



ANNUAL REPORT

2013

NASA Earth Science
Applied Sciences Program

LETTER FROM THE DIRECTOR



Lawrence Friedl, Director, Applied Sciences Program

Welcome to the NASA Applied Sciences Program's 2013 Annual Report. Every year we advance ways for public and private sector institutions to apply Earth observations to increase their

productivity, enhance our quality of life, and strengthen the economy—and this year was no different.

The year began with NASA's launch of *Landsat 8*, continuing many applications that land imaging data support. Applied Sciences achieved success with new applications, completed several projects, initiated new projects and feasibility studies, increased capacity building activities, led NASA's support of responses to many disasters, and enhanced applications user involvement in upcoming satellite missions.

We started new projects to aid natural resource management, and we requested proposals for water resources and for health and air quality management. We organized a *GPM* applications workshop, expanded

ARSET trainings, and held a symposium on GOMI project results. We transferred a NASA sensor to the U.S. Forest Service for operational fire support, won the 2013 Geospatial World Policy Award for Knowledge Transfer, and published the primer *Measuring Socioeconomic Impacts of Earth Observations*.

This report summarizes some of the achievements and initiatives that made 2013 noteworthy. You can find more information in our full report at <http://appliedsciences.nasa.gov/ar2013>.

We appreciate the project teams and our partners for their dedication and enthusiasm in applying Earth observations to improve their decisions and actions. As NASA continues to advance our understanding of the Earth, we're excited about the many opportunities to demonstrate the value of Earth science applications and promote the use of Earth science to serve society.

A handwritten signature in black ink that reads "Lawrence Friedl". The signature is written in a cursive, flowing style.

PROGRAM DESCRIPTION

The NASA Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth science data and knowledge. The Program supports applied research and applications projects that foster uses of Earth-observing satellite observations and scientific knowledge by public and private sector organizations in their decisions, actions, and services.

All Program activities support goals to deliver near-term uses of Earth observations, build capabilities to apply Earth science data, and contribute to satellite mission planning. The portfolio of projects delivers results and societal benefits by applying Earth observations to improve water management, disaster response, disease tracking, ecosystem management, adaptation to climate risks, international development, and many other topics. The projects are carried out in partnership with end users to enable sustained use and sustained benefits.

Applied Sciences' applications areas address disasters, ecological forecasting, health and air quality, and water resources with wildfires as a cross-cutting theme. The Program's capacity building efforts focus on activities with developing countries and state and local governments to improve capabilities and workforce applying Earth observations. The Program also engages users in the planning for future Earth-observing satellites, envisioning potential applications early on and further enhancing the value of each satellite mission.

True to NASA's Vision, the Applied Sciences Program continually pursues new opportunities and effective ways to apply Earth science to benefit all humankind.

The Applied Sciences Program is part of the Earth Science Division of the NASA Science Mission Directorate. To learn more about the Applied Sciences Program, visit <http://AppliedSciences.NASA.gov>.

“To reach for new heights and reveal the unknown,
so that what we do and learn will benefit all humankind.”

NASA Vision



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To see the complete 2013 Annual Report online, visit <http://appliedsciences.nasa.gov/ar2013>.



WATER RESOURCES

“We are entering another era in streamflow forecasting. We’ve never used remote sensing data for real-time streamflow forecasting at our center.”

Kevin Werner, Colorado Basin River Forecast Center

The California Department of Water Resources (CDWR) and NASA applied MODIS, VIIRS, and TOPS products in irrigation management trials for crops in California, decreasing total applied water for tested crops by more than 30 percent relative to standard practice, without reducing crop yields or quality. The 2013 efforts focused on lettuce and broccoli, and CDWR pledged to fund two years of trials for other crops.

In 2013, EPA utilized *Landsat* and MODIS data in rule making on nutrient criteria for estuarine and coastal waters of Florida. EPA expects to finalize the rule in 2014 and apply the methods used to create the rule in criteria development across the country.

Program Management

At a 2013 Western States Water Council workshop on drought impacts, Applied Sciences presented projects focused on drought monitoring and impact mitigation, highlighting the potential for remote sensing data to enhance managers’ methods to address drought impacts. Workshop attendees identified the need for a drought impact data clearinghouse.

Water Resources actively participated in the Fourth Annual Global Workshop of the Agricultural Model Intercomparison and Improvement Project (AgMIP), which encompasses crop modeling, climate, and economics. The workshop addressed agricultural modeling

improvements by better incorporating forecasted supply and hydrologic extremes, and attendees formed an AgMIP water resources focus group.

The Water Resources area assessed 13 completed feasibility studies and selected nine to fund as full, multi-year applications projects. In late 2013, Water Resources also requested proposals for applications projects to improve seasonal, 30 to 180-day outlooks for water supply conditions; selected projects will have a new opportunity to apply for supplemental funds to conduct a socioeconomic impact analysis.



Depiction of fractional cover data, California, August 13–20, 2013, from the TOPS Satellite Irrigation Management Support interface, which an Applied Sciences team developed as part of a project to help farmers optimize irrigation management. Fractional cover is the proportion of ground area that is covered with green vegetation as viewed from directly overhead. Dark blues indicate little to no cover, light blue to light green indicates roughly 20 to 50 percent cover, green to light orange roughly 51 to 80 percent, and orange to dark red roughly 81 to 100 percent. To learn more, visit <http://ecocast.arc.nasa.gov/dgw/sims>.

Looking Ahead

In 2014, Water Resources will award the new projects on seasonal water supply, and it will examine remote sensing opportunities in water quality. The planned launches of *GPM* and *SMAP* in 2014 present new, key data sets for water resources management applications.



HEALTH & AIR QUALITY

The U.S. Forest Service integrated new, Applied Sciences-enabled modules into its BlueSky-SmartFire system. The system allows managers to assess smoke impacts on air quality, aiding decisions to manage natural resources and protect public health. The modules for fuel moisture and plume heights use *TRMM*, *MODIS*, and *MISR* data and improve biomass consumption estimates in the system. The project team will complete an impacts study in 2014.

“The NASA-funded project is giving us an immense amount of understanding of the West Nile virus disease. . . . The more we can put scientific information behind our messages to the public, the better.”

Lon Kightlinger, South Dakota Department of Health

Project Results

Health officials in South Dakota used a project’s NLDAS-based risk maps and forecasts of West Nile virus to help target mosquito control and disease prevention activities.

In 2013, Wyoming air quality managers worked with NASA’s Air Quality Applied Sciences Team (AQA) to use AIRS data and RAQMS model analyses in a request to EPA for an air quality exceedance waiver. AQA is a team of researchers focused on transferring scientific knowledge to state and local air quality managers.

Program Management

In May, the United States launched the Metadata Access Tool for Climate and Health (MATCH) portal. Using open data, it provides access to metadata for health surveillance, climate, ocean, and environmental data sets; links to early warning systems; and tools on health impacts of climate change. Health & Air Quality contributed to MATCH development.

The Health & Air Quality team and investigators organized, moderated, and presented at the Fourth Conference on Environment and Health at the 2013 AMS annual meeting. The team also sponsored or participated in the NCAR/CDC Colloquium on Climate and Health,

International Conference on Medical Geology, and GEO Health meeting.

Looking Ahead

In 2014, the applications area will select proposals for new projects about infectious disease, environmental health, and air quality management. The *SMAP* mission team will hold a health-related tutorial with CDC. NASA and AMS will highlight health and environment in coordination with CDC and the Weather Channel at the 2014 AMS meeting in Atlanta.



APPLYING SATELLITE DATA TO IMPROVE WATER FORECASTING



The Colorado River Basin intersects seven western states, providing water for tens of millions of people and irrigating some of the most productive agriculture in the United States. Snowmelt accounts for more than two-thirds of the runoff in the basin. Agencies like the Colorado Basin River Forecast Center (CBRFC) and the California Department of Water Resources are using satellite and airborne measurements of snow for more precise runoff forecasting to support decisions by water managers, reservoir operators, and others.

CBRFC, which is operated by the National Weather Service, generates daily and seasonal streamflow forecasts for the Colorado River Basin and eastern Great Basin. In 2013, in collaboration with an Applied Sciences-funded team, CBRFC integrated remotely sensed snow data from *Terra* and *Aqua* into its operations. To augment CBRFC activities, the project team implemented near-real-time processing and delivery of MODIS data.

“We are entering another era in streamflow forecasting. We’ve never used remote sensing data for real-time streamflow forecasting at our center,” said Kevin Werner, service coordination hydrologist at CBRFC.

The Colorado Basin River Forecast Center incorporated MODIS snow products into its operations, enhancing runoff forecasts used by water managers and reservoir operators.

One NASA data set CBRFC integrated was the MODIS snow covered area and grain size product, or MODSCAG. This product indicates the percentage of land area covered by snow. The surface conditions of snow affect the melt rate; dust, soot, and other materials on snow surfaces absorb solar energy, speeding up snowmelt. The project team included experts in these fields and assisted CBRFC to incorporate the MODIS dust radiative forcing in snow product, or MODDRFS, which quantifies the additional sunlight absorbed.



The snowpack typically melts out in the late winter or spring depending on elevation and climatic conditions. The satellite data products complement ground-based snowpack monitoring done at low to middle elevations using bladders called snow pillows. The snow pillows provide detailed information at specific locations. The MODIS products provide quantification of snow-covered areas across the entire Colorado River Basin. The combination improves the day-to-day forecasting of runoff as well as seasonal forecasting to predict conditions from April through July.

“The project’s data give us a better idea of the spatial distribution of snow,” noted Stacie Bender, a CBRFC hydrologist. “In mountainous basins, over variable terrain, remote sensing fills in gaps left by point measurements from *in situ* snow monitoring networks.”

During the 2013 snowmelt runoff season, CBRFC forecasters used the MODSCAG data as part of

adjustments to their streamflow forecasts. At times, there were divergences between the streamflow estimates from computer models and the *in situ* measurements. When the differences were significant, CBRFC forecasters used the MODSCAG snow cover product to adjust parameters in the model, such as the snow water equivalent (SWE, the amount of water in snow). When forecasters modified

factor of two better estimate of the actual inflow, helping managers optimize reservoir operations.

“The advantage of the ASO data is that it provides an actual measured volume of water in the basin and helps forecasters during the delicate topping-off time at the reservoir,” explained Bruce McGurk, hydrologist and former

“We’ve been able to integrate the project’s data set into our operations. This is significant—research reaching actual operations.”

Kevin Werner, Colorado Basin River Forecast Center



SWE in the model, the simulated streamflow was closer to the observed streamflow, instilling greater confidence in the forecasts.

“The project’s data have already improved our runoff forecasts,” said CBRFC’s Werner, “which will benefit our stakeholders who manage reservoirs and water by allowing them to have better understanding of inflow into the reservoirs and the improved foundation by which to decide whether to capture, release, or generate electricity with the flow.”

water and power planning manager of the Hetch Hetchy Water and Power Project of the City of San Francisco.

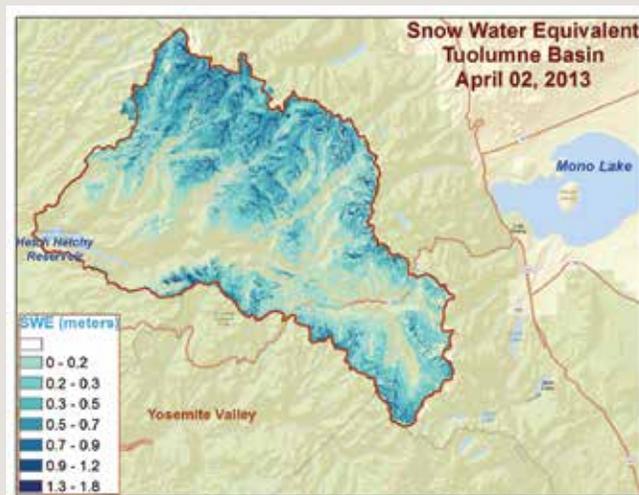
CDWR has committed resources through 2015 to continue its collaboration with NASA and has expressed interest in potential ASO measurements of the entire Sierra Nevada.

Thomas Painter (thomas.painter@jpl.nasa.gov) leads this project. To learn more about CBRFC and CDWR, visit www.cbrfc.noaa.gov and www.water.ca.gov.

Forecasting Sierra Nevada Runoff

The California Department of Water Resources (CDWR) also worked with the NASA project team, improving runoff forecasting in the Sierra Nevada. The team collected data from the JPL Airborne Snow Observatory (ASO), which entails a Twin Otter aircraft equipped with advanced lidar and imaging spectrometer instruments. In weekly flights over part of the Sierra Nevada and Upper Colorado River Basin in the spring of 2013, the team gathered data to help determine the amount of snow and when it would melt.

The team helped the City of San Francisco Public Utilities Commission improve prediction of water inflow into and operations of the Hetch Hetchy Reservoir, which supplies approximately 85 percent of the water to the San Francisco Peninsula. In June, the team and Hetch Hetchy modified the inflow forecast and operations based on ASO SWE data, and the new forecast provided a



Map depicting Airborne Snow Observatory measurements of snow water equivalent (the amount of water in snow), Tuolumne River Basin, Sierra Nevada, California, April 2, 2013.



Applied Sciences coordinated NASA's support of responses to 18 disasters in 2013. For the Oklahoma tornadoes, NASA provided analyses from ASTER imagery to improve damaged area assessments. For California's Rim Fire, NASA supplied MODIS and VIIRS data to aid incident planning and provided airborne imagery for post-fire remediation.



DISASTERS

NASA provided MODIS near-real-time flood maps and other products to assist the response to flooding in Colorado. For both the April and September earthquakes in Pakistan, NASA provided KML displacement maps and *EO-1* and ASTER imagery to assist responders in identifying damaged areas to allocate relief resources effectively.

NASA also supported the response to Typhoon Haiyan/Yolanda in Southeast Asia, providing information on rainfall, power outages, and building damage assessments, using data from *TRMM*, *EO-1*, *Suomi NPP*, *COSMO-SkyMed*, and other satellites. Aid and recovery groups in the field used the products to help communities map damaged areas and plan relief.

Program Management

The Disasters team participated in a workshop of the Global Flood Working Group. Attendees agreed to form a global flood partnership, which will provide globally applicable flood monitoring tools and services for better managing flood risk and reducing flood disaster impacts.

NASA supported the formation of the Committee on Earth Observing Satellites' Working Group on Disasters, enabling international coordination of satellite observations for disaster risk management. The initial focus is on flooding, volcanic events, and earthquake response.

Tim Stough began as a Disasters associate program manager to track projects, support their development, and communicate results. Stough will focus on geohazards, and current associate John Murray will focus on meteorological hazards, including volcanic ash and aviation safety. Murray co-authored a 2013 paper demonstrating the utility of *CALIPSO* to track volcanic aerosols for use in high-order trajectory models.

Looking Ahead

In 2014, the Disasters team will review results of 17 feasibility studies and select some to fund as full-scale application projects. The team will organize a special disasters track at the AMS Annual Meeting and will participate in FEMA disaster scenario exercises.



Terra/ASTER false-color image of Tacloban, the Philippines, November 15, 2013. Damage from the November 8 landfall of Typhoon Yolanda is seen in the tan hue south of Tacloban, where the storm surge washed away plants and buildings and left mud-covered ground. The small peninsula that includes Tacloban's airport is also brown, indicating a loss of plants and buildings. Black and dark blue indicate pockets of floodwater on the landscape south and west of Tacloban.



ECOLOGICAL FORECASTING

“[The] Trail and its protected corridor [is] an ideal indicator for environmental conditions that directly affect more than 120 million Americans.”

**Appalachian Trail Conservancy,
The Appalachian Trail MEGA-Transect**

A project with the National Park Service, Appalachian Trail Conservancy, USGS, and USFS applied MODIS data, TOPS model outputs, and climate change scenarios to assess potential effects on habitat and species along the Appalachian Trail. In 2013, the project rolled out a decision support system and initiated a smartphone app to enhance monitoring and forecasting of ecological conditions to support management along the 2,200 mile trail.

Project Result

A project with the National Marine Fisheries Service applied *Jason-2*, *Aqua*, and other satellite data of sea surface height, temperature, and chlorophyll to reduce whale ship strikes. In 2013, the project team demonstrated a consistent hot spot in the Santa Barbara Channel so moving shipping routes south could reduce the risks to blue whales.

Program Management

The Wildlife Conservation Society ran a Program-sponsored workshop to identify key conservation questions that remote sensing could address. The top 10 questions identified included one on uses of near-real-time ecosystem monitoring for environmental compliance and resource management decisions.

At the 2013 International Congress for Conservation Biology, the Program participated in a session on remote sensing and conservation GIS. The NASA exhibit booth featured hyperwall talks on applications and research, such as Applied Sciences investigator Pat Halpin illustrating applications of ocean observations data to identify likely whale locations for NOAA and DoD.

A special issue of *Frontiers in Ecology and the Environment* covered climate change effects on biodiversity, ecosystems, and ecosystem services. NASA's Allison Leidner, Forrest Melton, Gary Geller, and

Woody Turner co-authored papers presenting the state of the science and a management framework for addressing climate change impacts on living systems.

Looking Ahead

In 2014, Ecological Forecasting will support an astronaut training on Earth observations, hold a team meeting, and showcase uses of satellite observations to assist protected area managers at the World Parks Congress. The program will review results of 12 feasibility studies testing applications of satellite data, ecological models, and crowd-sourced observations to improve conservation and resource management.



WILDFIRES

“We are pleased to be able to transition the Autonomous Modular Sensor from its NASA-supported research phase to its USFS-supported mature operational phase.”

Michael Freilich, NASA Earth Science Division

Conservation International leads a project for a fire alert system in the tropics that uses VIIRS, MODIS, and *TRMM* data to improve wildfire prevention and management. In 2013, the system led to park rangers in Indonesia arresting 81 people illegally clearing land in a national park. Farmers in Bolivia posted signs in villages on elevated fire risk based on the system's daily flammability warnings.

Supporting the U.S. Bureau of Land Management, a project developed a prototype system to streamline collection of *Landsat*, MERRA, and other data; increase time for analysis; and enhance rehabilitation management decisions.



Program Management

At a technology transfer ceremony in April, the U.S. Forest Service received from NASA the Autonomous Modular Sensor, which it installed on an aircraft for operational wildfire support. The AMS system delivers near-real-time information to support fire incident teams and provide rapid, post-fire assessments for burned area remediation.

At the first International Smoke Symposium, fire and air quality managers, remote sensing experts, smoke forecasters, and others discussed wildland and agricultural fires and uses of observations to balance ecological needs, land management goals, health issues, and mitigation of smoke impacts. Applied Sciences co-sponsored the October event and served on the organizing committee.

Vince Ambrosia and Amber Soja began roles as Wildfires associate program managers to track projects, support their development, and communicate results.

CBS News showcased an Applied Sciences project tracking changes in soil moisture and vegetation in Southern California, demonstrating the feasibility of improving fire risk assessments months before fire incidents. To learn more, visit www.cbsnews.com/video/watch/?id=50150368n.

Looking Ahead

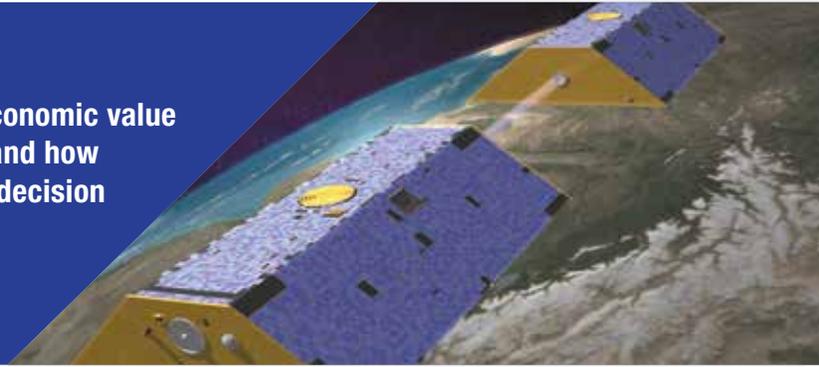
In 2014, the Wildfires element will review results of 17 feasibility studies and select some to continue as in-depth applications projects. The Wildfires team will represent NASA on a federal wildfire science and technology task force and on a new GEO task developing a global wildfire information system.



SOCIOECONOMIC BENEFITS

Applied Sciences has initiated and sponsored activities since 2010 to quantify socioeconomic benefits from the use of Earth observations. These activities serve to advance analytical techniques and build capacity in their use, as well as facilitate connections among the Earth science, social science, economics, and policy analysis communities.

In 2013, Applied Sciences sponsored a study on the economic value of *GRACE* satellite information in drought monitoring and how *GRACE*-enhanced drought products can better inform decision making for improved regional economic outcomes.



Geospatial World Forum

Applied Sciences helped organize a day-long seminar at the 2013 Geospatial World Forum, which focused on monetizing geospatial value and practices. The seminar, Societal Impacts and Benefits of Improved Environmental and Geospatial Information, featured tutorials on techniques, showcased Earth science and geospatial projects, and presented best practice examples on valuing geospatial applications.

Primer on Socioeconomic Impacts



In 2013, Applied Sciences published *Measuring Socioeconomic Impacts of Earth Observations: A Primer*. The primer includes an overview of socioeconomic impact analysis, a discussion of analytical techniques, two case studies, a focus on cost-benefit and cost-effectiveness analysis, and other concepts and

approaches. To learn more, visit the Documents page at <http://appliedsciences.nasa.gov>.

International Workshop

Applied Sciences sponsored the Information for Innovation and Socioeconomic Development Workshop hosted by the European Commission's Joint Research

Center in June as part of the INSPIRE conference. This workshop addressed Earth observations and geospatial data as a factor for economic and social development, economic impacts of open data, and communication methods to convey benefits of the data and information.

AGU Session

The Program helped organize Assessing Socioeconomic Benefits of Earth Observation Science sessions at the 2013 AGU Fall Meeting. The sessions included 18 papers on analytical techniques and socioeconomic impact analysis for air quality, drought, seagrass management, climate observing, and agriculture, among others.

Looking Ahead

Applied Sciences will co-sponsor the fifth annual workshop on socioeconomic benefits of Earth observations in 2014. This workshop, Assessing the Socioeconomic Impacts and Value of Open Geospatial Information, will examine impacts of increased access to data, valuation methods for open data, and advances in assessment methodologies for societal and economic benefits. The Program will also complete socioeconomic impact analyses of several projects and initiate new ones.

Socioeconomic Benefits Community of Practice
www.socioeconomicbenefits.org

IMPROVING AIR QUALITY INFORMATION WITH SATELLITE DATA



Awareness of local air quality conditions informs choices and actions for many people, from parents of asthmatic children, to athletes and outdoor enthusiasts, to elder care providers, to air quality managers. CDC recommends people take steps to limit breathing air with high levels of particle pollution, as it can contribute to heart problems, asthma symptoms, lung disease, and other health complications. How do people know the conditions in their locality?

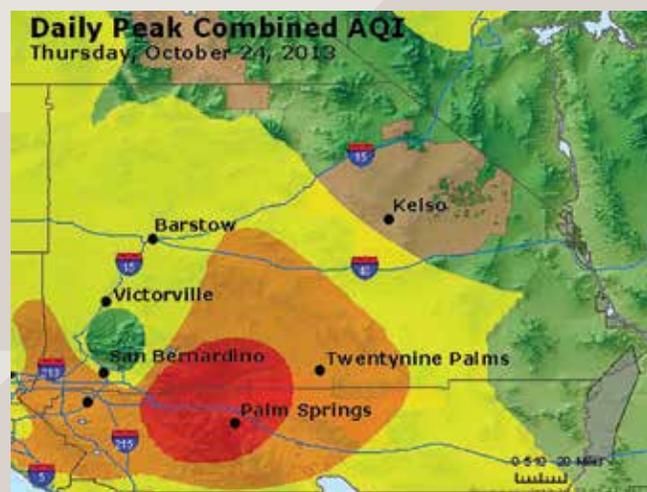
The U.S. Environmental Protection Agency along with partners developed the AirNow system to provide nationwide air quality information to the public. AirNow includes real-time maps of air quality as well as air quality forecasts. EPA and Sonoma Technology, Inc., through an Applied Sciences project, integrated data from *Aura*, *Terra*, *Aqua*, and other sources into AirNow, increasing the accuracy of fine particulate matter (PM_{2.5}) information.

The satellite observations can support estimates of surface PM_{2.5} concentrations. “This [the satellite data] gives you more data than our monitoring network. You can’t ever have enough data,” noted James Kelly, program manager at the Georgia Environmental Protection Division.

The project complements the coverage of the U.S. surface monitoring network, which has most of its monitors near populated areas. As a result, accuracy may be low in areas far from monitors. More than 42 million people reside farther than 40 kilometers from the nearest PM_{2.5} ground-based monitor and therefore have little or possibly inaccurate information about their near-real-time exposure to PM_{2.5}.

“Right now we’ve got a grid for the state and we’ve got . . . 11 monitors in Atlanta,” said Kelly. “And they’re trying to project [air quality in] 20 counties with 11 data points.”

To support broader coverage, the project team created the AirNow Satellite Data Processor (ASDP) to make



AirNow daily peak combined Air Quality Index (AQI) map of San Bernardino and Riverside counties, California, October 24, 2013. Yellow indicates moderate air quality conditions, orange unhealthy for sensitive groups, and red unhealthy. To learn more about AirNow and the AQI, visit www.airnow.gov.

operational use of satellite data products, including aerosol optical depth data from MODIS on *Terra* and *Aqua* and nitrogen dioxide data from *Aura*/OMI.

The system fuses the satellite-based estimates of surface PM_{2.5} concentrations with routine, ground-based measurements. This data fusion can fill in the monitoring gaps to improve estimates of surface PM_{2.5} concentrations in unmonitored areas as well as supplement monitor-dense areas. The project reduced relative errors in estimating surface PM_{2.5} from satellite

data to less than 50 percent for most of North America. In 2013, EPA integrated ASDP into the AirNow framework.

“The [ground] monitors are really, really accurate at the spot that they’re at. But then how do you spread that out across a large area? The big wide open spaces get even more pronounced when you go further west,”

ground-based monitors. EPA improved the information available so people can take protective action to avoid exposure to high PM_{2.5} levels and reduce health risks.

“What I hope can come from [the satellite products] is the ability to look at more data analysis to allow us to anticipate health impacts, particularly as it relates to

“This is the best tool I have seen so far that integrates satellite data with information from ground monitors.”

Cassie McMahon, Minnesota Pollution Control Agency



commented Darren Palmer, lead for air monitoring and quality in EPA Region 4.

The U.S. EPA integrated *Aura*, *Aqua*, and *Terra* data into the AirNow air-quality decision support system, which health officials use to alert the public about hazardous pollution.

There are many events that create particulate matter, such as wildfires, which often occur in sparsely populated areas yet affect largely populated areas with downwind smoke.

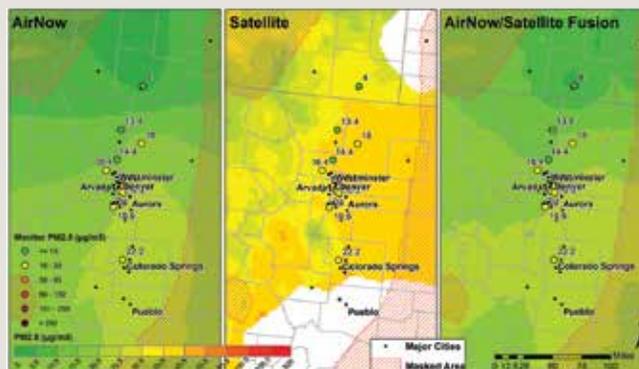
“I see the satellite data as being very useful. I think it’s great for forecasting and, to me, looking to try and find are there other areas that we should potentially be monitoring,” said Gordon Pierce, technical services program manager at the Colorado Department of Public Health and Environment. “We don’t have the resources to monitor everywhere in the state to see if there’s an issue, especially as conditions change over time.”

In 2013, the project team established a task force of air quality experts to review the ASDP products. The team also received feedback through a webinar and interviews with local, state, and regional EPA public health officials. EPA will keep the ASDP system in operation under the AirNow program and implement other enhancements in 2014.

Overall, EPA expanded AirNow coverage to reach millions of people not adequately covered by the network of

emergency room visits, doctor visits, [and] provider visits, related to asthma and upper respiratory illness,” said Bert Malone, deputy director of the City of Kansas City, Missouri, Health Department.

Phil Dickerson (dickerson.phil@epa.gov) leads this project. The project team includes EPA, NASA, NOAA, Dalhousie University, and Sonoma Technology, Inc. To learn more about the project, visit <http://asdp.airnowtech.org>.



Example of ASDP data fusion product. The image shows 24-hour average PM_{2.5} ground concentrations from AirNow (left panel), satellite-estimated PM_{2.5} levels (middle panel), and the fusion of satellite and ground monitor data (right panel). The dots show monitor locations and concentrations. Colors reflect the AQI, and white areas in middle panel indicate areas obscured by clouds.



SERVIR

“We want a long-term partnership with SERVIR using these state-of-the-art [modeled streamflow] tools for managing water resources.”

Ngombwa Achille
Integrated Water Resources Management Department, Rwanda

SERVIR is a NASA–USAID venture that fosters applications of Earth observations to help developing countries assess environmental conditions and climate change to improve their planning and actions regarding water resources, agriculture, disasters, health, and other topics.

A project with the Department of Forests in Nepal developed a fire alert system using MODIS data to help forest rangers and fire managers detect and monitor wildfires as well as assess aftermaths. In 2013, the department implemented the system, which broadcasts email and text messages within 20 minutes of detecting a wildfire, enabling officials to warn villagers of imminent danger.



In Rwanda, the Integrated Water Resources Management Department applied CREST modeling of streamflow to predict the likelihood of flooding along river networks. SERVIR, with NOAA support, trained 20 people from the department and the Rwanda Meteorology Agency

to estimate flows from various catchments in quantifying river capacities.

The Institute of Water Modeling in Bangladesh extended its flood forecasts from three to eight days by adopting a system that incorporates *Jason-2* data.

Program Management

SERVIR co-hosted the International Symposium on Land Cover Mapping for the African Continent. More than 80 NGO representatives, government officials, and policy advisors from 19 African countries discussed land cover data availability and mapping collaborations, including applications for biodiversity monitoring and carbon accounting.

NASA began operating ISERV, the International Space Station SERVIR Environmental Research and Visualization automated camera system. In 2013, ISERV captured more than 25,000 images of Earth, providing photos of World Heritage sites and disasters globally.

The new 11-project SERVIR Applied Sciences Team assembled at the 2013 AGU Fall Meeting, where team members discussed their individual projects and initiated work on team-wide projects. SERVIR held an AGU town hall to inform the broader geoscience community about Earth science applications with developing nations.

Looking Ahead

In 2014, NASA and USAID will establish a SERVIR hub in Southeast Asia. The Program will host a capstone event in Washington, D.C., for young professionals in developing countries building skills with geospatial data and information technologies to address regional needs.

To learn more about SERVIR, visit www.SERVIRglobal.net.



APPLIED REMOTE SENSING TRAINING

In a record-setting year, 593 people attended the 10 online and in-person courses offered. Participation increased 69 percent over the 2012 level and 257 percent over 2011. The participants represented 283 organizations, 53 countries, and 31 U.S. states—all record levels. Four courses covered water resources and flood monitoring, and six covered air quality.

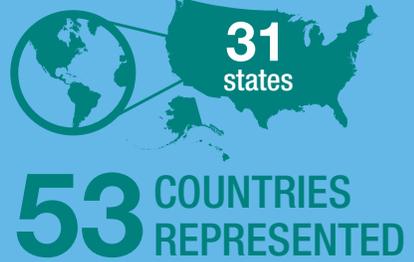
🌐 321 water resources/flooding
🌬️ 272 air quality



🌐 150 water resources/flooding
🌬️ 133 air quality



🌐 31 water resources/flooding
🌬️ 43 air quality



Applied Remote Sensing Training (ARSET) builds skills in accessing and using Earth observations data across applications topics through computer-based training courses for government and private sector professionals.

ARSET introduced its first webinar on Earth observations for flood monitoring. This online course had 110 participants from 54 organizations in 25 countries, and it featured live demonstrations on access to and use of Earth observations. ARSET also held its first webinar on snow data products for water management, reaching 22 managers from state and federal agencies.

ARSET conducted air quality training in Utah with a focus on smoke, dust, and fire. Representatives of federal agencies, the Nez Perce tribe, and state agencies in Colorado, Idaho, Utah, Washington, and Wyoming participated. A six-week webinar on the fundamentals of remote sensing and air quality management preceded this training.

The largest ARSET course of the year was a webinar on Earth observations data for water management, which recorded 171 participants from more than 60

organizations in over 25 countries. The five-week course comprised subjects such as precipitation, runoff, soil moisture, reservoir height, and groundwater, including a special session on applications of *GRACE* data.

Program Management

ARSET continued to enhance its evaluation activities as part of its assessment and planning processes. ARSET instituted online post-training surveys, enabling quicker analysis of results to refine and improve the course offerings.

In 2013, ARSET introduced live demonstrations during webinars to illustrate access to data and use in GIS for flooding and water resources applications.

Looking Ahead

Based on feedback from 2013 participants, ARSET will increase the number of case studies, hands-on exercises, region-specific examples, and live demonstrations. In 2014, ARSET will develop training modules and begin courses on ecological forecasting and ecosystem management.

To learn more about ARSET, visit <http://arset.gsfc.nasa.gov>.



“The ability to know how much Sargassum is offshore has never been available before. [SEAS] has really improved our ability to prepare . . . [for] what is headed in our direction.”

Reuben Trevino, City of South Padre Island, Texas



GULF OF MEXICO INITIATIVE

The *Sargassum* Early Advisory System, SEAS, continued to provide forecasts of *Sargassum* seaweed landings for the Texas coast. SEAS uses *Landsat* data, outputs from the Navy HYCOM ocean circulation model, and NOAA wind data. In 2013, SEAS issued more than 70 advisories to Texas coastal managers, allowing them to better prepare for expected seaweed landings. An impact assessment estimated savings of up to \$290,000 per year during periods of heavy landings through more effective allocation of resources to clean beaches, including better scheduling of personnel and use of rental equipment.

The Gulf of Mexico Initiative (GOMI) works with local, state, and federal agencies on applications of Earth observations to address regional priorities, inform decisions, and enhance the economic and ecological health of the region.

GOMI supported an enhanced, MODIS observations-based technique to detect ocean oil spills, helping NOAA improve its technological capabilities for disaster response.

GOMI also supported the development of an impervious cover app with the Mobile Bay National Estuary Program to improve generation of impervious cover data to assist coastal resource managers, urban planners, and developers.

Program Management

GOMI hosted a workshop to present the results of 48 special projects focused on applying Earth observations to water management, habitat conservation, disaster response, and other issues in the Gulf region. The workshop documented lessons learned, such as the importance of end user engagement, needs assessments, and strategies for transferring applications to partners.

Fifteen of the 48 GOMI projects were under way in 2013, and all but one project completed by the end of the year. Of those projects, four reached ARL 7 or 8, three reached ARLs 4–6, and eight reached ARLs 1–3. (See page 27 for a description of the ARL metric.)

Looking Ahead

In 2014, GOMI will develop a compendium of all 48 projects and their achievements. GOMI will continue to extend the applications developed by the four dozen projects broadly to state agencies and organizations in the Gulf region, further building capabilities to use Earth observations.

To learn more about GOMI, visit <http://gulfofmexicoinitiative.community.nasa.gov>.



DEVELOP

“DEVELOP was a life-changing experience for me. The internship gave me the skills to begin my geospatial career and has strengthened my curiosity to learn more about the Earth.”

Melissa Oguamanam, DEVELOP Participant

DEVELOP is a national training and development program for individuals to gain experience applying Earth observations through 10-week interdisciplinary projects with state and local governments.

In Alabama, the Mobile County Health Department used maps based on MODIS, TRMM, and other data to help target collection of insect specimens for risk assessments of Chagas disease transmission.

A project with a U.S. Department of Agriculture research unit applied *Terra*, *Aqua*, and *Landsat* observations to identify changes in rangeland cover and drought severity across the Great Plains, providing ranchers and land managers with a new risk management tool.

Fort Collins, Colorado, applied *Landsat 8* imagery to assess flooding in the region, assisting the city and land managers with recovery planning and risk mitigation.



Mobile, Alabama, proclaimed November 26 “NASA DEVELOP Day” in recognition of DEVELOP’s contributions to the region over the past decade.

Program Management

In 2013, 348 people conducted 78 applications projects (a 13 percent increase from 2012). Collectively, the projects involved 153 organizations in 24 countries. In the United States, DEVELOP had participants from 32 states, and the projects impacted all 50 states.

DEVELOP had 16 locations in 2013, including a new center at the University of Georgia at Athens. Teams created project videos for DEVELOP’s ongoing virtual poster sessions. The Stennis Space Center team received a second place EPA Gulf Guardian Award.

DEVELOP presented at 28 science and policy conferences. DEVELOP hosted its annual project showcase at NASA Headquarters, and NASA Administrator Charles Bolden spoke with DEVELOPers about their work. The event included project posters, fast-paced “flash” talks, and award presentations.

“Our current strategy for the 2013 planting season is completely derived from the DEVELOP maps, which give our groups a clearer understanding of the goals for reforesting the Central Wetlands.”

Blaise Pezold, Wetland Tree Foundation

Looking Ahead

In 2014, DEVELOP will establish an office in Richmond, Virginia. DEVELOP will introduce military veteran involvement in projects, and it will formalize its Young Professional initiative to create additional leadership opportunities for program graduates.

To learn more about DEVELOP, visit <http://develop.larc.nasa.gov>.

MAPPING AND FORECASTING FROST WITH SATELLITE OBSERVATIONS



In 2013, public and private sector organizations in Kenya began using an automated frost mapping system that incorporates satellite data. The system generates maps to help farmers and businesses manage the risk of frost damage to Kenyan crops such as tea and coffee.

Within a few hours of satellite data collection, the system emails user-friendly maps pinpointing areas with high potential for frost to the Kenya Meteorological Service (KMS) and other stakeholders. KMS worked with an Applied Sciences team and the Regional Centre for Mapping of Resources for Development (RCMRD), based in Nairobi, to develop the system using land surface temperature data from the *Aqua* and *Terra* satellites.

This past year, the Meteorological Service used the frost maps to identify areas of potential frost in the highlands of Kenya. In addition, the Tea Research Foundation of Kenya (created by the Ministry of Agriculture) incorporated the maps in efforts to improve crop



yields and avoid losses. The maps were also useful to agricultural insurance providers in their assessments of claimed losses, allowing them to serve their clients more effectively.

“The frost maps are excellent tools,” said James Kiguru, an accounts manager and agronomist at AON Risk Solutions, a global provider of insurance and risk management services. “[The maps] give us a much stronger basis to conduct our assessments and will boost development of frost insurances. . . . We are able to assist our clients—particularly farmers—when it comes to frost claims which otherwise would be attributed to negligence.”

The frost maps are part of KMS activities to respond to requests every winter from farmers and businesses for information regarding where and when frost conditions will occur.

“I shared these maps with colleagues in tea research, and we are excited to have an attempt in this direction,” said Ayub Shaka, assistant director, KMS.

Supporting Agriculture

In addition to reducing losses to current crops, the project's frost maps can help farmers avoid frost-prone times and locations for future planting. The result will be better crop yields, supporting people and livelihoods in African countries.

Applied Sciences funded this project through its SERVIR initiative, a NASA–USAID endeavor (see page 14). In East Africa, SERVIR partners with RCMRD.

SERVIR will use its Wireless Sensor Network (WSN) to more clearly define frost condition thresholds through

The Kenya Meteorological Service, Tea Research Foundation of Kenya, and insurance providers utilized maps incorporating MODIS data to improve crop risk management.

“[The frost maps] give us a much stronger basis to conduct our assessments and will boost development of frost insurances. . . . We are able to assist our clients—particularly farmers—when it comes to frost claims which otherwise would be attributed to negligence.”

James Kiguru, AON Risk Solutions



the collection of temperature, wind speed, and humidity observations in sample locations. (The WSN is a ground-based network of sensors that can be spread over three

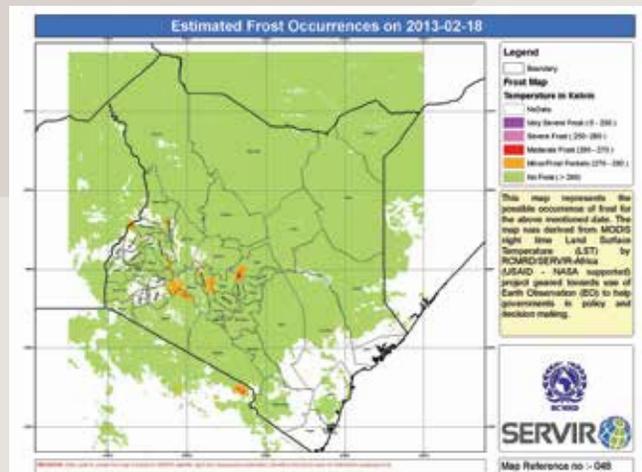


or four square kilometers to measure environmental conditions.) SERVIR will correlate the observations with the forecasts and satellite data products.

SERVIR has sponsored training workshops and will continue to train regional officials in the use of the frost alert system. SERVIR will also develop a decision guide for using WSN frost data and satellite frost risk maps.

In 2014, the frost mapping system will use KMS numerical prediction model forecasts, in addition to the satellite data-derived frost products, to help map areas of potential frost up to three days in advance.

Eric Kabuchanga (kabuchanga@rcmrd.org) leads this project. To learn more about the daily frost maps, visit <http://41.206.34.124/frostmaps>. To learn more about SERVIR, visit www.SERVIRglobal.net.



Estimated frost in Kenya and parts of adjacent countries, February 18, 2013. The map is based on MODIS land surface temperature data.

Kenya is ranked third in annual world tea production, and it has the highest tea productivity (yield per hectare) worldwide. The industry provides for the livelihoods of an estimated 4 million Kenyans, or about 10 percent of the total population.



APPLICATIONS AND SATELLITE MISSION PLANNING

“The Early Adopters program has gotten whole other organizations and industries enthusiastic about the mission. Their early engagement with the mission insures their benefits will be available much sooner than would otherwise be the case.”

Kent Kellogg, SMAP Project Team

Applied Sciences continued to involve the Earth science applications community in mission planning for Earth-observing satellites. Early and ongoing involvement in the planning allows the community to anticipate potential applications, inform design decisions, provide feedback on data products, and be prepared to use the data soon after launch.

GPM

The *Global Precipitation Mission (GPM)* will provide next-generation measurements of rain and snow worldwide every three hours. NASA held a *GPM* applications workshop in 2013, covering uses of *GPM* data for water resources, weather forecasting, agricultural modeling, food security, hydrological modeling, disaster response, ecological forecasting, and public health. *GPM* is a joint mission of NASA and the Japan Aerospace Exploration Agency; launch is planned for 2014.

SMAP



The *Soil Moisture Active Passive (SMAP)* satellite mission will map global soil moisture and its freeze/thaw state from space. *SMAP* expanded its Early Adopters program for organizations to

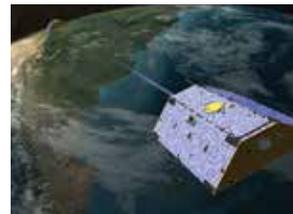
evaluate pre-mission data and prepare for use of *SMAP* data in their decisions. *SMAP* accepted 10 additional organizations as Early Adopters, bringing the total to 32. Some of the new organizations included Excelsis, Agrisolum Ltd., Yorkshire Water Services, and the U.S. Naval Ice Center. The *SMAP* launch is planned for 2014.

Orbiting Carbon Observatory-2

The *Orbiting Carbon Observatory-2 (OCO-2)* satellite mission will collect space-based, global measurements

of atmospheric CO₂ to characterize its sources and sinks on regional scales. The mission team plans to hold an applications workshop in 2014 as well as a workshop on data fusion with the *SMAP* mission. The launch of *OCO-2* is planned for 2014.

Gravity Recovery and Climate Experiment Follow-On



The *GRACE Follow-On* mission will detect very small variations in the Earth's gravitational field, continuing measurements of water and mass movement that *GRACE* began in 2002. Applied

Sciences addressed *GRACE-FO* applications at numerous events, including Water Forum III in Texas, which focused on drought and extreme events. The mission added an applications page to its website. *GRACE-FO* is a joint venture with Germany; launch is planned for 2017.

NASA launched *Landsat 8* in 2013, and it decommissioned the *Jason* satellite. See page 24.

ICESat-2



The *Ice, Cloud, and land Elevation Satellite-2 (ICESat-2)* mission will collect altimetry data and observations of ice sheets, sea ice, and vegetation canopy height begun by

ICESat in 2003. The mission initiated an early adopters

NASA created an Early Adopters program for organizations that have clearly defined uses for satellite mission data. Prior to launch, Early Adopters receive simulated data to evaluate for use in their decision-making activities. Using their own resources, Early Adopters provide feedback on data products to increase the missions' application value and streamline uses of the data soon after launch.

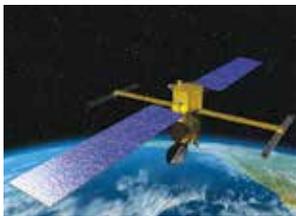


program in 2013, selecting six organizations for early data access to assess in their decision-making tools and provide feedback to the mission team. The team also held a teleconference on vegetation aspects of *ICESat-2*, which is planned to launch in 2018.

PACE

The *Pre-Aerosol, Clouds, and ocean Ecosystem (PACE)* mission will make measurements of global ocean color and of clouds and aerosols. *PACE* developed an applications traceability matrix in 2013, identifying five key applications topics and measurement concepts. The mission team also developed applications white papers. A 2020 launch is planned.

SWOT



The *Surface Water and Ocean Topography (SWOT)* satellite mission will survey the Earth's surface water. The mission held its first applications meeting, formed the *SWOT* Applications

Working Group, and added an applications section to the mission website. *SWOT* intends to create an applications plan in 2014. *SWOT* is a joint mission with the National Center for Space Studies (CNES) of France; launch is planned for 2020.

HyspIRI

The *Hyperspectral Infrared Imager (HyspIRI)* mission will measure vegetation health, study the world's ecosystems, and provide information on natural hazards. The *HyspIRI* Science and Applications Workshop provided updates on the mission concept, science products, applications, technology status, and preparatory airborne campaign. The mission also held a data products symposium,

including highlights of potential products addressing applications. With Applied Sciences support, *HyspIRI* initiated a study of the satellite orbit and optimum revisit interval for measurements of plant stress.

LANCE

The Land Atmosphere Near real-time Capability for EOS (*LANCE*) provides data and imagery to applications users, scientists, and agencies needing near-real-time data products. In 2013, *LANCE* distributed a weekly average of 16.1 TB of data, and it facilitated more than 100,000 imagery downloads. *LANCE* met with its user working group, which approved an enhancement to distribute a near-real-time, eight-day rolling NDVI product, aiding the dust modeling, weather forecasting, and agricultural monitoring communities.

Future Activities

NASA plans to launch five Earth science missions in 2014. The *GPM*, *OCO-2*, and *SMAP* satellites are scheduled to be in orbit, and two Earth-observing instruments—*RapidScat* and the *Cloud-Aerosol Transport System*, or *CATS*—are slated to fly aboard the International Space Station. *RapidScat* will measure ocean surface wind speed, producing data to aid weather forecasting and hurricane monitoring. The *CATS* mission will measure dust, smoke, and other particulates in the atmosphere.

In 2014, NASA will select new missions and instruments as part of its Earth Venture endeavor, and additional missions will initiate early adopters programs.

To learn more about each mission, visit <http://science.nasa.gov/earth-science/missions> or www.nasa.gov/mission_pages.

AUGMENTING MANAGEMENT AND MONITORING OF CORAL REEFS



Coral reef managers use environmental information to monitor conditions and threats to reef ecosystems, taking actions where possible to minimize human impact and support reef health. Increased ocean temperature is an important factor in bleaching, a threat to coral health. Broad-scale temperature data helps reef managers assess regional conditions and trends, and finer-scale data gives them insights for targeted actions, such as redirecting divers and snorkelers to suitable reefs.

“Reef managers can implement various strategies during times of coral bleaching to reduce or mitigate the potential negative impacts additionally caused by human use,” said Scott Donahue, science coordinator at the Florida Keys National Marine Sanctuary.

Coral Reef Watch (CRW) is an online tool that provides near-real-time and long-term monitoring, forecasting, and reporting of environmental conditions of coral reef ecosystems. Operated by NOAA, CRW uses satellite data, climate models, and *in situ* tools to provide bleaching alerts to the public and reef managers.



The University of South Florida and CRW staff led an Applied Sciences-sponsored project to apply *Terra*, *Aqua*, and other satellite data to enhance the spatial and temporal resolution and density of temperature data

in the tool. The top need identified in user surveys was higher resolution information, and the project has since achieved 100-times greater spatial resolution.

Applications of Earth observations enhanced a decision support system for management of coral reefs, supporting ecosystem health and economic activity.

Water temperatures that exceed thresholds for sustained periods lead to thermal stress in corals, and the CRW system helps pinpoint reefs likely to bleach. “Coral Reef Watch is very informative for what we are trying to do,” said Karen Bohnsack, [Southeast Florida] BleachWatch Program coordinator for the Florida Department of Environmental Protection’s Coral Reef Conservation Program.

With coral bleaching, corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease may become more likely, and the entire colony may die.

The project team developed global, 5-kilometer sea surface temperature (SST) products based on combinations of data from NASA, NOAA, and foreign geostationary and polar-orbiting satellites, including *Suomi NPP*, *GOES*, *NOAA-19*, *MSG*, *MTSAT*, and *Metop-A*. The combination helps users better visualize and quantify thermal stress conditions around the world. The team also created a 1-kilometer product using *Aqua*/

MODIS and AVHRR imagery for the Gulf of Mexico and reefs in the Florida Keys, Caribbean Sea, and off Mexico.

CRW's new products build on the 50-kilometer products it has provided, which allow reef managers to understand

where they place *in situ* temperature monitoring devices to help better correlate remotely sensed data with conditions experienced at depth."

In 2013, CRW released the new products. CRW

"The new data products provide observations closer to the scale of coral reefs. Managers want to know as much as we can tell them to help their management of reef resources."

Mark Eakin, Coral Reef Watch



conditions of offshore waters around the resources under their jurisdiction. The new products show what is happening closer to shore and within actual reef ecosystems. The new products also provide 25 to 100 times more satellite data per pixel than the old products. The new products also directly cover up to 95 percent of coral reefs around the world.

Enhancing Research and Public Support

As a result of the CRW improvements, reef managers can now make more informed decisions, including taking steps to protect coral ecosystems or target monitoring. In the short term, there are actions managers can take for immediate effect, such as reducing allowable pollutant loads or alerting recreational dive vessels to change locations.

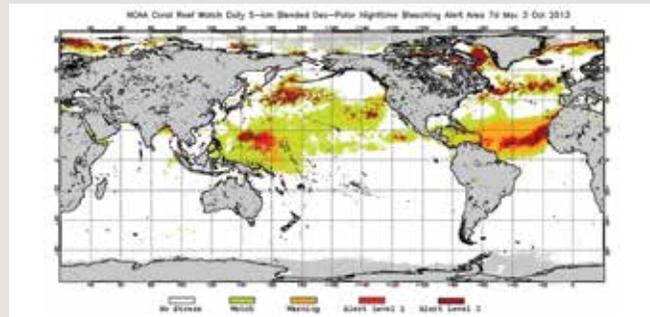
"One example would be working with local diving and snorkeling operators to redirect on-water tourist activities away from natural reef areas normally subject to high visitation to artificial reefs and shipwrecks," said Donahue of the Florida Keys National Marine Sanctuary. "This could reduce unintentional physical damage to corals until favorable thermal conditions return."

CRW enables decisions on where to conduct extensive monitoring and ways to engage the public to support reef health and collect information. "In times of severe thermal stress, that higher [5-kilometer] resolution helps us manage where we request researchers and citizen scientists alike to look for potential thermal stress in corals," said Donahue. "Also, over the long term, it may help reef managers refine

introduced its 5-kilometer Bleaching Alert Levels in October 2013. The team will enhance its products and add new ones, including a long-term mean SST climatology product, based on user input.

Climate change has contributed to rising ocean temperatures and growing ocean acidification, which affect coral reef health. People are now using space-based information from Coral Reef Watch to reduce further human impacts on the reefs—and the broader ecosystems and local economies they support.

Frank Muller-Karger (*carib@usf.edu*) and Mark Eakin (*mark.eakin@noaa.gov*) lead this project. To learn more about Coral Reef Watch, visit <http://coralreefwatch.noaa.gov>.



The coral bleaching alert area product shows ocean regions where thermal stress is high enough to impact corals. At this time, coral bleaching was ongoing in the U.S. territories of Guam and the Commonwealth of the Northern Marianas Islands.



“Landsat data is a key tool for monitoring climate change and has led to the improvement of human and biodiversity health, energy and water management, urban planning, disaster recovery and agriculture monitoring—all resulting in incalculable benefits to the U.S. and world economy.”

Charles Bolden, NASA Administrator



LANDSAT 8 LAUNCH, JASON DECOMMISSION

It's a Landsat!
2/11/2013, 10:02 a.m.
5,783 lbs., 1 oz.

Landsat 8 joined the NASA family of Earth-observing satellites on February 11, 2013. From its orbit 708 kilometers above the Earth, *Landsat 8* continues over four decades of continuous land imaging. The satellite circles the planet every 98 minutes, seeing every place on Earth at least every 16 days.

The spacecraft carries two instruments. The Operational Land Imager observes Earth's landscapes and can distinguish features like urban centers, farms, forests, and other land uses. Measuring land surface temperature, the Thermal Infrared Sensor aids water management and monitoring of water consumption, such as in the arid western United States.

Landsat 8 is a collaboration of NASA and the U.S. Geological Survey. As planned, NASA transferred leadership for satellite operations to USGS on May 30, 2013. *Landsat* satellites have been mainstays of space-based Earth observation applications since 1972.

To learn more, visit <http://landsat.usgs.gov/landsat8.php>.



False-color version of the first *Landsat 8* image, showing the meeting of the Great Plains with the Front Range of the Rockies in Colorado and Wyoming, March 18, 2013. Bright rusty red indicates a wildfire burn scar.

In Memoriam:
Jason, 2001–2013

Launched in 2001, the *Jason* satellite precisely mapped the sea level, wind speed, and wave height of more than 95 percent of Earth's ice-free oceans every 10 days. Through more than 53,500 orbits *Jason* supported a long-term record of sea level change. *Jason* was a pioneer in demonstrating the breadth and value of applications of Earth-observing satellite data, showing opportunities beyond imaging satellites.

The U.S. Department of Agriculture used *Jason* to evaluate global lake and reservoir heights as part of assessments of water storage and agricultural production for international markets. NOAA Fisheries used *Jason* in identifying the ocean habitats of large pelagic animals.

Jason was a joint mission of NASA and France's National Center for Space Studies (CNES). In June 2013, its final data transmitter failed, and NASA and CNES decommissioned the satellite in July. Applications and research supported by *Jason* continue with the *OSTM/Jason-2* satellite launched in 2008.

To learn more, visit <http://sealevel.jpl.nasa.gov>.



Depiction of the *Jason* satellite.

GROUP ON EARTH OBSERVATIONS

NASA Earth Science and Applied Sciences continued to be active in international Earth science and applications coordination, especially through GEO, a 158-member intergovernmental organization that improves the availability, access, and use of Earth observations to benefit society.

The GEO Global Agricultural Monitoring (GEOGLAM) initiative enhances international capacity to monitor crop production with Earth observations for improving food security and market stability. With NASA support, GEOGLAM merges MODIS data with crop condition reports to produce credible information monthly on crop conditions for maize, rice, soybeans, and wheat. In 2013, the Agricultural Market Information System (AMIS) began including the GEOGLAM crop health estimates in its monthly Market Monitor for agricultural traders, economists, and policy makers.



GEO Health

Applied Sciences supports two components in the GEO Health task: one on air quality and airborne diseases, and one on vector-borne diseases. In 2013, GEO held its fifth Health and Environment community meeting, which the Program sponsored and numerous organizations co-organized. The attendees agreed to analyze their task relative to U.N. sustainable development goals.

GEO Biodiversity

NASA continued its contributions to the GEO Biodiversity Observation Network (GEO BON), a framework for building and integrating national and regional observing systems. GEO met with the Convention on Biological Diversity's technical body on how GEO BON can help signatories meet their obligations. GEO BON representatives also published a *Science* paper on essential variables needed for the study and management of biodiversity change.

GEO and the Americas

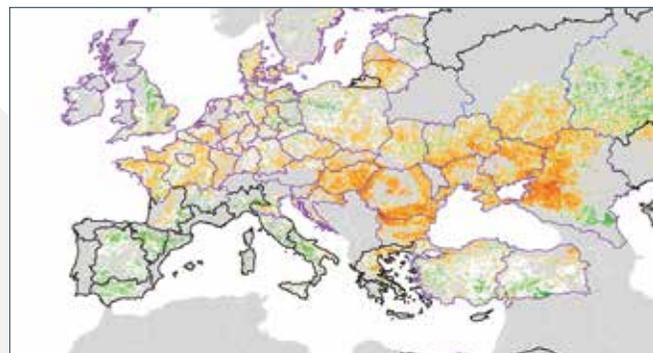
Applied Sciences helped organize a series of four webinars to increase involvement in GEO by organizations and government agencies across Central and South America. The events discussed GEO technical

activities, user needs, and future workshop topics. GEO plans additional webinars in 2014.

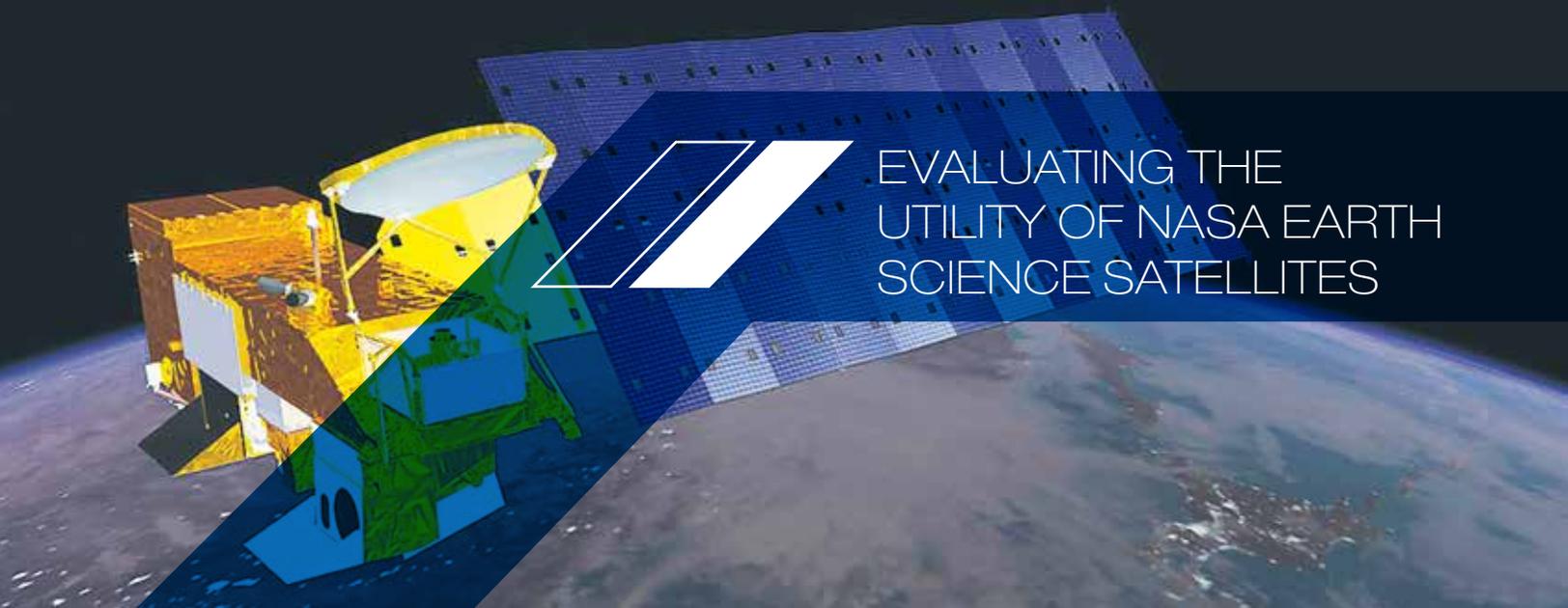
Looking Ahead

In 2014, GEO will hold a ministerial summit and its 10th Plenary Meeting. As part of the U.S. delegation, NASA will participate in numerous events on water resources, cholera, air quality, food security, data sharing, biodiversity, capacity building, and disasters, among others.

To learn more about GEO, visit earthobservations.org.



Part of a global map of wheat growing regions in AMIS countries. The image shows differences in wheat crop vegetative growth for August 28, 2013, relative to a 12-year average. Orange to red areas indicate less vegetation vigor than average, and green areas higher than average vigor.



EVALUATING THE UTILITY OF NASA EARTH SCIENCE SATELLITES



In 2013, NASA held its biennial Earth Science Senior Review to evaluate satellite missions operating beyond their design lifetimes. The review determined whether to continue funding for operating the satellites and developing their respective data products. The review considered the scientific value, technical performance, national utility, and proposed cost of extending each mission in relation to NASA Earth science objectives.

The 2013 Senior Review assessed 13 satellite missions: *ACRIMSAT*, *Aqua*, *Aura*, *CALIPSO*, *CloudSat*, *EO-1*, *GRACE*, *Jason*, *OSTM/Jason-2*, *QuikSCAT*, *SORCE*, *Terra*, and *TRMM*.

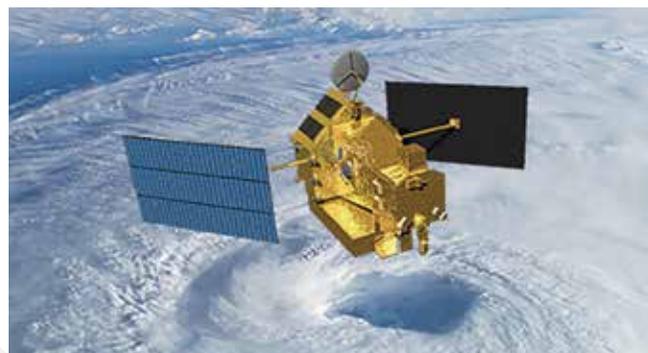
As part of the review process, the Applied Sciences Program organized the National Interests Panel, which assessed the missions' value for applied, non-research purposes. The panel included representatives from 13 federal and nongovernmental organizations: six civilian agencies, two military branches, two professional associations, two nonprofits, and one scientific institution. Francis Lindsay and John Haynes, program managers in Applied Sciences, chaired the panel.

The National Interests Panel evaluated the utility of satellite data for applied and operational uses that serve national interests, such as public services, military operations, government administration, policy making, and business and economic uses. This panel assessed data products by value, frequency of use, and latency. Based on these factors, it assigned each mission an overall utility rating.

The panel determined that three satellite missions have very high utility: *Aqua*, *Terra*, and *TRMM*. These missions generate highly valued data products routinely used for important activities, and loss of the data products would have significant negative impact on national agencies and organizations. The panel found eight missions with high utility and two with some utility.

The Senior Review combined the utility findings with inputs from other panels assessing the missions' scientific value, cost, and technical performance. The review concluded that all 13 missions have made unique and important contributions to Earth science. The Senior Review found that the continuation of all the missions would make "critical contributions to enabling NASA to continue to meet its science objectives."

To view the 2013 Senior Review report, visit <http://science.nasa.gov/earth-science/missions/operating>.



Depiction of the *TRMM* satellite. Top of page: depiction of *Aqua*. Left: depiction of *Terra*.

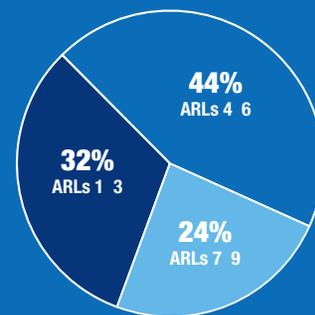


PROGRAM PERFORMANCE

The Applied Sciences Program achieved its 2013 performance goal to advance 25 percent of its Earth science applications projects by one Application Readiness Level (ARL). Sixty-eight percent of projects advanced one ARL, and 35 percent advanced more than one ARL. The Program's project portfolio spanned the ARL range; four projects achieved ARL 9, the highest level.

The nine-stage ARL metric tracks the maturity of applications projects from idea through operational use. ARL 1 represents research, and ARL 9 represents sustained use in decision making.

ARLs 1–3 are proof-of-concept stages, ARLs 4–6 development stages, and ARLs 7–9 deployment stages.



Capacity Building

The Program's capacity building efforts reached new levels. DEVELOP had 348 total participants (17 percent above the two-year average); its 78 projects in 2013 was also an increase. Fifteen GOMI projects were active in 2013, and four reached ARL 7 or 8. SERVIR began tracking its 11 Applied Sciences Team projects; all were ARLs 1–4. ARSET conducted 10 training courses involving organizations from 31 states; the 593 people trained constituted a 69 percent increase over 2012.

Financials

Applied Sciences' effective fiscal year 2013 budget was \$32.5 million; the appropriated \$34.6 million budget reduced \$2.1 million by sequestration. The Program primarily funded competitively selected applications projects (55 percent); four capacity building project offices at NASA Centers (33 percent); and Program-wide activities (12 percent), such as socioeconomic impact studies and applications workshops.

At the end of FY 2013, the Program had committed 97 percent of its funds, and the remaining 3 percent was primarily located at three NASA Centers awaiting obligation. The Program improved the "costing" of funds, with a sizable 45 percent increase in FY 2012 costing levels.

New Associates

Three additional associate program managers joined Applied Sciences to track projects, support their development, and communicate results. Tim Stough started in Disasters; Vince Ambrosia and Amber Soja began in Wildfires.

Global Challenges

Applied Sciences led an ESD strategic study of global challenges that NASA Earth science could help address. The study involved 240 sources and assessed hundreds of challenges. NASA prioritized three to examine and possibly pursue: food security, disasters, and freshwater availability. The Program will lead efforts in 2014 to explore potential NASA partnerships with private sector organizations to tackle them.

Future Performance Goal

The 2014 goal calls for 25 percent of the applications projects to advance one ARL. The Program will assess the annual performance goal after 2014 and adjust the target percentage as appropriate.



The NASA Applied Sciences Program and its collaborators received several accolades in 2013 for contributions and success in leading and publicizing Earth science applications.



RECOGNIZING ACHIEVEMENTS IN EARTH OBSERVATIONS



Leading Geospatial Knowledge Transfer

NASA Earth Science received a 2013 award for “exemplary implementation of geospatial policies and programs” for the Applied Sciences Program. *Geospatial World*, a premier geospatial industry magazine, presented the award at the annual Geospatial World Forum in the Netherlands. The award recognized the Applied Sciences Program for its efforts to “pioneer innovative methods to apply Earth observations to support the economy, safety of life and property, and quality of life.” To learn more, visit <http://bit.ly/1qw2J35>.



Guiding Hydrological Applications

Soroosh Sorooshian received the 2013 Horton Medal from the American Geophysical Union. The honor recognizes “outstanding contributions to hydrology.” In his work with NASA Earth Science and the Applied Sciences Program, he has addressed hydrometeorology, water resources systems, climate studies, and applications of remote sensing. To learn more, visit <http://bit.ly/1pMPj2v>.



Building Successful Partnerships

Nancy Searby, Capacity Building program manager, received the 2013 Cooperative External Achievement Award from NASA Headquarters. The honor recognized her “outstanding leadership to promote NASA partnerships with government agencies and civil society and collaborations in the use of NASA Earth science for societal benefits.” In addition, Lauren Childs-Gleason, DEVELOP national lead, received the NASA Silver Achievement Medal for her service to DEVELOP.



Promoting Earth Science

The Applied Sciences Program’s annual report won two silver 2013 Communicator Awards from the International Academy of the Visual Arts, one for government annual report and one for overall design. The report also received a gold 2013 Hermes Creative Award from the Association of Marketing and Communication Professionals, in the publications/annual report category. Booz Allen Hamilton, which developed and designed the annual report, nominated the report for the awards.

See the online report for more 2013 awards.



LOOKING AHEAD

“Building on a successful year, we are enthusiastic about continuing our progress into 2014 and beyond. As always, we will continue to help Earth science serve society.”

Lawrence Friedl, Applied Sciences Program

In store for 2014 are more project results; new applications projects; new SERVIR and DEVELOP locations; new training modules on ecosystems and disasters; over five mission applications workshops; expanded Early Adopters efforts; project impact assessments; a socioeconomic benefits workshop; a space apps challenge; project videos; and a new website, among other items.

Applied Sciences Program

We will start numerous projects in 2014. New Water Resources projects will address seasonal outlooks of water supply conditions. New Health & Air Quality projects will address a range of topics. The Ecological Forecasting, Disasters, and Wildfires management teams will assess their feasibility studies and select some to continue as full-scale applications projects.

We will enhance our capacity building efforts. DEVELOP will expand participation in the spring and fall terms and add a focus on veterans involvement. ARSET will develop new training modules for ecosystems. GOMI will produce a summary report on all four dozen projects. SERVIR plans to select a new hub with USAID in Southeast Asia.

Satellite Mission Planning

NASA Earth Science plans numerous activities to continue engaging applications communities in mission planning, including applications workshops by *SMAP*, *OCO-2*, and other missions. *SMAP* and *ICESat-2* will accept additional Early Adopters, and *SWOT* and other missions will initiate early adopters programs. Applied Sciences will be very involved in NASA's evaluation of approaches to ensure sustained land imaging observations.

Socioeconomic Benefits

We will sponsor the fifth international workshop on socioeconomic benefits of Earth observations, focusing

on valuation methods for open data and advances in methodologies. The Program will complete impact analyses on several projects and initiate new analyses.

Space Apps Challenge

NASA will conduct its third annual International Space Apps Challenge. Applied Sciences will be actively involved, sponsoring numerous challenges focused on Earth and the environment.

NASA and Earth Science

NASA plans to launch five Earth science missions in 2014. The *GPM*, *OCO-2*, and *SMAP* satellites and the RapidScat and CATS instruments are scheduled for Earth orbit.

The new NASA strategic plan will include a goal to “Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.”





ABBREVIATIONS

ACRIMSAT: Active Cavity Radiometer Irradiance Monitor Satellite	COSMO-SkyMed: COntellation of small Satellites for the Mediterranean basin Observation	JPL: Jet Propulsion Laboratory	QuikSCAT: Quick Scatterometer
AgMIP: Agricultural Model Intercomparison and Improvement Project	CREST: Coupled Routing and Excess Storage	KML: Keyhole Markup Language	RAQMS: Regional Air Quality Modeling System
AGU: American Geophysical Union	CRW: Coral Reef Watch	KMS: Kenya Meteorological Service	RCMRD: Regional Centre for Mapping of Resources for Development
AIRS: Atmospheric Infrared Sounder	DoD: Department of Defense	LANCE: Land Atmosphere Near real-time Capability for EOS	SEAS: Sargassum Early Advisory System
AMIS: Agricultural Market Information System	EO-1: Earth Observing-1	MATCH: Metadata Access Tool for Climate and Health	SMAP: Soil Moisture Active Passive
AMS: American Meteorological Society	EOS: Earth Observing System	MERRA: Modern-Era Retrospective analysis for Research and Applications	SMD: Science Mission Directorate
AMS: Autonomous Modular Sensor	EPA: U.S. Environmental Protection Agency	MISR: Multi-angle Imaging SpectroRadiometer	SORCE: Solar Radiation and Climate Experiment
AQAST: Air Quality Applied Sciences Team	ESD: Earth Science Division	MODDRFS: MODIS Dust Radiative Forcing in Snow	SST: sea surface temperature
AQI: Air Quality Index	FEMA: Federal Emergency Management Agency	MODIS: Moderate Resolution Imaging Spectroradiometer	Suomi NPP: Suomi National Polar-orbiting Partnership
ARL: Application Readiness Level	FY: fiscal year	MODSCAG: MODIS Snow Covered Area and Grain size	SWE: snow water equivalent
ARSET: Applied Remote Sensing Training	GEO BON: GEO Biodiversity Observation Network	MSG: Meteosat Second Generation	SWOT: Surface Water and Ocean Topography
ASDP: AirNow Satellite Data Processor	GEO: Group on Earth Observations	MTSAT: Multi-functional Transport Satellite	TOPS: Terrestrial Observation and Prediction System
ASO: Airborne Snow Observatory	GEOGLAM: GEO Global Agricultural Monitoring	NASA: National Aeronautics and Space Administration	TRMM: Tropical Rainfall Measuring Mission
AVHRR: Advanced Very High Resolution Radiometer	GIS: geographic information system	NCAR: National Center for Atmospheric Research	USAID: United States Agency for International Development
BLM: Bureau of Land Management	GOES: Geostationary Operational Environmental Satellite	NDVI: Normalized Difference Vegetation Index	USDA: United States Department of Agriculture
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation	GOMI: Gulf of Mexico Initiative	NGO: nongovernmental organization	USFS: United States Forest Service
CATS: Cloud-Aerosol Transport System	GPM: Global Precipitation Mission	NLDAS: North American Land Data Assimilation System	USGS: United States Geological Survey
CBRFC: Colorado Basin River Forecast Center	GRACE: Gravity Recovery and Climate Experiment	NOAA: National Oceanic and Atmospheric Administration	VIIRS: Visible Infrared Imaging Radiometer Suite
CDC: Centers for Disease Control and Prevention	GRACE-FO: GRACE Follow-On	OCO-2: Orbiting Carbon Observatory-2	WSN: Wireless Sensor Network
CDWR: California Department of Water Resources	HYCOM: HYbrid Coordinate Ocean Model	OMI: Ozone Monitoring Instrument	
CNES: National Center for Space Studies (of France)	HyspIRI: Hyperspectral Infrared Imager	OSTM: Ocean Surface Topography Mission	
	ICESat-2: Ice, Cloud, and land Elevation Satellite-2	PACE: Pre-Aerosol, Clouds, and ocean Ecosystem	
	INSPIRE: Infrastructure for Spatial Information in the European Community	PM_{2.5}: fine particulate matter	
	ISERV: International Space Station SERVIR Environmental Research and Visualization		



NASA Earth Science Applied Sciences Program

<http://AppliedSciences.NASA.gov>

Special thanks and recognition to William Corley, Lacey Olivares, and Elizabeth Nicastro for the development and design of this report.

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NP-2014-07-1029-HQ