National Aeronautics and Space Administration

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the earth observer

Editor's Corner

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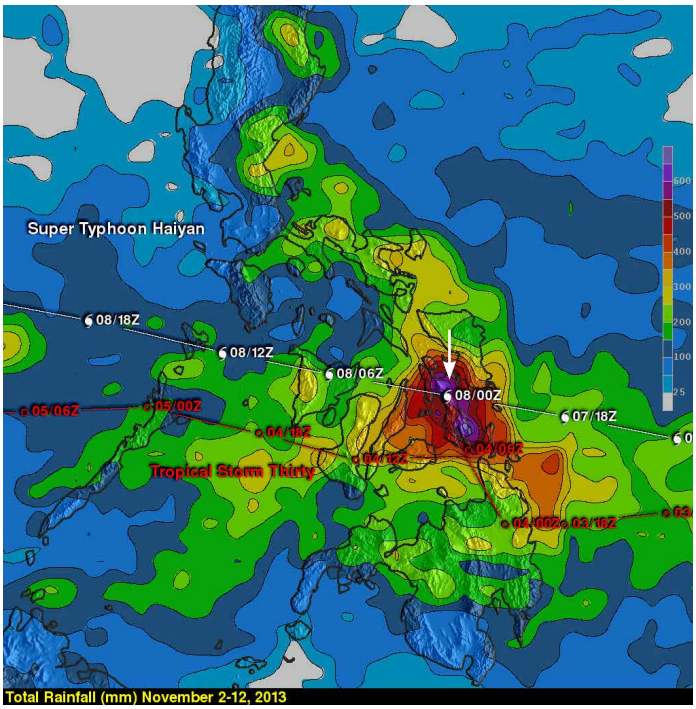
The NASA Earth science story is composed of hundreds, if not thousands, of chapters about individual and group efforts, projects, experiments, missions, etc. that come together to form a whole that is greater than the sum of its parts. One remarkable chapter involves the more than four-decade-long Landsat Program—joint with the U.S. Geological Survey (USGS). As with many successful flight projects, Education and Public Outreach (EPO) efforts have been an important component of the Landsat Program's success.

For the eighth Landsat mission in the series—the Landsat Data Continuity Mission (LDCM[1])—a small staff of educational professionals brought along new expertise, creativity, and personal networks that improved and significantly expanded the reach of the mission. In the words of **Jim Irons** [NASA's Goddard Space Flight Center—*LDCM Project Scientist*], "The EPO staff strove to engage the public in the enterprise and excitement of the mission. They worked to convey the importance and societal value of LDCM, informing the public of the impact of the Landsat Program on their daily lives. Further, the staff used the mission to promote both formal and informal science, technology, engineering, and math (STEM) education." In this issue, we invite you to read a chapter that details Landsat's EPO effort—see page 17.

Another exciting chapter tells the story of NASA's Precipitation Measurement Missions. Nearly sixteen years of satellite measurements from the NASA–Japan Aerospace Exploration Agency (JAXA) Tropical Rainfall Measuring Mission (TRMM), launched in 1997 have been invaluable in increasing our ability to observe tropical/semi-tropical

[1] LDCM is now known as Landsat 8.

continued on page 2



Haiyan and Tropical Storm 30W Bring Heavy Rains to the Philippines

Typhoon Haiyan, known locally in the Philippines as Yulonda, will go down as a historic storm, making landfall in the central Philippines as perhaps the most powerful tropical cyclone to ever make landfall with sustained winds estimated at ~315 kph (195 mph). In addition to the fierce winds and powerful surge, Haiyan brought copious amounts of rainfall to the central Philippines along with Tropical Storm Thirty and another tropical disturbance (90w), which all passed through the central Philippines within a ten-day period. During the period from November 2-12, 2013, the combined rainfall from these tropical cyclones in the Tropical Rainfall Measuring Mission (TRMM)-based TRMM-based, near-real time Multi-satellite Precipitation data (TMPA) analysis [*left*] shows that most of the island of Leyte had rainfall totals greater than 500 mm (~19.7 inches, dark red) with a peak amount of over 685 mm (~27 inches, lighter purple, marked with an arrow) located over the southeast corner of the island.
Image credit: Hal Pierce, SSAI/NASA GSFC

editor's corner

In This Issue

Reminder: To view newsletter images in color, visit: *eospso.nasa.gov/earth-observer-archive.*

NOTE: *There were no science team meetings scheduled during our production period; therefore, there are no Meeting Summaries in this issue.*

precipitation and provide more comprehensive coverage than ground observations alone. These measurements have helped to improve our knowledge of Earth's water cycle.

TRMM's successor, the Global Precipitation Measurement (GPM) Core Observatory, has successfully completed post-environmental Comprehensive Performance and Functional testing, a suite of tests performed to verify that the GPM Core satellite still meets requirements after completing environmental testing. The satellite is now being prepared for shipment and will arrive at the Tanegashima Space Center in Tanegashima, Japan in late November. Turn to page 4 of this issue to learn details about the spacecraft and the instruments onboard, the data and ground system, as well as the mission applications.

Still another chapter involves our ongoing record of Total Solar Irradiance (TSI). A continuous record of NASA/NOAA TSI observations from several different instruments dates back to 1979, the most recent being the Total Irradiance Monitor (TIM), one of four instruments onboard the Solar Radiation and Climate Experiment (SORCE). SORCE, in orbit since January 2003, has well exceeded its planned lifetime and contributed immensely to our understanding of solar irradiance (including establishment of a lower TSI value of 1360.8 W/m^2). However, as happens with many aging missions, its battery systems have been degrading. The SORCE Team at the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) has done a masterful job optimizing power in the face of degrading battery performance, and coaxing maximum life—and maximum science—out of the mission. But after another battery cell failure in mid-August, all four instruments have been temporarily powered off—except during times of short eclipse periods. The main focus at this point in the mission is to manage the remaining battery capability to obtain overlapping measurements from SORCE/TIM and the Total Solar Irradiance Calibration Transfer Experiment (TCTE) flying onboard a U.S. Air Force satellite that was successfully launched from Wallops Flight Facility on November 19, 2013. The TIM instrument on TCTE will enable an intercalibration with SORCE/TIM and ensure continuity of the TSI record.

Student investigators also contribute chapters to NASA's story. *The Earth Observer* has frequently reported on the activities of the DEVELOP National Program, an Applied Sciences Program that allows student teams to use NASA satellite data to address real-world environmental issues. These teams also work in collaboration with state or federal agencies to provide vital data that can be used in making management decisions. On page 12 of this issue we report on how a DEVELOP team based at NASA's Ames Research Center used satellite and other observations to investigate the links between changes in snowpack and soil moisture in the Sierra Nevada and the frequency of wildfires. The results were used to create wildfire risk maps for the region.

David Starr, who retired from NASA on September 30, moves to a new chapter in his life after serving as EOS

Validation Scientist since 1995. Starr wore many other "hats" during his 26-year career, such as being Chief of Goddard's Mesoscale Atmospheric Processes Laboratory since August 2000. He also was mission scientist for a number of NASA field campaigns (e.g., PODEX, TC4, CRYSTAL-FACE, SUCCESS, FIRE-Cirrus-II and FIRE-Cirrus-I), some of which involved hundreds of scientists and multiple aircraft. Starr was deeply involved in cloud physics research and was in a leadership role in both the GEWEX Cloud System Study (GCSS) and International Commission on Clouds and Precipitation (ICCP). More recently, he has been the Science Study Lead for the ACE *Tier-2* Decadal Survey mission; he plans to remain involved with ACE on a part-time basis. Many thanks to Starr for his contributions over the years and best wishes in retirement!

The nineteenth session of the Conference of the Parties (COP-19) is being held November 11-22, 2013, at the National Stadium in Warsaw, Poland. Each year NASA and other U.S. agencies, academic institutions, non-governmental organizations, and private sector companies convene in the U.S. Center exhibit space to inform attendees about key climate initiatives and scientific research taking place in the United States.

Jack Kaye [NASA Headquarters—*Earth Science Associate Director for Research*], **Carmen Boening** [NASA/Jet Propulsion Laboratory—*Scientist*], **Cynthia Rosezweig** [NASA's Goddard Institute for Space Studies—*Senior Research Scientist*], and **Bruce Doddridge** [NASA's Langley Research Center—*Head of Chemistry and Dynamics Branch*] are supporting the two-week event by delivering a variety of hyperwall and side-event talks taking place in the U.S. Center. The hyperwall presentations topics include Earth's Climate from Space, Oceans and Water Resources, Aerosols and Atmospheric Composition, and World of Change and Urbanization[2].

The presenters will also demonstrate the interactive *Eyes on Earth* application that delivers data and images from NASA's fleet of Earth-observing satellites to home computers. During non-presentation times, Kaye, Boening, Rosenzweig, and Doddridge will serve as docents for visualizations playing on the hyperwall, providing context for using NASA data to study Earth's climate.

In addition, the Fall Meeting of the American Geophysical Union (AGU) continues to be a major focus for NASA. As it has done for many years, the Science Communications/EOS Project Science Support Office has organized NASA's presence at this year's meeting—planned for December 9-13 in San Francisco, CA. As of now, the exhibit schedule includes 20 Hyperwall talks (20 minutes each) and 42 side events (30 minutes each). Two hyperwall talks have been tentatively scheduled during the Ice Breaker event held in the exhibit hall on Monday, December 9, from 6:00–8:00 PM local time. If you plan to be in San Francisco for AGU, please make time in your schedule to visit our exhibit.

Finally, though it hardly seems possible, we approach the end of another chronological chapter at NASA. As I look back over the last five issues of *The Earth Observer*, and see a sampling of the things NASA Earth Science has accomplished, I am reminded that despite significant challenges brought about by a budget sequestration, furloughs, and other circumstances, we managed to remain committed to the science, measurements, and communication and public engagement for which we are known. On behalf of *The Earth Observer* staff, we thank you for your continuing efforts and wish everyone an enjoyable and productive 2014! ■

[2] The hyperwall presentation agenda is posted at *eospso.gsfc.nasa.gov/sites/default/files/publications/COP-19_Hyperwall%20Flyer_Final_0.pdf*.

Acronyms Not Defined in Editorial and Article Titles (in order of occurrence)

Editorial

NOAA	National Oceanic and Atmospheric Administration
PODEX	Polarimeter Definition Experiment
TC4	Tropical Composition, Cloud and Climate Coupling
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment
SUCCESS	SUbsonic aircraft: Contrail and Cloud Effects Special Study
FIRE	First International Satellite Cloud Climatology Project Regional Experiment
GEWEX	Global Energy and Water Exchanges Project
ACE	Aerosol–Cloud–Ecosystems
EOS	Earth Observing System

Article Titles

GPM	Global Precipitation Measurement
MOPITT	Measurements of Pollution in the Troposphere

feature articles

GPM Core Observatory: Advancing Precipitation Instruments and Expanding Coverage

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The GPM mission centers on deploying the GPM Core Observatory and consists of a network, or constellation, of additional satellites that together will provide next-generation global observations of precipitation from space.

Precipitation Measurement Science

To study the effects of precipitation and how it influences other phenomena, scientists study moisture and precipitation in the atmosphere. Water, in all its forms, is difficult to measure consistently around the globe. Rain, snow, and other precipitation types, such as hail and sleet, vary greatly over land and oceans. Obtaining reliable, ground-based measurements of precipitation, from rain gauges for example, often presents a challenge due to large data gaps between monitoring instruments on land, and even larger gaps over oceans.

Satellite observations, however, cover broad areas and provide more frequent measurements that offer insights into when, where, and how much it rains or snows worldwide. Earth-observing satellites carry numerous instruments designed to observe specific atmospheric constituents such as water droplets and ice particles. These observations are detailed enough to allow scientists to distinguish between rain, snow, and other precipitation types, as well as to observe the structure, intensity, and dynamics of storms. These data are also fed into the weather forecast models that meteorologists use to issue weather warnings.

Global Precipitation Measurement Mission

The Global Precipitation Measurement (GPM) mission is an international partnership co-led by NASA and the Japan Aerospace Exploration Agency (JAXA). The mission centers on deploying the GPM Core Observatory and consists of a network, or *constellation*, of additional satellites that together will provide next-generation global observations of precipitation from space—see **Figure 1**. The GPM Core Observatory will launch from the Tanegashima Space Center in Tanegashima, Japan, aboard a JAXA H-IIA rocket in early 2014. The spacecraft will carry an advanced radar/radiometer system and will serve as a reference standard to unify precipitation measurements from all satellites that fly as part of the constellation.

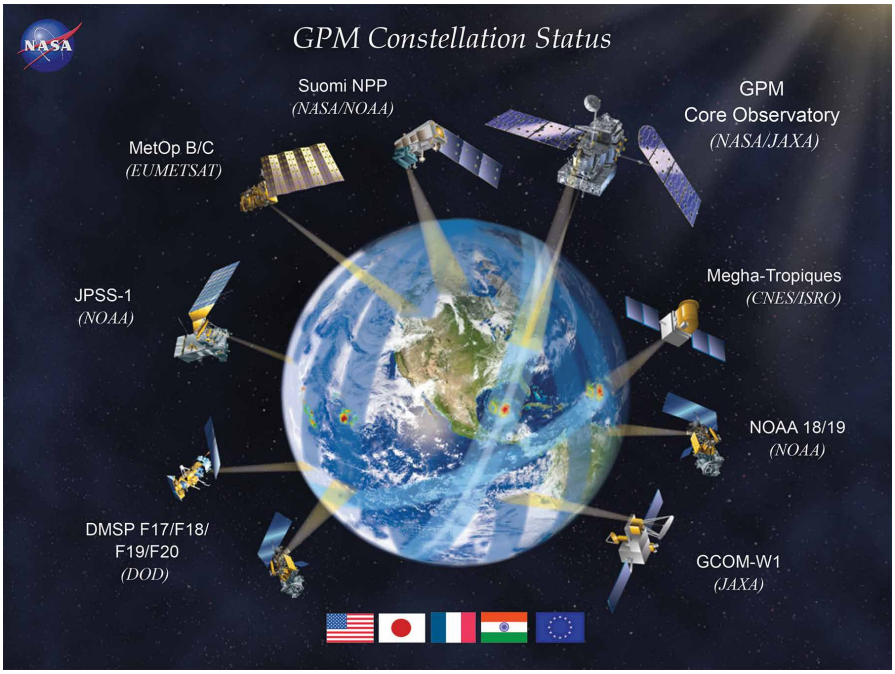

Figure 1. The GPM mission, initiated by NASA and JAXA, comprises a consortium of U.S. and international space agencies, including the French Centre National d'Études Spatiales (CNES); U.S. Department of Defense, Defense Meteorological Satellite Program (DMSP); European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); Indian Space Research Organisation (ISRO); and the U.S. National Oceanic and Atmospheric Administration (NOAA). The satellites pictured here are expected to form the GPM satellite constellation. **Image credit:** NASA

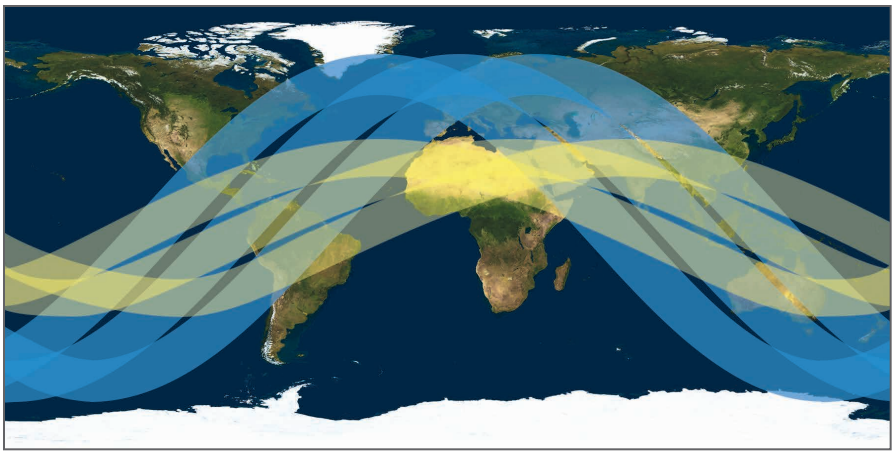

Figure 2. This graphic compares the area covered by three TRMM orbits (yellow) versus three orbits of the GPM Core Observatory (blue). **Image credit:** NASA

The GPM mission concept builds on the success of the Tropical Rainfall Measuring Mission (TRMM), a joint NASA and JAXA satellite launched in 1997 that measures precipitation over tropical and subtropical regions, from approximately 35° N latitude (e.g., the Mediterranean Sea) to 35° S latitude (e.g., the southern tip of South Africa)—see *Successes from TRMM* on page 8.

Measurements from the GPM Core Observatory, however, will provide even greater coverage—between approximately 65° N latitude (e.g., the Arctic Circle) and 65° S latitude (e.g., the Antarctic Circle)—see **Figure 2.** These measurements, combined with those from other satellites in the constellation, will provide global precipitation observations approximately every three hours. This integrated approach and unified dataset will help advance scientists' understanding of Earth's water and energy cycles.

The GPM constellation will provide measurements on the:

- intensity and variability of precipitation;
- three-dimensional structure of cloud and storm systems;
- microphysics of ice and liquid particles within clouds; and
- amount of water falling to Earth's surface.

Observations from the GPM constellation, combined with land-surface data, will improve:

- weather forecast models;
- climate models;
- integrated hydrologic models of watersheds; and
- forecasts of hurricanes, landslides, floods, and droughts.

Above all, global observations from GPM mission satellites will continue and expand the data records that began with previous precipitation missions, such as TRMM, and improve precipitation estimates around the globe. The mission will help scientists understand how local, regional, and global precipitation patterns change over time.

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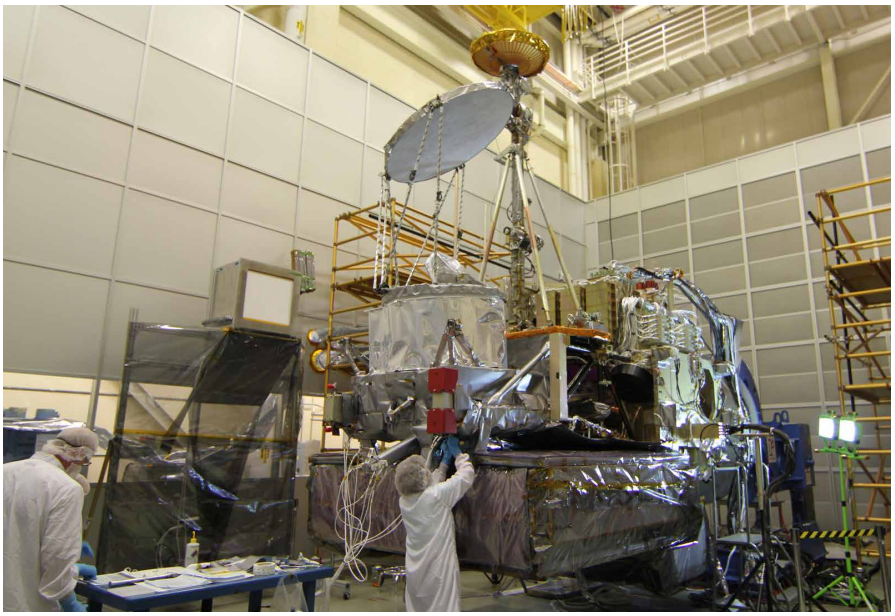
GPM Core Observatory

The GPM Core Observatory improves upon the capabilities of its predecessor, the TRMM satellite, with advanced precipitation instruments and expanded coverage of Earth's surface. The GPM Core will carry two instruments: the *GPM Microwave Imager* (GMI) and *Dual-frequency Precipitation Radar* (DPR). These instruments

will collect improved observations that will allow scientists to better "see" inside clouds. The GMI has the capability to measure the amount, size, intensity, and type of precipitation, from heavy-to-moderate rain to light rain and snowfall. The DPR will return three-dimensional profiles and intensities of liquid and solid precipitation. These data will reveal the internal structure of storms within and below clouds.



The GPM mission concept centers on the GPM Core Observatory, pictured here. The drum-shaped instrument and disc [*center*] is the GMI. The large blocky foil-covered instrument [*bottom of the spacecraft*] is the DPR. The antenna [*top*] is the high gain antenna for communications. The observatory was built and tested at NASA's Goddard Space Flight Center. **Image credit:** NASA

The GPM Core Observatory—characteristics listed in **Table 1**—will be able to observe storms forming in the tropical oceans and track these storms as they move poleward into middle and high latitudes. With the advanced observations from the GMI and DPR, scientists will be able to study the internal structure of these storms throughout their life cycles, and view how they change over the long term. This capability will help scientists understand why some storms change in intensity as they move from the tropics to the mid-latitudes.

Together, the GMI and DPR will provide a database of measurements against which other partner satellites' microwave observations can be meaningfully compared and combined to generate uniform global precipitation datasets. Measurements from the GMI will also serve as a reference standard for cross-calibration of other satellites in the GPM constellation. For example, when overlapping measurements of the same Earth scene are made, measurements from GMI will be used to calibrate precipitation estimates from GPM constellation sensors within a consistent framework.

The GMI—built by Ball Aerospace & Technology Corp. under contract to NASA's Goddard Space Flight Center (GSFC)—is a multichannel microwave radiometer designed to sense the total precipitation within all cloud layers, including light rain and snowfall.

Table 1.

GPM Core Observatory Characteristics	
Altitude: 407 km (253 mi)	**Orbit duration:** 93 min
Inclination: 65°	**Orbits per day:** about 16
Speed: 7 km/sec (~4 mi/sec)	**Design life:** 3 yrs
Orbit: circular, non-sun-synchronous	**Fuel life:** 5 yrs

GPM Microwave Imager

The GMI—built by Ball Aerospace & Technology Corp. under contract to NASA's Goddard Space Flight Center (GSFC)—is a multichannel microwave radiometer designed to sense the total precipitation within all cloud layers, including light rain and snowfall. It does this by measuring the intensity of microwave energy that is constantly emitted by all parts of the Earth system—including rain and snow, which has a unique signature.

Specifically, GMI uses 13 channels to measure the intensity of microwave radiation emitted from Earth's surface and atmosphere. The lower-frequency channels (10 to 89 GHz, similar to those of the microwave imager onboard the TRMM satellite) detect heavy-to-moderate rainfall. GMI's advancements include four additional high-frequency channels (166 to 183 GHz) that will measure moderate-to-light precipitation—see **Table 2.**

Each object, such as rain, snow, and Earth's surfaces, emits or scatters energy differently, based on the object's temperature and physical properties. Scientists use their knowledge and the contrast between the signals received by the different channels to distinguish between rain and snow and to calculate precipitation rates and quantify precipitation intensity.

Table 2. This table compares the TRMM Microwave Imager with the GPM Microwave Imager.

Instrument	Channels	Frequency Range	Swath Width
TMI (on TRMM)	9	10-85.5 GHz	758.5 km (471 mi)
GMI (on GPM)	13	10-183 GHz	885 km (550 mi)

Dual-frequency Precipitation Radar

Ground-based weather radars emerged during World War II and have since been used to measure precipitation, mostly over land. The first spaceborne precipitation radar, however, did not launch until November 1997 onboard the TRMM satellite. TRMM's Precipitation Radar (PR) instrument provides three-dimensional maps of tropical and subtropical rainfall over land and oceans, which have revolutionized scientists' understanding of storms.

The GPM Core Observatory will carry the next-generation spaceborne precipitation radar—the DPR. The DPR will make detailed three-dimensional measurements of precipitation structures and rates and, with the Core's expanded coverage, will do so across much more of Earth's surface than previous sensors. NEC Toshiba Space Systems, Ltd. built the DPR, which was designed by JAXA and the National Institute of Information and Communications Technology in Japan.

One of the major advancements of the DPR is the addition of a second radar frequency. In addition to the DPR's K_u-band radar that will measure moderate-to-heavy rain at 13.6 GHz (similar to the PR), its K_a-band radar will measure frozen

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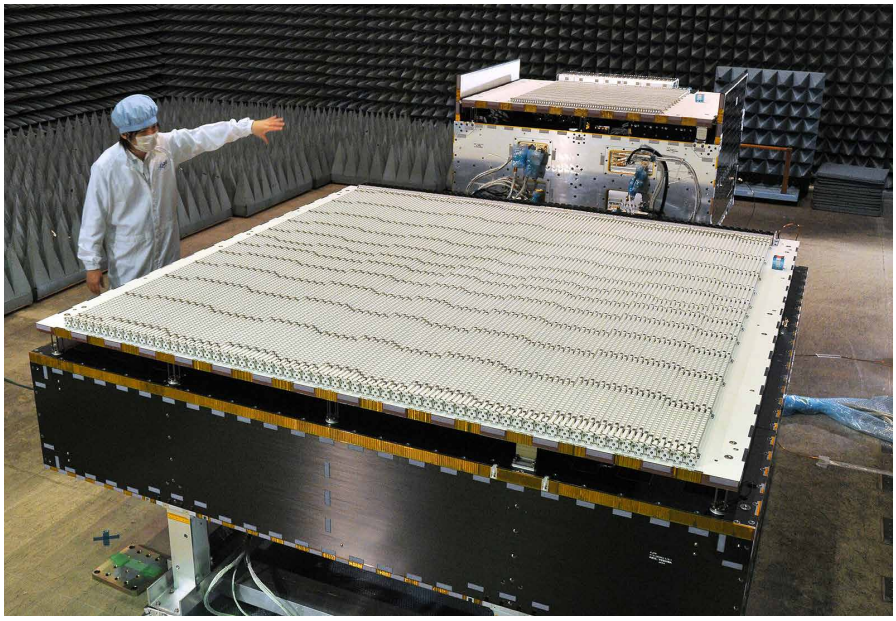


In this photo, a JAXA technician stands next to the DPR. The K_u-band radar [*foreground*] measures 2.4 x 2.4 x 0.6 m (~7.9 x 7.9 x 2 ft), while the K_a-band radar [*background*] measures 1.44 x 1.44 x 0.7 m (~4.7 x 4.7 x 2.3 ft).

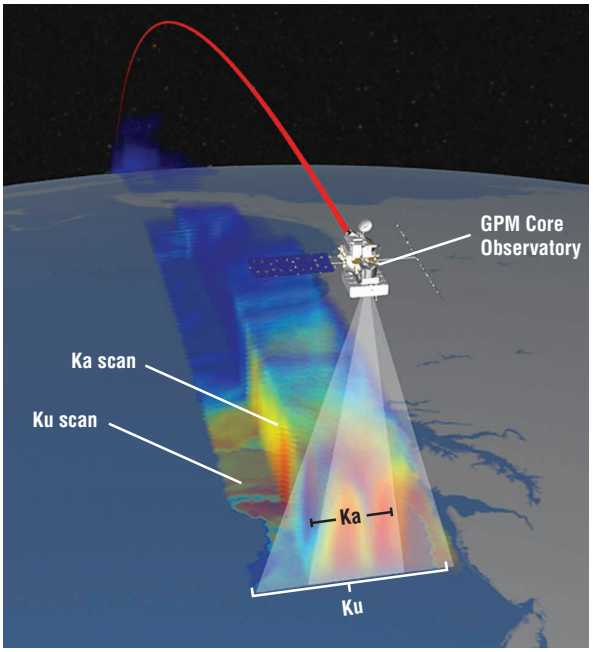
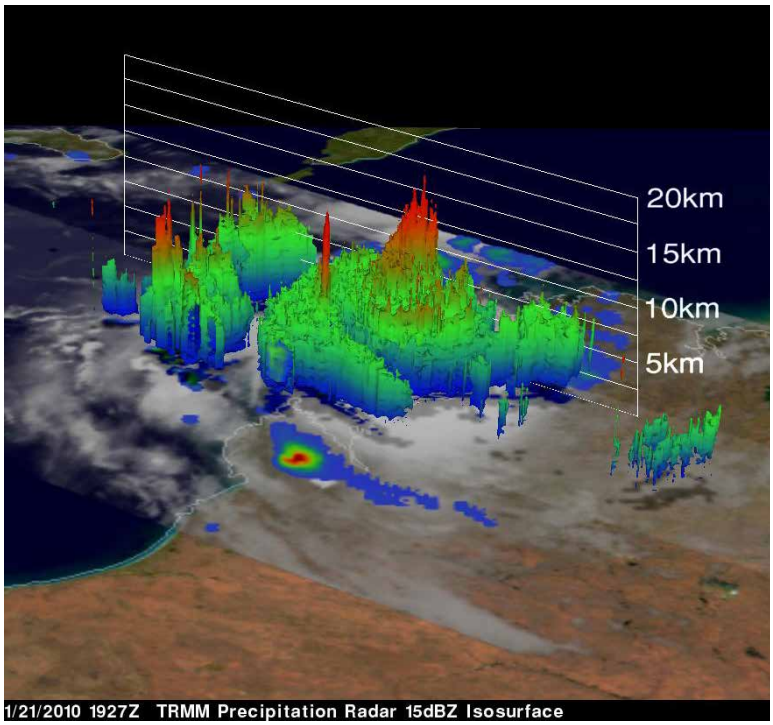


Figure 3. This illustration shows the scanning capabilities of the DPR onboard the GPM Core Observatory, which will provide data to show the three-dimensional structure of storms. Red, orange and yellow shades indicate heavy-to-moderate rainfall, while darker shades indicate light rainfall. The K_a-band radar swath is nested within the wider K_u-band radar swath. **Image credit:** NASA

precipitation and light rain at 35.5 GHz. Simultaneous measurements from the overlapping swaths of K_a/K_u-band data—see **Figure 3**—will provide new information on particle *drop size distributions*—i.e., how many raindrops of different sizes are in the cloud layers and how they are distributed throughout the storm system.

Improved observations of precipitation size, shape, and distribution will offer scientists insight into the microphysical processes of precipitation and help to distinguish between regions of rain and snow. They will also provide bulk precipitation properties such as precipitation intensity, water fluxes, and water content. Information on the distribution and size of precipitation particles, together with microwave radiometer measurements made by the GMI, will improve the accuracy of rain and snowfall estimates.

Successes from TRMM



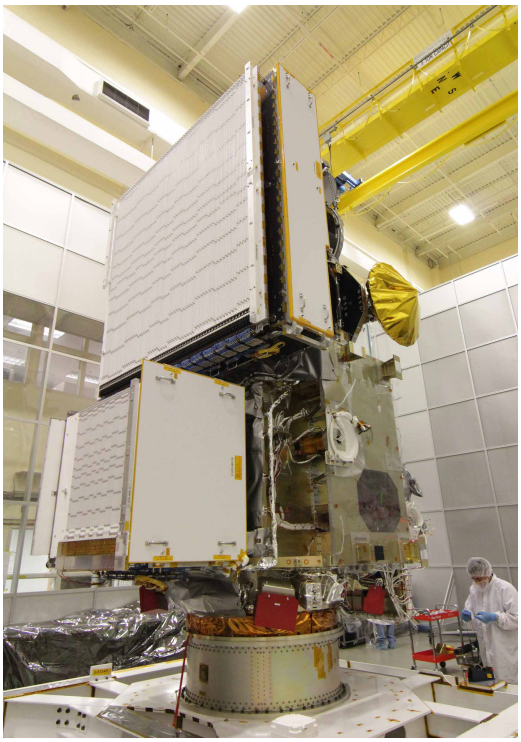
This three-dimensional image, made with data from TRMM's Precipitation Radar, shows Tropical Cyclone Magna off the coast of Australia on January 21, 2010. Red shades indicate taller, more intense thunderstorms near Magda's eyewall. **Image credit:** NASA

The TRMM satellite was primarily designed to measure heavy-to-moderate rainfall over tropical and subtropical regions. Measurements from TRMM have advanced our understanding of mean annual tropical rainfall—particularly over oceans—and have returned many innovative analyses, including the first three-dimensional images from space of storm intensity and structure. TRMM has also provided frequent and detailed observations of precipitation for more than 15 years.

How the Instruments Work

GPM Microwave Imager

The GMI is a *conical-scanning radiometer*, which consists of two main assemblies: the detectors that measure microwave energy, and the scanning antenna that collects the microwaves from the scene and reflects them to the detectors. The scanning antenna spins at 32 rpm to collect microwave data along the circular track it traces on the ground. When the antenna faces the arc away from the satellite, it collects data from the scene along the satellite's ground path. When the antenna faces towards the spacecraft, the instrument does calibration checks to ensure that its measurements are accurate. The GMI's 1.2-m (~4-ft) diameter antenna will provide significantly improved spatial resolution over that from the TRMM Microwave Imager.



Dual-frequency Precipitation Radar

The DPR employs two cross-track scanning precipitation radars—a K_u- and K_a-band radar. Both radars will have a spatial resolution of 5 km (~3 mi) and emit 4100 to 4400 pulses per second, with 250-m (~820-ft) pulse lengths. In the time that it takes the K_u-band radar to measure its wider swath with 250-m (~820-ft) pulse lengths, the K_a-band radar will measure its swath with both 250- and 500-m (~1640-ft) pulse lengths. This will allow the K_a-band radar to collect measurements that require high sensitivity—crucial for observing smaller water droplets and ice particles. Each radar will return its own data that scientists can analyze separately or together. For example, by using differences in how the K_u- and K_a-band radar return pulses change intensity when they encounter different precipitation types, scientists expect to be able to distinguish rain from snow.

The spacecraft consists of the structural/mechanical subsystem, solar array drive and deployment subsystem, power subsystem, attitude and thermal control subsystems, propulsion and guidance subsystems, navigation and control subsystems, high-gain antenna and radio-frequency communications subsystems, and the command and data-handling subsystem.

Spacecraft Design

The GPM Core Observatory, developed and tested at GSFC, will supply power, orbit and attitude control, communications, and data storage for GMI and DPR. The spacecraft consists of the structural/mechanical subsystem, solar array drive and deployment subsystem, power subsystem, attitude and thermal control subsystems, propulsion and guidance subsystems, navigation and control subsystems, high-gain antenna and radio-frequency communications subsystems, and the command and data-handling subsystem.

Two deployable solar arrays will charge the spacecraft's battery and power the observatory's components through the power supply electronics. A solid-state data recorder will provide data storage aboard the spacecraft, and the S-band high-gain antenna will transmit GMI and DPR data, either in real time or played back from the data recorder.

As the GPM Core Observatory orbits 407 km (~253 mi) above Earth's surface, the GMI and DPR instruments will constantly scan coordinated areas of the surface below—see **Figure 4.** The GMI will scan an 885-km (~550-mi) wide swath, while the DPR's K_u- and K_a-band radars will take overlapping scans in the center of the GMI swath. Specifically, the K_a-band radar will scan across a region of 120 km (~75 mi), nested within the wider scan of the K_u-band radar of 245 km (~152 mi). Measurements within the overlapped swaths are important for improving precipitation retrievals of data and, in particular, the radiometer-based retrievals.

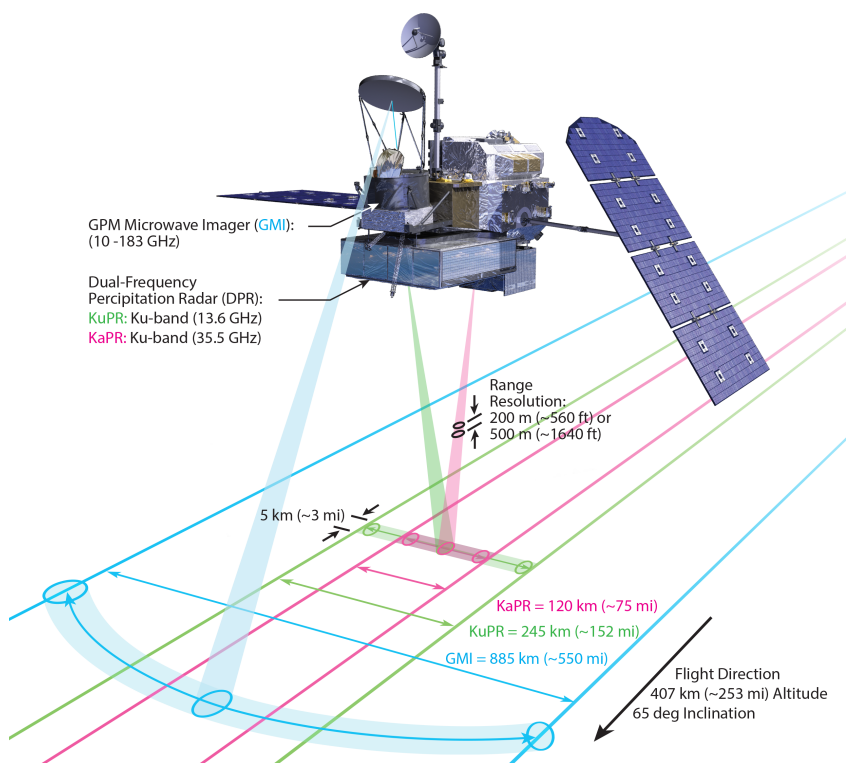


Figure 4. This image shows the GMI and DPR instruments aboard the GPM Core Observatory and their respective swaths. **Image credit:** NASA

Ground System and Data

The GPM mission ground system includes all the assets needed to command and operate the GPM Core Observatory in orbit, and to manage and distribute data received from the Core and other satellites in the constellation.

To communicate with the GPM Core Observatory, the Mission Operations Center (MOC) at GSFC sends software commands through the ground station in White Sands, NM, to NASA's geosynchronous Tracking and Data Relay Satellite System (TDRSS). This system of three active satellites is used by NASA to communicate with

satellite platforms—in this case, the GPM Core Observatory. In return, the GPM Core Observatory transmits spacecraft and instrument telemetry, which report on the satellite's location and functioning, and science data from the instruments to TDRSS. Once data are transmitted to TDRSS, it sends the information to the White Sands ground station. From White Sands the data go to the MOC, which passes the science data to the Precipitation Processing System (PPS) at GSFC—see **Figure 5.**

Data from the GPM Core Observatory's GMI instrument are returned continuously through the TDRSS Multiple Access link, while data from the DPR are returned once an orbit—approximately every 90 minutes—through the TDRSS Scheduled Access link. The partner agencies that control the other satellites in the GPM constellation send their respective satellite data to the PPS via their own data facilities.

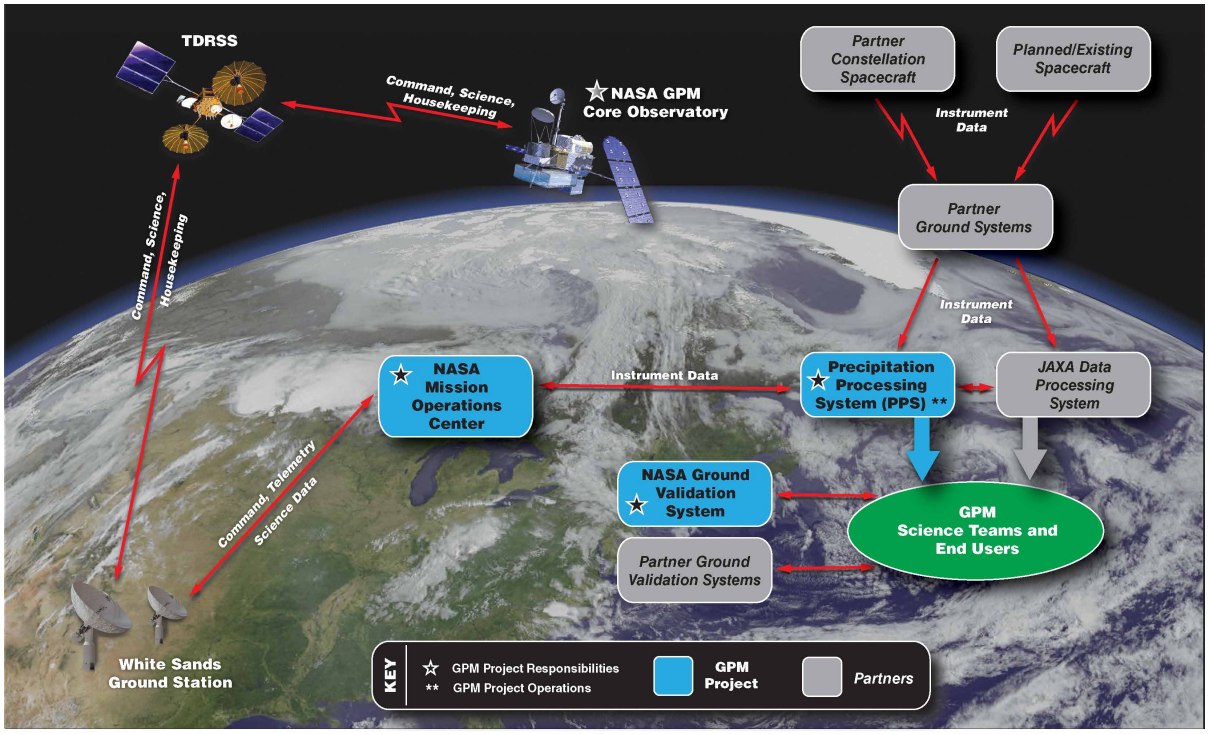


Figure 5. This graphic shows how data travel from the GPM Core Observatory and the constellation satellites to the Precipitation Processing System at GSFC. **Image credit:** NASA

The PPS processes all the data returned by GPM constellation satellites, with the exception of data from the DPR. DPR data are sent to JAXA's Mission Operations Systems for initial processing and returned to the PPS as a basic radar product for further processing and integration into global precipitation data products. GPM precipitation datasets will be freely available for download from the PPS website at *pps.gsfc.nasa.gov*.

GPM Mission Applications: A Global Understanding for a Better Future

Water is fundamental to life on Earth. Knowing where and how much precipitation falls globally is vital to understanding how weather and climate impact our environment, including the effects on agriculture, fresh water availability, and natural disasters. The use of advanced spaceborne instruments to measure global precipitation every three hours can reveal new information for a diverse range of applications across agencies, research institutions, and the global community.

Among the applications of GPM mission data are improvements to our understanding and forecasting of tropical cyclones, extreme weather, floods, landslides, land surface models, the spread of water borne diseases, agriculture, freshwater availability, and climate change. Data from the GPM Core Observatory, combined with data from other satellites within the constellation, will lead to advances in precipitation measurement science that will benefit society for years to come. ■

feature articles

DEVELOPing the Link Between Fire and Ice: How Changes in Snowpack Impact Wildfire Occurrence in the Sierra Nevada

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In 2013 the Sierra Nevada Water Resources DEVELOP National Program team—a group of six DEVELOP interns working at NASA's Ames Research Center—conducted a project to analyze the effects of declining spring snowpack on wildfire occurrence in the Sierra Nevada.

Introduction

In California alone, wildfires cause over $800 million in property damage and place countless lives in danger each year. Recently, the California Rim Fire—the third largest wildfire in California's history—burned more than 390 mi^2 (250,000 acres) of wilderness west of Yosemite National Park. The Rim Fire impacted vital infrastructure linked to the water supply for millions of California residents and affected homes and businesses near Yosemite National Park. Fires such as this contribute to the loss and degradation of human capital and infrastructure, impact vulnerable ecosystems through changes in species distribution and hydrology, and exacerbate climate change through the release of stored carbon into the atmosphere. Smoke from fires also contributes to air pollution and respiratory diseases.

Wildfire events are of paramount concern for the U.S. Forest Service (USFS), as characterizing locales most vulnerable to large wildfire outbreaks is necessary for proper forest management: Vulnerable regions must be identified, especially in the context of climate change, so that management techniques used to prevent these destructive wildfires (e.g., prescribed burns and forest thinning) can be thoughtfully implemented to make the best use of USFS resources.

2013 Sierra Nevada Water Resources DEVELOP Team Members

- **Andrew Nguyen**, San Jose State University
- **Chase Mueller**, University of Texas at San Antonio
- **Roy Petrakis**, University of Arizona
- **Spencer Adkins**, Brigham Young University
- **Olivia Kuss**, Indiana University - Purdue University of Indianapolis
- **Monica Kumaran**, Harker High School
- **Marc Meyer,** U.S. Department of Agriculture, Forest Service Pacific Southwest Region, *Advisor*
- **Cindy Schmidt,** Bay Area Environmental Research Institute, *Mentor*

Climate variability and change are also of increasing importance to the USFS, especially in regions such as California's Sierra Nevada where freshwater is stored in the winter snowpack and released during spring snowmelt. This release provides water to the region throughout the summer, when precipitation is minimal. Increasing minimum temperatures during the spring are causing decreases in winter snowpack, resulting in a decreasing spring snowmelt. This causes spring thaw and peak stream flow to occur earlier in the year, decreasing water availability during the late summer months. Concurrently, there has been an increase in the frequency and severity of large wildfires in the western U.S. since the 1980s—clearly of increased importance to the USFS for all the reasons described above.

DEVELOP Searches for a Link

While many previous studies have conclusively linked rainfall patterns and wildfires, fewer studies have made any such link to snowpack-related phenomena. In 2013 the Sierra Nevada Water Resources DEVELOP[1] National Program team—a group of six DEVELOP interns working at NASA's Ames Research Center—conducted a project to analyze the effects of declining spring snowpack on wildfire occurrence in the Sierra Nevada. The team used remote sensing and geographic information

[1] There have been numerous previous reports on DEVELOP projects in *The Earth Observer*. The program is part of NASA's Applied Sciences Program; it is a capacity-building internship that allows student teams to use NASA satellite data to address real-world environmental issues. These teams also work in collaboration with state or federal agencies to provide vital data that subsequently can be used in making management decisions.

system (GIS) applications to create a wildfire risk map for the region. The project focused primarily on the effects of snowpack and soil moisture on wildfire occurrence in the Sierra Nevada ecoregion for the years 2003 to 2012.

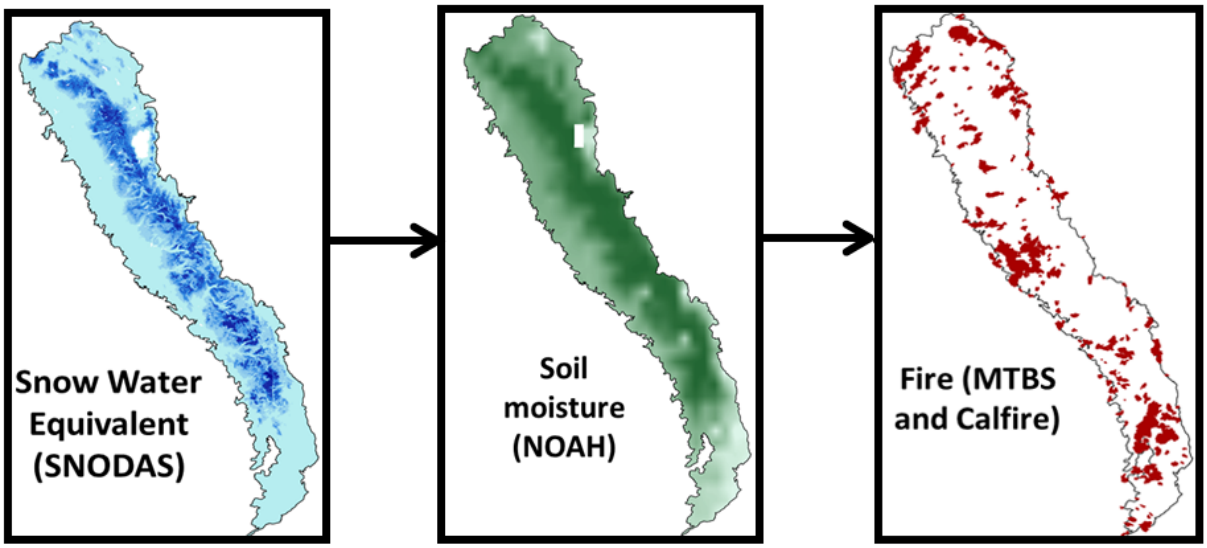
Data Collection

The first step in the investigation was to correlate snowpack amount, in the form of *snow water equivalent* (SWE), with wildfire events within the Sierra Nevada study region—see **Figure 1.** This required collecting information from a variety of sources, including snow-extent products that are derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra satellite. The MODIS snow extent products were collected for *water years* 2003-2012. (A water year runs from October to September.)

Figure 1. Here, the Sierra Nevada study region is shaded in green. **Image credit:** DEVELOP team members

The work continued by assembling SWE, soil moisture, and fire occurrence data—see **Figure 2**. In particular, the team used output from the National Weather Service's Snow Data Assimilation System (SNODAS) program model that assimilates satellite-derived, airborne, and ground-based observations of snow-covered area to calculate SWE—see the left image in Figure 2. The MODIS snow-extent products were used to validate SWE from the SNODAS model. Also used were soil moisture (SM) data from the North American Land Data Assimilation *Phase 2* (NLDAS-2) system's Noah Land-Surface Model, which provides soil moisture estimates with depth—see the center image in Figure 2. For information on wildfires, the team analyzed historical trends obtained from the Fire and Resource Assessment Program - California Department of Forestry and Fire Protection (FRAP-CALFIRE) and the Monitoring Trends in Burn Severity (MTBS) datasets—see the right image in Figure 2. FRAP-CALFIRE is a database of recorded wildfires provided by several California State agencies. Many historical records from field observations were digitized; satellite data were then used to populate recent wildfire records in the database. The MTBS database uses Landsat data for spatially mapping and characterizing the severity of fires and uses fire occurrence datasets (e.g., fire name, type, size, point of ignition, date of ignition), collected by federal and state organizations, to validate and add pertinent information to the maps.

Figure 2. The team investigated the relationship between SWE [*left*], soil moisture [*center*], and fire occurrence [*right*]. See the text for descriptions of the parenthesized terms. **Image credit:** DEVELOP team members



Conducting Case Studies

To correlate SWE with wildfire occurrence, the team conducted two *case studies* within the larger study area—see **Figure 3**. The two specific wildfire events were the 2008 Butte (BTU) Lightning Complex wildfire in the northern region of the study area, and the 2008 Piute Fire in the study area's southern region. These choices investigated the environmental conditions leading up to a specific event and identified variations in snowpack distribution and amount, topography, and hydrology at scales suitable to allow correlation with changes at larger scales (i.e., the entire Sierra Nevada).

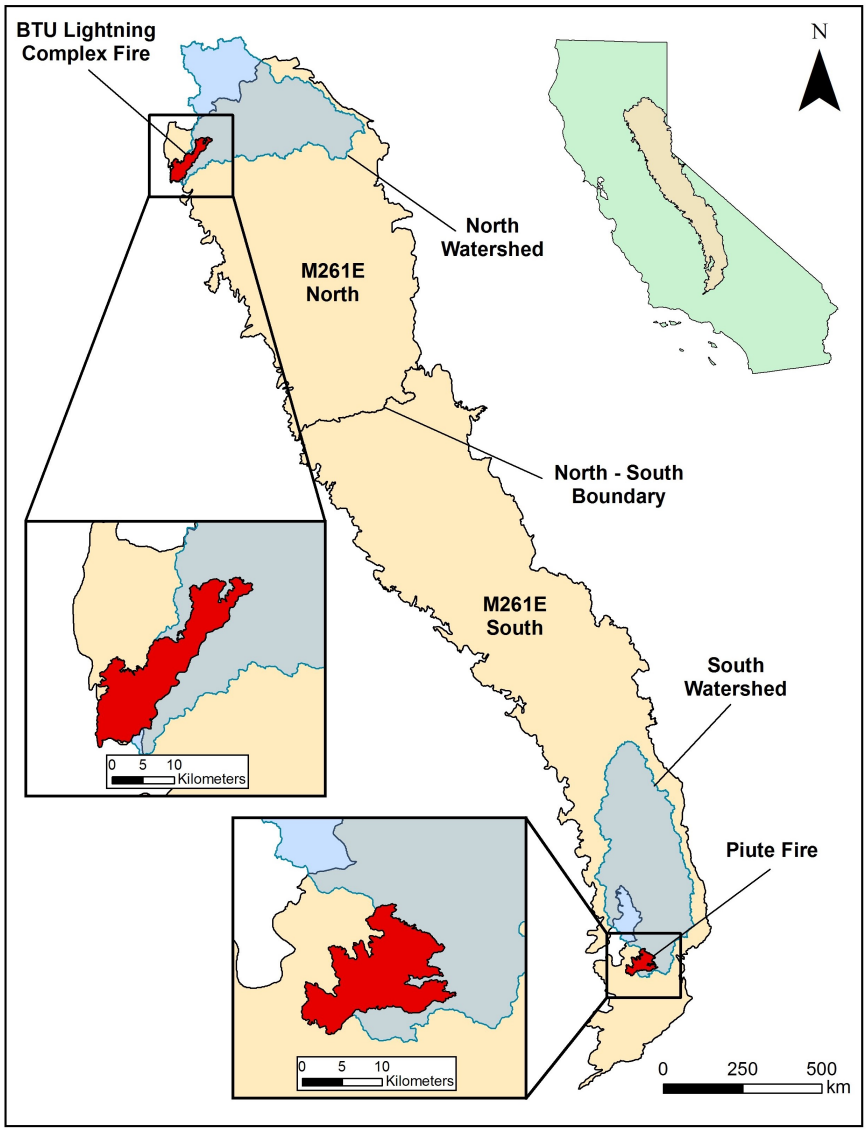


Figure 3. In this map, where M261E is the ecological section designated by USFS to represent the Sierra Nevada, the location of case-study wildfires are colored red, while the encompassing watersheds appear light blue. Analysis of the BTU Lightning Complex fire and Piute Fire helped confirm that SWE and SM are indicators of wildfire occurrence—conclusions that can be extended to the entire Sierra Nevada region. **Image credit:** DEVELOP team members

Creating Wildfire Risk Maps

Data collected on past and current surface variables (i.e., SWE, soil moisture, and fire occurrence), and temperature and precipitation data from Oregon State University's Parameter-elevation Regressions on Independent Slopes Model (PRISM) website were used as input for a Generalized Additive Model (GAM). The model output was used to generate wildfire risk maps for 2007-2009 and 2010-2012 using Esri's *ArcMap* software. The analysis concluded that snowpack and soil moisture are the two primary indicators of *wildfire risk*—defined as the probability of a wildfire as a function of the area's climatic and surface conditions.

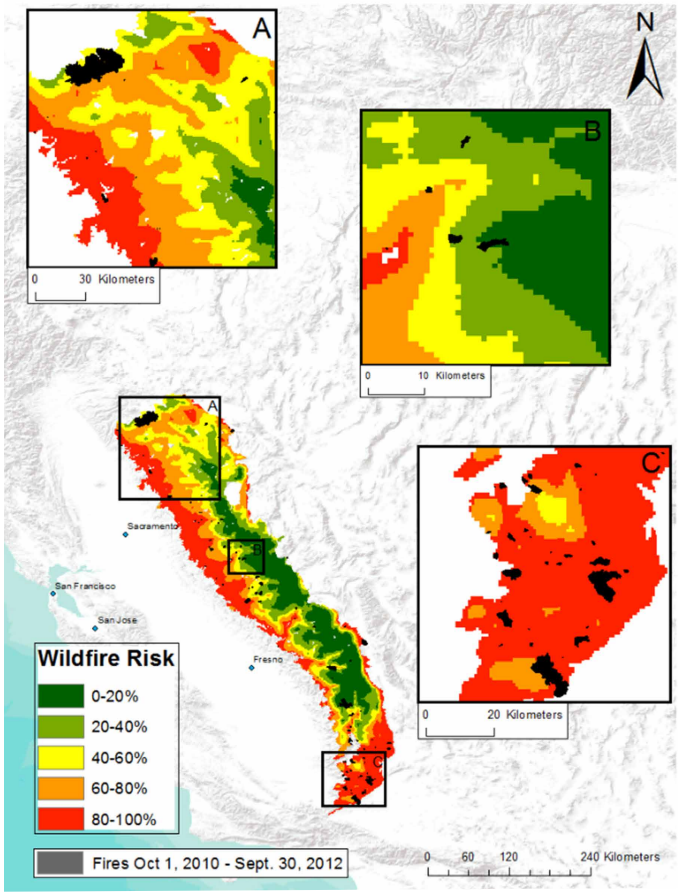


Figure 4. Wildfire risk map [*lower left*] reflecting conditions for 2007-2009. Wildfire occurrences (black) for 2010-2012 were overlaid to delineate areas of risk predicted by the model. Boxed areas (A, B, and C) are magnifications to better show fire polygons over predicted risk areas. The model based on 2007-2009 data accurately predicted 81% of the fires that occurred in 2010-2012. **Image credit:** DEVELOP team members

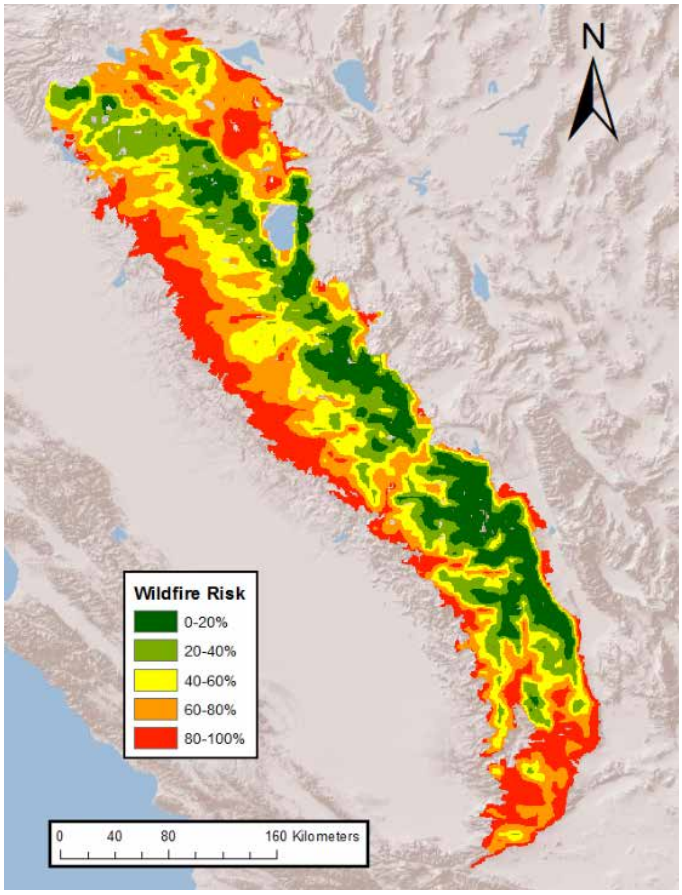


Figure 5. This image depicts the 2010-2012 wildfire risk map produced by the GAM for the Sierra Nevada. The map is based on climatic and surface conditions. Risk colors are categorized into percentages. **Image credit:** DEVELOP team members

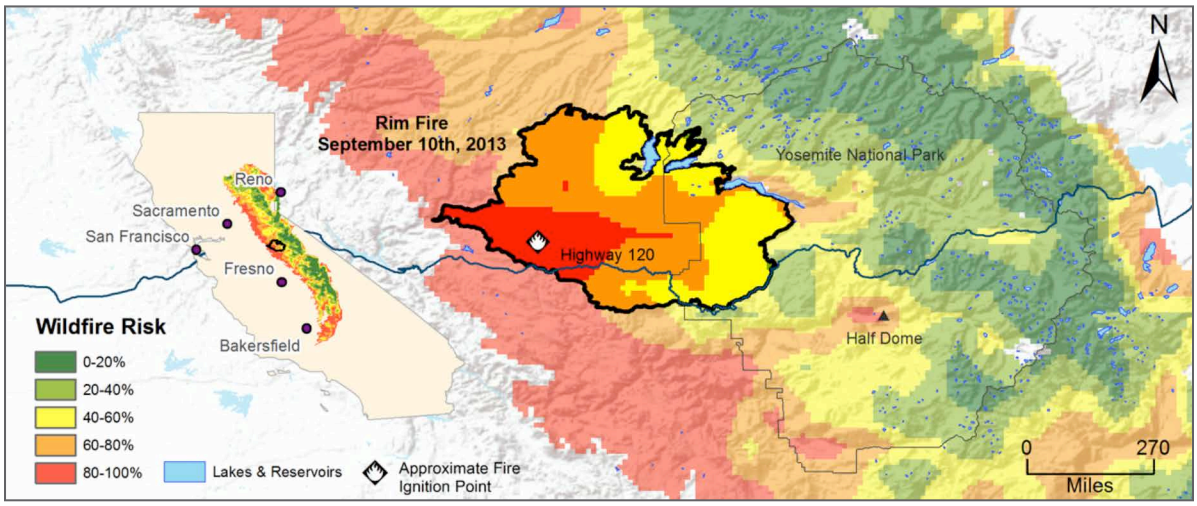


Figure 6. The 2010-2012 wildfire risk map overlaid with the September 10, 2013 Rim Fire extent polygon. **Image credit:** DEVELOP team members

The GAM includes a tool to conduct various statistical analyses to determine the accuracy of the model. The team used this tool to test the predictive abilities of the model by comparing the 2007-2009 wildfire risk map with 2010-2012 wildfire data. The test showed that areas that experienced wildfire-favorable conditions (according to the 2007-2009 wildfire risk map), overlapped with 81% of burn areas from 2010 to 2012—see **Figure 4**.

The next step was to generate a 2010-2012 wildfire risk map—see **Figure 5**. While the comparison between the 2007-2009 and 2010-2012 wildfire maps showed that fire risk declined in some areas within the study region, the entire study region showed an overall increase. Many areas that were in the 0-20% risk range on the 2007-2009 map were in the 20-40% and 40-60% risk ranges on the 2010-2012 map. Further analysis showed particularly interesting results for the 2013 Rim Fire and the 2010-2012 wildfire risk map: The fire started in an area that had been assessed as having an 80-100% wildfire risk and burned into regions with a 40-80% risk—see **Figure 6**. While further statistical analysis is needed to strengthen confidence in the model, the current results show that the GAM model is a useful tool for tracking wildfire risk.

Confirming the Link

The observed anticorrelation between snowpack distribution and extent and wildfire occurrence was further supported by using MODIS snow-extent data to gain higher confidence in snowpack values—a key dataset for this project. This strengthened the study's conclusions for application throughout the entire Sierra Nevada region, but with some notable differences: The trends in snowpack and soil moisture decreased more significantly in the case study regions as compared with the larger study region during the years leading up to the fires. Clearly, localized preexisting conditions have significant effects on specific events, requiring further characterization of snowpack's role in wildfire activity.

Summary

As our climate continues to change, we may expect spring snowmelt to occur earlier in the season and a higher probability for prolonged droughts, thus increasing the potential risk of high-intensity wildfire events. These earlier snow melts may also have the potential to cause catastrophic flash floods and mudslides, especially in recently burned areas with steep slopes, where vegetation roots once stabilized the soil. The techniques and tools outlined in this study will be particularly useful in helping forest managers monitor regions at risk for wildfire and to strategically improve prevention strategies, such as prescribed burning. ■

Landsat Reaches Out: Education and Public Outreach 2006-2013

Jeannie Allen, NASA's Goddard Space Flight Center/Sigma Space Corp., jeannette.e.allen@nasa.gov

Introduction

Education and public outreach (EPO) has been an important component of the Landsat Program for many years. For the eighth mission in the series of Landsat satellites—the Landsat Data Continuity Mission (LDCM)—a small staff of educational professionals built upon this rich heritage and brought along new expertise, creativity, and personal networks that improved and significantly expanded the reach of the mission. This EPO team implemented successful initiatives with different audiences on a national scale, particularly through partnerships. Members of the team learned a great deal from these efforts and from partners—both within and external to NASA.

The Landsat Data Continuity Mission (LDCM), now known as Landsat 8, benefited substantially from a proactive education and public outreach (EPO) effort during mission implementation. A small, energetic, and dedicated staff of communications experts managed the effort with funding from the LDCM Project Office at NASA's Goddard Space Flight Center (GSFC). As with all NASA flight projects, the EPO staff strove to engage the public in the enterprise and excitement of the mission. They worked to convey the importance and societal value of the LDCM, informing the public of the impact of the Landsat program on their daily lives. Further, the staff used the mission to promote science, technical, engineering, and math education for both formal and informal education audiences. In return, LDCM has received increasing public recognition and support while helping to inspire future scientists and engineers who will work on subsequent Landsat missions. NASA is currently assessing the value of flight project EPO. The results of the LDCM effort serve as an example of the significant return that can be achieved by a modest investment in flight project EPO.

—Jim Irons [GSFC—*Landsat 8 Project Scientist*]

LDCM EPO connected people to the excitement and power of design, engineering, discoveries, and data, as well as to the Landsat community of people and how they work. EPO heightened audience awareness, deepened understanding, enabled development of new workforce skills, and motivated people to learn more.

The EPO team focused a great deal on the build-up to launch in mid-February 2013. LDCM has been performing extremely well since launch and was renamed Landsat 8 when NASA transferred operational responsibility to the U.S. Geological Survey (USGS) on May 30, 2013[1]. The USGS adds more than 500 scenes to the no-cost public archive each day. That treasure trove of over 40 years of data and the fascinating stories of what researchers and others are doing with it for public benefit provided fertile ground and rich resources for Landsat's EPO.

Developing a Strategic Plan

The EPO team developed a strategic plan early in the life of the mission detailing the vision, goals, and objectives, along with timelines and benchmarks to accomplish this effort. A major aspect of the plan included the two pillars of NASA EPO: identification of target audiences and development of the messages to convey.

The LDCM EPO team partnered with the U.S. National Park Service, the U.S. Fish and Wildlife Service, and the University of California, Berkeley, on an ongoing program with LDCM content: *Earth to Sky*. **Image credit:** U.S. Fish and Wildlife Service

[1] To learn more about LDCM and its instruments read *LDCM: Continuing the Landsat Legacy* in the March-April 2013 issue of *The Earth Observer*, [**Volume 25**, **Issue 2**, pp. 4-9].

Two-year college instructors learn to collect ground-reference data for case studies that integrate Landsat data with geographic information systems (GIS) during a project called Integrated Geospatial Education and Technology Training (iGETT, *igett.delmar.edu*), co-led by LDCM EPO staff and partners. **Image credit:** Jeannette Allen

Crafting the LDCM Message

The EPO team consulted with the scientists and engineers involved in the development of the LDCM at NASA and USGS, as well as the Landsat Science Team, to craft compelling messages for public communications. Landsat scientists were asked the following questions: What is the most important message to convey to the public regarding the Landsat program? What are the most exciting and meaningful aspects of the LDCM to you, personally?

Building on a rich set of responses, the LDCM science leadership and the EPO team selected the messages they considered most central to the mission, and together refined the wording to be as cogent and appealing as possible to nontechnical audiences. They came up with an overarching message and a series of five submessages.

Overarching message

Landsat: Improving and expanding an unparalleled record of Earth's changing landscapes…for the benefit of all.

Submessages

- Landsat provides essential maps for understanding and caring for the places where we live and work.
- Pixel by pixel, Landsat satellites have been consistently gathering data about our planet since 1972.
- Landsat records almost the entire global land surface, every season, every year.
- Landsat data are unmatched in quality, detail, coverage, and value.
- Landsat satellites use state-of-the-art technology.
- Landsat extends the range of human sight.

The EPO team consulted with the scientists and engineers involved in the development of the LDCM at NASA and USGS, as well as the Landsat Science Team, to craft compelling messages for public communications.

These messages served as touchstones for all of the EPO efforts; they were at the heart of all activities conducted and products produced by the team. The initial effort to craft the message helped ensure that all EPO efforts were aligned with the messages that the LDCM science leadership had endorsed.

Tailoring the Message to Specific Audiences

The strategic plan outlined how the team would reach all audiences under the purview of NASA EPO, but as with any outreach, the message and means of delivery had to be custom-tailored to each audience. While the overarching message was universal, certain submessages might be emphasized more than others depending on the audience—and the means of delivery differed for different settings.

LDCM sought to engage a wide range of audiences. These included the public, particularly in the GSFC region; visitors to parks, museums, and community centers (i.e., informal education); teachers and instructors (and through them, their students) in kindergarten through lower-level undergraduate school (i.e., formal education); the science-interested public; and audiences internal to NASA. The EPO team did reach them all, which was quite an achievement since different audiences require different approaches. What follows is a series of representative products and programs that highlight the means that were used to reach these audiences and to connect them to Landsat 8.

Reaching the Public Audience: "Where's My House?"

The LDCM team had opportunities to reach the public in the greater Washington, DC, metropolitan area through events coordinated by the GSFC Office of Communications (formerly the Public Affairs Office). One such event was the U.S. Science and Engineering Festival in summer 2012. Under the direction of the LDCM EPO lead **Holli Riebeek**, the EPO team chose to focus on two of the submessages: that Landsat provides maps for the places where we live and work, and that Landsat excels at recording change over time.

Visitors to Earth Day 2012 on the National Mall explore a Landsat scene, learning that Landsat provides maps for the places where we live. **Image credit:** Jeannette Allen

Festival visitors looked at large printed posters of Landsat scenes of the Washington, DC area and quickly made their own connections, such as: *Where's my house?* The EPO team kept large posters of the Washington, DC area on tables for visitors to find their communities and to explore the entire region. The team also helped visitors to think about *how* they were recognizing certain landmarks, using characteristics such as size, shape, pattern, shadow, texture, and association. The team also displayed pairs of images showing the same place at different times, and provided simple guidelines for investigations by visitors, to discover for themselves exactly what had changed. This activity provided an opportunity to share how Landsat satellites have been consistently gathering data about our planet since 1972.

Reaching the Public Audience: Launch of LDCM – Landsat Website and Social Media

The overwhelming excitement of an upcoming launch, combined with Landsat's high values for society, are natural mission connections by which to build public awareness. The EPO team designed and implemented a wide array of activities and created several new publications to promote the launch of LDCM. The most publicly visible aspect of these efforts is the Landsat website (*landsat.gsfc.nasa.gov*), designed by team members **Mike Taylor** and **Laura Rocchio**. The site highlights the breadth of materials available for data users, the general public, and educators, and was recently redesigned to make the interface even more user friendly. In preparation for launch, team member **Tassia Owen** created an online Launch Party Kit that provided materials for people to plan and conduct their own launch party.

The team also employed a variety of social-media-based activities to promote the launch that, to date, have reached more than 17,914,000 people. The team focused heavily on *Twitter* and *Facebook* to promote launch events and to provide current information about the launch and status of the satellite. The EPO team developed a social media plan, including scheduled Tweets to promote interest in the launch during the preceding month. The team also supported the GSFC Office of Communications' LDCM Launch Social, which included a live NASA television broadcast with presentations from engineers and scientists; a meet-and-greet with

NASA Administrator, Charles Bolden; and lunch and a tour of NASA's Vandenberg Air Force Base, sponsored by the Air Force. The team helped plan the event and escorted guests, provided materials, and posted regular updates to Facebook and Twitter during the event.

Perhaps the greatest indicator of the impact of this initiative was the fact that Landsat *trended* on Twitter on February 10 and 11—meaning that it was among the *top ten* topics being discussed in the U.S. Between February 11 and February 14 alone, the *#landsat* hashtag (which characterized most Landsat Tweets) reached 4,843,441 accounts. The overall reach was likely far greater, since this period does not include the time during which Landsat was trending, nor does it include the NASA social event associated with the launch.

Successful EPO depends on connecting with people in ways that evoke their interest and engagement. In pursuit of this objective, LDCM EPO has established a number of strong partnerships that take advantage of the strengths of those organizations.

Reaching Visitors to National Parks and Wildlife Refuges: Earth to Sky

Successful EPO depends on connecting with people in ways that evoke their interest and engagement. In pursuit of this objective, LDCM EPO has established a number of strong partnerships that take advantage of the strengths of those organizations. The team sought organizational partners that had wide national dissemination networks and expertise in reaching audiences beyond the experience of the EPO team.

One example is the partnership with the U.S. National Park Service (NPS). The NPS is known among federal agencies for its skill at engaging visitors at parks. NPS interpretation professionals teach that education in such settings is about creating opportunities for visitors to form their own emotional and intellectual connections to the resources at hand. The LDCM EPO team also learned from NPS that emotional connections are crucial to successful EPO, and that people do not "connect" with facts without a foundation in emotional and personal values.

Under the leadership of team member **Anita Davis**, NASA, NPS, the U.S. Fish and Wildlife Service (USFWS), and the University of California, Berkeley have established a professional development, multi-year partnership called *Earth to Sky,* through which educators learned from scientists and each other about NASA mission content, using both face-to-face interactions and distance learning. *Earth to Sky* participants created myriad programs and products that have brought Landsat to millions of park and wildlife refuge visitors. Evaluation by professionals with no stake in the program's outcome was a critical element for success. *Earth to Sky* is ongoing, and may be accessed at *earthtosky.org*.

Reaching Two-year Colleges: Integrated Geospatial Education and Technology Training

Team member **Jeannie Allen** co-led another interagency partnership (between NASA, the USGS Land Remote Sensing Program, the National Council for Geographic Education, Esri, and DelMar College) that served 40 geographic information systems (GIS) instructors and their students at community colleges and two-year tribal colleges across the country. Allen and her associates won a grant from the National Science Foundation's Advanced Technological Education Program for a professional development program, the 2008-2012 Integrated Geospatial Education and Technology Training (iGETT—*igett.delmar.edu*) program. Through two consecutive summer institutes and monthly webinars, project participants learned to integrate Landsat and other land remote sensing data with GIS technology to address community problems in agriculture, disaster management, forestry, geology, and land cover/land use change. They wrote exercises for their students, which were edited and made publicly available. The iGETT team won a second grant for 2012-2015 to expand and improve upon this training for 36 more instructors.

Reaching the Science-Interested Public: Library of Congress Partnership

LDCM was featured in a multi-year GSFC partnership program with the Library of Congress's (LOC) Science, Technology, and Business Division. A series of presentations

by scientists and engineers either working for or affiliated with NASA served the science-interested public at the LOC. The audience at these talks customarily included a number of LOC staff and occasionally personnel from the Congressional Research Office. LDCM-associated presentations included talks on mapping water use, predicting disease outbreaks, improving food security, characterizing land cover change, and the amazing longevity of Landsat 5. Presentations were taped, archived, and webcast by the LOC and may be accessed at *www.loc.gov/rr/scitech/events/events.html#past.*

GIS instructors at community colleges took advantage of rich opportunities for interaction while learning to analyze Landsat data through the iGETT project. **Image credit:** Jeannette Allen

Reaching Data Users, Potential Data Users, and Audiences Internal to NASA: Societal Benefits Fact Sheets and the Landsat Applications Book

Multiple individuals and groups use Landsat data operationally for a variety of purposes. The LDCM EPO team created a series of fact sheets designed to appeal to data users and potential data users, and to help inform decision making both within NASA and external to the agency. Topics for the series were derived from the list of societal benefit areas developed by the international Group on Earth Observations (GEO), a voluntary partnership of governments and other organizations. More GEO information may be found at *www.earthobservations.org/about_geo.shtml.*

Landsat addresses most of the GEO-identified areas: agriculture, carbon and climate, disasters, ecosystems and biodiversity, energy, fire, forest management, human health, urban growth, and water. LDCM EPO staff emphasized the human side of Landsat's multiple uses for these fact sheets, putting photographs of people on the front of each fact sheet and details about specific ways Landsat data are used for human benefit in the text. Visit *landsat.gsfc.nasa.gov/?page_id=3510* for downloadable fact sheets and supplemental information.

When a disaster strikes, such as a tornado in Alabama, Landsat is often the only way to get a big-picture view of what is happening on the ground. Public awareness of the value of Landsat data requires strategically planned outreach. **Image credit:** American Red Cross

The Landsat Applications book, titled *Landsat: Continuing to Improve Everyday Life*, highlights case studies that focus on the human side of Landsat data use. Research shows that for audiences to accept new ideas, their affective or emotional side must be addressed. To achieve this, the writing in the Applications book used storytelling to connect with people who were not already using remote sensing data. In contrast to traditional science writing, a good story has conflict and character development, and the conclusion is described at the end of the piece rather than at the beginning. A PDF of the book can be found at *landsat.gsfc.nasa.gov/?p=5199*. The book is intended as a living document that will be expanded with more stories.

Conclusion

Perhaps the team's greatest strength was its focus on the human sides of LDCM. Key to the EPO team's success was a collegial and highly cooperative spirit among team members, and the strong support of Landsat science leadership. Establishing national-scale interorganizational partnerships was another key to success. These connections enabled the team to take advantage of the expertise of other professionals and also to

reach far more people than could have been done without partnership. Evaluation—both *formative* (during project development) and *summative* (after project is complete)—by professionals with no stake in the outcomes of the projects in question was also an integral part of the team's accomplishments. As NASA outreach activities continue, both partnerships and evaluation will likely remain critical elements of success.

The examples here of LDCM EPO activities are not intended to encompass all that was accomplished by the team during the period in question, but rather summarily report on representative samples of the work. A full report on the LDCM EPO efforts will be posted to *landsat.gsfc.nasa.gov*. ■

Perhaps the team's greatest strength was its focus on the human sides of LDCM. Key to the EPO team's success was a collegial and highly cooperative spirit among team members, and the strong support of Landsat science leadership.

Landsat Education and Public Outreach Team Members
All these individuals are contractors affiliated with NASA's Goddard Space Flight Center.

- **Jeannie Allen**, Sigma Space Corp. (SSC)
- **Anita Davis**, SSC
- **Tassia Owen**, SSC
- **Holli Riebeek**, Science Systems and Applications, Inc.
- **Laura Rocchio**, SSC
- **Mike Taylor**, SSC

For Additional Information

NASA Landsat
www.nasa.gov/mission_pages/landsat/main

NASA Landsat Science
landsat.gsfc.nasa.gov

NASA Landsat Education
landsat.gsfc.nasa.gov/?page_id=11

USGS Landsat
landsat.usgs.gov

announcement

New MOPITT Web Application for Level-2 Version 5 Data

The Atmospheric Science Data Center at NASA's Langley Research Center, in collaboration with the Measurements Of Pollution In The Troposphere (MOPITT) Science Team, is pleased to announce the release of the MOPITT Search and Subsetting Web Application. The application enables a more-efficient approach to selecting and ordering MOPITT data subsets by supporting spatial, temporal, and parameter subsetting for the following MOPITT Level-2 *Version 5* (V5) products, which address vertical profiles and total column retrievals for carbon monoxide (CO):

- **MOP02T** MOPITT V5 Derived CO [thermal infrared (TIR) radiances]
- **MOP02N** MOPITT V5 Derived CO [near infrared (NIR) radiances]
- **MOP02J** MOPITT V5 Derived CO [TIR/NIR radiances]

Data can be downloaded in HDF and NetCDF formats. For more information and to use the MOPITT Search and Subsetting Web Application, visit: *subset.larc.nasa.gov/mopitt/login.php*.

Antarctic Ozone Hole Slightly Smaller than Average This Year

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

The ozone hole that forms each year in the stratosphere over Antarctica was slightly smaller in 2013 than the average in recent decades, according to NASA satellite data.

The ozone hole is a seasonal phenomenon that starts to form during the Antarctic spring (August and September). The September-October 2013 average size of the hole was 8.1 million mi^2 (21 million km^2). For comparison, the average size measured since the mid-1990s when the annual maximum size stopped growing is 8.7 million mi^2 (22.5 million km^2). However, the size of the hole in any particular year is not enough information for scientists to determine whether a healing of the hole has begun.

"There was a lot of Antarctic ozone depletion in 2013, but because of above-average temperatures in the Antarctic lower stratosphere, the ozone hole was a bit below average compared to ozone holes observed since 1990," said renowned ozone expert **Paul Newman** [NASA's Goddard Space Flight Center (GSFC)].

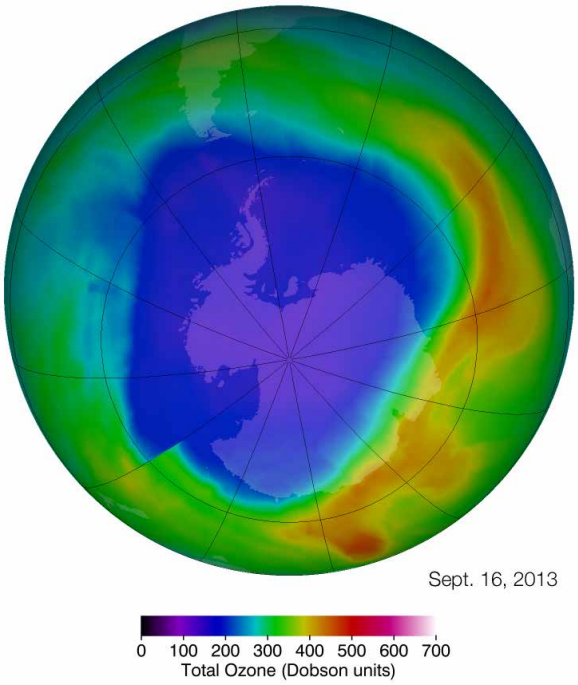
The ozone hole forms when the sun begins rising again after several months of winter darkness. Polar-circling winds keep cold air trapped above the continent, and sunlight-sparked reactions involving ice clouds and chlorine from manmade chemicals begin eating away at the ozone. Most years, the conditions for ozone depletion ease before early December when the seasonal hole closes.

Levels of most ozone-depleting chemicals in the atmosphere have gradually declined as the result of the 1987 *Montreal Protocol*—an international treaty to protect the ozone layer by phasing out production of ozone-depleting chemicals. As a result, the size of the hole has stabilized, with variation from year-to-year driven by changing meteorological conditions.

The single-day maximum area this year was reached on September 16 when the maximum area reached 9.3 million mi^2 (24 million km^2)—about equal to the size of North America. The largest single-day ozone hole since the mid-1990s was 11.5 million mi^2 (29.9 million km^2) on September 9, 2000.

Science teams from NASA and the National Oceanic and Atmospheric Administration (NOAA) have been monitoring the ozone layer from the ground and with a variety of instruments on satellites and balloons since the 1970s. These ozone instruments capture different aspects of ozone depletion. The independent analyses ensure that the international community understands the trends in this critical part of Earth's atmosphere. The resulting views of the ozone hole have differences in the computation of the size of the ozone hole, its depth, and record dates.

NASA's observations of the ozone hole during 2013 were produced from data supplied by the Ozone Monitoring Instrument onboard NASA's Aura satellite and the Ozone Mapping and Profiler Suite (OMPS) onboard the NASA–NOAA Suomi National Polar-orbiting Partnership (NPP) satellite. Long-term satellite ozone-monitoring instruments have included the Total Ozone Mapping Spectrometer, the second generation Solar Backscatter Ultraviolet instrument, the Stratospheric Aerosol and Gas Experiment series of instruments, and the Microwave Limb Sounder, which was onboard the Upper Atmosphere Research Satellite, and is now onboard Aura. ■



The Antarctic ozone hole reached its maximum single-day area for 2013 on September 16. The ozone hole (purple and blue) is the region over Antarctica with total ozone at or below 220 Dobson units—a common unit for measuring ozone concentration. **Image credit:** GSFC

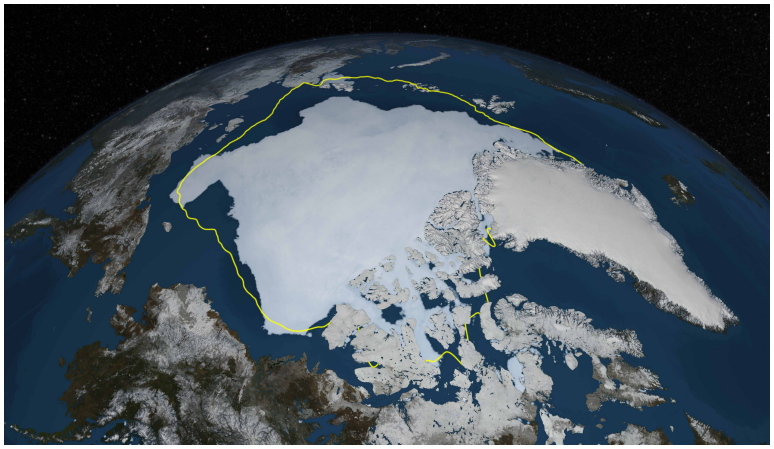
in the news

Arctic Sea Ice Minimum in 2013 is Sixth Lowest on Record

Maria-José Viñas, NASA's Goddard Space Flight Center, Earth Science News Team, maria-jose.vinasgarcia@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact. In that vein, we have retained the original title, although we realize that it is biased toward emphasizing low sea ice coverage and could instead have been 'Arctic Sea Ice Minimum in 2013 is Substantially Higher Than in 2012'.

After an unusually cold summer in the northernmost latitudes, Arctic sea ice appears to have reached its annual minimum summer extent for 2013 on September 13, the NASA-supported National Snow and Ice Data Center (NSIDC) at the University of Colorado in Boulder has reported. Analysis of satellite data by NSIDC and NASA showed that the sea ice extent shrunk to 1.97 million mi^2 (5.10 million km^2).



This image shows the extent of Arctic sea ice on September 12, 2013, the day before NSIDC estimated sea ice extent hit its annual minimum. The white line shows the 30-year (1981-2010) average minimum extent. The data were provided by the Japan Aerospace Exploration Agency from their Global Change Observation Mission-Water (GCOM-W1) satellite's Advanced Microwave Scanning Radiometer-2 (AMSR2) instrument. **Image credit:** NASA's Scientific Visualization Studio/Cindy Starr

This year's sea ice extent is substantially higher than last year's record low minimum. On September 16, 2012, Arctic sea ice reached its smallest extent ever recorded by satellites at 1.32 million mi^2 (3.41 million km^2). That is about half the size of the average minimum extent from 1981 to 2010.

This summer's minimum is still the sixth lowest extent of the satellite record and is 432,000 mi^2 (1.12 million km^2) lower than the 1981-2010 average, roughly the size of Texas and California combined.

The 2013 summertime minimum extent is in line with the long-term downward trend of about 12% per decade since the late 1970s, a decline that has accelerated after 2007. This year's rebound from 2012 does not disagree with this downward trend and is not a surprise to scientists. "I was expecting that this year would be higher than last year," said glaciologist **Walt Meier** [NASA's Goddard Space Flight Center (GSFC)]. "There is always a tendency to have an uptick after an extreme low; in our satellite data, the Arctic sea ice has never set record low minimums in consecutive years."

The ice cap covering the Arctic Ocean shrinks and expands with the passing of the seasons, melting in the summer and refreezing during the long, frigid Arctic winter. This year, cooler weather in the spring and summer led to a late start of the melt season and overall less melt.

Specifically, Arctic temperatures were 1.8 to 4.5 °F (1 to 2.5 °C) lower than average, according to NASA's Modern Era Retrospective analysis for Research and Applications, a merging of observations and a modeled forecast. The colder temperatures were in part due to a series of summer cyclones. In August 2012, a big storm caused havoc on the Arctic Ocean's icy cover, but this summer's cyclones have had the opposite effect: under cloudier conditions, surface winds spread the ice over a larger area.

"The trend with decreasing sea ice is having a high-pressure area in the center of the Arctic, which compresses the ice pack into a smaller area and also results in clear skies, which enhances melting due to the sun," said atmospheric scientist **Richard Cullather** [GSFC/University of Maryland, College Park, Earth System Science Interdisciplinary Center]. "This year, there was low pressure, so the cloudiness and the winds associated with the cyclones expanded the ice."

The remaining Arctic sea ice cover is much thinner on average than it was years ago. Satellite imagery, submarine sonar measurements, and data collected from NASA's Operation IceBridge, an airborne survey of polar ice, indicate that the Arctic sea ice thickness is as much as 50% thinner than it was in previous decades, going from an average thickness of 12.5 ft (3.8 m) in 1980 to 6.2 ft (1.9 m) in recent years. The thinning is due to the loss of older, thicker ice, which is being replaced by thinner seasonal ice.

Most of the Arctic Ocean used to be covered by *multiyear ice*, or ice that has survived at least two summers and is typically 10 to 13 ft (3 to 4 m) thick. This older ice has declined at an even faster rate than younger ice and is now largely relegated to a strip along the northern coast of Greenland. The rest of the Arctic Ocean is dominated by *first-year ice*, or ice that formed over the previous winter and is only 3 to 7 ft (1 to 2 m) thick.

"Thinner ice melts completely at a faster rate than thicker ice does, so if the average thickness of Arctic sea ice goes down, it's more likely that the extent of the summer ice will go down as well," said senior scientist **Joey Comiso**[1] [GSFC]. "At the rate we're observing this decline, it's very likely that the Arctic's summer sea ice will completely disappear within this century." Comiso added that the slight rebound in the 2013 sea ice minimum extent is consistent with a rebound in the multiyear ice cover observed last winter.

"The character of the ice is fundamentally different: it's thinner, more broken up, and thus more susceptible to melt completely," Meier said. "This year, the cool temperatures saved more of the ice. However, the fact that as much of the ice melted as it did is an indication of how much the ice cover had changed. If we had this weather with the sea ice of 20 years ago, we would have had an above-normal extent this year."

The sea ice minimum extent analysis produced at GSFC—one of many satellite-based scientific analyses of sea ice cover—is compiled from passive microwave data from NASA's Nimbus 7 satellite, which operated from late October 1978 to August 1987, and the U.S. Department of Defense's Defense Meteorological Satellite Program, which has been used to extend the Nimbus 7 sea ice record onward from August 1987. The record began in October 1978. ■

[1] Comiso is the coordinating lead author of the Cryosphere Observations chapter of the upcoming Fifth Annual Report of the Intergovernmental Panel on Climate Change.

Congratulations AMS and AGU Award Winners!

The Earth Observer is pleased to recognize the following Earth scientists from NASA Centers that have received awards from the American Meteorological Society (AMS) and American Geophysical Union (AGU).

Pawan K. (P.K.) Bhartia [NASA's Goddard Space Flight Center (GSFC)—*Head of the Atmospheric Chemistry and Dynamics Lab*], has been chosen to receive the American Meteorological Society (AMS) *2014 Remote Sensing Prize*. This prestigious award is granted biennially to individuals in recognition of advances in the science and technology of remote sensing, and application to knowledge of Earth, oceans, and atmosphere, and/or to the benefit of society. The citation for PK's award reads *"For scientific advances in the remote sensing of global ozone concentration and trends, and for developing new techniques for retrieving aerosol properties from space."*

Arthur Hou [GSFC—*Global Precipitation Measurement (GPM) Project Scientist*], and **Duane Waliser** [NASA/Jet Propulsion Laboratory (JPL)—*Chief Scientist of the Earth Science and Technology Directorate*] have been named *2014 Fellows of the AMS*. To be elected a Fellow of the AMS is a special tribute for those who have made outstanding contributions to the atmospheric or related oceanic or hydrologic sciences or their applications during a substantial period. This designation is conferred upon not more than 0.2% of all AMS members in any given year.

John LaBrecque [NASA Headquarters—*Earth Surface and Interior Program Manager*], has been chosen to receive the 2013 American Geophysical Union (AGU) *Edward A. Flinn III* award. This award is bestowed upon the unsung heroes who provide the ideas, motivation, and labors of love that build and maintain the structures without which our science could not flourish. The AGU Flinn Award is awarded not more than once annually to an "individual who personifies the Union's motto 'unselfish cooperation in research' through their facilitating, coordinating, and implementing activities."

David Rind [NASA Goddard Institute for Space Studies] and **Warren Wiscombe** [GSFC] have been named *2013 Fellows of the AGU*. The AGU Fellows program recognizes members who have made exceptional contributions to Earth and space sciences as valued by their peers and vetted by section and focus group committees. This honor may be bestowed on only 0.1% of the membership in any given year.

Congratulations to P.K. Bhartia, the late Arthur Hou*, Duane Waliser, John LaBrecque, David Rind, and Warren Wiscombe on these awards, and all of this year's other AMS and AGU award recipients.

*We regret to report that Arthur Hou passed away on November 20, 2013. We will highlight Arthur's contributions to satellite precipitation observations in a coming issue.

NASA Satellite Data Improving Volcanic Ash Forecasts for Aviation Safety

Katie Bethea, NASA's Langley Research Center, katherine.l.bethea@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

As frequent travelers know, flight delays are all too familiar. Lately, NASA has been looking into a much less frequent, but potentially very dangerous problem that has recently caused major disruptions in aviation services—volcanic eruptions. Explosive volcanic eruptions produce *ash*, or tiny, hard, jagged particles, that can be blown thousands of miles away from their source. Volcanic ash is quite dangerous to airplanes, grounding and diverting flights with a huge economic impact to travelers and citizens who rely on goods and services delivered by aircraft.

On April 17, 2010, the Moderate Resolution Imaging Spectroradiometer (MODIS) captured this image of the Eyjafjallajökull volcano in Iceland erupting and spreading a huge ash plume over northern Europe. **Image credit:** NASA

In a recent study, researchers used NASA's three-dimensional (3D) satellite data to improve forecasts of volcanic ash plumes to benefit aviation. Currently, NASA has a number of instruments in space that can "see" volcanic ash particles. Each of these instruments provides information about the ash, helping detect, locate, and characterize the physical and chemical properties of the ash plume. However, none of these instruments paints a complete enough picture of the ash plume and its constituents to effectively inform the aviation community of the threat.

That's changing…

The 2010 eruption of Eyjafjallajökull, a volcano in Iceland, produced a large plume over the airspace of Europe, grounding more than 100,000 travelers with an impact of more than $1 billion U.S. dollars. This eruption was a wakeup call to the atmospheric science and aviation communities. "The Icelandic eruption, such a dramatic event, made us take a hard look at what each of our satellites can tell us," said **John Murray** [NASA's Langley Research Center (LaRC)—*Associate Program Manager for Natural Disasters*]. "We knew we needed to understand how to integrate them to make better forecasts."

Murray knew they needed to look more closely at the unique capabilities of NASA satellite imagery to improve warnings produced by the world's nine operational Volcanic Ash Advisory Centers (VAACs). These advisory centers use relatively simple representations of atmospheric particles to develop forecasts that are then used to guide decision makers as to where aircraft could safely fly. Such models often provide useful information about the volcanic ash distribution in the short term, but lack accurate information about ash plume concentration, layering, and long-term dispersion.

"The dispersion of a volcanic plume in the atmosphere is like ink in water," explained **Jean-Paul Vernier** [LaRC]. "Models, which are used to simulate both, rely on source information like how much ink or ash is introduced and how the flow—either the current or wind—transports the material." For longer-lasting plumes typically injected at higher altitudes near commercial cruise levels, explained Vernier, forecasters need a combination of trajectory models with refresh information about the plume's height and location. That is where NASA's 3D data comes in.

NASA's Cloud Aerosol–Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite mission, launched in 2006, is uniquely suited to provide updated information about ash plume height and location. CALIPSO uses a space-based lidar system to provide unprecedented 3D views of atmospheric particles—like volcanic ash—and clouds in the atmosphere.

In their study, the research team focused on the June 2011 volcanic eruption of Puyehue-Cordón Caulle in Chile, which disrupted air traffic throughout much of the Southern Hemisphere. This Chilean eruption was

powerful, ejecting ash in the upper troposphere, or 3 to 9 miles (~5 to 15 km) above Earth's surface. The higher ejection caused the plume to be long lasting, circling the globe at least three times in the southern latitudes.

CALIPSO data allowed the research team to track the plume on its trip around the globe. Researchers looked at the different channels of the CALIPSO lidar to be able to differentiate between clouds and ash. "CALIPSO gives us very accurate information about the 3D location of ash," said Vernier. "However, the CALIPSO lidar data comes to us in curtains and we don't know what's between two curtains. We use trajectory models to fill in those gaps."

The team used volcanic ash observations from CALIPSO overpasses as initiation points for the trajectory model. By accumulating several days of observations transported by the model forward in time, it is possible to produce a more accurate forecast than using a simple dispersion model.

Duncan Fairlie [LaRC] added that a key advancement with this technique was being able to use *cloud clearing algorithms*—mathematical formulas—developed by Vernier. These algorithms give a clearer view of the ash and help to distinguish between the ash plume and clouds.

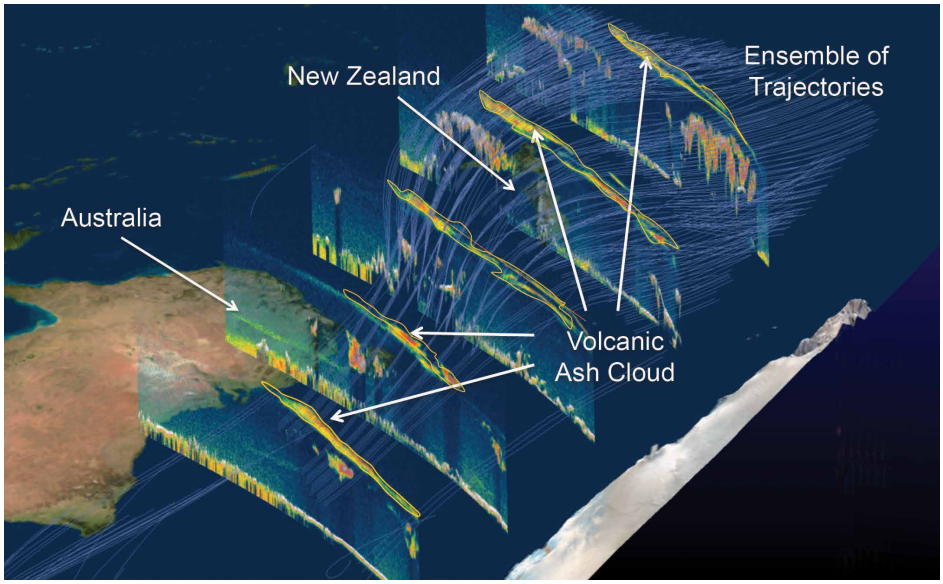


Figure. Shown here are CALIPSO data profiles from Australia and New Zealand with the model trajectories. **Image credit:** NASA

Upon comparing the model results with independent CALIPSO observations, the research team saw that the model successfully reproduced the 3D structure of volcanic ash clouds. "We saw remarkable agreement between the trajectory model and the independent CALIPSO observations," said Fairlie. "To be honest, we were blown away."

Their results were especially compelling for the aviation community in southern Australia and New Zealand—see **Figure**. In the three weeks following the Chilean eruption, the Darwin, Australia VAAC found the Puyehue-Cordón Caulle plume had persisted, however the long-term dispersion model forecast of the plume became increasingly unreliable. Thus, the Darwin VAAC was heavily dependent on fundamental satellite observations, which can't always see through the clouds to locate ash plumes.

"Our model, however, provided additional information about the 3D structure of the volcanic plume, especially the extension of the plume's forward trajectory that was not available to the Darwin VAAC at the time of their advisories," said Murray. "For example, the model clearly showed the head of the volcanic ash cloud crossing the southern part of Australia directly east of the Darwin VAAC's advisory area on June 21."

Vernier, Fairlie, Murray, and their colleagues are now working with the international volcanic ash community to aid in the integration of CALIPSO data trajectory modeling to the VAAC modeling process to help the aviation community and their efforts to operate more safely and efficiently when volcanic ash events occur. This process is especially challenging with low ash concentrations, such as those observed in this study, because much of the VAAC workload consists of making judgment calls between potential ash and false alarms.

"The combination of CALIPSO observations of volcanic ash clouds and a Lagrangian trajectory model offers a potential new capability that VAACs could use to improve aviation safety worldwide," said Murray. "Additionally," said Vernier, "future NASA missions, such as SAGE III on ISS[1], will be useful to continue monitoring the dispersion of volcanic ash in the atmosphere."

Details of this study can be found in the September 2013 issue of the American Meteorological Society's *Journal of Applied Meteorology and Climatology*. ■

[1] To learn more about the Stratospheric Aerosol and Gas Experiment (SAGE) III on the International Space Station (ISS) please refer to the September–October 2013 issue of *The Earth Observer* [**Volume 25, Issue 5,** pp. 4-8].

NASA Earth Science in the News

Patrick Lynch, NASA's Earth Science News Team, patrick.lynch@nasa.gov

NASA Using Surplus Military Drones to Investigate Hurricanes, September 14; *FoxNews.com*. NASA is now using surplus military drones to investigate hurricanes from Maine to the Caribbean. The space agency launched two Global Hawks from its Wallops Flight Facility (WFF) in Virginia to get a close-up look at Hurricane Humberto. "The purpose is to give people warning of what's going to be happening. How strong is it going to be? Do I need to board up the house or not?" said **Chris Naftel** [NASA's Dryden Flight Research Center—*Global Hawk Project Manager*]. The U.S. Air Force donated the Global Hawk surveillance drones to NASA, which then replaced the drones' "spy gear" with scientific instruments to examine severe storms, and specifically hurricanes. "[We] will have a permanent ground station [at Wallops]. So Global Hawks will be a permanent part of our future here," said **Shane Dover** [WFF—*Director of the Wallops Aircraft Office*]. There were two questions on which NASA scientists focused during the Hurricane and Severe Storm Sentinel (HS3) campaign. One is what role thunderstorms within a hurricane play in its intensification. Researchers are not sure if the thunderstorms are a driver of storm intensity or a symptom of it. The other is what role the Saharan Air Layer plays in the tropical storm development.

Antarctic Ice Sheet Melting from Below, Scientists Say, September 16; *Christian Science Monitor*. An expedition to one of the most remote sites on the planet—the sprawling Pine Island Glacier in Antarctica—has revealed that currents of warm water beneath the glacier are melting the ice at a staggering rate of about 2.4 in (6 cm) per day. An international team of researchers—funded largely by the National Science Foundation and led by NASA glaciologist emeritus **Bob Bindschadler**—journeyed to the southernmost continent to study the glacier, which is the longest and fastest-changing glacier on the West Antarctic Ice Sheet. This region, in the far reaches of Antarctica, has been of particular interest to scientists because it is among the most rapidly melting ice masses in the world, thinning as it flows to the Amundsen Sea at a rate of about 2.5 mi (4 km) each year.

***2013's Summer Arctic Sea Ice a Top 10 Low,** September 20; *LiveScience.com*. It's official: The Arctic icepack reached its summer low on September 13, the National Snow and Ice Data Center (NSIDC) and NASA said. The Arctic ice cover melted down to 1.97 million mi^2 (5.10 million km^2)—about the size of Texas and California combined. The final tally puts 2013 in sixth place out of the top 10 record-low-ice years since tracking began with satellites 30 years ago. It also continues an overall downward trend in the extent of summer sea ice, the NSIDC said. (The year 2012 is the top record holder, with the lowest summer ice extent ever recorded.) The rebound in ice cover after a record-low year was expected, said glaciologist **Walt Meier** [NASA's Goddard Space Flight Center (GSFC)]. "There is always a tendency to have an uptick after an extreme low; in our satellite data, the Arctic sea ice has never set record low minimums in consecutive years."

NASA Uses Radar to Find Human Heartbeats in Collapsed Buildings, September 25; *Los Angeles Times*. NASA engineers have built a device that uses radar to detect heartbeats in the rubble of collapsed buildings, with technology typically used to explore planets, including Earth. The Finding Individuals for Disaster and Emergency Response (FINDER) device, developed with the Department of Homeland Security, could help search-and-rescue teams find survivors trapped underneath the wreckage—even when those victims cannot call for help. Identifying people who are still alive in a collapsed building is a major challenge for urban rescue missions, said **Jim Lux** [NASA/Jet Propulsion Laboratory (JPL)—*FINDER Task Manager*]. Trapped victims often cannot be heard, and using microphones to pick up their voices depends on their ability to call for help. "The other search technique relies on the victims making noise," Lux said. The FINDER device uses radar to locate unconscious and unresponsive victims, using techniques similar to those used to guide missiles and air traffic. FINDER sends out a low-powered microwave signal—a fraction of what cellphones use—toward the rubble. Some of the microwave bounce off the rubble, but some of it manages to penetrate the debris and bounce off trapped victims.

New Space Station Instrument Raises Windy Science from the Dead, October 30; *UniverseToday.com*. Here is a cool example of a satellite recycling project: NASA used to have a probe called the Quick Scatterometer (QuikSCAT) that observed ocean-surface wind speeds—including those from hurricanes, storms, and

typhoons. After 10 years of loyal service, the satellite failed in 2009 and a full replacement looked expensive. Now, however, spare parts for QuikSCAT are going to be used on the International Space Station (ISS) for a low-budget fix, which the agency says will work just fine. The parts are old—they are from the 1990s—but incredibly, they are functional. NASA also added some newer, commercially available hardware to make the instrument, ISS-RapidScat, fit on the space station and the SpaceX Dragon spacecraft that will deliver it to the ISS in early 2014. Because this is very much a low-cost project, certain design compromises were made—like not using radiation-hardened computer chips, which is normal in scatterometers of this sort. This type of device harmlessly sends low-energy microwaves off the Earth's surface to get the information it needs. "If there's an error or something because of radiation, all we have to do is reset the computer. It's what we call a managed risk," stated **Howard Eisen** [JPL—*ISS-RapidScat Project Manager*]. There is another big difference with this scatterometer mission: it is in an orbit different from most. A typical mission will do a sun-synchronous orbit that crosses Earth's Equator at the same time on every orbit (say, 12:00 noon, local). However, the ISS passes over different parts of Earth at different times. "This means the instrument will see different parts of the planet at different times of day, making measurements in the same spot within less than an hour before or after another instrument makes its own observations," NASA stated.

*See news story in this issue for more details.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Patrick Lynch*** *on NASA's Earth Science News Team at* ***patrick.lynch@nasa.gov*** *and let him know of upcoming journal articles, new satellite images, or conference presentations that you think would be of interest to the readership of* ***The Earth Observer****.* ■

Climate Models Show Potential Twenty-first Century Temperature and Precipitation Changes

New data visualizations from the NASA Center for Climate Simulation and NASA's Scientific Visualization Studio at Goddard Space Flight Center show how climate models estimate possible temperature and precipitation pattern changes throughout the twenty-first century. The models were used in the Fifth Annual Report (AR5) from the United Nations' Intergovernmental Panel on Climate Change (IPCC).

For the IPCC's *Physical Science Basis* and *Summary for Policymakers*, scientists referred to an international climate modeling effort to study how the Earth might respond to four different scenarios of changing levels of carbon dioxide and other greenhouse gas emissions throughout the twenty-first century. The *Summary*, the first official piece of AR5, was released on September 27.

One modeling effort, the Coupled Model Intercomparison Project Phase 5 (CMIP5), includes dozens of global climate models developed at institutions around the world—including NASA's Goddard Institute for Space Studies. CMIP5 attempts to document and understand the models' responses to several forcings through a series of numerical experiments.

The visualizations show temperature and precipitation changes that are similar to those included in the IPCC report AR5. This work was done by the NASA Center for Climate Simulation, which calculated average temperature and precipitation changes from models that ran the IPCC's four different emissions scenarios. The final products are visual representations of changes in temperature and precipitation patterns through 2100, compared to the historical average from the latter part of the twentieth century, i.e., from 1971 to 2000.

This baseline is slightly different from the 1986 to 2005 baseline used in the IPCC report. The visualizations differ from the AR5 representations because the AR5 reference period was slightly warmer than the visualization's baseline, even though the same model data is used.

For more information and to watch visualizations of the four CMIP5 temperature and precipitation scenarios, visit: *svs.gsfc.nasa.gov/goto?4110*.

NASA Science Mission Directorate – Science Education and Public Outreach Update

Theresa Schwerin, Institute for Global Environmental Strategies, theresa_schwerin@strategies.org
Morgan Woroner, Institute for Global Environmental Strategies, morgan_woroner@strategies.org

GLOBE Student Art Competition and Exhibition

The second Annual GLOBE Student Art Competition received more than 250 entries, representing every GLOBE geographic region. The competition called on students to illustrate and write about what makes their local environments unique. Winners of the 2014 competition will be announced via GLOBE social media and web page beginning **November 15**. To view the entries, visit: *www.facebook.com/TheGLOBEProgram*.

Art from the 2013 competition is now on display at the National Center for Atmospheric Research Mesa Lab in Boulder, CO. The exhibition, featuring 20 works of student art, will remain on display through December 2013.

"Ask NICE!" Educator Professional Development Series

A new Educator Professional Development series from NASA Innovations in Climate Education (NICE) begins this fall. The following online sessions will be offered:

- **Thursday, November 21, 2013, from 4:00-5:00 PM ET** – Climate Change Summary: What We Know and How We Know It
- **Thursday, January 16, 2014, from 4:00-5:00 PM ET** – Impacts of Climate Change/The GLOBE Program: Green-Up
- **Additional Sessions** to be announced

This series is sponsored by Minority University Research and Education Program (MUREP)-NICE, and is part of the Digital Learning Network program, organized to expand the reach of NICE projects. For more information, visit: *nice.larc.nasa.gov/node/135*.

New Online Interactive Map

Explore NASA's Earth-observing mission with a new online interactive map. Built around this year's Earth Science Week theme *Mapping Our World*, this colorful online map allows users to easily point and click to view information on satellite imagery and visualizations, including what missions gathered the data, how the images were created, and why the missions are critical to learning more about our home planet. To view the interactive map, visit: *nasaesw.strategies.org/interactive*.

FameLab: Exploring Earth and Beyond – New Regional Competition Announced

Date: December 8, 2013

Location: American Geophysical Union, Annual Meeting, San Francisco, CA

FameLab has announced a new regional competition to take place December 8, 2013, in San Francisco, CA. The competition is being held in tandem with the American Geophysical Union (AGU), Annual Meeting; however, competitors do not have to be registered for the meeting to participate.

FameLab: Exploring Earth and Beyond is a science communications competition allowing early-career scientists from numerous disciplines the opportunity to show off their skills. Contestants have three minutes each to convey their research without the aid of slides and charts (hand-held props are acceptable). A panel of experts in both science and science communication will do the judging. Regional competitions will be held, including an online option for those unable to travel. Winners will face off at National Geographic headquarters in Washington, DC in April 2014 for a chance at winning the grand prize and the opportunity to compete at the FameLab International Final in the United Kingdom in June 2014.

For more information, a complete listing of rules and eligibility requirements, and to register, visit: *famelab-eeb.arc.nasa.gov*.

Professional Development Opportunity in Remote Sensing for High School/Undergraduate GIS Instructors

Application deadline: December 20, 2013

Date: June 2014

Integrated Geospatial Education and Technology Training (iGETT[1])-Remote Sensing is an 18-month professional development program for educators who teach courses in geographic information systems (GIS). The program is designed for courses at two-year colleges and at high school and four-year institutions that are interested in collaborating with educators in two-year programs. Hands-on instruction at two summer institutes and monthly webinars will enable participants to identify, download, and analyze appropriate federal land remote sensing data, and to integrate remote sensing data with GIS software to solve practical problems.

Most expenses will be covered, and all participants will receive personal stipends and software for their labs. For more detailed information and an application to join the project in February 2014 visit: *igett.delmar.edu.*

[1] Read about how Landsat is working with iGETT on page 20 of this issue.

EOS Science Calendar

January 8–10, 2014
ESIP Federation Meeting, Washington, DC
www.esipfed.org/meetings

January 28–31, 2014
SORCE Science Team Meeting, Key West, FL.
lasp.colorado.edu/home/sorce/news-events/meetings/2014-sorce-science-meeting

April 23–25, 2014
Land-Cover/Land-Use Change Science Team Meeting, Rockville, MD.
lcluc.umd.edu/meetings.php?mid=52

March 17–19, 2014
AIRS Science Team Meeting, Pasadena, CA.
airs.jpl.nasa.gov

Global Change Calendar

December 9–13, 2013
American Geophysical Union Annual Meeting, San Francisco, CA.
fallmeeting.agu.org/2013

February 2–6, 2014
American Meteorological Society Meeting, Atlanta, GA.
annual.ametsoc.org/2014

February 23–28, 2014
AGU Ocean Sciences Meeting, Honolulu, HI.
www.sgmeet.com/osm2014

April 27–May 2, 2014
European Geosciences Union General Assembly 2014, Vienna, Austria.
www.egu2014.eu

July 28–August 1, 2014
Asia Oceania Geosciences Society, Sapporo, Japan.
www.asiaoceania.org/aogs2014

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Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. Newsletter content is due on the weekday closest to the 15th of the month preceding the publication—e.g., December 15 for the January–February issue; February 15 for March–April, and so on.

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