National Aeronautics and Space Administration

2016 ANNUAL REPORT

NASA Earth Science
Applied Sciences Program

WHAT'S APPLIED SCIENCES?

The Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth science data and knowledge. The Program supports and funds applied research and applications projects that foster uses of Earth-observing satellite data and scientific knowledge by public and private sector organizations in their policy, business, and management decisions. The project results and enhanced decision-making improve quality of life and strengthen the economy.

All Program activities support goals to deliver near-term uses of Earth observations, build capabilities for applying 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, international development, food security, and many other topics. The projects are carried out in partnership with end users to enable sustained use and sustained benefits.

We have three lines of business: Applications, Capacity Building, and Satellite Mission Planning. Our Applications areas address disasters, ecological forecasting, health and air quality, water resources, and wildfires. Capacity Building works with users in the U.S. and developing countries to improve skills and workforce in applying Earth observations. Satellite Mission Planning engages users to envision potential applications for future Earth-observing satellites, helping them prepare to use the data and further enhance the value of each satellite mission.

True to NASA's vision, we'll continue to pursue new opportunities and effective ways for NASA Earth Science to serve society and benefit humankind.

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

FROM THE DIRECTOR

Lawrence Friedl, Applied Sciences Program

Penguins to plant stress. Raging fires to raging floods. Great apes to Great Lakes. Our projects and activities covered a wide spectrum in 2016. As you'll find inside, all these and more are some of the innovative ways our partners used Earth observations to support their activities. This report captures just a few examples of how Earth observations inform decisions and benefit society.

Our three lines of business—Applications, Capacity Building, and Satellite Mission Planning—had another successful year. We added 21 new projects to our applications portfolio. Our ARSET training program reached more people than in any other year. We held productive workshops to help users prepare for upcoming satellite missions. And let's not overlook that we surpassed our performance goal—for the fifth year in a row.

We continued our strong involvement with the worldwide Group on Earth Observations, leading several activities in the Group's new 2017-2019 Work Programme. We're also promoting uses of Earth observations for the international Sustainable Development Goals and the benefits and opportunities those create.

As you read through this year's report, you may notice that there are lots of quotes—from end users, our partners, and a few of us. We hope they'll help you get to know Earth science applications and our Program's work a bit better. And perhaps you'll think of ways that Earth observations can help your organization—if so, we have quotation marks waiting for you.

We hope you enjoy the report and all the many ways people are Making Space for Earth.

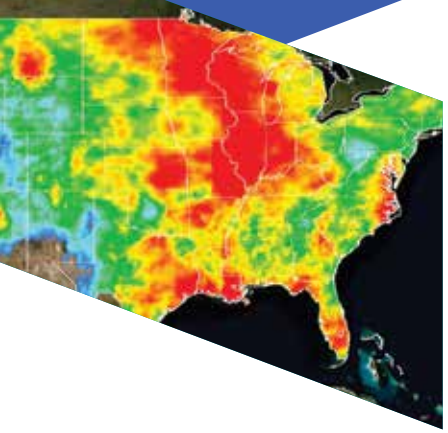
WHAT'S INSIDE

Check out our website, ***http://AppliedSciences.NASA.gov***

2016: OUR YEAR IN REVIEW

"We had a strong year in 2016 with many successes and several firsts. We made great progress and initiated new ways to advance Earth science applications. Our thanks to everyone involved!"

Lawrence Friedl, Applied Sciences Program



What a year it was for NASA Earth Science and the Applied Sciences Program! Our partners used Earth observations in creative, innovative ways to benefit their organizations and society. We formed new and lasting partnerships, new projects and teams started, we trained another record number of people…the list could go on. Most importantly, we successfully supported our three main goals: providing near-term uses of Earth-observing satellite data, building capacity with Earth observations, and contributing to satellite mission planning.

Applications Areas

Our Program's applications areas had another productive year; see just a few examples on pages 8-27.

The Water Resources area solicited proposals on water security, water quality, and agriculture water use, and we selected eight of 44 projects for awards. These projects will apply Earth observations to support the sustainability of water supplies and provide timely information on variability in water use over time.

The Health & Air Quality area tracked 25 projects in 2016. Its successful, five-year Air Quality Applied Sciences Team, AQAST, completed (see page 32), and the follow-on team began, expanding to include public health topics as well. The area accepted the leadership role in the Group on Earth Observations Health & Environment Community of Practice.

The Ecological Forecasting area led NASA's presence at the 2016 World Conservation Congress, which featured a NASA presentation with Jane Goodall and an applications project we did with the Jane Goodall Institute. The area solicited proposals on large-scale conservation, energy, food security, marine ecosystems applications, and on ecosystem services valuation workshops. We selected 13 projects of the 33 proposals.

Space was the place for our Disasters area. It used Earth-observing satellites to support the response to more than 20 national and international disasters—including floods, tropical cyclones, volcanic eruptions, earthquakes, and more. The Disasters area also guided and participated in hurricane simulation exercises with U.S. federal, state, and local authorities.

The nine projects in the Wildland Fires area advanced their applications development. One project assisted the Southeast U.S. wildfires in 2016 with critical fire modeling data, and two provided information on the burn severity and potential soil erosion in sensitive watersheds and environments in fires, including Canada's massive Fort McMurray fire.

We also issued a solicitation for proposals to apply Earth observations for international food security and domestic agricultural practices. We will select consortia for this new pursuit in 2017.

Capacity Building

Our Capacity Building program continued to grow in 2016, engaging more people from across the globe. ARSET conducted 15 online and in-person trainings, reaching a total of 3,277 participants. The trainings included people from 1,392 unique organizations in 130 nations and all 50 U.S. states. ARSET held its first-ever trainings on coastal management and carbon monitoring, and it launched its own Twitter feed *(@NASAARSET)*.

“NASA’s work on Earth science is making a difference in people’s lives all around the world every day.”

Thomas Zurbuchen, Associate Administrator
Science Mission Directorate

DEVELOP opened a new node in Tempe, Arizona, in collaboration with the Maricopa County Department of Public Health and Arizona State University. DEVELOP had 77 applications projects involving 359 participants, 101 U.S. partners, and 24 international partners across its three, 10-week terms. In celebration of the National Park Service’s (NPS) Centennial, DEVELOP collaborated with NPS on 17 feasibility projects across 25 states that demonstrated applications of NASA Earth observations for America’s national parks and monuments.

SERVIR opened a fourth hub in 2016. This SERVIR–West Africa hub in Niamey, Niger, is a joint project between NASA and USAID to strengthen environmental monitoring in four West African countries (see page 6). We selected 16 scientists from across the U.S. as members of the 2016-2019 SERVIR Applied Sciences Team. They will lead projects that bring the latest in Earth observations and geospatial technologies to regional issues affecting the four global SERVIR hubs.

Satellite Missions

Two NASA Earth Science missions launched in 2016—*Jason-3* and *CYGNSS*. Both are providing unprecedented Earth-observing data and open up new applications opportunities.

As part of the Earth Venture program, NASA selected the future MAIA instrument and *GeoCARB* mission; both of which have significant applications dimensions. MAIA will investigate the effects of air pollution on human health, while *GeoCARB* will monitor vegetation health and plant stress, supporting carbon management decisions.

"This year, new Earth science missions got underway to enable studies that will unravel the complexities of our planet from the highest reaches of Earth's atmosphere to its core." Charlie Bolden, NASA Administrator

As always, we supported future instruments and satellite missions to identify potential applications and build communities of data users. The *SWOT* mission conducted its first Applications User Survey to assess end-user needs and data requirements. The *PACE* mission drafted an applications plan, and *ICESat-2* added three more Early Adopters.

The TEMPO mission held its first Applications Workshop, and the future mission ECOSTRESS developed multiple tutorials to help potential end users simulate applications products. Check out pages 28-31 for more about NASA Earth Science missions and applications.

Program Activities

We continued our strong involvement with the international Group on Earth Observations. GEO adopted its 2017-2019 Work Programme, and our program managers lead numerous initiatives and activities. To support their roles, we issued a first-ever solicitation for projects to engage people across the U.S. in the work of GEO—see page 35. Our work promoting uses of Earth observations for the Sustainable Development Goals progressed, and Applied Sciences organized the U.S. exhibit at the GEO Plenary in St. Petersburg, Russia.

Four new members joined the Applied Sciences Advisory Committee, ASAC, which advises NASA Earth Science on applications topics. The Committee's meeting in December focused on the recent National Academy of Sciences Continuity report, the on-going Earth Science Decadal Survey, and roles of applications in satellite missions. Sadly, ASAC member Molly Macauley died in July 2016. Please see our tribute to Molly on page 38.

Our on-going work to quantify the economic and social benefits of Earth observations took big steps forward. We initiated nine impact studies, sponsored an international workshop, and selected a multi-organization consortium on the value of Earth observations. Resources for the Future will lead this five-year cooperative agreement with us; see page 7.

NASA held its fifth annual International Space Apps Challenge in April, and 161 locations in 61 countries held events. NASA invited engineers, coders, artists, and storytellers to connect over six themes: Solar System, Technology, Aeronautics, Space Station, Journey to Mars, and Earth. More than 15,000 people participated. They produced 1,300 project solutions, and the Earth area had the most with 320. And, of the six projects receiving global awards, two were Earth science projects. In fact, NASA Earth Science took over the responsibility for the International Space Apps Challenge in August, and the 2017 event will focus on Earth topics.

Our congratulations to NPS on its 100th anniversary. In addition to DEVELOP's focus on NPS (see page 3), NASA's Earth Observatory commemorated the Centennial with a special feature. *National Parks from Space* highlighted America's natural and historic treasures through breathtaking satellite imagery and feature articles. See their beauty for yourself here: *https://earthobservatory.nasa.gov/Features/NationalParks*

We're proud that it was another award-winning year for the Applied Sciences Program. Several members of our Capacity Building program received recognition for their work. Andrew Molthan, whom we've often worked with, received the prestigious Presidential Early Career Award for Scientists and Engineers. Please see page 36 for more.

In October, we held a special meeting for the Applications areas to address tactical, logistical, and operational items. It was a chance for us to learn from one another on smart practices, such as engaging project teams, solicitation styles, and communications.

As we look to 2017 and our future projects, missions, and applications opportunities, we're excited about the many possibilities we see to enable the use of Earth observations in benefiting our nation and the world.

2016: IN WORDS AND NUMBERS

"The information from NASA—and the analysis—help us achieve our operational objective: go fast, go big, go smart."

Brandon Bolinski, FEMA

19

***ICESAT-2* MISSION**
EARLY ADOPTERS

WATER RESOURCES
PROJECTS IN 2016
44 PROPOSED
8 SELECTED

8 SATELLITES THAT COMPOSE
THE *CYGNSS* MISSION

"We will use every product that [ICIMOD and SERVIR] provide as very useful scientific information to support our analysis."

Maan Kshetri, World Food Programme

10

DEVELOP PARTNERS
IN THE UNITED STATES IN 2016

$47.6M
APPLIED SCIENCES
FY2016 BUDGET

57%

PROJECTS ADVANCING
AT LEAST ONE
APPLICATIONS READINESS LEVEL

9 PROJECTS
IN THE WILDLAND
FIRES PORTFOLIO

13

NEW HAQAST
MEMBERS

37.084N
76.380W
LOCATION OF NASA'S 2016 LOW LATENCY
DATA WORKSHOP

SERVIR-WEST AFRICA HUB
LAUNCH DATE

13

NEW ECOLOGICAL
FORECASTING
PROJECTS SELECTED

"We've not used remote sensing to its full potential."

Hanem Abouelezz, NASA DEVELOP partner, Rocky Mountain National Park

WHAT'S NEW?

With a year full of innovations, advancements, and milestones, that question could take us a while to answer—and that's a nice problem to have. In the interest of keeping things short and sweet, we're giving you the bite-size version of some new things below:

NEW DIGS

Our Capacity Building program's SERVIR element expanded its world hubs to four, with the opening of the latest NASA/USAID SERVIR hub in Niger, Africa. Located at the Agriculture, Hydrology and Meteorology Research Center in Niamey, Niger, SERVIR-West Africa will use publicly available data from space to manage climate-sensitive issues, such as food security and water resources, in the countries of Burkina Faso, Ghana, Niger, and Senegal.

"What we seek in the long term are African solutions to African problems."
Alex Deprez, Director
USAID West Africa

DRINK UP!

We initiated a new NASA-wide Western Water Applications Office. This WWAO is a dedicated effort to support Western states to apply Earth science data and models to inform water management decisions. NASA's JPL, GSFC, and ARC run this initiative that engages water managers at local, state, and regional levels as well as companies and non-profits.

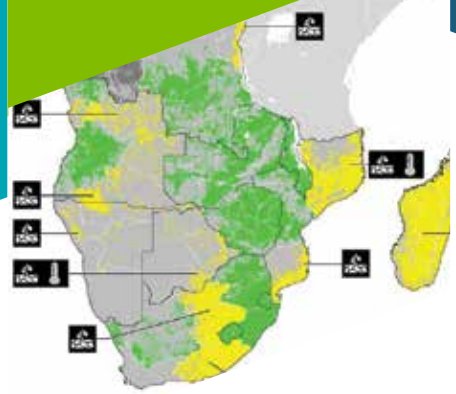
"Don't hug us for 18 months and go away."
Tim Quinn, Association of California Water Agencies

We won't, Tim.

KEEPING PEOPLE FED

The Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Initiative announced a new activity this year under its Countries at Risk component—the Early Warning Crop Monitor (EWCM) bulletin. The EWCM provides timely crop condition assessment for countries at risk of food insecurity, reflecting a consensus of the international, regional, and national organizations concerned with monitoring food security.

"[The EWCM] will strengthen global agricultural monitoring by improving the use of remote sensing tools for crop production projections and weather forecasting."
G20 Ministerial Declaration



HAQAST

BREATHING EASY

Thirteen scientists from across the U.S. are now a part of our new Health and Air Quality Applied Sciences Team (HAQAST), a collaboration that works in partnership with public health and air quality agencies to use NASA data and tools for public benefit. HAQAST is a follow-up to our Air Quality Applied Sciences Team, AQAST. (See page 32)

"This new team is making public health a much greater focus. It's not just about getting data about air pollution—it is getting it directly to public health organizations."
Tracey Holloway, Director
HAQAST

A TEAM MENTALITY

A highlight for SERVIR in 2016 was the selection a new Applied Sciences Team (AST). The SERVIR AST consists of principal investigators and co-investigators, who kicked off 16 applications targeted toward water and water-related disasters, food security, weather and climate, as well as land use and ecosystems.

"SERVIR is connecting [us] with long-term rainfall data records—from historical satellite-based observations and real-time estimates, to short-term rainfall forecasts."

Dula Shanko, Deputy Director General
National Meteorology Agency of Ethiopia

RESOURCES FOR THE FUTURE

A NEW ENDEAVOR

NASA selected Resources for the Future to lead a consortium that will quantify the socioeconomic benefits of Earth observations. It's a five-year cooperative agreement with three main aspects: advancing analytic techniques to quantify the impacts (in economic and social terms) from uses of Earth observations; building capacity in the Earth science community regarding socioeconomic terms, concepts, and methods; and, advancing communication on the benefits and value of Earth observations.

"This new consortium…will be dedicated to discovering and disseminating the importance of space-derived information—information that can directly benefit our personal health, the economy, and our environment."

Richard Newell, President
Resources for the Future

PROJECTS IN MOTION

We launched our Applied Sciences Video Series in 2016, with a playlist of 15 videos on the NASA.gov YouTube channel. The videos highlight a variety of Applied Sciences projects that are bringing real-world benefits in the areas of public health, disaster guidance, wildlife conservation, water resources, and more.

"A dedicated YouTube playlist is an exciting addition to Applied Sciences. The videos bring a fresh, entertaining perspective to the applications and users."

John Haynes, Program Manager
Health & Air Quality Applications

A NEW VENTURE

NASA selected the second complete spaceflight mission in the Earth Venture series. This competition was the first time that NASA Earth Science had a formal requirement for applications as part of a proposed Earth Venture mission concept. Proposers were required to include a plan for providing data and information products to applications users, and for enabling applications projects.

"Earth Venture challenges the science community to propose relatively low-cost investigations for important measurements. We encourage them to also support applications of the measurements to promote societal benefits in addition to the research."

Eric Ianson, Director
NASA Earth Science Flight Program

There were many more new things this year that you'll find throughout this Annual Report, so you can see why we're so proud of 2016.

"It is very important for the agricultural sector to monitor vegetation stress, and ESI provides a mechanism to see the onset of stress and allows for potential mitigation steps to be taken."

Christopher Hain, NASA

SEEING STRESS FROM SPACE

The U.S. is predicting droughts sooner with satellites

Unlike us humans, soybeans and wheat can't turn to acupuncture or aromatherapy when they're stressed out.

And, yes, plants can certainly feel stress. Stress that's caused by too little moisture and exacerbated by high temperatures. "Agricultural stress occurs when crops do not have adequate soil water during their growth cycle," explained agricultural researcher Christopher Hain. "Even if the stress doesn't lead to failure of the crop, it can have significant impacts on end-of-season yield."

Now a new tool is letting the U.S. agriculture community tap into space-based data to see this stress before it takes its toll.

Heads Up

Kyle Schell, a family rancher near Wall, South Dakota, knows how quickly fortunes can change for his business. "When droughts or flash droughts hit, and we as managers do not make adjustments, we start to do detrimental things to the ranch resource," he said. "Having a good idea when these droughts are coming gives us the opportunity to make adjustments early, in order to not adversely affect the grass and hay acres."

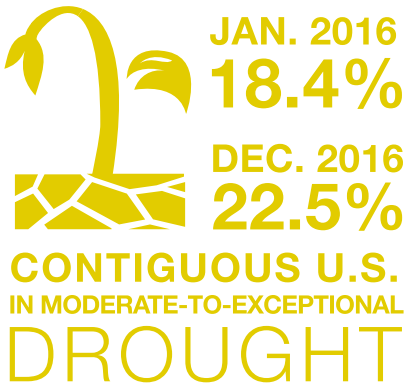
Providing that critical information sooner was the focus of an Applied Sciences project which used Earth observations to detect drought conditions across North America at a much earlier stage. Working with the Atmosphere-Land Exchange Inverse model, Hain and a team of scientists from NOAA, USDA-ARS, the National Drought Mitigation Center, and the University of Maryland integrated land-surface temperature measurements from the *GOES* satellite with vegetation, albedo, and landcover data from *Terra* and *Aqua*. The result was the development of a tool called the Evaporative Stress Index (ESI), which in many cases can indicate the beginnings of a drought two-to-four weeks earlier than current drought indicators.

What's the benefit from adding the space-based data? They allow the ESI to assess moisture conditions on the ground—independent of precipitation. And that means the ESI can show how crops are responding to irrigation. It also means that the ESI is especially helpful for predicting a phenomenon called flash droughts. Unlike typical droughts that can take months or years to develop, flash droughts occur much more suddenly and can damage crops in a matter of weeks—well before the stress causes visible signs of damage.

"When vegetation is already turning brown, it's too late," Hain emphasized.

Another Source

The ESI became operational in 2016 as a part of NOAA's online *GOES* Evapotranspiration and Drought Product System. This decision-support system supplements information sources already available to the water resource and agriculture communities, such as the U.S. Drought Monitor.



"New tools and products like the ESI will help our nation's drought early-warning capacity, which can then help communities detect flash droughts as they come on quickly." Mark Svoboda, U.S. Drought Monitor

David Ollila, a sheep field specialist for South Dakota State University Extension, remarked how the ESI saw the first glimpses of a spring flash drought—much sooner than the Drought Monitor did. "This tool appears to provide a much quicker and more representative reflection of what is happening," he noted. "The lag time in which the Drought Monitor recognized the severity of this year's drought negatively impacted the ability for USDA Farm Service Agency support and relief… until it was at a point of being too late. Forage production was measured at five-to-fifteen percent of a normal year. That is catastrophic."

For Schell, the ESI provides another tool for weighing his options. "I will monitor all of the drought resources available, including ESI, and if certain thresholds are met by certain dates, a destocking practice will begin," he explained. "For example, if we are below-normal in precipitation on May 1st and the Drought Monitor and ESI are indicating drought, I will sell some or all of our replacement yearling heifers."

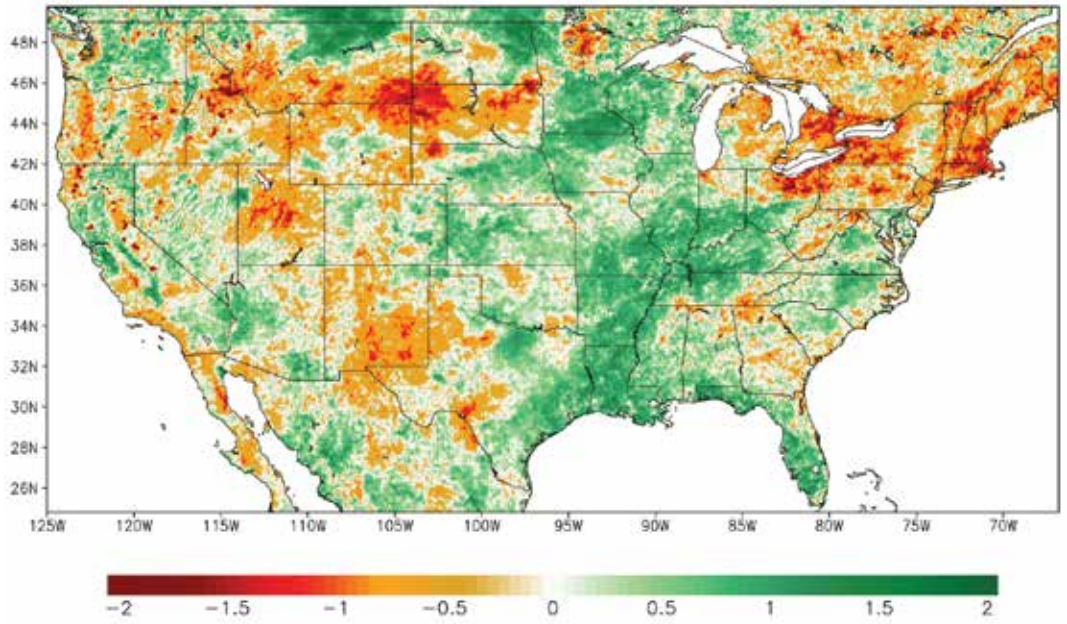
It's not just cattle and corn that benefit from the ESI, either. A state agency is also turning to it for guidance. As senior hydrologist for the Texas Water Development Board (TWDB), John Zhu uses ESI data as both an early drought indicator and as a reference for TWDB's short-term drought forecast. "I've found that ESI is particularly useful for our drought monitoring program…We want to know what kind of drought it is and how long it will last."

Going Global

With the successes already seen from the ESI for North America, Hain and his team also focused on much larger scales. "We developed a new method to use MODIS and VIIRS land surface temperature so that we could produce a global ESI product from just a single sensor," Hain said. "We'll be developing an operational global ESI dataset which will serve a large group of engaged stakeholders."

Initially, the stakeholders will include groups like the USDA Foreign Agricultural Service, the Global Drought Information System, and the GEOGLAM Early Warning Crop Monitor—and Hain is working on engaging more. "Ultimately our goal is to get global ESI datasets out to as many stakeholders as possible."

Christopher Hain *(christopher.hain@nasa.gov)* leads this project. In 2016, Hain moved to NASA Marshall Space Flight Center as a research scientist.



ESI for the 3-month period ending August 31, 2016. Color indicates evapotranspiration rates. Red shading indicates anomalously low rates, and green shading represents anomalously high rates.

TOP 3 CROPS PRODUCED IN THE U.S.

CORN

SOYBEANS

WHEAT

BIOMASS AND THE BEAST

How free and open data are fostering innovative applications in Africa

"We intentionally freely distribute our datasets and maps, and we're quite glad to see them being used in this way."

Patrick Jantz, SERVIR Applied Sciences Team

A SERVIR project put space-based rainforest data online. Now the data are giving great apes more space.

Web of Life

The ecological footprint of the world's tropical rainforests is enormous. It's estimated they support 50 percent of all terrestrial life, yet cover less than seven percent of the globe.

What's more, continuing deforestation not only threatens the habitat of many species, but also contributes to carbon emissions. The reason? Rainforests, and their living biomass, store large amounts of global carbon; known as a forest's "carbon stock". When humans clear rainforests, there's less biomass to store carbon.

Aiming to support the global conservation initiative called REDD+ (Reducing Emissions from Deforestation and forest Degradation), members of the SERVIR Applied Sciences Team (AST) focused on creating an open-source database that mapped the world's tropical rainforest biomass. "Making data freely available is not only how science advances, but also how people can most effectively make use of knowledge and information for their various applications," noted SERVIR AST member Scott Goetz. The team's hope was this intentionally shared data would ultimately spark applications ideas for conserving areas of unprotected rainforest around the world.

First though, the team needed Earth observations to map these global oases.

Taking Stock

Goetz, along with team members Patrick Jantz and Nadine Laporte, used field measurements, NASA lidar observations, and MODIS images from *Aqua* and *Terra*, to create a global map estimating the amount and distribution of aboveground rainforest biomass across the Earth's tropics.

Next, they wanted to determine where conservation efforts were already protecting tropical rainforests. For this, the team downloaded 5,600 world protected areas from a global database. Many countries designate specific locations as protected in an effort to slow or stop rainforest loss. This preservation, however, can at times create other problems for the local ecology. The fragmented nature of these habitats can interrupt species' migration routes, limit food and water availability, and impact biodiversity. Knowing this, the team assessed ways to link these protected areas to each other along their nearest highest-biomass corridors, which identified new tracts of land that conservation efforts could target.

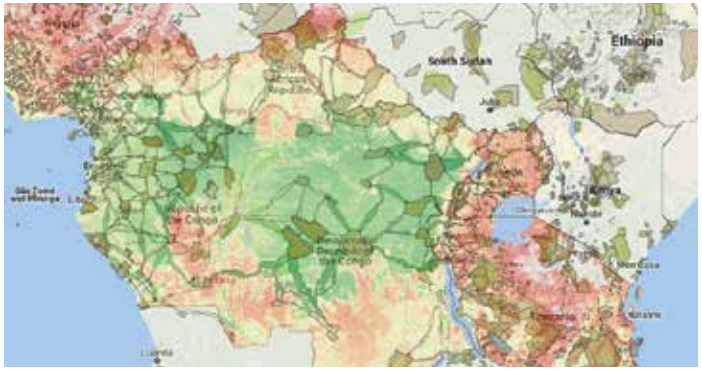
The final analysis revealed 16,257 corridors—green pathways that could potentially connect thousands of isolated patches of rainforest around the world. These corridors collectively cover 3.4 million square kilometers and contain an estimated 51 gigatons of carbon.

A Pathway to Conservation

This open-source corridor data went online in 2016 and already inspired an application—guiding great ape conservation in Africa.

GRASP is the Great Apes Survival Partnership, a United Nations initiative for ensuring the long-term survival of gorillas, chimpanzees, bonobos, and orangutans and their habitats. In a GRASP-REDD+ mapping project, the UN worked with the Max Planck Institute for Evolutionary Anthropology to develop an online tool. This tool superimposes the SERVIR AST-identified biomass corridors with the distribution of Africa's great

"You cannot protect apes in Africa or Asia without also protecting the forests in which they live." Doug Cress, GRASP



GRASP-REDD+ Mapping Project image of Central Africa with carbon stock, protected areas, and biomass corridors information

apes. In 2016, GRASP-REDD+ launched the tool during a conservation meeting with nine West African countries in Monrovia, Liberia.

So how are these giant primates reaping the benefits of biomass?

"The carbon tool helps to identify areas where REDD+ investments could potentially generate biodiversity benefits, in our case for great apes. We looked at corridors which could potentially link great ape habitats, and where REDD+ could provide the necessary seed funding to protect these areas," explained Johannes Refisch, GRASP Program Manager. "The government of Liberia has confirmed that it will use the carbon tool for its national REDD+ prioritization work."

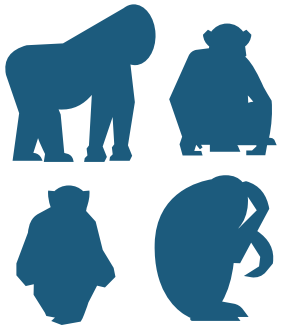
Harrison S. Karnwea, the managing director of Liberia's Forestry Development Authority was excited about the application of this new data. "This will help us a great deal here in Liberia," he said. "It will help us in determining which areas are important and should receive our highest priority. Conservation is a great resource, and applying it scientifically in this way is very innovative."

For GRASP Program Coordinator Doug Cress, it is crucial that conservation efforts like this continue to work as a partnership—where rainforest preservation and species conservation go hand in hand. "You cannot protect apes in Africa or Asia without also protecting the forests in which they live," he remarked. "This project does an excellent job of emphasizing the overlap."

And Jantz says there is more great news in store for the great apes. "We are now in the process of supporting the creation of forest corridors in the Murchison-Semliki Landscape [in Uganda] to conserve eastern chimpanzee populations and looking at possible incentives such as funding through REDD+ to encourage farmers to conserve forest on their land."

Dan Irwin *(daniel.e.irwin@nasa.gov)* leads our SERVIR program. Check out the GRASP-REDD+ Mapping Project web tool here: *http://apescarbon.eva.mpg.de/*

SERVIR is a NASA-USAID venture that fosters applications of Earth observations to help developing countries assess environmental conditions and changes to improve their planning, decisions, and actions. *https://www.servirglobal.net*



THE GREAT APES
GORILLAS, CHIMPANZEES, BONOBOS & ORANGUTANS

NEPAL: ONE YEAR LATER

Lowering a lake to reduce a potential disaster

"[Lake Imja Tsho is] one of the fastest-growing and potentially dangerous glacial lakes in high altitude regions."

The Kathmandu Post

5 MILLION CUBIC METERS WOULD FILL **2,000** OLYMPIC-SIZE POOLS

Last year, we highlighted the unprecedented global effort to help Nepal recover from the devastating 2015 Gorkha earthquake. In the effort, our Disasters program formed an Induced Hazards team that identified additional hazards spurred by the quake. Co-led by NASA's Dalia Kirschbaum and SERVIR team member Jeff Kargel, this international team of volunteers mapped more than 4,300 landslides in the weeks after the earthquake. The team also provided damage proxy maps and vulnerability assessments to support Nepal's response. Our efforts continued well after the aftershocks stopped.

In fact, Kargel's help was crucial to a Nepalese effort in 2016—the lowering of a glacial lake that threatened to breach its banks. Called GLOFs, or glacial lake outburst floods, these sudden releases of water are caused when a lake's moraine dam suddenly fails. The resulting flood can consist of millions of cubic meters of water, sand, and boulders rushing into unsuspecting villages downstream.

The glacial lake in question was Imja Tsho—one of many lakes that scientists have been monitoring for decades. The fear was the Gorkha quake could have weakened the moraine dam to the point where a GLOF was imminent. "In Nepal, a startling GLOF occurred in 1985 which triggered national consciousness of glacial lakes and their instabilities," Kargel explained. "It was soon realized that many glacial lakes had started forming in the 1960s, and have been growing ever since."

To assess the lake's expansion, Kargel and his team used Earth observations from ASTER, ALI, and *Landsat*, along with topographic maps and previous satellite imagery. "We added to the [earlier satellite] observations and produced a compelling picture of how the lake had grown…and that the growth rate had dramatically accelerated in the past decade," Kargel noted. "We also conducted the most complete depth survey, and our map showed that the lake volume was much greater than previously thought."

Construction of the outlet channel for Lake Imja Tsho

Enter the UN Development Program-funded Community Based Flood and Glacial Lake Outburst Risk Reduction Project, CFGORRP. Kargel's data and images assisted this project, which guided the government's decision to lower the lake's level. Based on the findings, the Department of Hydrology and Meteorology in Nepal signed a letter of agreement with the Nepalese Army Engineering Department to lower Lake Imja Tsho by approximately 3.5 meters. The $7 million project took many months—with more than 140 engineers draining five million cubic meters of water—and successfully concluded in autumn 2016. "The lake lowering didn't eliminate the hazard," Kargel emphasized, "but it greatly reduced it."

The Kathmandu Post estimated that the lowering of the lake would directly benefit more than 96,000 vulnerable people downstream. The project manager of CFGORRP, Top Bahadur Khatri, agreed and remarked, "We have successfully mitigated a disaster right now."

Jeff Kargel *(kargel@hwr.arizona.edu)* led our assistance to this project.

GETTING OUT FROM UNDERWATER

Earth observations guided efforts to aid communities swamped by historic flooding

Flooding killed more than 125 people in the U.S. in 2016. When disasters threaten the lives of Americans, NASA Earth Science uses its perspective from space to assist response and recovery efforts. We maintain a close partnership with many federal agencies, including USGS, NOAA, and FEMA.

In 2016, those partnerships strengthened—particularly with FEMA. "This year we focused on deeper collaborations with FEMA," said Andrew Molthan, NASA Disaster Response Support Team member. "Both in terms of providing products that are well-aligned to support their flood response and by improving ways to share those products for effective and timely decisions."

During domestic flooding events, NASA provides data and images from its own satellites, like *GPM*, *Aqua*, *Terra*, and *EO-1*, and teams with other U.S. agencies and international partners to tap into their space-based fleets as well. With this constellation of domestic and international satellites, we use Earth observations to map heavy rainfall, predict where flooding will occur, image the extent of ongoing floods, and help identify other impacts such as power outages.

These collaborations helped thousands of Americans recover from a year marked by several devastating and deadly floods.

The Mighty Mississippi

The first flooding disaster of the year actually straddled the calendar from 2015 into 2016. Waves of heavy rainfall brought record-setting flash flooding and subsequent river flooding to the central and lower Mississippi River Valley.

Located at the confluence of the Mississippi and Missouri rivers, the town of West Alton, Missouri, is no stranger to floods. This time, though, the water came too quickly. "We couldn't do anything to stop this one," said West Alton Mayor Willie Richter. "Normally we have about two weeks lead time to try and sandbag and prepare for what might happen. This time we only had about three or four days."

As flooding swamped the Midwest and South, Molthan and fellow NASA Disaster Response Support Team member Dalia Kirschbaum reached out to our Centers and NASA's academic partners. In a coordinated support to the disaster, the NASA Team provided technical expertise and data to response agencies, guiding and assisting their efforts.

Even when the successive rounds of downpours ended, massive flooding continued to move downriver from Illinois to Louisiana. Our Team took advantage of clear skies to collect targeted imagery for mapping the flood waters. NASA's *EO-1* satellite was among the first satellites to provide optical imagery of the submerged areas for our partners. *Aqua* and *Terra* also pitched in, helping our Team produce visual images that mapped flooded areas along the Mississippi River. In particular, *Terra*'s ASTER instrument detected the extent of the inundation around St. Louis, and soon FEMA had these images.

On the ground in nearby West Alton, Mayor Richter showed FEMA his view. Missouri had major transportation impacts from the flooding, as portions of interstates and railroads were forced to close. "As soon as we could access a majority of the town, we had an initial FEMA damage assessment," he said. "I went door to door with them so they could see the damage first hand. FEMA also setup a command center in town so the people could apply for help."

"Geospatial technologies help us understand complex situations by defining the event boundary. We can estimate the number of anticipated shelter requirements, the number of tarps needed, or the amount of water bottles we need to send to an impacted area. GIS is instrumental in painting that early picture of impact."

Christopher Vaughan, FEMA

Christopher Vaughan, a geospatial information officer with FEMA, stressed the importance of the immediate partnership between our agencies during floods. "NASA is helping us derive the extent of the disaster earlier," he noted. "For example, with flood extent maps, you can derive what's inside that flooded area and estimate the levels of impact. That's one of the hardest challenges for the emergency management community early on—determining how big and bad it's going to be."

As the flooding gradually pushed down the Mississippi River, our interagency collaboration continued through much of January. And it wasn't long before our efforts were needed again.

Louisiana's 500-Year Deluge

"We were moving as fast as possible to save what we could," Ginger Harris Heuvel said. She and her family were scrambling to safety in their attic as the waters came rushing in. "We could see the water rising as if a firehose was pumping water into the house." Unbeknownst to her, Earth observations were already working to help.

The exceptional rainfall began on Friday, August 12, and it was historic—NOAA later estimated it was a one-in-500 year event for central Louisiana. As the flooding started and worsened, FEMA reached out to NASA to request assistance in assessing the imminent disaster. Our Team tapped into the Global Flood Monitoring System (GFMS), a University of Maryland activity sponsored by our Disasters program, to provide FEMA with the potential for flooding and predicted flood inundation for the next several days.

The GFMS forecast model uses rainfall data from the *GPM* satellite. As rounds of rain continued, *GPM* monitored the seemingly never-ending onslaught. When the downpours finally stopped days later, estimates topped out at more than 30 inches of rain in parts of Louisiana. Rain gauges on the ground in Heuvel's hometown of Watson confirmed the staggering accumulation of 31.4 inches—the highest rainfall total measured during the disaster.

Clouds obscured some of what our satellites could see during the peak of the flooding. Luckily, radar could see it—it doesn't need clear skies or daylight to produce images. Our partner USGS activated the International Charter on Space and Major Disasters, enabling delivery of additional satellite images and space-based synthetic aperture radar, or SAR.

Using these, JPL experts on the Team compared before and after images of flooded areas. Before long, FEMA had flood extent and flood proxy maps thanks to validation from NOAA's aerial imagery and USGS' high water marks.

"We estimated that Louisiana would have about 27,000 damaged homes," said Glen Russell, a remote sensing coordinator with FEMA. "But it was through the acquisition of SAR data and other remotely sensed data that we were able to see that that was a much larger impact than we had forecast."

Terra ASTER image of flooding along the Mississippi River near Baton Rouge, Louisiana, on January 17, 2016

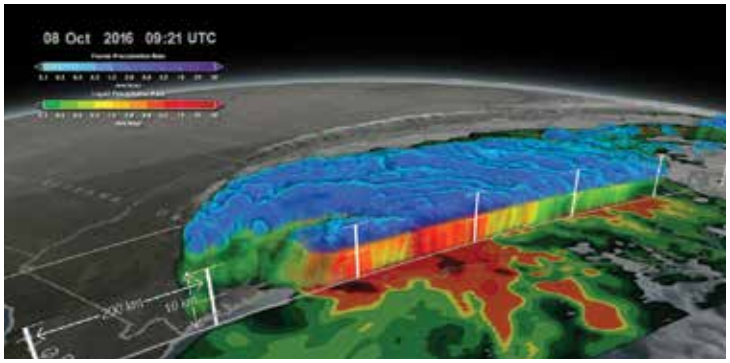
Heuvel's home was one of those casualties. "We were rescued by our local Livingston Parish Sheriff Office Deputies…as we waded out our front door in five feet of water," she said. "Ninety percent of Livingston Parish went under." The combined scope of Earth observations helped FEMA managers decide to increase the amount of resources sent to Louisiana. Before long, Heuvel and her family had a new place to live.

"We have been blessed with a very nice FEMA trailer and are so thankful to be able to use it," Heuvel added. "There are FEMA trailers and campers in most every yard. Everyone is in the state of repair at this time…We all have a long road ahead of us."

Matthew's Misery

When Tara Bullard saw Hurricane Matthew's rain bands continuing to drop downpours over her hometown of Lumberton, North Carolina, she worried for what was coming next. "There was nowhere for all of the water to go."

As she feared, Bullard, the principal of West Lumberton Elementary, soon saw her community become a victim of Matthew. Months later, there were still painful scars. "My school sustained heavy damages as a result of the flooding…We are still displaced, with no immediate plans of returning. I still have students and families living in hotels."



GPM's Dual-frequency Precipitation Radar sensor showing 3D rain rates within Hurricane Matthew as it spins along the Carolina coast on October 8, 2016

Well before Hurricane Matthew's impacts were being felt in Lumberton, our Disaster Response Support Team was monitoring the storm and collaborating with other federal agencies and international partners. This coordinated effort kept watch from the beginning—tracking Matthew as it battered Hispaniola and Cuba and then made its way toward the U.S.

As Matthew's effects were being felt along the Southeast coast, *Suomi NPP*'s VIIRS instrument provided crucial insights for detecting which communities had lost power. For Matthew's potential flooding impacts, the Team once again turned to GFMS and mapped locations from northeastern Florida to North Carolina that were likely to be inundated.

NASA Earth Science's real-time Land Information System (LIS) also assisted our NOAA and USGS partners in their hurricane planning and response. The LIS incorporated vegetation information from VIIRS and soil moisture observations from *SMAP* to identify areas of saturated soils that were prone to flash flooding—helping partners identify where flooding would be likely as the rainfall continued to accumulate.

When Matthew's rains ended, the flooding was just beginning for many communities in the Carolinas. Team members from NASA Marshall used multiple Earth observations to generate flood extent maps for eastern North Carolina, along with storm surge-affected regions along the eastern coast of Florida. NASA Goddard's Near Real-Time Global MODIS Flood Mapping also used *Terra* and *Aqua* imagery to identify the extent of the massive flooding. Our Team aggregated and compared its water detections against the pre-Matthew water extent, as FEMA and other response partners retrieved them through an online portal.

"By utilizing hazard layers that NASA produces, we can develop a more detailed and informed analysis of the housing and infrastructure damage in communities," noted Brandon Bolinski, a regional hurricane program manager for FEMA. He added, "FEMA leadership can then make informed decisions on placing response assets in the field."

Even as waters were receding days later, responders were still assessing the full scope of the disaster—Matthew caused more than two dozen deaths in North Carolina alone. For Bullard, NASA's assistance in this effort left her optimistic that this team approach would help victims in future disasters. Ever the educator, she remarked, "I hope that our situation has the potential to teach and positively impact the way others may respond to a similar situation."

David Green *(david.s.green@nasa.gov)* leads our Disasters program.

31.4"
TOTAL RAINFALL
IN WATSON, LA

ATLANTA: GREEN AND CLEAN

Earth observations help the city manage its water and urban forests

"The spatial analysis with the NASA DEVELOP team has been really valuable in that it helped us to really think about what are the criteria that we want to use when prioritizing places that will work."

Sara Gottlieb, TNC

The City of Trees. Hotlanta. The Big Peach.

Whatever you call it, Atlanta is a bustling American metropolis of concrete and steel. It also boasts extensive parks, gardens, and urban forests. As with other growing metro areas, the city has been seeking ways to balance this green canopy and its vital infrastructure—especially as its population is expected to double by 2060.

Fortunately for A-Town, the Georgia chapter of The Nature Conservancy (TNC) has already been formulating a plan for one of the city's potential challenges—its water supply. "The Nature Conservancy is developing an urban conservation program focused on reducing stormwater impacts in the Atlanta metro area," explained Sara Gottlieb of TNC.

This conservation plan is part of TNC's North American Cities program, which emphasizes a greater role for nature in urban settings. By promoting greenspace as an alternative to traditional stormwater infrastructure, like costly culverts and drains, TNC advocates re-introducing natural buffers while protecting existing ones. This "green" infrastructure helps decrease urban runoff and also reduces the amount of pollutants entering local waterways.

It's an ambitious plan; and the greater Atlanta region is huge—about the size of Connecticut. It also has one of the most extensive urban canopies in the U.S. Where should TNC and its partners concentrate their conservation efforts? For that question, TNC turned to NASA DEVELOP for help.

Green Guidance

DEVELOP teams integrated data from *Landsat* and *Terra* into land-use models to locate reforestation targets as well as identify locations that impacted local water quality. The teams applied the results to create a land-use prioritization map of metropolitan Atlanta's major watersheds for TNC and its partners.

DEVELOP Lead Christopher Cameron said the project identified a few specific areas where TNC could focus its conservation efforts. "Reforestation and green space development opportunities exist along several waterways adjacent to Atlanta," he noted. The project also indicated which communities were major sources of runoff that additional green infrastructure could help minimize.

Cameron added, "The majority of open or managed land with the highest potential to affect water quality occurs north of Atlanta. The downstream effects of any land management practices at these locations could be significant."

Seeing the Forest for its Trees

TNC received that crucial, fine-detailed information it was lacking. Myriam Dormer, an urban conservation associate at TNC, remarked, "Now we have a smaller subset of places within Atlanta where we can target reforestation projects and then target engagement strategies."

Gottlieb affirmed, "The results of these analyses will be used immediately to inform decisions about land protection and reforestation to benefit communities by protecting drinking water supplies, providing opportunities for outdoor recreation, and serving as educational settings to demonstrate the importance of maintaining greenspace in urban areas."

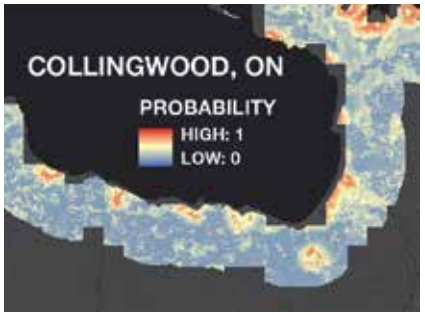
Keeping ATL peachy-keen takes a team effort, it seems. As Gottlieb stressed, "We could not have completed these analyses without access to NASA's resources and Earth observations."

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, and other organizations. *https://develop.larc.nasa.gov/*

FIGHTING PHRAGMITES

Space-based data are aiding Great Lakes communities as they combat an invader

Located on the southern shore of Georgian Bay in Ontario, the idyllic Great Lakes town of Collingwood has been battling a growing problem—an invasive wetland reed called *Phragmites australis*. And the town is not alone in its fight.



Risk map for *Phragmites australis* near Collingwood, ON. Areas in red show a higher probability for *Phragmites*

"*Phragmites* are a very serious problem in the Great Lakes Basin," said David Ullrich, Executive Director of the Great Lakes and St. Lawrence Cities Initiative (GLSLCI). *Phragmites*, a non-native subspecies of a natural Great Lakes reed, can quickly take over a location, crowding out native plants and animals with dense stands of stalks that grow more than 5 meters tall.

"They turn wetlands into monocultures that are much less attractive to fish and wildlife," Ullrich added. "They also reduce the natural value of wetlands to cleanse water and help reduce flooding."

Using NASA's eyes in the sky, a DEVELOP project helped guide Collingwood's battle from above.

Tracking a Tenacious Threat

In partnership with the Michigan Tech Research Institute (MTRI) and GLSLCI, a DEVELOP team led a project that built on earlier MTRI research on *Phragmites* in the region. The goal of this project was two-fold. The first was to create a current risk map based on habitat suitability for *Phragmites* throughout the basin.

"We focused our study within 10 kilometers of the U.S. and Canadian coastline, based on *in situ* data previously collected and the number of communities impacted by *Phragmites*," said team member Sean McCartney.

The second goal was to create a *future* risk map for the entire basin through the year 2020. "Forecasting results help local governments enact policies to plan for and mitigate the spread of *Phragmites*," McCartney added.

To do this, the project tapped into precipitation data from NASA's *TRMM* and *GPM* satellites, used Earth observations from the Shuttle Radar Topography Mission, and modeled variables such as soil drainage and topography. The current and predicted *Phragmites* risk maps gave guidance to the project partners' on-going monitoring and mitigation efforts.

And, at GLSLCI's 2016 annual meeting in Niagara Falls, New York, the DEVELOP team shared its findings. Here, Great Lakes mayors and local officials from the U.S. and Canada were able to see the threat they faced from this noxious nuisance.

Armed With Information

For Collingwood, which is in the second year of its "Fight the Phrag!" program, the data is now helping inform officials where to focus both control and eradication efforts around its marshes and shorelines.

"The Earth observations to map and model *Phragmites* makes it easier because in one image, a person can see the scope of the problem," Ullrich explained. "If all of this information had to be gathered from ground-level observations, it would take much longer, be much more labor intensive, and be much more costly."

And that means Collingwood's Phrag fighters can save their time and resources for combat.

Mike Ruiz *(Michael.L.Ruiz@nasa.gov)* leads our DEVELOP program.

"The Earth observations to map and model *Phragmites*…put people in our cities in a better position to take preventative steps in advance to try to limit or stop the spread."

David Ullrich, GLSLCI

THE YEAR IN APPLIED SCIENCES

JANUARY

5-7 Final meeting of NASA AQAST; EPA Campus, North Carolina

10-14 American Meteorological Society 96th Annual Meeting; New Orleans

17 Launch of *Jason-3* mission; Vandenberg Air Force Base, California

19-21 The Food-Energy-Water Nexus 16th National Conference and Global Forum on Science, Policy and the Environment; Virginia

20-21 *PACE* Science Team Meeting; California

25 DEVELOP: Start of Spring Term: 109 participants, 26 projects, 56 partners

FEBRUARY

1-3 *NISAR* Science Definition Team Meeting; NASA JPL

8 Applied Sciences Program Review; Washington, D.C.

10 ARSET: Start of Advanced Webinar Series on Creating and Using Normalized Difference Vegetation Index from Satellite Imagery

17-20 Sustaining Wildland Ecosystems through Monitoring and Communication to Stakeholders Workshop; Montana

19 Release of Research Opportunities in Space and Earth Sciences 2016

21-26 Ocean Sciences Meeting; New Orleans

MARCH

1-3 Wildland Fire Applications Team Meeting; Idaho

3 Announcement of Telly Award for *A Voice for Whales* video

7 *Geospatial Information and Earth Observations: Supporting Official Statistics in Monitoring the SDGs* at the UN Statistical Commission; New York

9 Data to Decisions Tutorial: Cost Benefit Analysis; Paris

10-11 Data to Decisions Workshop: Valuing the Social Benefits of Geospatial Information; Paris

10 NASA announces new Earth Venture Instrument awards: Multi-Angle Imager for Aerosols (MAIA) and *Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS).*

14-16 NASA-Chinese Academy of Sciences Workshop on Glacier Change and Associated Hazards in High Mountain Asia; China

16 ARSET: Start of Advanced Webinar Series on Using NASA Remote Sensing for Flood Monitoring and Management

29-31 Meeting of the Committee on Earth Science and Applications from Space; Washington, D.C.

31 ARSET: Start of Webinar Series on the Introduction to Satellite Remote Sensing for Wildfire Applications

APRIL

1 DEVELOP: End of Spring Term

6 DEVELOP: Spring Virtual Poster Session (VPS) Launches

21-22 NASA celebrates *Earth Day in the Nation's Capital*; Union Station, Washington, D.C.

22-24 NASA's International Space Apps Challenge

26-28 NASA Water Resources Team Meeting; Alabama

27 Energy Management Stakeholder Ideation Workshop; Virginia

28 *CloudSat* and *CALIPSO* satellites celebrate their 10th anniversary in orbit

MAY

2-4 Group on Earth Observations 2016 Work Programme Symposium; Geneva

4 40th anniversary of the launch of the *Laser Geodynamics Satellite (LAGEOS)*, the first NASA satellite dedicated to laser ranging

4-6 NASA Biodiversity and Ecological Forecasting Team Meeting; Maryland

5 National Water Quality Monitoring Conference; Florida

6 DEVELOP: Winner of Spring VPS Announced: *Catch Me If You Can: Near-Real-Time Monitoring of Water Hyacinth*

16 Western Water Applications Office Drought Response Workshop; California

16-17 Eagle Horizon Exercise for disaster simulation

19-20 SERVIR Applied Science Team Annual Meeting; Washington, D.C.

25 NASA announces an agreement between its Earth Science Division and Rio de Janeiro, to improve hazard monitoring and disaster response in and around the city

31 NASA Applied Sciences Advisory Committee teleconference meeting

JUNE

1-3 *HyspIRI* Data Product Symposium and Aquatic Forum; NASA GFSC

2 ARSET: Start of Webinar Series on Fundamentals of Satellite Remote Sensing for Health Monitoring

6 DEVELOP: Start of Summer Term: 136 participants, 30 projects, and 71 partners

7-10 Cascadia Rising Exercise for disaster simulation

9 ARSET: Start of Webinar Series on Remote Sensing of Forest Cover and Change Assessment for Carbon Monitoring

9 ARSET: Start of Webinar Series on the Introduction to Satellite Remote Sensing for Air Quality Applications

13-16 *SWOT* Science Team Meeting; California

14-16 Disaster Flood Response Workshop; Maryland

20-23 Air and Waste Management Association Annual Conference and Exhibition; New Orleans

29-7/1 Annual Conference of the Global Flood Partnership; Italy

30 SERVIR: New Applied Sciences Team Announced

JULY

4-8 GEO Biodiversity Observation Network (GEO BON) Open Science Conference and All Hands Meeting; Germany

6 ARSET: Start of Webinar Series on the Introduction to Remote Sensing for Coastal and Ocean Applications

6 ARSET: Start of Webinar Series on Fundamentals of Satellite Remote Sensing for Health Monitoring

11-20 ARSET Workshop: Application of Satellite Remote Sensing to Support Water Resources Management in Latin America and the Caribbean; Brazil

12-13 TEMPO Applications Workshop; Alabama

12-19 XXIII Congress of the International Society for Photogrammetry and Remote Sensing; Czech Republic

14 Launch of NASA/USAID SERVIR-West Africa hub in Niger, serving Burkina Faso, Ghana, Niger, and Senegal

21 Applied Sciences Program Review; Washington, D.C.

22 New Health and Air Quality Applied Sciences Team (HAQAST) announced

AUGUST

9 DEVELOP: Poster session for National Park Service Centennial; NPS Headquarters, Washington, D.C.

10 DEVELOP Annual Earth Science Application Showcase; NASA Headquarters, Washington, D.C.

11 DEVELOP: Summer VPS Launches

12 DEVELOP: End of Summer Term

28-29 ARSET Workshop: NASA Earth Observations, Data, and Tools for Air Quality Applications; South Korea

SEPTEMBER

1 ARSET: Start of Webinar Series on Applications of Remote Sensing to Soil Moisture and Evapotranspiration

1-10 IUCN World Conservation Congress; Honolulu

4 ARSET Workshop: From Earth Observations to Earth Applications: Satellite Applications for Biodiversity Conservation; Honolulu

6-9 CEOS Working Group on Disasters Workshop; Washington

11-17 International Data Week; Denver

12 DEVELOP: Start of Fall Term: 108 participants, 21 projects, 41 partners

13-15 SERVIR: Applied Sciences Team Kick-off Meeting; Alabama

15 Winner of DEVELOP's Summer VPS Announced: *A Deeper Look into California's Water Resources*

20-21 Health & Air Quality Applications Annual Team Meeting; North Carolina

26 ARSET Workshop: The Practical Use of Satellite Observations for Visibility and Air Quality Analysis; Wyoming

27-29 Low Latency Datasets for Time-Sensitive Applications Workshop; NASA LaRC

28-30 Western States Water Council Fall Meeting; Utah

OCTOBER

4-7 Applied Sciences Program Associates' Meeting; Maryland

5-7 *GRACE* Science Team Meeting; Germany

12 SERVIR Workshop: Conservation in Mesoamerica, Part I; Maryland

13 ARSET: Start of Webinar Series on Remote Sensing Training: Methods & Best Practices "Train the Trainer"

17-18 SERVIR Workshop: Conservation in Mesoamerica, Part II; Maryland

18-20 *HyspIRI* Science and Applications Workshop; NASA JPL

20 Trans-boundary Flood Interagency Meeting; NASA GSFC

24-28 SERVIR: Annual Global Exchange; Nepal

27 Applied Sciences Mission-Applications Review; Washington, D.C.

28 *Suomi-NPP* celebrates its 5th anniversary in orbit

29-11/2 American Public Health Association Annual Meeting & Expo; Denver

31-11/2 CEOS Plenary; Australia

NOVEMBER

1 World Bank Group Geospatial Day; Washington, D.C.

2-4 First HAQAST meeting; Atlanta

4 NASA selects Resources for the Future to lead a consortium tasked with quantifying the socioeconomic benefits of Earth observations

7-10 GEO-XIII Plenary; Russia

8-10 OFDA International Humanitarian Response Exercise; Virginia

13-17 American Society of Tropical Medicine and Hygiene Meeting; Atlanta

14 ARSET Workshop: Application of Satellite Remote Sensing Data for Fire & Smoke Monitoring; California

14-16 NASA-Rio-UCCRN Training Partnership: Sea Level Rise, Urban Heat Islands and Water Quality; New York

14-17 International Smoke Symposium; California

14-18 Vigilant Guard Exercise; California

17 Applied Sciences Program Review; Washington, D.C.

17 Air Quality and Health Showcase; NASA GSFC

18 DEVELOP: End of Fall Term

19 NASA launches NOAA *GOES-R* mission

29 Applied Sciences: Release of GEO Work Programme solicitation

DECEMBER

6 NASA announcement of Earth Venture Mission: *GeoCARB*

6-7 ECOSTRESS Team Meeting; Maryland

7-8 NASA Applied Sciences Advisory Committee meeting; Washington, D.C.

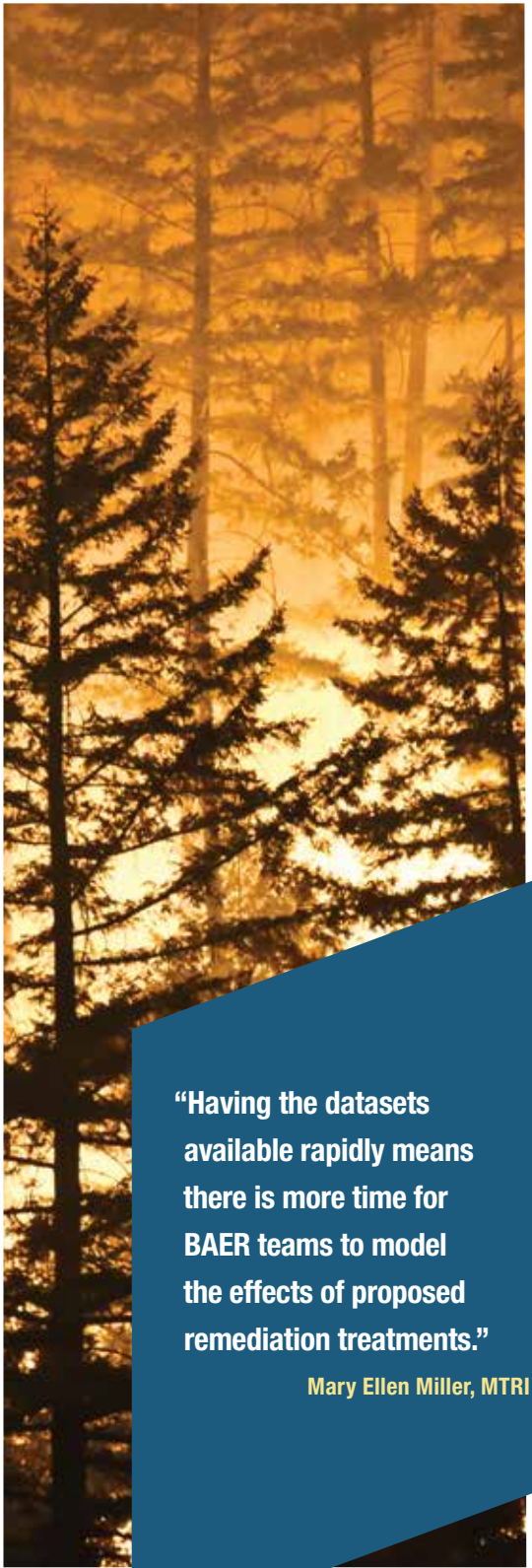
11 High Mountain Hazards and Disasters: Satellite Observations Workshop; San Francisco

11 Winner of DEVELOP's Fall VPS Announced: *Keeping Deforestation Out of Africa: Kenya's Protected Areas*

12-16 American Geophysical Union Fall Meeting; San Francisco

14 Ignite@AGU; San Francisco

15 NASA launches *CYGNSS* Earth Venture mission



> **"Having the datasets available rapidly means there is more time for BAER teams to model the effects of proposed remediation treatments."**
>
> **Mary Ellen Miller, MTRI**

BLAZING FAST RELIEF

A NASA-supported tool is accelerating wildfire recovery

Burned Area Emergency Response teams—they may be one of most important parts of wildfires that you've probably never heard of. As the last flames of a raging wildfire are being contained, these BAER crews begin safeguarding lives, property, and natural resources threatened by additional perils that fires create.

Scorched Earth

"Wildfire reduces or removes vegetation and ground cover protecting forest soils," said Mary Ellen Miller, a research engineer from Michigan Tech Research Institute. "This loss of forest vegetation increases the risk of runoff, flooding, and landslides when soils become saturated."

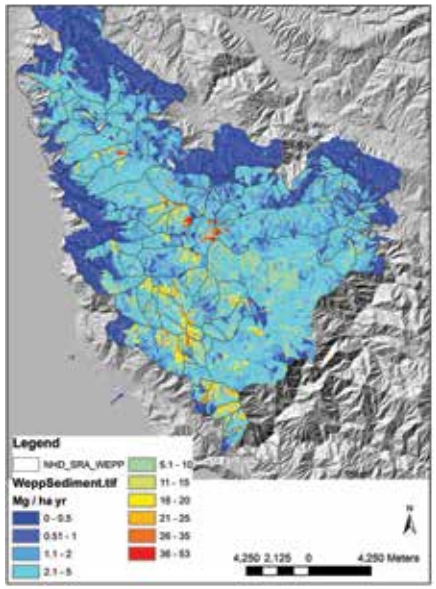
For BAER crews, this means time is of the essence. Their first task? Create a burn severity map that reflects the changes in both land-cover and soil properties caused by the fire. The maps inform the teams' recommendations and decisions on stabilization and recovery for the burned area, or burn scar. Actions typically include treatments such as laying down mulch, erecting silt fences, or planting quick-growing seeds. "In order to be effective, those treatments must be in place before the first major storm hits," Miller added.

Assembling the spatial data needed to make these recommendations typically took multiple days—time the BAER teams can ill afford. With the need for speed in mind, Miller's team created a database that now automatically integrates and assembles NASA satellite and other data needed to start the recovery planning process much sooner.

Rapid Response with RRED

In partnership with the U.S. Forest Service, Miller led an Applied Sciences project that developed an online tool called the Rapid Response Erosion Database. This RRED supports faster post-fire remediation by accelerating the time-sapping collection of spatial data.

With RRED, BAER teams and other users first upload their soil burn severity maps, which they derive from both satellites and field data. "*Landsat 8* is frequently used by BAER teams; however, multi-spectral aerial imagery and other imaging platforms like *EO-1*'s ALI, MODIS, and VIIRS can be used as well." Miller noted. Once the user uploads the map, RRED combines it with vegetation, soil, and elevation layers derived from Earth observations, and delivers a composite map pre-formatted for model input.



First year post-fire hill slope erosion predictions for the Soberanes Fire

With that data quickly assembled, the teams can focus the bulk of their efforts on modelling the effects of multiple weather scenarios. They can assess alternatives and determine which locations in the burn scar are most vulnerable to erosion, flooding, and landslides.

The extra time RRED gives was critical for busy response teams in California in 2016,

"I found [RRED] to be an excellent resource that was easy to use…The erosion model results assisted the teams in identifying areas of concern and in developing recommendations for emergency protective measures." Jeremy Lancaster, California Geological Survey

as wildfires scorched more than a half-million acres across the Golden State.

Soberanes Fire

An illegal campfire sparked the Soberanes Fire. It eventually became California's largest wildfire of the year, burning more than 132,000 acres. By the time crews finally contained the blaze, it was the most expensive firefighting operation in U.S. history.

For his post-fire strategy, Watershed Emergency Response Team member, Jeremy Lancaster, turned to Miller and RRED for rapid guidance. He was concerned about the impacts any rainfall runoff could have on nearby roads, infrastructure, recreation areas, and wildlife—things known as "values at risk".

"The state teams used the [RRED] results…to identify areas of elevated sedimentation [with the] potential to impact drainage structures and other values at risk. The erosion model results assisted the teams in identifying areas of concern and in developing recommendations for emergency protective measures," Lancaster said. "Typically these include t-posts, silt fences, debris racks, etc."

236 MILLION
COST OF SOBERANES
FIREFIGHTING OPERATION

Less than a month later, California had another wildfire on its hands. And RRED helped response teams once again.

Cedar Fire

The Cedar Fire swept across California's Sequoia National Forest during the late summer. This wildfire became Miller's first chance to see how BAER team members were successfully using RRED on their own—with minimal help from her. "I stepped back and instead assisted Forest Service teams in performing the modeling independently," Miller said. "Spoiler alert—they did great!"

USFS Soil Scientist Lizandra Nieves-Rivera used RRED to guide her BAER team's post-fire recommendations for the local recreation areas, roads, and drainage structures impacted by the Cedar Fire. The potential threats to, and distance from, the values at risk didn't justify additional actions, so the team proposed no mulch treatments. "The comparison between [the storm models] helped the team determine, explain, and backup the high cost versus the level of risk," she observed.

For Miller, this was a big step for RRED as a decision-making tool. "The independent use of our new Rapid Response Erosion Database was an important milestone for the project," she remarked.

Blazing a Trail

In 2016, Miller worked feverishly to expand the RRED database from 17 fire-prone Western states to the entire Lower 48. She said the next stage of this project is to fully transfer RRED to a USFS server in 2017. Miller added, "We also plan to continue to make the database more user friendly with our new open-source interface. BAER teams are under serious time constraints so streamlining the process is important for operational use."

Further down the road, Miller and her team hope to make RRED available to a much wider audience. "I would like to expand spatial coverage to include all fire prone areas of the world."

What happens after a wildfire depends a lot on preparations and activities before any wildfire. Thanks to Miller and her team's application of Earth observations, communities are better prepared to deal with the aftermath of fires.

Mary Ellen Miller *(memiller@mtu.edu)* leads this project.

500,000+
ACRES BURNED IN
CALIFORNIA WILDFIRES
IN 2016

TAKING THE BITE OUT OF MOSQUITOES

Spaceborne data are monitoring these airborne assailants in the name of public health

NDVI & TOPS

NDVI: The Normalized Difference Vegetation Index is an Earth science indicator of vegetation rigor. Some wavelengths of light are more sensitive to and revealing of vegetation than others. The NDVI index uses differences in wavelength sensitivities to identify vegetated areas and provide insights on plant health and stress.

TOPS: The Terrestrial Observation and Prediction System is a data and modeling software system designed to seamlessly integrate data from satellite, aircraft, and ground sensors with weather, climate, and applications models to produce nowcasts and forecasts of ecological conditions.

Aedes aegypti

It's a simple tactic in mosquito combat—find out where the little bloodsuckers are headed and cut them off at the pass. An online system is using NASA data to do just that.

Cyber (Mosquito) Warfare

When California public health agencies need to stop a flying menace, they turn to an online weapon first.

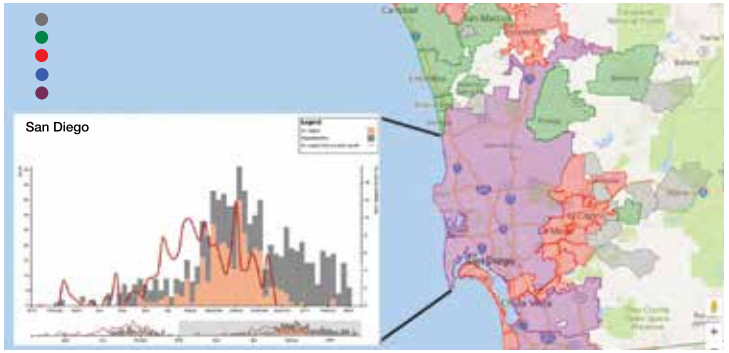
Called the California Vectorborne Disease Surveillance Gateway, or CalSurv Gateway, this decision support system acts as a central repository for crucial mosquito information. For example, control agencies can input and share surveillance data detailing where potential disease-carrying mosquitoes have been collected in traps. And thanks to Earth-observation data, they can also access maps that highlight which communities are the most susceptible to the next mosquito invasion.

"Models based on NASA data have been a valuable complement to California's decision support system for mosquito-borne viruses for more than a decade," said Chris Barker, an associate professor of epidemiology at the University of California, Davis. "The CalSurv Gateway was originally developed with support from NASA and NOAA to address West Nile virus." Recently though, Barker has been leading an Applied Sciences project that's enhancing CalSurv's database for invasive mosquitoes, specifically *Aedes albopictus* and *Aedes aegypti*.

These mosquitoes are bringing a new crop of disease threats to the U.S. and Golden State.

Where Are They Going?

Barker's project focused on using Earth observations to help control agencies stay one step ahead of these non-native pests. Once an agency enters its *Aedes* mosquito collection data into the CalSurv Gateway, the data is then integrated into a model that helps predict where they will likely go next—depending on a location's suitability. To determine that, CalSurv uses a mosquito habitat model from NASA's Earth Exchange computing platform that integrates land-surface temperature data from NASA TOPS and airborne NDVI data. From that, the system creates distribution and suitability maps.



Inset graph: *Aedes aegypti* detections in San Diego over time, with modeled estimates of mosquito population growth (red line) based on temperature data from NASA TOPS

CalSurv's data and maps allow control agencies to focus surveillance and control efforts in the right places from the start. "Early detection of new infestations is critical because it gives a much better chance for eliminating the mosquitoes locally," Barker emphasized. "Once the

> "Mosquito reproduction is strongly influenced by temperature and water availability, and NASA Earth observations link these physical processes to the biological parameters… This helps to optimize our surveillance and control programs by targeting efforts in critical areas." California Department of Public Health

mosquitoes have become widespread, elimination becomes a very difficult proposition."

The project's maps are an important guide to Paula Macedo, the laboratory director of Sacramento-Yolo Mosquito & Vector Control. She explained, "The estimated spread/distribution information on the CalSurv Gateway predicted that our service area is suitable for invasive *Aedes* species. The maps have helped us determine the ideal timing for initiating and terminating surveillance and have helped us better target our efforts."

Zika Emerges

For the first two years of Barker's project, there were two diseases that *Aedes* mosquitoes were notorious for carrying. "At that time, Dengue and Chikungunya virus were the chief concerns," Barker noted. Then came Zika.

"In 2016, the project expanded to include Zika virus since it emerged as a global health threat," Barker said. This new threat spurred Barker and his team to develop local guidance maps for the seasonal patterns of the *Aedes* mosquitoes' population growth, which were also added to CalSurv Gateway late in 2016.

This addition is now part of the arsenal of maps and charts Susanne Kluh and her team use for their surveillance decisions. Kluh, the scientific-technical director at Greater Los Angeles County Vector Control, knows the challenges her agency faces. "Mosquitoes with the potential for carrying Zika are already present in Southern California and they are also spreading as we speak," she stressed. "The possibility for Zika, or any of the other invasive *Aedes* transmitted diseases, to be spread locally in the near future is thus not a far stretch."

That possibility drove the project's recent urgency to provide more maps and data in CalSurv. "Now our models are beginning to allow us to test 'what-if' scenarios and optimize surveillance and control strategies in ways that would never be possible with field data collection alone," Barker said.

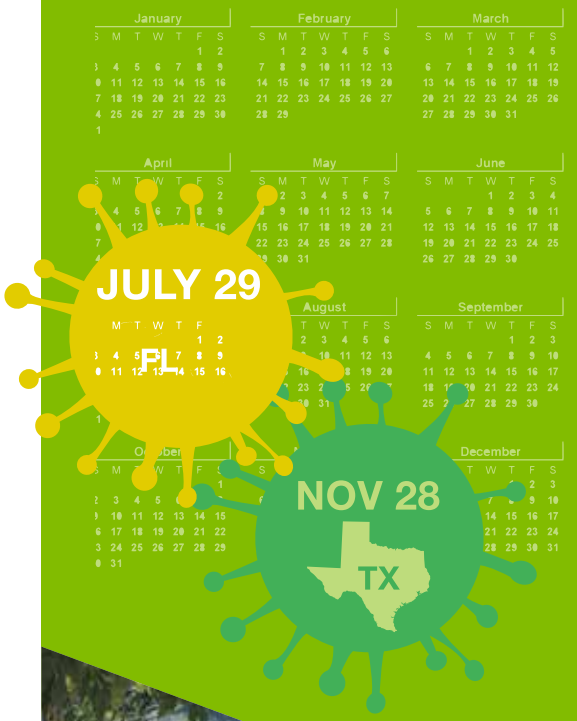
Buzzing Along

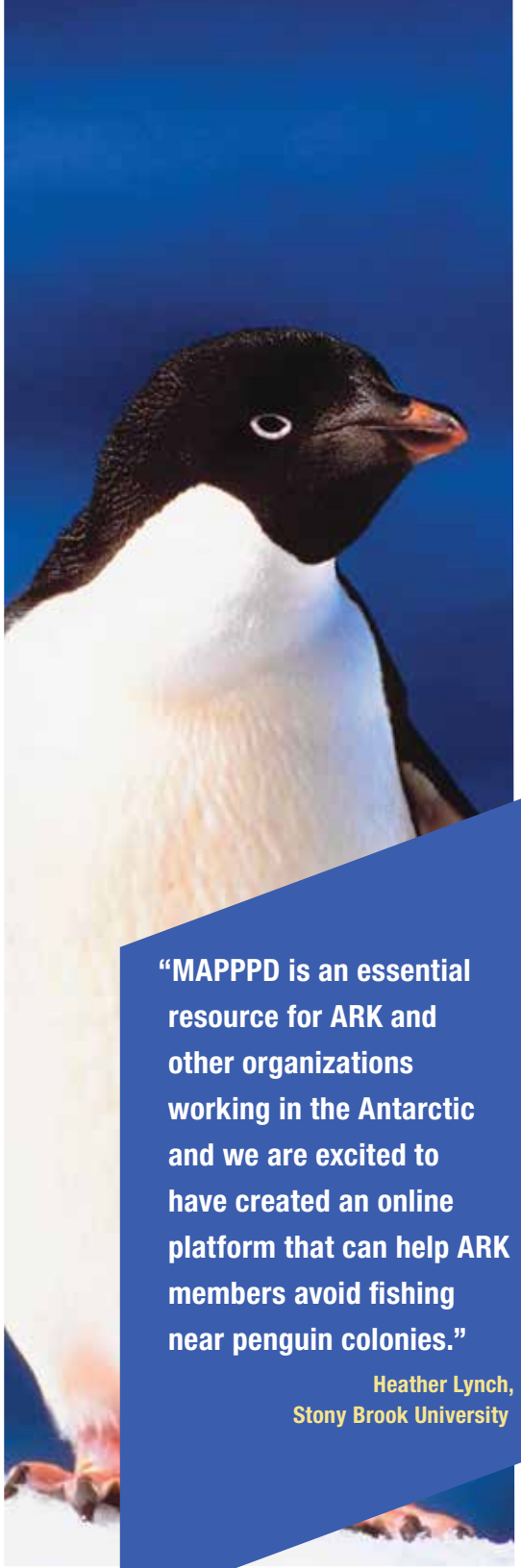
What's next for the project? Along with the *Aedes* maps already in CalSurv, Barker's team has been working to include maps that show the estimated risk for contracting Zika itself. For that, Barker will need to determine and integrate mosquito abundance.

"When you collect these mosquitoes, it's not so easy to know how many you have in a given area," Barker said. "Our estimates for Zika virus risk will be based on a model for transmission that accounts for local temperatures and mosquito abundance in each city." Barker expects the risk maps to be online by spring of 2017.

That information will be critical for Kluh's agency. She fears that the region's large, diverse, and well-traveled population could make it easy for anyone to bring Zika to the nation's second-largest city. "The capability of modeling likely outbreak scenarios is going to be of great value in the attempt to best use our limited resources to get and stay ahead of the disease."

Chris Barker *(cmbarker@ucdavis.edu)* leads this project.





"MAPPPD is an essential resource for ARK and other organizations working in the Antarctic and we are excited to have created an online platform that can help ARK members avoid fishing near penguin colonies."

Heather Lynch,
Stony Brook University

HOUSTON, WE HAVE A PENGUIN

At the bottom of the world, NASA satellites are guiding commerce and conservation

A Frozen Oasis

Along Antarctica's coastline, marine mammals, seabirds, and aquatic life thrive in the icy, krill-rich waters of the Southern Ocean. One of many species that depends on krill for their diet, Adélie penguins are distributed around the Antarctic coast and nest in some the world's most remote places.

As the krill goes, so does the Adélie; and scientists have long used these penguins as an early-warning signal for the ocean's ecological health. More recently, global companies have also turned to these squat swimmers to guide their Antarctic operations—and a tool we helped support is now connecting these unlikely partners.

A Bird's Eye View (of Poo)

That tool is MAPPPD, or Mapping Application for Penguin Populations and Projected Dynamics. Conservation foundation Oceanites, Inc., partnered with Heather Lynch of Stony Brook University and Mathew Schwaller of NASA Goddard to create this online database. MAPPPD is the first free, open-access Antarctic decision support system that integrates remotely sensed inputs, such as *Landsat 7* images and MODIS sea ice data, to provide an assessment of Adélie and other penguin species across the frozen continent.

How does a satellite like *Landsat* monitor the whereabouts of small, aquatic birds? It detects the 'signature' of their excrement.

"Satellite–based penguin surveys are detecting the guano left behind by penguins nesting at the colony," Lynch explained. "Male and female penguins take turns incubating the nest…and the guano left behind builds up in exactly the same areas occupied by the nests themselves.

Gentoo penguins nesting at the base of an emergency hut at Petermann Island, Antarctica

We can use the area of the colony (as defined by the guano stain) to work back to the number of pairs that must have been inside the colony."

With these "poo views", MAPPPD automatically classifies penguin areas, generates abundance estimates, and pushes those to the database so models can be updated in real time. And it includes more than just satellite data. "MAPPPD also continues to serve as a hub for ground-based surveys, and for data coming from citizen science efforts," said Lynch.

For conservationists, businesses, and other Antarctic stakeholders, this penguin information is crucial for ensuring they conduct their operations with as little impact as possible on the Southern Ocean and Antarctic ecosystem. By knowing where these flightless waterfowl are located, they know where to minimize their presence—and MAPPPD is helping direct them.

Penguins Providing Guidance

The Association of Responsible Krill harvesting companies (ARK) is composed of five international companies that rely on sustainably harvested Antarctic krill for their products. It's also a user of MAPPPD.

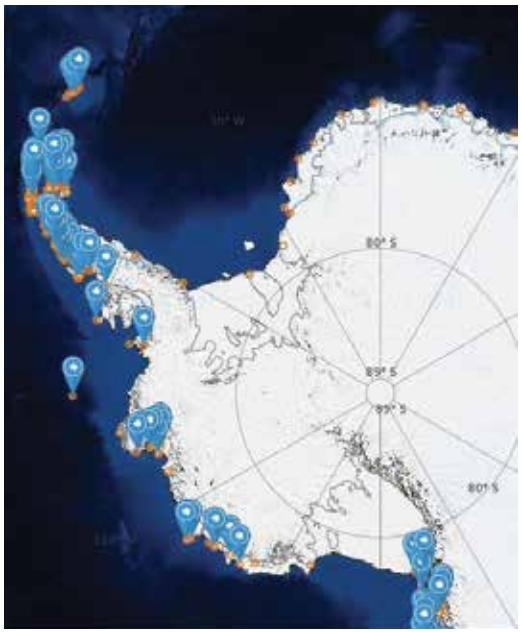
"[MAPPPD] will not only alert us to any change, but also enable us to understand what's causing it. I would anticipate it being incredibly useful at a large, regional, and small scale." Amanda Lynnes, IAATO

ARK companies announced this year that they have voluntarily halted fishing in waters near MAPPPD-indicated penguin colonies. "Leaving enough prey for natural krill predators is an important element in ensuring fisheries proceed sustainably," Lynch emphasized. "Without up-to-date knowledge on the locations of penguin colonies, ARK companies cannot possibly avoid the colonies, even if they agreed to do so."

One of the founding members of ARK is Aker BioMarine. It is a Norwegian-based company that recently built a new manufacturing plant in Houston, Texas. "We opened the U.S. facility because it gave us a more central location for global distribution," said CEO Matts Johansen. This Houston facility is helping support a booming international krill oil market—a market that depends on responsible harvesting to survive. "Aker BioMarine works closely with Oceanites and MAPPPD," Johansen added. "A long-term and sustainable fishery is the best way to ensure the future of the krill fishery and their operations in the Antarctic."

The International Association of Antarctica Tour Operators (IAATO), headquartered in Newport, Rhode Island, also uses MAPPPD to guide its environmentally-responsible Antarctic excursions. IAATO operators work on the principle that tourism, when managed effectively, is a powerful conservation tool. IAATO turns to MAPPPD to help tailor its tours so they have a minimal impact on the ecosystem.

"The bulk of our operations are in the Antarctic Peninsula area where there is a lot of overlapping human activity and where there has been a lot of environmental change," noted Amanda Lynnes, IAATO's communications and environmental officer. "We recognize that long term monitoring projects are vital for detecting change, and MAPPPD now makes these critical data sets accessible to a wide audience."



MAPPPD image of Adélie penguin colonies in West Antarctica

Mapping What's Ahead

Lynch's review of various *Landsat* surveys has also led to a new finding. "While Adélie populations have declined, and continue to decline on the Antarctic Peninsula, they are actually increasing in abundance in the Ross Sea and in Eastern Antarctica," she said. "It appears that these gains are at least cancelling and perhaps even more than compensating for losses on the Peninsula."

And as these penguin populations shift, MAPPPD will keep guiding Antarctic stakeholders. "MAPPPD will help the Antarctic community, including IAATO, manage human activity," Lynnes added. "This must always be a collaborative effort."

For Lynch, the possibilities for MAPPPD are just beginning: "With all the new data streaming in from satellites, and a new approach to sharing data and models through MAPPPD, I'm extremely optimistic we can start making some real progress on these long-standing puzzles in Antarctic ecology."

Heather Lynch *(heather.lynch@stonybrook.edu)* leads this project.

Check out MAPPPD here: *www.penguinmap.com*

>38,000

ESTIMATED ANTARCTIC TOURISTS **IN 2015-16**

4

NUMBER OF PENGUIN SPECIES IN MAPPPD'S DATABASE

A STELLAR YEAR FOR ARSET

Many Firsts…And Knowledge that Lasts

"Each time I attended [an] ARSET training, I learned something new for monitoring and forecasting flash floods."

ARSET webinar attendee

It was another successful—and busy—year for our Applied Remote Sensing Training (ARSET) program with a record 15 events. ARSET held nine online webinars—including two advanced webinars—and six in-person workshops. It trained 3,277 people from 130 countries and 1,392 organizations in areas ranging from disasters, health and air quality, land, water resources, and wildfires. What's more, several of the trainings were new topics for ARSET. And ARSET held a webinar that broke an attendance record. What a year!

A clear standout was a "train-the-trainer" webinar—one that prepared and inspired attendees to pass their learning to others. One hundred and fifty-six people from 131 organizations and 46 countries attended this three-week series, which taught the methods and best practices of remote-sensing training. The webinar held sessions that explained the process of building a training program, the ways of effective outreach and communication, and how to assess end-user needs.

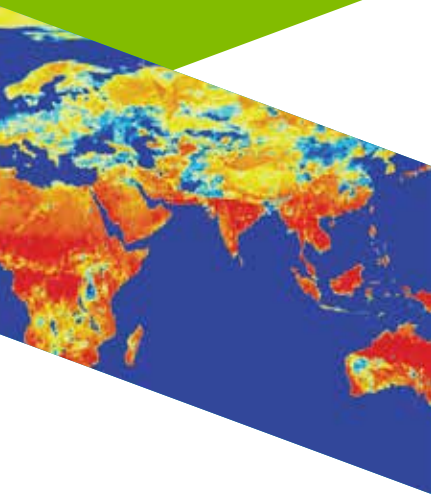
The result? In a follow-up survey, nearly half of the participants reported they were already engaged in training others. "I enjoyed very much this training," said an attendee from the Brazilian government, who also added that this webinar was, "very well organized [and had] very clear pronunciation from instructors."

ARSET also set a record on June 9, 2016. Its webinar training had more attendees and participating countries than any other in ARSET's eight-year history. Nearly 770 people from 80 nations participated in *Applications of Remote Sensing to Soil Moisture and Evapotranspiration*. This webinar included sessions on the access and applications of *SMAP* and MODIS-based data in decision and policy making. An attendee from Ecuador's municipal government remarked, "Knowing the evapotranspiration rates is really useful for having an idea of the water budget in my working area. This is going to be really useful to improve water management."

Since 2009, ARSET has reached 8,000+ participants from more than 2,600 organizations and 152 countries.

Ana Prados *(ana.i.prados@nasa.gov)* leads our ARSET program.

ARSET (Applied Remote Sensing Training) builds skills in accessing and using Earth-observations data across applications topics through computer-based training for commercial, non-profit, and government professionals. *https://arset.gsfc.nasa.gov*



768
WEBINAR ATTENDEES
LARGEST TRAINING EVER

1,023
PEOPLE TRAINED
MOST IN ONE DAY

130
COUNTRIES
REACHED IN 2016

MEET TANBIR SINGH

We're very proud of Tanbir Singh. He went from an ARSET attendee to a 2016 ARSET instructor, leading his own air quality demonstration at an ARSET workshop. Here's his story.

Tanbir Singh is a research scholar at Panjab University in Chandigarh, India. Singh's research focuses on how fine particulate matter ($PM_{2.5}$) and other aerosols in crop residue burning emissions impact human health. But in the past, critical data had been sorely lacking.

"We don't have the sufficient ground-based monitors for $PM_{2.5}$ monitoring in our study area," he stressed. That lack of timely and fine-scale air pollution data had been frustrating for Singh because it is so desperately needed, especially in his part of the world. "Around 7 million people prematurely die every year due to air pollution, and a majority of them are from Asia."

In 2015, his research supervisor introduced him to ARSET as a way to incorporate Earth observations into his work—and to fill the gaps in his data. Singh took the ARSET advanced webinar, *Satellite Remote Sensing of Particulate Matter Air Quality*. "The webinar highlighted the applications of satellite data for air pollution so well that after… I correlated the ground-based $PM_{2.5}$ with the [MODIS-derived] Aerosol Optical Depth (AOD) data and modelled for the other locations where we don't have ground monitors," Singh noted.

He didn't stop there, however. Singh wanted to explore more applications of remote sensing in the field of air pollution. And, more importantly, he wanted to spread his new-found knowledge to others in the air quality community. In 2016, he went to Busan, South Korea, for the ARSET workshop, *NASA Earth Observations, Data and Tools for Air Quality Applications*.

As Singh suspected, other attendees had been struggling to get the data they needed as well. So this trainee led a training session himself.

"I got a chance to demonstrate to the participants how we can easily work on the Python platform—which is free software—to retrieve various aerosol products like AOD from satellite data," he explained. "I demonstrated how to retrieve the AOD value over their regions and how to create maps using the different Python scripts."

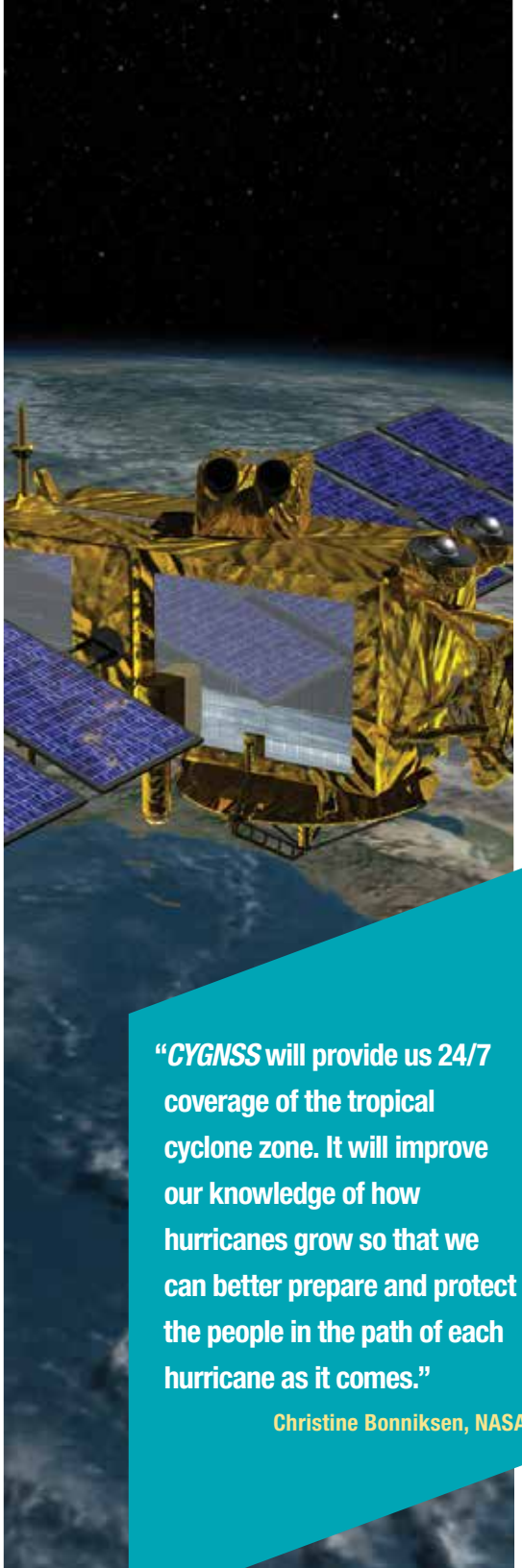
For Pawan Gupta, who leads ARSET's air quality team, it was a terrific chance to see how a student was now an instructor. "Tanbir's presentation provided excellent feedback to ARSET about the effectiveness of the online training he received," Gupta said. "He was able to teach what he learned to others."

Singh's thoughts on the potential for using Earth observations for heath and air quality benefits? Well, he remarked, "Almost all Asian countries, including India, are in their developing phase and with this industrialization and modernization, air pollution is also increasing. The applications of satellite data in the field of air pollution is an emerging, economic, and powerful tool."

"In India, and in many other countries, we need to have 24-hour monitoring satellites especially dedicated for environment and air pollution monitoring."

Tanbir Singh

60% OF THE WORLD'S **POPULATION** LIVES IN ASIA



> **"*CYGNSS* will provide us 24/7 coverage of the tropical cyclone zone. It will improve our knowledge of how hurricanes grow so that we can better prepare and protect the people in the path of each hurricane as it comes."**
>
> **Christine Bonniksen, NASA**

HEADS UP!

Jason-3

That loud, rumbling sound in California on January 17, 2016, was the launch of *Jason-3*, the *Joint Altimetry Satellite Oceanography Network*. In fact, it is the *fourth* mission in a U.S.-European series of satellite missions that measure the height of the Earth's oceans. *Jason-3* takes these measurements with its radar altimeter, and the measurements help determine ocean circulation patterns and monitor sea surface levels around the globe.

Jason-3 will continue significant applications and research activities. The maritime industry uses the satellite data for modelling currents and wave heights for shipping operations. Information on lake and reservoir heights aids assessments of water storage and agricultural production. Fisheries use *Jason*-series data in stock assessments and for identifying the ocean habitats of large pelagic animals. *Jason-3* data also support research on sea level changes, ocean currents, and global weather patterns.

Jason-3 continues the international cooperation between NASA, NOAA, EUMETSAT, and the French space agency, CNES. Louis Uccellini, Director of the NOAA National Weather Service, said that *Jason-3* sea surface height measurements are used operationally in many of NOAA's missions: "One of the most important uses is by the National Weather Service to estimate ocean heat content, which [is] essential for operational real-time prediction of the dangerous, rapid intensity fluctuations that frequently occur in tropical cyclones in the Caribbean, Gulf of Mexico, and Eastern Pacific."

CYGNSS

What did you do December 15, 2016? At NASA Earth Science, we launched our first Earth Venture satellite mission, *Cyclone Global Navigation Satellite System*. This *CYGNSS* mission uses a fleet of eight small satellites to study how tropical cyclones form and strengthen. The satellites employ a bistatic, scatterometry technique based on GPS signals. They continuously monitor surface winds over the tropical oceans and can detect the small variations in wind speed and direction that happen around the eye of these storms—something that wasn't possible from satellites before this mission.

It's also the first time that satellites can look into the middle of tropical cyclones and predict how strong they'll be when they make landfall. "Being able to do that makes all the difference in your preparation," remarked Chris Ruf, *CYGNSS* principal investigator at the University of Michigan. "Whether to evacuate or not. Whether to open up the levees and let the water drain…all the sorts of things you do in preparation for a hurricane."

GOES-R

The *Geostationary Operational Environmental Satellite-R (GOES-R)* mission blasted off on November 19, 2016. As a collaborative effort between NASA and NOAA, the mission improves the detection and monitoring of weather—which directly affects public safety, property, and economic development.

"The historic launch of *GOES-R* is another highlight of the effective NOAA-NASA partnership, which responsibly delivers life-saving weather satellite missions our nation has come to rely upon yesterday, today…and will continue into the future," said Stephen Volz, Assistant Administrator of NOAA's Satellite and Information Service.

GOES-R is the sixteenth geostationary weather satellite in the *GOES* series. As planned, it received the new name *GOES-16* when it reached its final orbit a few weeks after launch.

24 CONSECUTIVE YEARS
NASA SATELLITES HAVE MONITORED
SEA SURFACE LEVELS

TIME FLIES

CALIPSO

In 2016, the joint NASA/CNES *Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)* mission celebrated 10 years of successful data collection.

Three sensors on *CALIPSO* combine to probe the vertical structure and properties of thin clouds and aerosols over the globe. The mission gives the height of natural and man-made particles suspended in the atmosphere, such as desert dust, wildfire smoke, and air pollution. *CALIPSO* data have shown in three dimensions how Saharan dust travels across the Atlantic Ocean, which can impact Atlantic hurricanes and local air quality in the U.S. After volcanic eruptions, people apply *CALIPSO* data to assess the height of ash plumes used in aviation safety alerts.

CloudSat

CloudSat, a collaborative mission between the U.S. and Canada, uses a first-of-its-kind radar system to provide information about the vertical structure of clouds from space. The mission celebrated 10 years in orbit studying cloud processes and quantities of liquid water and ice they contain.

CloudSat also provides details on tropical cyclone formation and structure. In October 2016, *CloudSat* flew east of the eye of Hurricane Matthew as the storm headed toward the U.S., providing a three-dimensional look at the outer rain bands and anvil clouds.

Suomi-NPP

Launched in October 2011, the joint NASA/NOAA *Suomi National Polar-orbiting Partnership (Suomi NPP)* satellite mission marked five years in space. *Suomi NPP* has five instruments on board that provide data used to generate dozens of environmental data products. The data support applications and give insights on atmospheric temperature and moisture, clouds, thunderstorms, tornado potential, ice detection, precipitation and floods, dense fog, volcanic ash, oil spills, and wildfires, among others.

LAGEOS

NASA's *LAser GEOdynamics Satellite (LAGEOS)* mission turned 40 years old in 2016. When it launched, it was the first spacecraft dedicated exclusively to high-precision laser ranging. *LAGEOS* is a passive satellite with no on-board sensors or moving parts, and it has transformed studies of Earth's shape, rotation, and gravitational field.

"*LAGEOS* is elegantly simple—a ball covered with reflecting prisms," said Stephen Merkowitz, manager of NASA's Space Geodesy Project. "But it set a new standard for laser ranging and has provided 40 years of continuity for these measurements." In fact, *LAGEOS* has 426 prisms—more than the number of dimples on a common golf ball!

LAGEOS is expected to fall to Earth in about 8.4 million years. There's a one in seven chance that it will happen on a Thursday.

5.7 BILLION+

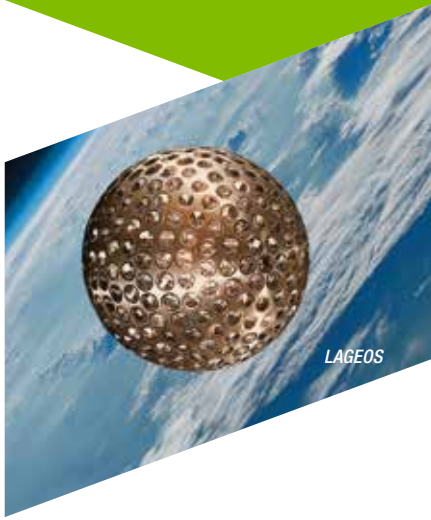
NUMBER OF LIDAR MEASUREMENTS MADE BY *CALIPSO* IN 10 YEARS

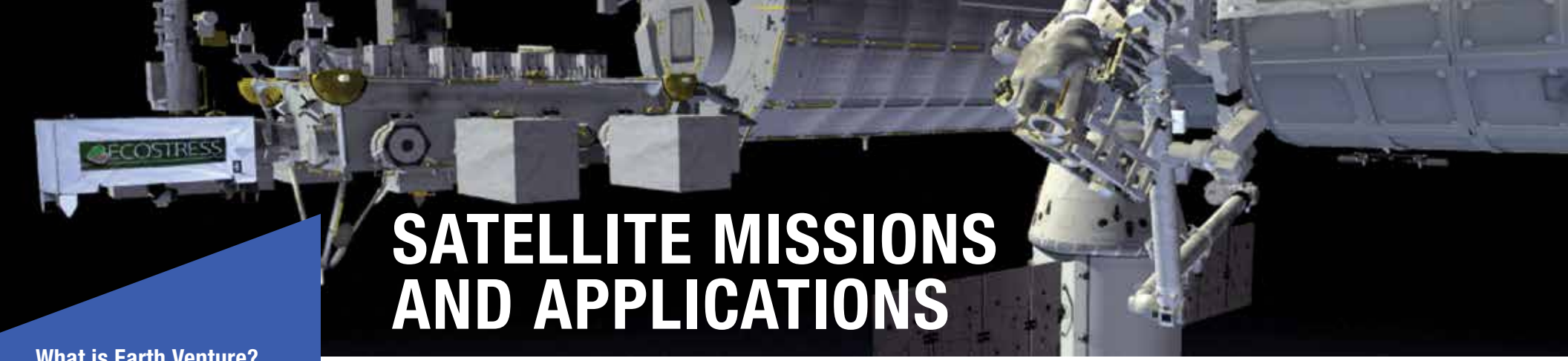
824 KM

HEIGHT OF *SUOMI NPP* ABOVE THE EARTH'S SURACE

"[*CloudSat*] has been far and away one of the most valuable things we've done for cloud observations."

Matt Rogers, Colorado State University





SATELLITE MISSIONS AND APPLICATIONS

What is Earth Venture?

NASA Earth Science Division's Earth Venture program consists of science-driven, competitively-selected, low-cost missions that complement NASA's larger missions. The Earth Venture program selects investigations that range from wholly contained missions to cutting-edge instrumentation missions on airborne and space-based platforms.


GPM

Activities continued in 2016 to support NASA's Earth science satellite missions—introducing new users to the missions and anticipated applications.

ICESat-2

Scheduled to launch in 2018, the *Ice, Cloud, and land Elevation Satellite-2* satellite continued through its development stage in 2016. This year the Applications Team accepted three new Early Adopters, expanding the number to 19. The team held a workshop on land ice, sea ice, and ocean data products for marine and coastal monitoring.

ECOSTRESS

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station sensor will launch to the ISS in 2018. This Earth Venture instrument will characterize vegetation health and water use at field scales, with observations for a given location about every four days. In 2016, the mission held a Science and Applications Team Meeting and initiated applications activities for drought impacts on agriculture.

MAIA

The Multi-Angle Imager for Aerosols will measure the particle types, sizes, concentrations, and geolocation of atmospheric aerosols. Scientists and applications specialists will combine MAIA measurements with human health records to examine connections between aerosol pollutants and human health. MAIA held its first Science Team Meeting in 2016. Launch of this Earth Venture instrument is after 2019.

TROPICS

The *Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats* mission collects microwave measurements to determine tropical cyclone position, structure, and intensity. The mission began organizing a group of potential users from the applied research, operational forecasting, and emergency management community. The first *TROPICS* Applications Workshop is planned for May 2017. Launch is slated for 2021.

SWOT

With an expected launch in 2021, the *Surface Water and Ocean Topography* satellite adds to the *Jason* series of ocean altimeter missions. In addition to measuring ocean surface topography, *SWOT* will make the first global survey of Earth's surface water and measure water storage changes in lakes, wetlands, and reservoirs. In 2016, *SWOT* continued its Early Adopter program and held a Science Team meeting. The mission is joint with France's Centre National d'Etudes Spatiales, with contributions from the Canadian Space Agency.

NISAR

The *NASA-ISRO Synthetic Aperture Radar* satellite will observe ecosystem disturbances, ice sheets, and natural hazards such as earthquakes and landslides. The mission, a collaboration between NASA and the Indian Space Research Organization, released an Applications Workshop report, which addressed ways to increase uses of *NISAR* data. Three *NISAR* Applications Workshops are planned for 2017; the anticipated launch is in 2021.

"MAIA brings together scientists, engineers, and experts in air quality, epidemiology, and public health. I'm thrilled to be working with such a diverse and distinguished group." David Diner, MAIA principal investigator

TEMPO

The Tropospheric Emissions: Monitoring of Pollution sensor is planned to fly in geostationary orbit and monitor major air pollutants hourly across North America. In 2016, TEMPO held its fourth Science Team Meeting and its first Applications Workshop —more than 150 participants attended. Launch is expected by 2021.

PACE

The *Plankton, Aerosol, Cloud, ocean Ecosystem* satellite will measure clouds and aerosols as well as ocean color, which informs ocean ecology and aquatic carbon storage. The *PACE* Applications Working Group engaged key stakeholders from NRL, EPA, NOAA, and the Bureau of Ocean Energy Management, in decisions about *PACE*'s data and availability for applications like coastal management and disasters. Launch is expected in 2022.

GEDI

The Global Ecosystem Dynamics Investigation (GEDI) lidar is an Earth Venture instrument scheduled to fly on the ISS. GEDI will provide unprecedented three-dimensional measurements of tropical and temperate forests around the globe. GEDI will determine the vertical structure, biomass, and carbon balance of Earth's forests for applications in land use, habitat diversity, and climate studies. The 2016 International Workshop on Vegetation Lidar and Application from Space in Japan featured the GEDI mission.

GeoCARB

In 2016, NASA selected the *Geostationary Carbon Cycle Observatory* for an Earth Venture Mission award. *GeoCARB* will monitor plant health and vegetation stress throughout the Americas, and it will give unprecedented detail of natural sources, sinks, and exchange processes that affect carbon in the atmosphere. *GeoCARB* also measures solar-induced fluorescence for changes in vegetation photosynthesis and plant stress.

On the Launch Pad

Four missions are planned for 2017 launches:

SAGE III-ISS

The Stratospheric Aerosol and Gas Experiment instrument is scheduled to fly aboard the ISS. It will collect global measurements of Earth's ozone, and will study aerosols, water vapor, and other trace gases in the atmosphere. These data will build on earlier SAGE missions which contributed to informed policy decisions, such as supporting the Montreal Protocol.

LIS

The Lightning Imaging Sensor will measure the amount, rate, and characteristics of lightning across the Earth. From the ISS, lightning observations will deliver real-time information over data-sparse regions of the globe, like rainforests and oceans. Weather forecasters and the aviation industry will use this enhanced lightning capability to improve storm forecasts and transportation decisions.

TSIS-1

The Total and Spectral solar Irradiance Sensor will determine the Earth's total energy input from the sun and detect how our atmosphere responds to changes in the sun's energy output. Deployed on the ISS, TSIS-1 supports applications in space weather and climate risks.

GRACE-FO

The *Gravity Recovery and Climate Experiment Follow-On* mission will detect very small variations in the Earth's gravitational field. Composed of twin tandem satellites, *GRACE-FO* will reveal changes in groundwater storage, ice sheets, and sea level. It will extend the record of observations from *GRACE* started in 2002. The team formed an Applications Working Group and completed an Applications Plan in 2016.

CLEARING THE AIR

AQAST connected scientists and managers to address air quality management challenges

"Your work has been invaluable to us... In AQAST, we have a team of experts to turn to."

Patrick Reddy, Colorado Department of Public Health and Environment

In 2016, we marked the fifth year of our highly successful Air Quality Applied Sciences Team, AQAST. This team of 19 competitively-selected air quality scientists worked directly with U.S. air quality managers. Through community meetings and short-term projects, the team helped the managers apply Earth observations and scientific knowledge to serve the managers' information needs. Along the way, team members partnered with almost three dozen federal, regional, state, and local air quality agencies on nearly 90 projects.

Building and Supporting a Community

The heart of AQAST was to do more than science-as-usual. While some NASA teams focus on one particular satellite mission, AQAST organized itself around the air quality theme, freeing it to use data products from any Earth-observing satellite. This team worked together to support a user community and broaden the utilization of NASA data and tools—not the usual approach for scientists.

The relationships AQAST built with the air quality community can't be underestimated. "Nowhere is the transformative impact of AQAST more evident than in the attitude of air quality managers at AQAST meetings," remarked Daniel Jacob, AQAST Team Leader and Harvard University researcher. "In the first meeting, the managers were openly skeptical about the value of satellite data…We succeeded in completely turning around this attitude."

Over the years, AQAST provided information and support needed to help the U.S. make smarter air quality decisions. In one particular application, *Aura*'s OMI provided more accurate data on the trends of U.S. and global nitrogen dioxide (NO_2) levels in the air. As a result, states now use this NO_2 data to evaluate regional air quality models that inform policy and planning.

AQAST's innovative approach meant the team learned how to balance scientific creativity with pragmatic problem solving. AQAST Deputy Leader Tracey Holloway of the University of Wisconsin-Madison noted that successful communication is the key. "Most researchers have been trained to come up with an idea, do the work, and publish the results," she said. "As AQAST showed, researchers have to step out of their labs and spend time cultivating dialogue with the communities they want to support."

Team Takeaways

AQAST helped us learn how to improve on a team-based approach. For one, AQAST commented that they would like greater engagement with the Headquarters-based program manager. Also, Jacob noted that the AQAST team was perhaps too large. "While it allowed us to cast a wide net of interactions with air quality agencies," he said, "it made it more difficult to oversee the activity of individual team members." We're taking these comments to heart.

As planned, AQAST passed the baton to a new team expanded to serve public health and air quality managers—our Health and Air Quality Applied Sciences Team, HAQAST, with Holloway as the leader. Supporting the transition, Jacob remarked, "Maintaining the deep relationships developed by AQAST with the air quality management community is essential for AQAST's legacy…We look forward to seeing AQAST live on in the form of HAQAST."

Our utmost thanks to the AQAST members, leaders, and the air quality management community for blazing the trail on this new approach to applying Earth science.

For more: *http://aqast.org/* and *https://haqast.org/*

AQAST PARTNERS

FOR GOOD MEASURE

What's the value of Earth observations? How do you measure their social and economic benefits? These and other related questions are ones we continued to pursue in 2016.

And the Award Goes to…

Following several years of successful, yet ad hoc activities for determining the value of Earth observations, we competitively selected a multi-disciplinary organizational consortium tasked with developing analytic methods for quantifying the socioeconomic benefits from them.

Called, *Valuation of Applications Benefits Linked with Earth Science*, or VALUABLES, this five-year consortium is led by Resources for the Future, a nonpartisan think tank devoted to economic and policy analysis about natural resources and the environment. Three expert groups compose this consortium—the Socioeconomic Valuation Working Group, the Scientific Council, and the Community Outreach Team.

VALUABLES enables experts to build awareness about socioeconomic terms and concepts in the Earth science community. It also catalyzes a community of practice between Earth scientists, social scientists, and economists. And, it pursues innovative outreach methods to disseminate the findings and results.

Data to Decisions

We sponsored an international workshop focused on the societal value of Earth observations. The event focused on the areas of disasters and ecosystems, and it examined use cases ranging from information collection to users' decisions. The workshop also compared different approaches to the valuation of geospatial information.

The workshop held a tutorial focusing on topics like benefit cost analysis, communications, and nonmarket factors. In a hands-on exercise, attendees represented different stakeholder groups in a hypothetical minerals project. Each group analyzed and advocated for their preferred balance of social, environmental, and economic impacts, drawing on techniques learned from the tutorial.

From the workshop events, participants recognized the necessity of teasing out the benefits of Earth observations at different steps in the value chain. Some noted a lack of quality in prior, formal studies, and they suggested a critical review of existing literature and the need for higher quality, primary valuation studies. We passed along these findings to the VALUABLES Consortium.

Our thanks to East Carolina University for organizing the event, and to USGS and the intergovernmental Organisation for Economic Co-operation and Development for co-sponsoring it. More information is available here: *http://www.geovalue.org/.*

What's Our Impact?

Three of our Program's applications areas pursued impact studies for existing projects in their portfolios. The Water Resources, Health & Air Quality, and Wildfires areas sponsored microeconomic analyses on the value and benefits—in social and economic terms—from uses of Earth observations.

In total, we started nine impact studies. Some examples: one study addresses the monetary value of satellite observations for cholera prediction and intervention; another examines data for water quality and guiding utility planning; and two studies assess the value of Earth observations for response and rehabilitation efforts after a wildfire. Stay tuned for the results.

"Our mission is to build an unparalleled community of practice and greater acceptance and visibility of the value of Earth science benefits. I am lucky to be working with many gifted and experienced colleagues in this awesome enterprise."

Yusuke Kuwayama,
VALUABLES Consortium Director

SOMEWHERE IN TIME

Latency

Latency is the term used for the time between data acquisition by Earth-observing satellites and the data availability by the users. Certain uses and applications need data in different timeframes, or different latencies. For example, hurricane forecasts, wildfire detections, and some scientific field campaigns are time sensitive, and need certain data as soon as possible, such as a few hours or less. Whereas, assessments of crop conditions, air quality trends, or sea level rise could accommodate longer latencies, such as a day to weeks.

LATENCY TERMS:

REAL-TIME < 1 HOUR
NEAR REAL-TIME 1-3 HOURS
LOW LATENCY 3-24 HOURS
EXPEDITED 1-4 DAYS

"It was an excellent workshop."

Those were the words of Greg Yetman from the Center for International Earth Science Information Network in September 2016. Greg was one of more than 100 contributors to the *Workshop to Develop a Portfolio of Low Latency Datasets for Time-Sensitive Applications*.

Organized by numerous parts of NASA's Earth Science Division, the workshop was a chance for Earth science data users and producers to discuss the broad needs of time-sensitive data for research and applications.

What low latency data are needed? What's the existing portfolio of low latency data? What potential benefits are not being fulfilled because of long data latencies? When should Earth Science satellite missions invest in low latency data? This workshop addressed all that and more.

In lively and constructive break-out sessions, attendees developed an inventory of existing and planned NASA Earth Science low latency data sets and information products. They identified 173 products with information on the satellite, instrument, data provider, latency, and applications and research topics. The inventory is online at *http://tinyurl.com/nhmv9ky* so people, like you, can access the inventory and update it as needed.

An inventory is just one step to increasing access to low latency datasets. As the workshop addressed, discoverability and usability are equally critical: Discoverability so users can determine what data are available and where; Usability so users can visualize the data to discern meanings or integrate the data into analysis tools. From the discussions, attendees recommended that all NASA programs register their Earth-observation data in the existing Common Metadata Repository, develop metadata tags for low-latency products, form a Latency Working Group, and increase training opportunities.

We also discussed how future missions would consider low latency as part of the mission concept. Part of this was to emphasize that new missions should survey user communities to determine the need for and value of low latency data products. Part of this was simply to raise awareness in the applications community.

"I gained a better understanding of how proposed NASA missions need to incorporate the desire for low latency data very early in the mission design process," observed Michael Brennan of the National Hurricane Center, "and how that desire needs to be weighed against other mission priorities."

As benefits of Earth observations are discovered, the demand to receive faster data and information will likely also grow. And, as attendees recognized, low latency data provide rich opportunities to expand Earth science applications and increase the return on investment in Earth observations.

Our thanks to the workshop organizers, NASA's Langley Research Center for hosting this event, and especially to all the participants. We're glad that attendees like Greg Yetman found it so positive and productive. We did too.

For more information, contact Diane Davies *(diane.k.davies@nasa.gov)* or David Green *(david.s.green@nasa.gov)*

GROUP ON EARTH OBSERVATIONS

Countries have borders, Earth observations don't

Again in 2016, we led and made contributions to international achievements on Earth observations. A key focus for these efforts is the international Group on Earth Observations, GEO, which includes more than 200 Member Countries and Participating Organizations that coordinate observations and promote benefits for society.

GEO Work Programme

GEO adopted a three-year plan of work for the 2017-2019 timeframe. This new Work Programme includes tasks with different levels of maturity and resource commitments. The U.S. is involved in 48 of the 64 tasks (75 percent), and NASA Earth Science has strong connections to more than 25 of them. Applied Sciences continued our active participation, support, and leadership of many tasks.

GEO-XIII Plenary

GEO held its annual meeting in St. Petersburg, Russia, in November. We sponsored, designed, and produced a new exhibit for the U.S. presence at the event. Multiple video screens showcased U.S. observation systems and societal benefits. Importantly, we achieved our goal to include material from all 13 agencies in USGEO—the interagency United States Group on Earth Observations—which formulates U.S. positions in GEO. Also, picking up on 2016 as an election year, we provided special ballots for GEO Plenary attendees to vote for their favorite U.S. Earth observations.

National Involvement

Near the end of the year, we issued a first-of-its-kind request for proposals to generate broad U.S. contributions to GEO. We actively reached out to organizations outside the Federal government—companies, universities, non-profits, and NGOs—for project ideas that will advance tasks in the new GEO Work Programme. We focused on nine specific tasks where NASA Earth Science has interests and where we in Applied Sciences have leadership roles. The competitive review and selection of awards will occur in 2017.

Here are highlights of some GEO tasks we lead:

AmeriGEOSS: We helped organize the first-ever AmeriGEOSS Week for this task that improves coordination on Earth observations in the Americas. Bogota, Colombia, hosted the event, and four training courses reached more than 180 participants. Themes included food security, disasters, water resources, as well as biodiversity and ecosystems.

Health: We accepted the role as the new leader of the GEO Health & Environment Community of Practice. Our program manager, John Haynes, began efforts to reinvigorate this group, hosting telecons on key topics and introducing a Community Activity into the GEO Work Programme.

GWIS: Our support continued for GEO's Global Wildfire Information System Initiative, providing active fire, burned area, and other fire-related information. The international team matured the wildfire web service and web map capabilities to beta-test status in 2016.

EO4EA: We supported this Earth Observations for Ecosystem Accounting activity aimed at advancing uses of observations to measure the value of natural capital and ecosystem services. Conservation International hosted a kick-off workshop, and GEO adopted it as an Initiative.

EO4SDG

We were lead author of an implementation plan to connect Earth observations with the United Nations' Sustainable Development Goals (SDG). GEO accepted the plan for a new GEO Initiative called Earth Observations for SDG.

GEO BON

GEO accepted the GEO Biodiversity Observation Network as a Flagship. GEO BON undertook a major reorganization, overhauling its working groups to focus anew on Essential Biodiversity Variables and Biodiversity Observation Networks.

Global Flood Risk

This Initiative we lead co-convened the 2016 meeting of the Global Flood Partnership to assess the latest developments in flood forecasting and risk mitigation.

GEOGLOWS

GEO Global Water Sustainability incorporated four Community Activities in 2016 and became a GEO Initiative. GEOGLOWS organized an event at the GEO-XIII Plenary and held a town hall at the American Geophysical Union Meeting.

AWARDS AND ACCOLADES

Flying High in 2016

Two DEVELOP teams received awards in the poster competition at the 2016 Wernher Von Braun Symposium sponsored by the American Astronautical Society. The Chaco Canyon Cross-Cutting project won 1st place in the graduate competition, and the Lake Victoria Water Resources project won 2nd place in the undergraduate competition.

In the inaugural year for the AGU Data Visualization Storytelling Competition, two DEVELOP participants—Allison Daniel and Sara Lubkin—each won a Grand Prize. They both received more than $6,000 worth of travel funding and presented their project stories on the NASA hyperwall at the AGU Fall Meeting.

A Blue Ribbon! That was the prize the American Public Health Association bestowed on NASA Earth Science for the best exhibit booth at the 2016 APHA conference. Organized by our Health & Air Quality applications area, the exhibit featured NASA's eye-catching hyperwall display with a well-organized—and well-attended—series of talks at the booth.

The Presidential Early Career Award for Scientists and Engineers, PECASE, represents the highest honor bestowed by the U.S. government on scientists and engineers early in their careers. Andrew Molthan, whom we've often sponsored, received this prestigious award for the pursuit of innovative research and a commitment to community service.

At the National Space Club's annual gala, John "J.T." Reager received the David Johnson Award for Outstanding Innovative Use of Earth Observation Satellite Data. The award recognized J.T.'s remarkable work using *GRACE* time-variable gravimetric data to estimate the potential for catastrophic flooding.

Applied Sciences personnel were part of a 2016 Team Excellence Award NASA Headquarters bestowed on NASA Earth Science, recognizing the development of positive approaches to support Federal agencies in uses of NASA Earth observations to benefit the nation.

An AQAST project received the Outstanding Local Government Achievement Award for Exemplary Public/Nonprofit Collaboration in 2016. The East-West Gateway Council of Governments in the St. Louis area recognized AQAST's Ozone Garden for community science projects around air quality issues and environmental awareness.

SERVIR Director Dan Irwin won the Rotary Humanitarian Science, Technology, Aerospace, Robotics (STAR) award for environmental improvement. The Rotary Club of Sierra Madre honored Irwin at the 2016 banquet for STAR awards, which recognize and celebrate scientific achievements that improve human lives.

"Without it, we would be blind."

Tim Chavez, CAL FIRE Battalion Chief 3113, Riverside County Fire Department, on the use of MODIS and VIIRS data for locating fast-moving wildfires in between measurements from the national infrared operations program and daytime helicopter-borne missions.

"They used these SERVIR products as evidence-based communication to inform the highest level governmental decision makers in Nepal on the issue."

ICIMOD Remote Sensing Specialist Faisal Qamer, explaining how the World Food Programme used the products and analysis to understand the drought onset and severity patterns across Nepal.

"It allows us to contextualize the disaster…How big is the event? How severe is the event? We use the data to provide size, scope, and severity."

FEMA Geospatial Information Officer Chris Vaughan, on the guidance provided by NASA's geospatial data and satellite imagery.

"Earth observations from space, provided by NASA, touch all of our lives every single day."

Resources for the Future President Richard Newell, referring to NASA selecting his organization to lead a five-year consortium that will quantify the socioeconomic benefits of Earth observations.

"I've been going to workshops and sessions for the past three days, and your session gave me exactly what I was looking for."

Feedback from a participant who attended the workshop, *From Earth Observations to Earth Applications: Satellite Applications for Biodiversity Conservation*, at the World Conservation Congress in September 2016.

"I wasn't aware of all of the tools available for near-real-time monitoring of fires and smoke. Thanks for a great course!"

Attendee feedback from ARSET's November 2016 *Application of Satellite Remote Sensing Data for Fire & Smoke Monitoring* workshop.

"We could not have completed these analyses without access to NASA's resources and Earth observations."

Sara Gottlieb, Conservation Planner with the Georgia chapter of The Nature Conservancy, referring to a project with NASA DEVELOP.

THE MACAULEY AWARD

In 2016, Resources for the Future established the Molly K. Macauley Award for Research Innovation and Advanced Analytics for Policy. This award offers a competitive grant for new research aimed at leveraging Earth observations and other advanced technologies and analytical techniques to inform environmental, climate, energy, and natural resource policy.

"There is a Molly-shaped hole in the world."

Lawrence Friedl, NASA

A TRIBUTE TO MOLLY MACAULEY

Molly, we miss you. A respected colleague and honest friend, Molly counseled our Program and many of us for years.

She died July 8, 2016—suddenly and tragically.

Molly left behind a lifelong commitment to connecting science and decision-making. From her professional home of 33 years at Resources for the Future, she brought her passion for environmental economics, renewable energy, and satellites. Proudly wearing the unofficial title of space economist, she was a pioneer in the field.

We knew her in many roles and contexts. She served on countless committees for the National Academy of Sciences, including the first Earth Science Decadal Survey. She contributed as a principal investigator in our Water Resources area and in NASA's carbon monitoring system program. She guided our Program's ventures into the realm of socioeconomic impact assessments and quantifying the value of information from Earth observations. She served as a long-time member of our Applied Sciences Advisory Committee, ASAC. She was a strong and tireless voice, author, and advocate for remote sensing.

Yet, any list of her roles doesn't do her justice. It was the ways that she engaged in the roles, and with the issues, and with people. It was how she contributed—quietly discerning key points and then offering succinct, insightful summaries. It was how she could both joyfully laugh and also cogently, aptly, and politely criticize within the same meeting, if not the same hour. We admired her energy and intellect, and her counsel was offered with grace, poise, and respect.

We also came to learn of her likes for early morning coffee and strong wireless signals—she was always the one to count on for the internet access code. And a tribute to Molly would be incomplete without mentioning her love for dogs—especially her Plott Hound, Leo, and Weimaraner, Wilga.

Yes, Molly, we miss you. Thank you for the life you shared with us. We'll strive to carry on your work and your attitude as they have made us—and the world—better.

"She left us a tremendous base on which to build, an opportunity for which we are truly grateful."

RFF President Richard Newell

"I will especially miss her wisdom and graciousness. I aspire to someday have even 5% of the poise she possessed."

ASAC Chair Kass Green

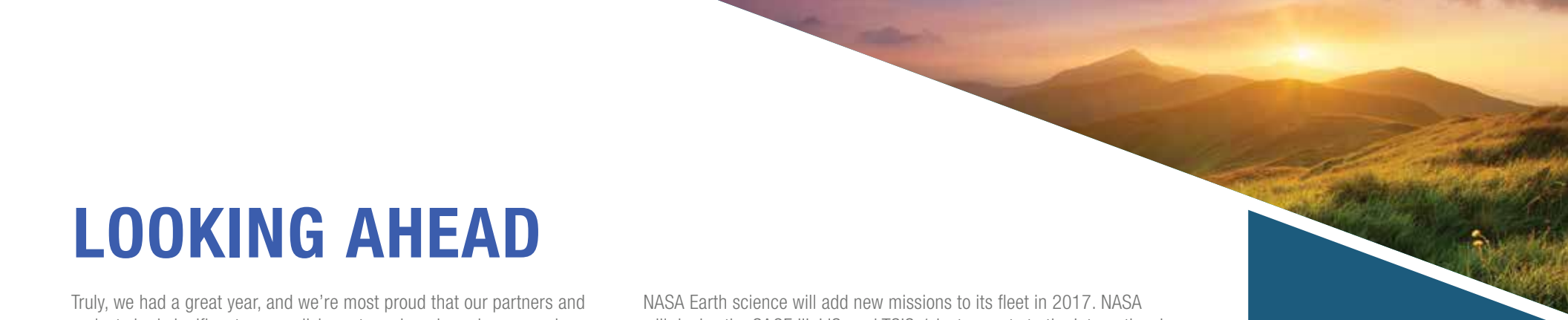
"She had the ability to punch through to the heart of issues that we were facing…and the breadth of her knowledge amazed all of us."

Former ASAC Chair Ray Hoff

"I think of space as a natural resource. We have, from space, a very unique vantage point for looking at Earth."

"The benefit of Earth observations, beyond their intrinsic merit in enhancing science, is a derived benefit. The benefit of information is derived from the values we hold for what the information is about. It's not the information itself that matters, but what the information is about."

Molly Macauley



LOOKING AHEAD

Truly, we had a great year, and we're most proud that our partners and projects had significant accomplishments and made real progress in using Earth observations. Now, it's on to 2017.

Applying Earth Science

Our Applications areas will be busy with projects and activities. Twenty-one new ones will begin in Water Resources and Ecological Forecasting. The Health & Air Quality and Disasters areas will select new projects, and Ecological Forecasting will solicit projects focused on two Sustainable Development Goals together with ESD's Research program. The HAQAST team will have its first full year and begin its Tiger Team projects. The Wildfires area will support an Arctic Wildfire Management workshop, Disasters will conduct an international event on disaster risk reduction in the Americas, and each area will hold a team meeting.

Building Capacity

DEVELOP will open a new node at Boston University and integrate socioeconomic data into more of its projects. ARSET will continue in-person and webinar trainings and, in March, will introduce its first ones addressing the Sustainable Development Goals. The next SERVIR Applied Sciences Team gets into full swing with projects at all four international hubs, building regional capacity for using cutting-edge Earth-observing data and tools.

Supporting Satellite Missions

We'll continue our support of new Earth-observing satellites, engaging applications users to enhance the benefits from and interest in the missions. *SWOT* and *ICESat-2* will solicit more Early Adopters, and *GRACE*, *SWOT*, and *SMAP* applications will be the subject of a NASA terrestrial hydrology workshop. The *PACE* mission will present applications areas at its Science Team Meeting in January, and *SWOT* will hold its second Applications User Workshop in April.

NASA Earth science will add new missions to its fleet in 2017. NASA will deploy the SAGE III, LIS, and TSIS-1 instruments to the International Space Station and launch the tandem satellites of *GRACE Follow-On*.

Program Activities

We'll solicit proposals and select a consortium to lead our new food security and agriculture initiative. We'll select projects aligned with tasks we lead in the worldwide Group on Earth Observations. In fact, the U.S. hosts the GEO Plenary in October, and we'll be heavily involved in conducting the week-long event. The new VALUABLES Consortium, led by Resources for the Future, will kick off its activities on the socioeconomic benefits of Earth observations.

Beyond our routine financial tracking of the projects we invest in, we'll conduct a major review of the billing status for each one. Communications will again be a big focus. We'll showcase societal benefits, workforce, and economic growth through Earth science applications and the research and satellites that enabled them.

These are just some items ahead for us in 2017. And as always, we'll continue Making Space for Earth.

To learn more about our Program, visit *http://AppliedSciences.NASA.gov*

"Many thanks to the project teams and partners for their creativity and commitment to applying Earth observations. We're excited about 2017 and beyond."

Lawrence Friedl, Applied Sciences Program

4 NEW EARTH SCIENCE MISSIONS IN 2017

- GRACE-FO
- LIS
- SAGE III
- TSIS-1

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STUDIES AND ANALYSIS
Booz Allen Hamilton

ACRONYMS

AAAS American Association for the Advancement of Science
ALI Advanced Land Imager
AMSR-E Advanced Microwave Scanning Radiometer-Earth Observing System
ASTER Advanced Spaceborne Thermal Emission and Reflection Radiometer
CNES Centre National d'Etudes Spatiales
EO-1 *Earth Observing-1*
EPA U.S. Environmental Protection Agency
ESD NASA Earth Science Division
FEMA Federal Emergency Management Agency
GEOGLAM Group on Earth Observations Global Agricultural Monitoring
GPM *Global Precipitation Measurement*
GRACE *Gravity Recovery and Climate Experiment*
ICIMOD International Centre for Integrated Mountain Development
ISS International Space Station
MODIS Moderate Resolution Imaging Spectroradiometer
NOAA National Oceanic and Atmospheric Administration
NRL U.S. Naval Research Laboratory
OMI Ozone Monitoring Instrument
SAR Synthetic Aperture Radar
SMAP *Soil Moisture Active Passive*
Suomi NPP *Suomi National Polar-orbiting Partnership*
TRMM *Tropical Rainfall Measuring Mission*
UAVSAR Uninhabited Aerial Vehicle Synthetic Aperture Radar
USAID U.S. Agency for International Development
USDA-ARS U.S. Department of Agriculture-Agricultural Research Service
USFS U.S. Forest Service
USFWS U.S. Fish and Wildlife
USGS U.S. Geological Survey
VIIRS Visible Infrared Imaging Radiometer Suite

LIGHTS... CAMERA... APPLICATIONS!

NASA Earth Science Applied Sciences Program

VIDEO SERIES

To view any of our videos,
visit our YouTube Playlist

http://bit.ly/2lhLRh5

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Making Space for Earth

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