2008.

Based on expert opinion, the use of Earth observations could reduce at least a half million cases of malaria each year in sub-Saharan Africa.

In this approach, the team found that the impact of the Earth observations was not statistically significant from the variation in the available data. There were too many confounding factors to distinguish the impact from all the other factors involved in the malaria control activities, especially from a purely retrospective analysis.

The MEWS analysis demonstrated a potential approach to analyzing benefits as well as some difficulties in attributing benefits in health projects, which often have multiple confounding factors. As a result, the Program plans to approach its socioeconomic impact analyses more prospectively and support collection of data from the outset of a project to enable better impact assessments.





Exploring Science and Policy Connections

In 2011, Applied Sciences hosted four speakers in the third year of its Climate Policy Speaker Series to present views on climate and climate policy. The series is designed to assist the NASA community in learning about climate policy from various perspectives, such as economics, national security, conservation, and industry. The sessions include discussions about opportunities for Earth observations to inform the climate debate and monitor progress toward policy objectives.

In April, David Goldston, director of government affairs for the Natural Resources Defense Council, presented “Science in a Cold (Political) Climate: Climate Science, Policy, Politics, and Congress.” Goldston worked for Congress for more than 20 years on science and environmental policy, and wrote a monthly column on science policy for *Nature* for several years. He spoke on the outlook for action on climate policy, lessons to draw from the 2009–2011 period, and the roles of climate science in the policy debate and implications of those roles.



In July, David Antonioli, chief executive officer of the Verified Carbon Standard Association, presented “The Role of Voluntary Carbon Markets in Reducing Greenhouse Gas Emissions.” He discussed how standardized carbon accounting methodologies are developed and applied to ensure that emissions credits are real, measurable, and unique for functional carbon markets. In addition, he spoke about verification tools and standards for carbon credits that support actions by businesses, nonprofits, and government entities.

The Program hosted speakers on a range of climate topics as part of its ongoing Climate Policy Speaker Series.

The November event had two speakers. Matthew Banks, a senior program officer at the World Wildlife Fund, spoke about the Fund’s Climate Savers program, in which companies voluntarily reduce their greenhouse gas emissions. Inge Horkeby, director of environmental affairs at the Volvo Group, discussed Volvo’s involvement in Climate Savers as the first vehicle manufacturer in the program. He discussed the Volvo Group’s decision to join Climate Savers, the impact of the commitment to dramatically reduce greenhouse gas emissions corporate wide, and the benefits of the decision.

In 2012, Applied Sciences expects to have speakers from the fields of building design, psychology, media, and others. For information on this series, visit <http://science.nasa.gov/earth-science/climate-policy-speaker-series>.

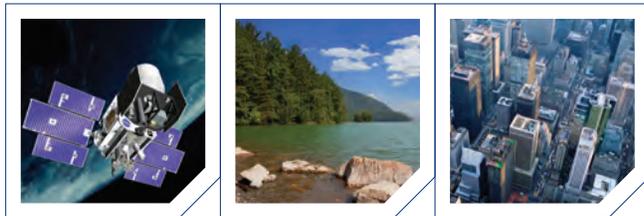




Engaging Users in Satellite Mission Planning

Existing and past satellite missions have demonstrated the value of NASA satellite observations to public and private organizations, which have applied the data with increasing sophistication. In preparing for future Earth-observing satellite missions, Applied Sciences is encouraging organizations to become involved in early-phase mission planning so they can anticipate potential applications, support mission design, be prepared to use the data soon after launch, and provide feedback on the data products.

Several activities in 2011 facilitated the consideration and integration of applications in the design, development, and planning for future Earth science satellites.



Mission Program Applications Leads

The Earth Science Division created the new role of program applications lead (PA) in 2011 for each NASA Earth science satellite mission in pre-formulation and development. Applied Sciences assigned people to the new PA role, which is the applications equivalent of the program executive and program scientist for each satellite mission.

Overall, the PAs help the mission team identify items that would increase or diminish the applications value of that mission. The PAs ensure that teams consider the use of the data products and measurements by end users other than the research science community during satellite

mission planning and requirements development. They work with the mission teams to examine applications-oriented concerns and opportunities for each mission. The PAs encourage key users to attend mission definition meetings, and they identify key studies to inform design trade-offs.

The Program continued to encourage and enable the applications community to contribute to Earth-observing satellite design and mission planning.

In 2011, Applied Sciences also identified deputy PAs (DPAs) from the NASA Centers, who will support the PAs in engaging and organizing the applications community for their respective satellite missions.

Missions and Applications Workshop

In September 2011, as a kickoff event for the PA/DPAs, the Program held a workshop in Arlington, Virginia, to clarify roles and responsibilities, review mission lifecycles, and identify prime opportunities for applications involvement in mission planning. The attendees discussed ways to engage diverse user groups in the mission phases, especially to bridge research and applications objectives of the mission.

The attendees also identified a possible applications traceability matrix as input to the traditional science traceability matrix. They proposed a possible mission applications review in the planning cycle to precede the mission concept review. The attendees highlighted the need for applications specialists to look across



The *SMAP* mission created an Early Adopters program for organizations to assess the potential value of *SMAP* to their decision-making activities years before launch. *SMAP* selected seven organizations in 2011 as Early Adopters and plans to select more in 2012.

satellite missions, obtaining data from multiple satellites rather than focusing on individual missions. They also emphasized the need to understand the science requirements so applications specialists can anticipate the data products and work on novel uses even prior to launch. A paper discussing missions and applications is available on the Program's website.

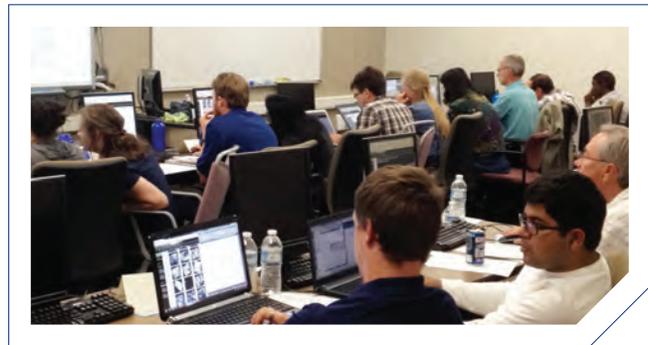
SMAP Applications Plan and Workshop

In 2011, the *Soil Moisture Active Passive (SMAP)* mission team released its *SMAP* Applications Plan to engage end users and build broad support for *SMAP* applications. As part of the plan, *SMAP* has an Early Adopters program for organizations that have clearly defined needs for *SMAP*-like data products and will evaluate and demonstrate the utility of *SMAP* data for their particular system or model. In 2011, *SMAP* selected seven organizations as Early Adopters, and it plans to select more in 2012.

The *SMAP* Applications Working Group organized a workshop focused on implementation of the applications plan, growth of the *SMAP* applications community, and perspectives from the *SMAP* Early Adopters. More than 100 people representing federal agencies, academia, and private industry attended the October 12–13 workshop in Washington, D.C.

Breakout sessions highlighted how *SMAP* data can be useful for various disciplines and identified possible technical challenges in incorporating *SMAP* data into existing models and tools. Among the conclusions, the attendees planned to address data usability for diverse user groups, define data formats and delivery times (i.e., latency) that will apply to science and applications communities, and address a need to increase the focus

on freeze/thaw products for future applications activities. To learn more about *SMAP* and its applications working group, visit <http://smap.jpl.nasa.gov>.



HyspIRI Symposium and Science Workshop

The *Hyperspectral Infrared Imager (HyspIRI)* mission team held a symposium on May 17–18, and a science workshop on August 23–25, near Washington, D.C. Focused on products for ecosystems and climate, symposium attendees addressed key questions regarding priority products for climate and societal benefit, how they would be produced, and how they would uniquely support NASA science and applications goals.

With about 180 attendees, the *HyspIRI* Science Workshop in August devoted a day to global and regional applications of potential *HyspIRI* measurements, including volcanic hazards, wildfires, carbon emissions, urban change, and mineral mapping. Other days of the workshop addressed scientific objectives, precursor science and technology, and mission requirements. To learn more about *HyspIRI* and the events, visit <http://hyspiri.jpl.nasa.gov>.



Engaging Users in Satellite Mission Planning

GEO-CAPE Community Workshop

The *Geostationary Coastal and Air Pollution Events (GEO-CAPE)* mission study team held its second open-community workshop on May 11–13, in Boulder, Colorado, to gather input and discuss developments in the mission definition. In addition to plenary sessions, the workshop featured parallel ocean color and atmospheric science sessions to discuss studies and prioritize future tasks.

The *GEO-CAPE* mission team scheduled the workshop to occur in coordination with an EPA air quality remote-sensing workshop as well as a meeting of NASA’s Air Quality Applied Sciences Team. At the workshop, the atmospheric science group endorsed its current science traceability matrix, and the ocean group identified key trades to focus on by the end of 2012. Workshop participants also confirmed that there were no co-dependent requirements between the atmosphere and ocean components, eliminating the need for all instruments to necessarily be on the same satellite. To learn more about *GEO-CAPE* and the workshop, visit <http://geo-cape.larc.nasa.gov/index.html>.

organized an event at the International Congress for Conservation Biology, December 5–9, in Auckland, New Zealand, to discuss ways in which the conservation groups and professionals could provide input into mission development.

The event informed attendees about upcoming satellite missions, with event organizers encouraging attendees to examine how new data types could advance conservation efforts. Attendees primarily discussed issues of data access and usage. For example, they highlighted a need for data products with backwards compatibility to enable time-series analysis and expressed interest in training opportunities on data access. The workshop revealed that there was little awareness that people could engage NASA in discussions of future missions, let alone the mechanisms for that engagement. Attendees concluded that the conservation community should be more proactive in its use of remote sensing. In 2012, Applied Sciences will look for further ways to articulate opportunities for engagement with NASA on satellite missions by conservation groups and others.



Earth Science Missions and Conservation Applications Workshop

Like current satellite missions, upcoming Earth science missions have a wide range of potential conservation applications. ESD and Conservation International

Earth Venture-2

In 2011, ESD announced the Earth Venture-2 (EV-2) solicitation, which calls for principal investigator-led satellite missions under the Earth System Science Pathfinder Program. The EV-2 announcement of opportunity called for satellite missions that advance scientific knowledge of Earth processes and systems, demonstrate measurement innovations, and establish new research avenues. The announcement stated that missions “demonstrating key applications-oriented measurements are solicited.” It also stated that the selection criteria were based primarily on the direct science return from the measurement.



The *SMAP* mission will organize a hydrology and water management joint mission tutorial in 2012 with *GPM*, *GRACE-FO*, and *SWOT*, bringing together product developers and users to imagine new applications using data across these future satellites.

ESD expects to announce selections in 2012 and expects the selected mission(s) to develop an applications plan during the formulation phase of the project. To learn more about EV-2, visit <http://essp.larc.nasa.gov/EV-2>.

Satellite Mission Requirements and Science Definition Teams

During the satellite development process, NASA defines and records the Level-1 Requirements for a satellite mission. This document identifies the mission, science, and programmatic (funding and schedule) requirements for the development and operation of the mission, including the baseline and threshold science requirements. In 2011, ESD began including language in the Level 1 Requirements that states, "Science implies research, applied research, and applications for the purposes of this requirements document."

ESD is including people familiar with applications in science definition teams (SDTs) to ensure that applications-oriented people help define satellite missions and SDTs incorporate both research and applications. ESD has SDTs in place for the *SMAP* and *ICESat-2* missions and for the *CLARREO* and *DESDynI-R* mission studies. NASA solicited for a *DESDynI-R* SDT in 2011 and will put the team in place in early 2012; NASA solicited for an *ICESat-2* SDT continuation in 2011. The solicitations for the *ICESat-2* and *DESDynI-R* SDTs explicitly invited applications-oriented representatives. The statement above regarding science implying research, applied research, and applications is now included in SDT solicitations.

Future Activities

The Applied Sciences Program will build on a productive 2011 and continue to engage the applications community in Earth science satellite missions. The Program will host an applications workshop for the *Suomi NPP* mission. Applied Sciences expects to initiate a study on the time-criticality of data delivery (i.e., latency) across a broad set of user types to inform design trade-offs for satellite missions. In addition, the *SMAP*, *GPM*, *GRACE-FO*, and *SWOT* missions are planning a joint workshop in the fall of 2012 focused on applications issues. Visit the Applied Sciences website for information about applications-oriented meetings and events for the satellite missions.





Collaborating across NASA's Earth Science Division

In 2011, the Applied Sciences Program pursued numerous activities to increase its linkages and partnerships within NASA's Earth Science Division. As part of this, Applied Sciences had joint activities with each of the major programs in ESD: Flight, Research & Analysis, and the Earth Science Technology Office.

Flight Program

The Flight Program supports satellite mission development and operations as well as management of NASA's Earth science data systems. During 2011, Applied Sciences collaborated with Flight's Data Systems program on two activities, ACCESS and LANCE, and on satellite mission planning (see pages 48–51).

ACCESS

The Advancing Collaborative Connections for Earth System Science (ACCESS) program supports efforts to advance existing components of NASA's distributed and heterogeneous data and information systems infrastructure. ACCESS projects increase the interconnectedness and reuse of key information technology software and techniques underpinning the advancement of Earth science research and applications. The tools and technologies ACCESS supports enhance the accessibility and usability of Earth science data, extending NASA's reach to new users and communities.



In 2011, Applied Sciences collaborated with ESD's Research, Technology, and Flight Programs to expand Earth science applications and users' feedback on NASA data products.

Applied Sciences supported an ACCESS project solicitation, which included language allowing for projects with innovative approaches that enhance the discovery, access, and usability of NASA Earth science data for applications. In 2011, ACCESS selected four projects that focus on applications topics that will begin work in 2012.

LANCE

The Land Atmosphere Near real-time Capability for EOS (LANCE) is the near real-time component of the Earth Observing System Data and Information System. LANCE provides data and imagery from the *Aqua*, *Terra*, and *Aura* spacecraft to applications users, scientists, and operational agencies needing near real-time data products. Applied Sciences and Flight's Data Systems program jointly sponsor the LANCE system.

In 2011, the LANCE team was very active in expanding the capabilities of the system and fulfilling direction from the LANCE User Working Group. LANCE consistently met its three-hour requirement for product generation, with system availability above 98 percent uptime for ingest, archive, and distribution. In addition, LANCE improved the delivery of *Terra* data products to approximately 90 minutes and delivery of *Aqua* and *Aura* products to about two hours following collection. The team delivered a new website and a prototype web mapping service, and it



The LANCE near real-time system improved the delivery of *Terra* data products to approximately 90 minutes and the delivery of *Aqua* and *Aura* products to about two hours from collection.

also developed a new Worldview image browse tool, which displays and allows comparisons of coincident near real-time data.

In 2011, representatives from FEMA and the Maryland Department of Natural Resources joined the LANCE User Working Group. ESD will hold a User Working Group meeting in 2012 to review LANCE status and ground system upgrades, data products from *Suomi NPP*, user feedback, and the Worldview tool.

Research & Analysis Program

ESD's Research & Analysis Program is organized around six science focus areas. Applied Sciences collaborated with several of the areas to support applied research and applications-oriented tasks.

Suomi NPP Science Team

Suomi NPP, launched in October 2011, is a key satellite mission to provide a range of data sets for research while also addressing operational requirements for meteorological observations.

ESD issued a *Suomi NPP* Science Team solicitation to review sensor and algorithm code, conduct data simulation studies, participate in calibration and validation planning, recommend algorithm improvements, and participate in the planning for science operations. Applied Sciences worked with the Research & Analysis Program to include language in the solicitation allowing for applications-oriented proposals. Applications team members were expected to communicate information on *Suomi NPP* to the appropriate applications communities and provide feedback from these communities back to the Science Team.

In 2011, Applied Sciences selected three projects, augmenting the *Suomi NPP* Science Team membership. The selected projects address air quality and public health applications, connections with NASA's Terrestrial Observation and Prediction System, and global agricultural monitoring.

Aura Science Team

Atmospheric composition is central to Earth system dynamics. The atmosphere couples several environmental issues, and changes in atmospheric composition affect ozone, air quality, and climate. ESD supports research on trends in atmospheric composition and the effects on global and regional air quality. *Aura* is a key satellite supporting that research.



The LANCE Worldview site, <http://earthdata.nasa.gov/labs/worldview>.



Collaborating across NASA's Earth Science Division

The Health & Air Quality Applications area collaborated with the Atmospheric Composition research area on its *Aura* Science Team solicitation to include language that allowed for applications-oriented proposals. In particular, applications team members were expected to address applied research topics, communicate *Aura* research results to the applications end users, and provide feedback from those users on *Aura* data products.

In 2011 Applied Sciences selected two projects to augment *Aura* Science Team members. One project addresses air pollution over the eastern United States using *Aura* NO₂ and SO₂ products, and the other addresses nighttime tropospheric ozone impacts and their relationship to air quality.



Atmospheric Composition Modeling and Analysis

The Atmospheric Composition: Modeling and Analysis Program (ACMAP) program supports research on data analysis, model utilization, and model evaluation to address issues of tropospheric air quality and oxidizing capacity, including the effects of climate change on air quality as well as air quality on climate change.

The Health & Air Quality Applications area worked with ACPMAP on a research solicitation to include language that allowed for applications-oriented projects. In 2011, Applied Sciences selected one project, increasing the ACPMAP selections.

Earth Surface & Interior

NASA supports research on changes to Earth's surface from tectonic and climatic processes, motions of the Earth's interior, global sea level, and natural hazards such as earthquakes and volcanoes. The Earth Surface & Interior research area promotes development and use of geodetic imaging data sets for understanding geohazards and the preservation of natural resources.

The Disasters Applications area worked with the Earth Surface & Interior research area on a geodetic imaging project solicitation to include language allowing for applications-oriented proposals. In particular, applications projects were expected to address issues of applied research and sustained use of the data sets in decision making. ESD will announce selections of geodetic imaging projects in 2012.

Carbon Cycle & Ecosystems

The Carbon Cycle & Ecosystems (CC&E) research area examines changes in carbon cycle dynamics, responses of ecosystems to climate, and land cover and land use change.

CC&E developed a carbon cycle science solicitation jointly with USDA to research the distribution and cycling of carbon and establish a scientific foundation for societal responses to global environmental change. The Ecological Forecasting and Water Resources Applications areas collaborated with CC&E to include language in the solicitation for applications-oriented proposals. Under a theme of integrated scientific-societal issues, applications projects were expected to enhance resource management and policy decisions that affect carbon emissions, sequestration, and fluxes.



Applied Sciences collaborated with Research's Carbon Cycle & Ecosystems focus area to support applications projects under a joint NASA–USDA solicitation. One project is implementing a carbon monitoring tool with the U.S. Forest Service across 10 million hectares in the Northern Rockies to include carbon sequestration in forest management.

In 2011, Applied Sciences selected two projects to support, augmenting the number of carbon cycle science projects. One project is improving the Forest Carbon Management Framework (ForCaMF), which NASA and the U.S. Forest Service developed as a carbon monitoring and management support tool. The project is installing ForCaMF to monitor carbon sequestration for use in forest management across 10 million hectares in the Northern Rockies. A second project, jointly funded with the Research & Analysis Program, is using *Landsat* imagery to detect historical U.S. forest disturbance.

Earth Science Technology Office

The Earth Science Technology Office (ESTO) manages the development and demonstration of advanced technologies for scientific measurements of the Earth. ESTO has three lines of business addressing instruments, components, and information systems.

Advanced Information Systems Technology

The ESTO Advanced Information Systems Technology (AIST) program develops technologies that reduce the risk, cost, size, and development time of space- and ground-based information systems. AIST projects also increase the accessibility and usability of data.

In 2011, AIST issued a solicitation focused on advanced data processing, data services management, sensor web systems, and operations management. Applied Sciences worked with AIST to include language for an applications-oriented “technology infusion option” as part of the proposals. This option would fund projects for additional years to integrate the new capabilities enabled by the technology development into decision making or an end-user application.

ESTO will announce selections of AIST projects in 2012. ESTO and Applied Sciences expect to support a few projects that have the technology infusion option.





Looking Ahead

The Applied Sciences Program is eager to build on a very productive 2011 and pursue new opportunities in 2012 and beyond to expand the application of Earth observations. We look to further increase users' capabilities and enable the conception of new applications in future satellite missions.

Delivering Results

In 2012, Applied Sciences will continue to complete projects and focus on transitions for sustained use of Earth observations by public and private organizations. More than three dozen projects that focused on the Gulf of Mexico region are due to complete in 2012. These projects will increase the use of Earth observations in the region to support water resources, disaster response, and ecosystem management, among other topics.



The Program will select, fund, and begin projects under the Water Resources and Disasters Applications areas as well as the topic of wildfires. These projects will follow the Program's new approach of starting with feasibility studies and then, after a year, selecting a subset to pursue as in-depth applications projects.

We expect to issue requests for proposals in the Ecological Forecasting and Health & Air Quality Applications areas, and perhaps a solicitation for a Water Resources Applied Sciences Team based on the successful ACAST model. We will also look at novel ways (in addition to proposal solicitations) to advance

applications through awards, prizes, and challenges. The Program will investigate and may begin designing a test-bedding center to prototype applications concepts.

Building Capacity

The new year will be an important one for SERVIR. In partnership with USAID, Applied Sciences will pursue SERVIR hubs in new regions. In 2012, we will select members of a new SERVIR Applied Sciences Team, broadening the scientific and applications base for that program to advance developing countries' uses of Earth observations. SERVIR will also develop a more formal training initiative.

DEVELOP will likely reach record levels of nominations for its summer internships. DEVELOP's new science advisor will be in place, and three new locations selected in 2011 will become operational for the 2012 summer term.

The ARSET training initiative will support domestic and international training events, including ones with the Desert Research Institute and the National Weather Center.

Assessing Socioeconomic Benefits

In 2012, the Applied Sciences Program will continue to build capabilities in determining and quantifying socioeconomic benefits of Earth observations. We will hold an international workshop on this topic in June, which will include a tutorial for workshop attendees.

We will continue to conduct socioeconomic impact analyses of our applications projects. In addition, we will examine the pathways from technology, satellite measurements, and research to practical Earth science applications, examining key heritage factors contributing to societal benefits.



“We appreciate the project teams for their creativity and energy in developing Earth science applications. Thanks to our partners for their collaboration and commitment to applying Earth observations to benefit the nation.”

Lawrence Friedl
Applied Sciences Program

National and International Leadership

Throughout 2012, Applied Sciences will be very active in the international Group on Earth Observations (GEO) and the domestic USGEO. GEO will begin a new four-year work plan in 2012, and it plans a major work plan symposium in May. Applied Sciences will continue to promote NASA's contributions to GEO and USGEO and deliver results.

ESD will take the lead of the Strategic Implementation Team of the international Committee on Earth Observation Satellites. Applied Sciences personnel serve as NASA applications contacts for the committee's societal benefit areas. In 2012, specific activities are planned in areas of disasters, agriculture, and health.

Imagining and Anticipating Applications

Applied Sciences will continue facilitating the applications community's participation in satellite mission planning. *ICESat-2* will hold an applications workshop, and *SMAP* will select additional Early Adopters. We will support applications representatives in science definition teams. The *SMAP*, *GPM*, *GRACE-FO*, and *SWOT* missions are planning a joint meeting in 2012 that will explore potential applications from data across those missions.

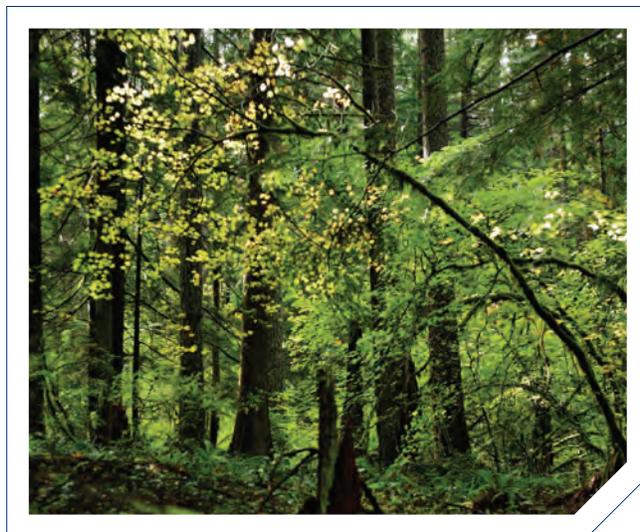
The Program will continue to pursue applications from missions currently in orbit. For example, we will hold a workshop with NOAA, USDA, and USGS on applications made possible with the 2011 launch of *Suomi NPP*. The LANCE system for near real-time data will hold a user working group meeting and examine new paths to serve users.

Program Productivity

In 2012, the Applied Sciences Program will enhance the way it operates. The Program will establish an associate role for each Applications area. The associates will further improve how we track projects, promote on-schedule project completion, identify investment opportunities, and highlight results and accomplishments.

Applied Sciences will conduct an assessment of the Capacity Building program and its four elements. The Program will enhance its database to further improve efficient access to information on our applications projects. We will also begin a study to examine other nations' applied science programs, looking for additional ways to enable and promote the use of Earth observations.

To learn more about the Applied Sciences Program and follow its progress, visit <http://AppliedSciences.NASA.gov>.







Acronyms

AAAS: American Association for the Advancement of Science

ACCESS: Advancing Collaborative Connections for Earth System Science

ACMAP: Atmospheric Composition: Modeling and Analysis Program

AGU: American Geophysical Union

AIST: Advanced Information Systems Technology

AQAST: Air Quality Applied Sciences Team

ARL: Applications Readiness Level

ARSET: Applied Remote Sensing Education and Training

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers

ATMS: Advanced Technology Microwave Sounder

CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation

CASI: Climate Adaptation Science Investigators

CC&E: Carbon Cycle & Ecosystems

CDC: Centers for Disease Control and Prevention

CIMIS: California Irrigation Management Information System

CLARREO: Climate Absolute Radiance and Refractivity Observatory

CloudSat: Cloud Satellite

CMAQ: Community Multiscale Air Quality

DESDynI-R: Deformation, Ecosystem Structure and Dynamics of Ice (Radar)

DPA: deputy program applications lead

DREAM: Dust REgional Atmospheric Model

ECV: Essential Climate Variable

E-DECIDER: Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response

Envisat: Environmental Satellite

EO-1: Earth Observing-1

EOS: Earth Observing System

EPA: Environmental Protection Agency

EPHTN: Environmental Public Health Tracking Network

ESD: Earth Science Division

ESTO: Earth Science Technology Office

ET: evapotranspiration

EV-2: Earth Venture-2

EVCM: Envirocast Vision Collaboration Module

FEMA: Federal Emergency Management Agency

ForCaMF: Forest Carbon Management Framework

GEO: Group on Earth Observations

GEO BON: GEO Biodiversity Observation Network

GEO-CAPE: Geostationary Coastal and Air Pollution Events

GEO-GLAM: Global Agricultural Geo-monitoring Initiative

GIS: geographic information system

GISS: Goddard Institute for Space Studies

GOES: Geostationary Operational Environmental Satellite

GOMI: Gulf of Mexico Initiative

GPM: Global Precipitation Mission

GPS: Global Positioning System

GRACE: Gravity Recovery and Climate Experiment

GRACE-FO: GRACE Follow-On

HAZUS-MH: Hazards U.S. Multi-Hazard

HypSIIRI: Hyperspectral Infrared Imager

IAC: International Astronautical Conference

IAF: International Astronautical Federation

ICCAT: International Commission for the Conservation of Atlantic Tunas

ICESat-2: Ice, Cloud, and land Elevation Satellite-2

JPL: Jet Propulsion Laboratory

LANCE: Land Atmosphere Near real-time Capability for EOS

MEMA: Maryland Emergency Management Agency

MERRA: Modern Era Retrospective-analysis for Research and Applications

MEWS: Malaria Early Warning System

MODIS: Moderate Resolution Imaging Spectroradiometer

NASA: National Aeronautics and Space Administration

NCA: National Climate Assessment

NCEP: National Centers for Environmental Prediction

NDMC: National Drought Mitigation Center

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NO₂: nitrogen dioxide

NPP: National Polar-orbiting Partnership

NREL: National Renewable Energy Laboratory

NWS: National Weather Service

OMI: Ozone Monitoring Instrument

OMPS: Ozone Mapper Profiler Suite

OSI: Office of Strategic Infrastructure

OSTM: Ocean Surface Topography Mission

PA: program applications lead

PM2.5: fine particulate matter

QuikSCAT: Quick Scatterometer

SAC-D: Satélite de Aplicaciones Científicas (Version D)

SAROPS: Search and Rescue Operations

SDT: science definition team

SMAP: Soil Moisture Active Passive

SO₂: sulfur dioxide

SORCE: Solar Radiation and Climate Experiment

SWOT: Surface Water Ocean Topography

TOPS: Terrestrial Observation and Prediction System

TRMM: Tropical Rainfall Measuring Mission

USACE: United States Army Corps of Engineers

USAID: United States Agency for International Development

USDA: United States Department of Agriculture

USFS: United States Forest Service

USGEO: United States Group on Earth Observations

USGS: United States Geological Survey

VAAC: Volcanic Ash Advisory Center

VIIRS: Visible Infrared Imager Radiometer Suite

WestFAST: Western States Federal Agency Support Team

WONDER: Wide-ranging Online Data for Epidemiologic Research



Applied Sciences Program

<http://AppliedSciences.NASA.gov>

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