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Editor's Corner

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In this issue we highlight the recently launched ISS-RapidScat mission that will observe ocean surface vector winds from the space station. RapidScat was successfully launched on September 21 at 1:52 AM EDT, from Cape Canaveral Air Force Station in Florida, as part of the SpaceX-4 Dragon resupply mission to the ISS. The mission provides data to scientists and weather forecasters to mitigate the loss of SeaWinds instrument data from the QuikSCAT mission.

A unique aspect about the mission is that the space station's orbit will allow ISS-RapidScat to make the first direct observations of ocean wind variability over the course of the day. This unique diurnal sampling also enables ISS-RapidScat to serve as a calibration standard for other instruments in the international scatterometer constellation, thus improving the ability to monitor ocean wind variability and change over multiple decades. Congratulations to the NASA/JPL RapidScat team on a successful launch! To learn more about the specifics of the mission, turn to page 4 of this issue.

The GPM Core spacecraft launched on February 27 and *The Earth Observer* has reported on the progress of the mission in our last several issues. On September 4, GPM made its full official data release to the public. This release includes Level-1 and Level-2 orbital data from DPR, GMI, and the partner radiometers. For more information on this release, including a list of the partner radiometers, turn to page 19 of this issue.

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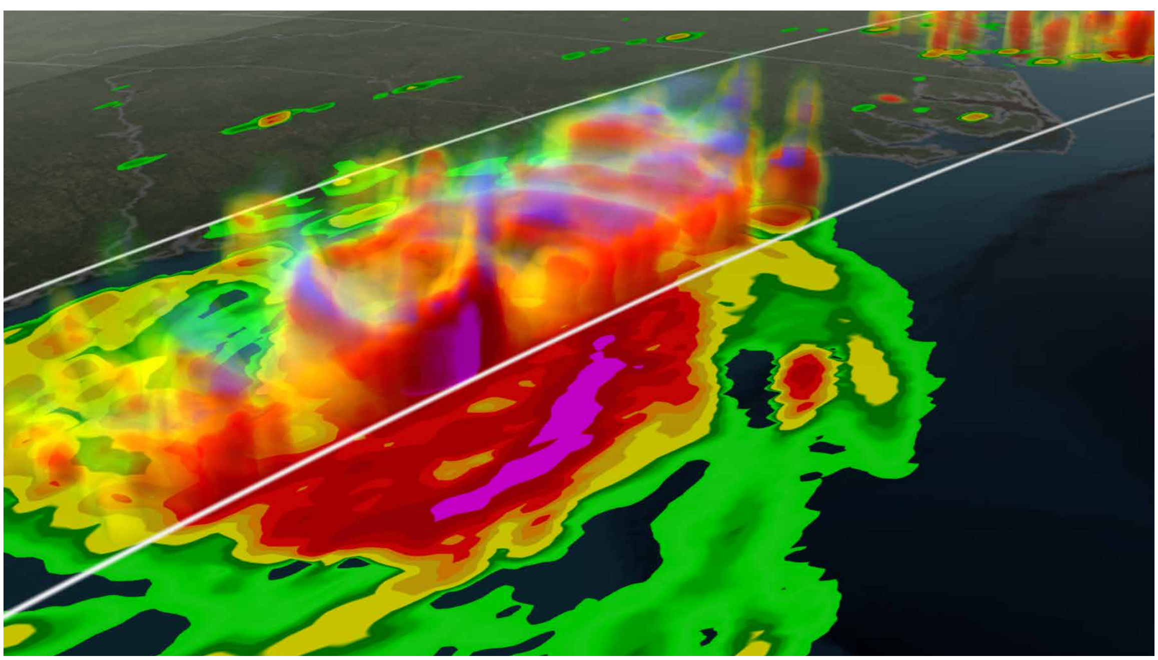

On July 3, 2014, the Global Precipitation Measurement (GPM) Core Observatory observed Hurricane Arthur as it passed off the South Carolina coast. This image combines data from GPM's Dual-frequency Precipitation Radar (DPR) and GPM Microwave Imager (GMI) to produce a three-dimensional view of the storm that helps scientists dissect and study its structure. Violet areas at the tops of the clouds indicate frozen precipitation, while colors ranging from light green to red indicate areas of low to high liquid precipitation. **Image credit:** NASA

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In This Issue

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

GPM's predecessor, TRMM, continues to perform well, providing a valuable intercomparison period while both missions collect data. However, TRMM has been in orbit since 1997 and is almost out of fuel. In July, the TRMM team announced that the spacecraft will no longer perform *drag makeup maneuvers,* so that its remaining fuel can be conserved for potential risk mitigation maneuvers during the descent phase of the mission. TRMM will continue to collect data during the approximately 20-month descent from its current altitude of 395 km to the passivation altitude of 335 km.

Meanwhile, we reported extensively on the July 2 launch of OCO-2 in our July–August issue[1]. Since early August, the spacecraft has been in position at the front of the Afternoon Constellation, or "A-Train," flying in a sun-synchronous orbit that overflies the ground track of the CloudSat radar and CALIPSO lidar and crosses the equator at ~1:36 PM local time. The "first light" spectra from OCO-2 were released on August 6. Since that time, a comprehensive series of instrument and observatory calibration activities have been underway. If all continues as planned, OCO-2 will complete its in-orbit checkout period and begin nominal operations on September 23. The OCO-2 team expects to start delivering calibrated, geo-located spectral radiance products to the GES DISC by the end of this calendar year. The first carbon dioxide (CO_2) products will be available within 90 days of that.

Following on the heels of RapidScat are two more launches planned before February 2015. CATS, the new lidar instrument for ISS, is scheduled to ship to SpaceX at Cape Canaveral on October 1 for integration on the SpaceX-5 Dragon. Following integration, the current launch target is December 9. If that date is achieved, the CATS instrument would be operational just after the New Year. The CATS web page (*cats.gsfc.nasa.gov*) has been updated with new graphics and information.

The SMAP mission is also preparing for launch, which at the moment is scheduled for January 29, 2015 (under review) from Vandenberg Air Force Base (VAFB). The spacecraft is expected to be shipped to VAFB in mid-October for integration on the Delta II launch vehicle, with an Operational Readiness Review planned for early November at NASA/JPL.

The SMAP Science Team has compiled a well-written 180-page *SMAP Handbook* that provides the community with comprehensive information on programmatic, technological, and scientific aspects of the mission. The handbook is available for download at *smap.jpl.nasa.gov/Imperative*. Print copies can be requested by sending an e-mail to *smap_science@jpl.nasa.gov*, with the word "Handbook" on the subject line of the message.

[1] See the Editorial as well as "Orbiting Carbon Observatory-2: Observing CO_2 from Space" in the July–August 2014 issue of *The Earth Observer* [**Volume 26**, **Issue 4**, pp. 1-2, 4-12].

As should be evident from our discussion of RapidScat and CATS, NASA Earth Science fully intends to take advantage of the ISS platform over the next few years. Two other instruments (SAGE-III and LIS) are planned for the space station—both currently scheduled for launch in 2016. In addition the results of the second Earth Venture Instrument (EVI-2) solicitation have been announced. The two winning proposals, chosen from over 20 submissions, are the Global Ecosystem Dynamics Investigation (GEDI) and the Lidar and ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)—both of which will be installed on the space station by 2019.

GEDI will use a laser-based system to study a range of ecosystems. These data will help scientists better understand the changes in natural carbon storage from both human-influenced activities and natural climate variations. Meanwhile, ECOSTRESS will use a high spatial resolution thermal infrared imager to measure plant *evapotranspiration*—the loss of water from leaves and evaporation from the soil. These data will provide a critical link between the water cycle and effectiveness of plant growth—both natural and agricultural. The two instruments will complement each other, giving scientists new ways to understand how ecosystems are affected by changes in climate and land use change.

The principal investigator for GEDI is **Ralph Dubayah** [University of Maryland, College Park]. He will manage a team with extensive experience in observing and modeling forest and vegetation dynamics. The team includes partnerships with NASA's GSFC, Woods Hole Research Center, the U.S. Forest Service, and Brown University.

The principal investigator for ECOSTRESS is **Simon Hook** [NASA/JPL]. Hook has served as project scientist for the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) instrument on Terra and has been involved in numerous sub-orbital field campaigns. The team includes partnerships with the U.S. Department of Agriculture, Princeton University, and University of Idaho.

Congratulations to both the GEDI and ECOSTRESS teams. *The Earth Observer* will report more on both of these missions as they develop[2].

Missions are crucial to Earth science research and applications, but equally important are our modeling efforts. In this issue, we report on the development of aerosol data assimilation methodologies and near-real-time aerosol forecasting systems and how they have significantly accelerated in the last decade, in part inspired by—but also crucially benefitting from—the wealth of aerosol observations available from the Earth Observing System and other satellite measurements. In recognition of the growing number of operational aerosol models, and the desire to develop common practices and compatible aerosol forecast products for both research and applications, there was a community-wide desire for a discussion of best practices and data requirements for aerosol simulations and forecasting. The result has been a series of workshops and the development of the International Cooperative for Aerosol Prediction, or ICAP (*icap.atmos.und.edu*). We invite you to learn more about the development of operational aerosol modeling, ICAP, and the related meetings by turning to the article on page 14 of this issue.

On the outreach front, the Earth Observing System, Science Program Support Office organized and coordinated NASA's Hyperwall presence at the *Our Ocean Conference* hosted by U.S. Secretary of State **John Kerry** in June. Several of NASA's senior-level managers used the Hyperwall to deliver presentations that highlighted NASA's role in studying Earth's ocean from space. The talks were well attended, including appearances by John Kerry and environmental activist and American actor and film producer Leonardo DiCaprio. To learn more about the event and to see photos, turn to page 10 of this issue. ■

[2] To learn more about ECOSTRESS visit *science.nasa.gov/missions/ecostress*; to learn more about GEDI visit *science.nasa.gov/missions/gedi*.

Undefined Acronyms in Editorial and Article Titles)

CALIPSO	Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations
CATS	Cloud–Aerosol Transport System
DPR	Dual-frequency Precipitation Radar
GES DISC	Goddard Earth Sciences Data and Information Services Center
GMI	GPM Microwave Imaging
GSFC	Goddard Space Flight Center
EOS	Earth Observing System
GPM	Global Precipitation Measurement
ISS-RapidScat	International Space Station Rapid Scatterometer
JPL	NASA/Jet Propulsion Laboratory
LIS	Lightning Imaging Sensor
MODIS	Moderate Resolution Imaging Spectroradiometer
OCO-2	Orbiting Carbon Observatory 2
QuikSCAT	Quick Scatterometer
SAGE-III	Stratospheric Aerosol and Gas Experiment III
SMAP	Soil Moisture Active/Passive
TRMM	Tropical Rainfall Measuring Mission

feature articles

ISS-RapidScat: Measuring Ocean Winds from the International Space Station

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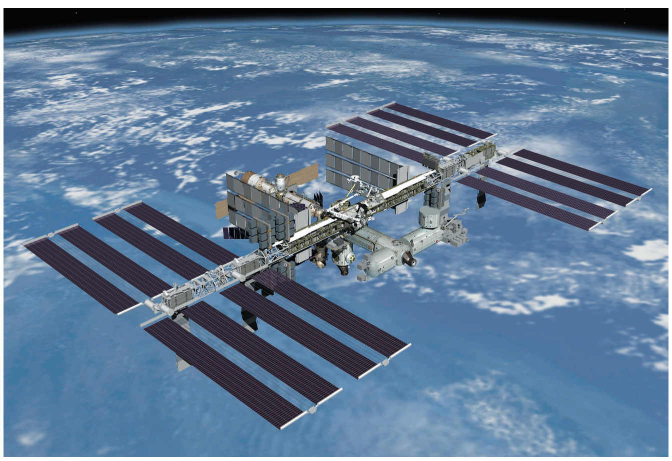
Radar scatterometers are the only remote-sensing instruments that can provide accurate, frequent, high-resolution measurements of ocean-surface wind speed and direction under most weather and cloud conditions.

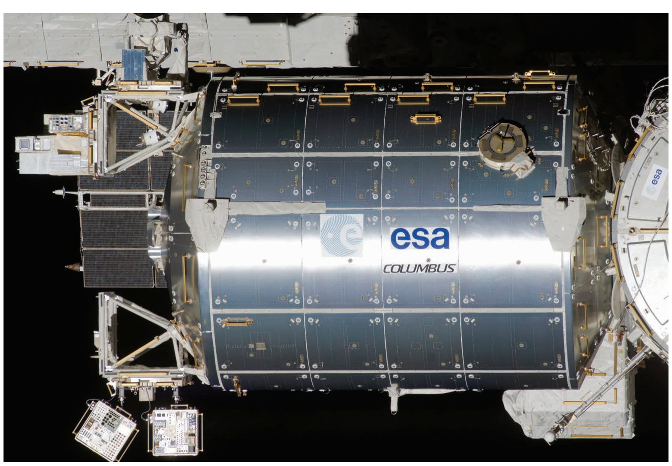
Introduction

NASA and its international partners have used radar scatterometers to measure ocean winds from orbit for several decades—see *History of Scatterometry* on page 5—and scientists have begun to build a continuous, long-term record of this important parameter[1]. That continuity was jeopardized in 2009 when the SeaWinds instrument onboard NASA's Quick Scatterometer (QuikSCAT) satellite malfunctioned, dramatically reducing its scanning capabilities. With no other ocean-wind missions planned for the near future, NASA found itself facing the possibility of a significant gap in the record of this important scientific measurement.

In an effort to mitigate this problem, NASA's International Space Station (ISS) program manager made an offer to a group of scientists and engineers at NASA/Jet Propulsion Laboratory (JPL) in the summer of 2012 that was too good to pass up. If they could have a new scatterometer instrument ready by 2014, it could get a free ride to the ISS onboard a scheduled resupply mission and occupy a vacant berth on the Columbus module for two years—shown in lower photo below.



ISS-RapidScat is the first International Space Station-based Earth-observing science instrument to measure winds. **Image credit:** NASA



The ISS-RapidScat payload will be berthed to the ISS Columbus module—a 7-m (~23-ft) long research laboratory installed in February 2008. **Image credit:** NASA

It was a great offer, but when you consider that most spaceborne missions take many years—if not decades—to prepare, with only two years to put the mission together from start to finish, there was obviously not enough time to design and build a new instrument from scratch. So instead, the engineers made creative use of already available materials: They built the new instrument largely from hardware that had originally been used as an *engineering model*—a copy of an instrument built specifically for testing—for the two SeaWinds instruments that were launched a decade earlier. (Fortuitously, JPL has a track record of doing just this sort of thing—see *History of Scatterometry* for details.) This remarkably fast two-year dash from proposal to launch earned the new radar scatterometer its name: ISS-RapidScat. The RapidScat instrument successfully launched onboard the SpaceX-4 Dragon cargo spacecraft mounted atop a Falcon-9 launch vehicle on Sunday, September 21, 2014 at approximately 1:52 AM EST from Cape Canaveral Air Force Station.

How a Scatterometer Works

Radar scatterometers are the only remote-sensing instruments that can provide accurate, frequent, high-resolution measurements of ocean-surface wind speed and direction under most weather

[1] For climate research, NASA seeks to develop data records that are not only long-term but also continuous. Thus, an interruption in continuity of measurements is something scientists hope to avoid.

continued on page 6

History of Scatterometry

NASA deployed its first scatterometer on Skylab, the first U.S. space station, which flew from 1973 to 1979. That experiment proved that sea-surface winds could be accurately measured from orbit.

NASA's Seasat-A Scatterometry System followed in 1978, operating for three months before its power system failed. Another 18 years would pass before NASA flew another scatterometer in space. But during that time, the European Space Agency (ESA) launched two of its own, both called the ESA Scatterometer (ESCAT)—one on its European Remote Sensing-1 (ERS-1) satellite in 1991, and the other on its ERS-2 satellite in 1995.

The NASA Scatterometer (NSCAT) was launched in 1996 on Japan's first Advanced Earth Observing Satellite (ADEOS I). When the satellite suffered a power-system failure less than a year after launch, NASA needed a quick replacement.

There were already plans for a new scatterometer, SeaWinds, to be launched in 2002 onboard Japan's ADEOS II satellite. However, the premature demise of NSCAT prompted NASA to quickly assemble a second SeaWinds instrument from spare parts for the one intended for ADEOS II, and launch it onboard NASA's Quick Scatterometer (QuikSCAT) satellite in 1999. SeaWinds onboard ADEOS II followed as scheduled in 2002 but, like the first ADEOS, the second satellite failed after less than a year in orbit.

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) followed up in 2006 with two Advanced Scatterometer (ASCAT) instruments on its MetOp-A and MetOp-B satellites.

The SeaWinds instrument onboard QuikSCAT remained fully operational long past the three years the mission was designed to last. But in 2009, the lubricant that coated the antenna's bearings dried up and the radar antenna's spin mechanism failed, preventing the antenna from rotating. Since then, SeaWinds has only been able to observe Earth's surface directly below the instrument. Data from QuikSCAT, however, remain important for calibrating the other orbiting scatterometers.

The Indian Space Research Organization (ISRO) launched its scatterometer, OSCAT, in 2009, which operated until February 2014. China launched the K_u–band Rotating Fan-beam Scatterometer (K_u-RFSCAT) in 2011. This leaves a working constellation of four operational radar scatterometers in orbit: the partially functional SeaWinds onboard QuikSCAT, the two ASCAT instruments, and K_u-RFSCAT. ISS-RapidScat will raise the number to five and, in a sense, bring NASA full-circle as the agency once again flies a scatterometer onboard a space station. Another Indian scatterometer is expected to join the group in 2015.

Key Science Objectives

- ISS-RapidScat will provide ocean vector wind data to scientists and weather forecasters to mitigate the loss of QuikSCAT's SeaWinds data.
- Data from ISS-RapidScat will serve as a calibration standard for the international scatterometer constellation, thereby continuing the SeaWinds data record, and enabling monitoring of climate variability and change over multiple decades.
- ISS-RapidScat will allow scientists to fully sample the diurnal and semidiurnal wind cycles (between 51.6° N and 51.6° S latitude) from space at least once every two months.

and cloud conditions. They do this indirectly, by sensing the wind's effect on the water. As active remote-sensing instruments, they send pulses of microwaves to the ocean surface and measure the intensity of the water-reflected return pulse. In general, stronger return signals represent rougher sea surfaces caused by stronger winds, while weaker return signals indicate smoother surfaces associated with lighter or no winds. Sequential measurements reveal the wind's direction, since waves line up in the direction the wind is blowing.

Instrument Overview

ISS-RapidScat is a pencil-beam, conically scanning radar scatterometer, operating at 13.4 gigahertz. Onboard the space station, ISS-RapidScat will fly in a non-sun-synchronous orbit, which will enable it to sample each location at several different times of day—see *Key Science Objectives* on page 5. It will observe a data swath approximately 900-km- (~552-mi-) wide, covering the majority of Earth's ocean between 51.6° N and 51.6° S latitudes within each 48-hour period, during which it will complete 31 orbits—see **Figure 1**.

This path contrasts with the other scatterometers currently flying, which have sun-synchronous orbits that return them to each location at the same local time of day. The space station's orbit will allow ISS-RapidScat to observe—in aggregate—all points within the above-mentioned latitudes at all times of day over a period of roughly two months—see **Figure 2**. Over a period of two years, this will enable estimation of the diurnal (daily) and semidiurnal (twice daily) wind components from ISS-RapidScat data alone—see *Changes Throughout the Day* on page 8.

Though ISS-RapidScat consists mostly of QuikSCAT engineering-model parts, a new, smaller reflector and digital interface were needed in order to comply with ISS interface requirements. The new antenna is about half the area of the SeaWinds antenna to permit it to rotate without obstruction in its ISS berth, a downgrade that is offset by flying at an altitude ranging from about 375 km (230 mi) to about 435 km (270 mi)—about half the altitude of the other orbiting scatterometers. ISS-RapidScat's accuracy will be about the same as that of SeaWinds onboard QuikSCAT, and combining its data with that of the European Space Agency's Advanced Scatterometer (ASCAT) will produce a *temporal resolution*—the time between measurements at the same place—comparable to that of QuikSCAT.

Mounting ISS-RapidScat on the space station presented its engineering team with some other challenges as well. For one thing, the docking point (where the instrument will be mounted) faces outward toward space, not toward Earth. To compensate, NASA engineers designed a downward-pointing mounting device, called a Nadir Adapter, to enable the

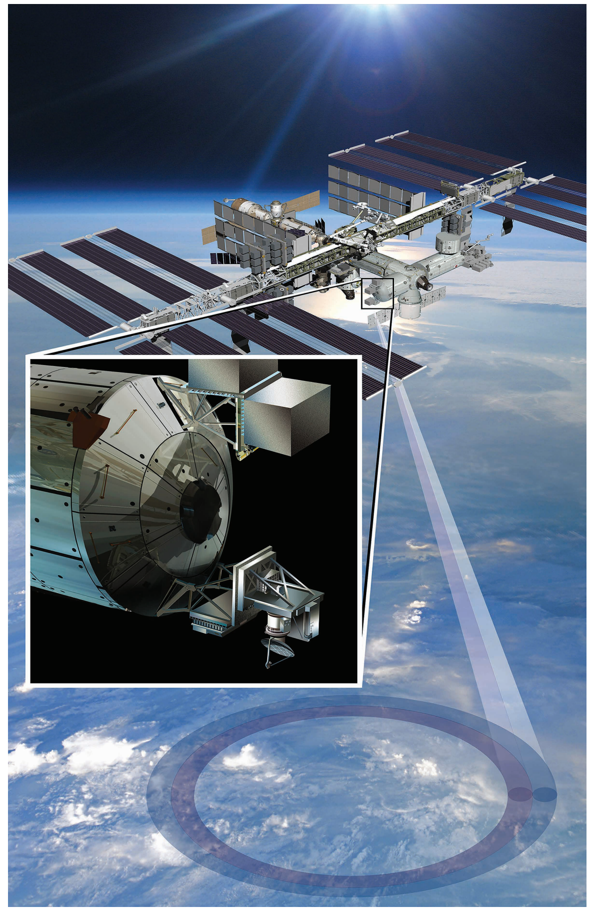


Figure 1. This artist's rendering of NASA's ISS-RapidScat instrument [inset] shows where the payload will be located onboard the ISS, on the end of the station's Columbus module. The conically scanning instrument will collect data across a 900-km- (~552-mi-) wide swath. **Image credit:** NASA/JPL-California Institute of Technology

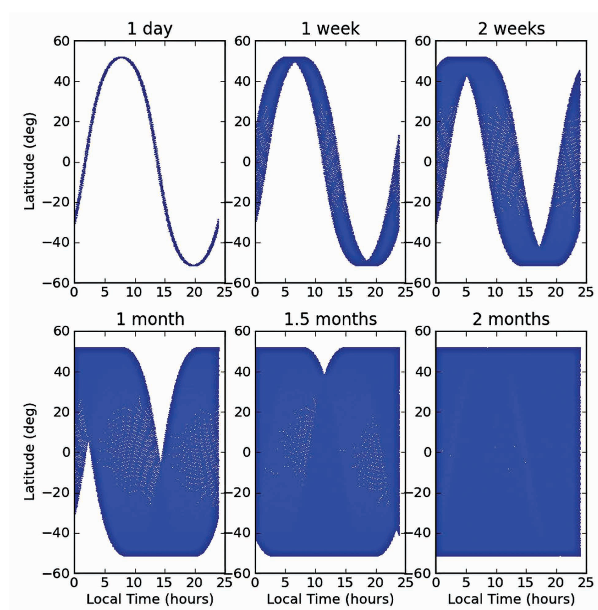


Figure 2. The ISS revisits the same latitude at slightly different local times on each orbit. **Image credit:** NASA/JPL-California Institute of Technology

instrument to view Earth—see **Figure 3**. The adapter also houses new power and digital interface electronics.

Another concern was that one of the space station's docking ports will be within the scatterometer's field of view. To avoid having to turn off the instrument when the docking port is in use, the engineers devised a unique scanning pattern that will avoid the port while still scanning across the vast majority of the instrument's viewing range.

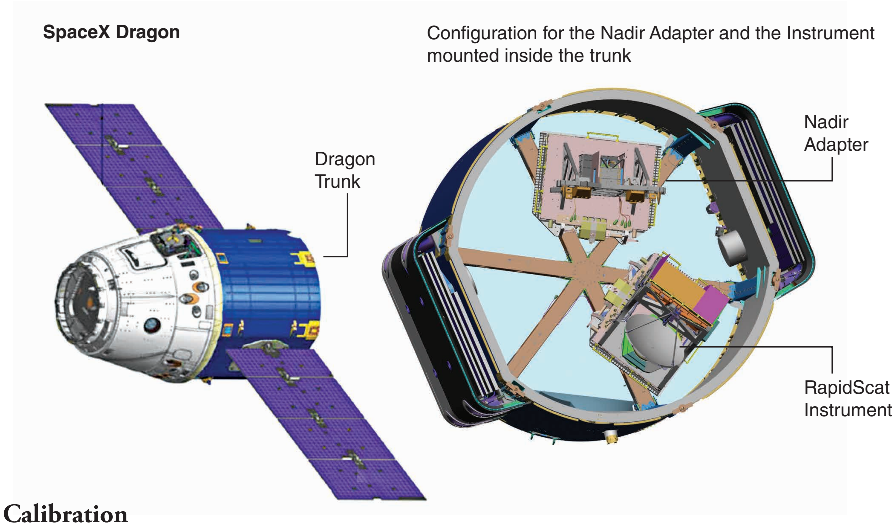


Figure 3. RapidScat was carried to the International Space Station onboard a SpaceX-4 Dragon cargo spacecraft [*shown left*] with the instrument and its Nadir Adapter strategically mounted inside [*shown right*]. Upon arrival, ground controllers at NASA's Johnson Space Center maneuvered the station's Canadarm2 robotic arm to extract both the RapidScat Instrument and the Nadir Adapter from the Dragon Trunk and install them (separately) onto the Columbus Module [shown in bottom photo on page 4]. **Image credit:** SpaceX

Calibration

Instruments need to be calibrated periodically to ensure that they produce accurate and consistent data throughout their lifetimes despite environmental changes, such as fluctuations in electrical power and temperature. Instruments that collect the same kind of data also need to be cross-calibrated with each other so that researchers can combine the different datasets seamlessly. ISS-RapidScat will be used as the "gold standard" to develop bias corrections, thus providing all spaceborne radar scatterometers, current and planned, with a common reference frame. Of particular note is that the resulting data can be used to correct past measurements and validate future observations, thereby creating a consistent, long-term, ocean-wind dataset.

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Scientists can calibrate an orbiting scatterometer by pointing it at a large, homogeneous landmass, such as the Amazon rain forest, and watching for inconsistencies in the resulting data over time. However, photosynthesis and evaporation change the amount of water within plants over the course of a day, leading to variations in the radar backscatter signal. When different instruments observe the same location at different times of day, that variation adds uncertainty to the calibration process.

Over the course of its mission, ISS-RapidScat will pass over the same spot on Earth's surface at all times of day. Therefore, scientists will be able to use its data to create a profile of that location's variability throughout the day, which can assist with the calibration of all spaceborne scatterometers—those that conduct their measurements over land as well as those observing the sea.

Four functioning scatterometers are currently in orbit: SeaWinds onboard QuikSCAT, the two ASCAT instruments on the EUMETSAT MetOp-A and MetOp-B satellites, and China's K_u-RFSCAT. However, there have been limited opportunities to cross-calibrate data from SeaWinds with data from the ASCAT instruments, largely because they do not pass over the same regions of Earth at the same time of day. ISS-RapidScat will sometimes fly over the same place at the same time as each of the currently operating instruments and, as currently planned, the scatterometer that the ISRO intends to launch in 2015. Over time, this will reveal any biases connected with wind speed or underlying geography. In particular, NASA will cross-calibrate data from ISS-RapidScat and SeaWinds on QuikSCAT whenever they share the same targeted regions, helping to alleviate any issues that might arise due to ISS-RapidScat's unique environment on the space station.

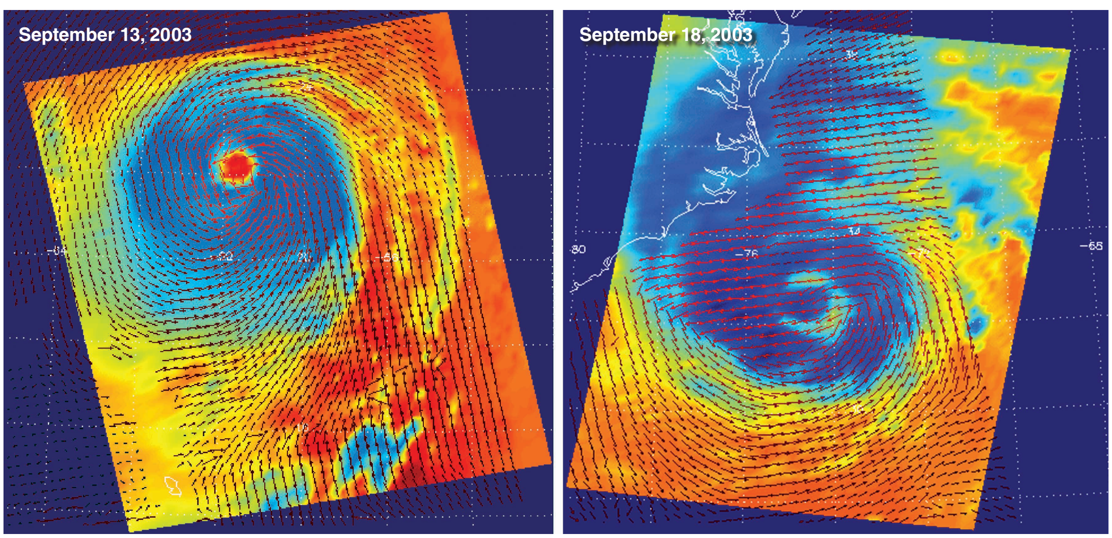
Changes Throughout the Day

In the tropics, sunlight and ocean tides create *diurnal* (daily) and *semidiurnal* (twice daily) cycles in the rise and fall of winds. These wind cycles, in turn, strongly influence the formation of tropical clouds and rain, important components of Earth's water and energy cycles.

To date, all satellite radar scatterometers have flown in sun-synchronous orbits, which means they observe winds over a given location on the ocean only once or twice a day, and at the same local time each day. All the scatterometers flown to date combined have not collected enough observations at enough different times of day for scientists to understand diurnal and semidiurnal wind cycles.

For one, nine-month period in 2003, oceanographers received data from two scatterometers of the same kind: the twin SeaWinds instruments on the QuikSCAT and ADEOS II spacecraft. QuikSCAT crossed the equator at 6:00 AM and at 6:00 PM local time, while ADEOS II crossed the equator at 10:30 AM and 10:30 PM local time, which allowed scientists to make initial estimates of daily wind cycles in some parts of the ocean. During this brief period, however, scientists also realized how difficult it is to cross-calibrate even two such similar instruments and recognized the advantage of having a single instrument in a non-sun-synchronous orbit—like ISS-RapidScat.

Since the space station revisits the same latitude at slightly different local times on each orbit, ISS-RapidScat will allow scientists to fully sample the diurnal and semidiurnal wind cycles from space (between 51.6° N and 51.6° S latitude) for the first time ever, roughly every two months. It is expected that within the planned two-year life of the mission, scientists will be able to estimate these cycles more accurately than if they were relying on data from multiple instruments.



For a brief period in 2003, oceanographers received data from two scatterometers of the same kind. These two images show ocean-surface wind speed and direction (arrows) associated with Hurricane Isabel as viewed by the two SeaWinds scatterometers: one onboard ADEOS-II [*left*] and the other onboard QuikSCAT [*right*]. The wind data from both SeaWinds instruments is overlaid on data that show the temperatures of clouds and the surface, as viewed by the Atmospheric Infrared Sounder (AIRS) onboard NASA's Aqua satellite. The image on the left was taken on September 13, when Isabel was a Category 5 storm. The image on the right shows Isabel near North Carolina on September 18. Dark shades represent cold cloud tops, while light shades represent warm ocean-surface temperatures. **Image credit:** NASA

Measuring the Wind to Understand the Ocean

The ocean covers about 70% of Earth's surface, and understanding the behavior of winds over the ocean is important to a variety of oceanographic, meteorological, climate, public safety, and commercial interests.

Near-surface ocean-wind data are critical to determining short- and long-term weather forecasts, tracking storms, and analyzing long-term climate trends. For example, ocean-wind datasets are expected to help reveal whether the extent of the tropical and subtropical circulation is changing and, if so, how those changes might affect rainfall patterns over the continents. These datasets could also improve our ability to forecast El Niño and La Niña events.

Our ability to monitor hazardous weather events like hurricanes, typhoons, and other storms at sea suffered a major loss when SeaWinds' functionality became curtailed in 2009 and was further exacerbated by the demise of ISRO's OSCAT scatterometer in February 2014. These losses also limited the ability to improve wind atlases, to which SeaWinds on QuikSCAT had contributed. Such atlases are important to sailors who need to plan their routes over the high seas (and to surfers in their quest to catch the perfect wave).

Even the seafood industry has a stake in ISS-RapidScat. Offshore winds blow warm surface waters away from shorelines, permitting cool, nutrient-rich water to well up from the ocean depths, thereby nourishing marine life. So the question of whether the winds that drive ocean upwelling are changing as climate changes is of great importance to the long-term health of fisheries.

The ocean covers about 70% of Earth's surface, and understanding the behavior of winds over the ocean is important to a variety of oceanographic, meteorological, climate, public safety, and commercial interests.

ISS-RapidScat will restore all those capabilities, helping civil agencies plan their responses and enabling ships to reroute their courses, potentially saving lives and many millions of dollars. The National Hurricane Center of the National Oceanic and Atmospheric Administration (NOAA)'s National Weather Service has endorsed ISS-RapidScat as beneficial to its mission, and forecasters at both NOAA and the European Centre for Medium-Range Weather Forecasts eagerly anticipate using data from ISS-RapidScat in their work.

Conclusion

ISS-RapidScat will once again demonstrate the agile reuse of flight-worthy hardware to build a science-class instrument. During its planned two-year mission, ISS-RapidScat will provide data on near-surface ocean winds that will advance our ability to understand and forecast climate changes, enhance our ability to forecast weather and monitor hazardous storms, and contribute to important research on the interplay of winds, oceans, and sea life.

For more information, visit *winds.jpl.nasa.gov/missions/RapidScat*.

Partners

ISS-RapidScat is a partnership between the following organizations:

- NASA/Jet Propulsion Laboratory;
- The International Space Station Program;
- NASA's Science Mission Directorate;
- NASA's Johnson Space Center;
- NASA's Kennedy Space Center;
- NASA's Marshall Space Flight Center; and
- The European Space Agency. ■

NASA Provides a Global View at the *Our Ocean Conference*

Heather Hanson, NASA's Goddard Space Flight Center/Global Science & Technology, Inc., heather.h.hanson@nasa.gov

There were three main conference themes: pollution, acidification, and fisheries. While some Hyperwall presentations discussed these topics directly, many more-generally stressed that from space we can collect the global observations needed to "see" the entire planet every day, or every few days.

The Earth Observing System (EOS) Science Program Support Office (SPSO) organized and coordinated NASA's Hyperwall presence at *Our Ocean Conference 2014,* hosted by U.S. Secretary of State **John Kerry**. The meeting took place at the U.S. Department of State in Washington, DC, June 16-17. To learn more about the event, visit *www.state.gov/e/oes/ocns/opa/2014conf.*

Several senior-level managers from NASA Headquarters (HQ) and Goddard Space Flight Center (GSFC) used the Hyperwall to deliver presentations highlighting NASA's role in studying Earth's ocean from space. The presenters included: **Ellen Stofan** [NASA HQ—*NASA Chief Scientist*], **Michael Freilich** [NASA HQ—*Director of the Earth Science Division*], **Jack Kaye** [NASA HQ—*Associate Director for Research of the Earth Science Division*], **Eric Lindstrom** [NASA HQ—*Program Scientist for the Physical Oceanography Program*], **Paula Bontempi** [NASA HQ—*Program Scientist for the Ocean Biology and Biogeochemistry Program*], **Piers Sellers** [GSFC—*Deputy Director of the Science and Exploration Directorate*], and **Kathy Tedesco** [NASA HQ—*Program Scientist for the Ocean Biology and Biogeochemistry Program*].

There were three main conference themes: *pollution*, *acidification*, and *fisheries*. While some Hyperwall presentations discussed these topics directly, many more-generally stressed that from space we can collect the global observations needed to "see" the entire planet every day, or every few days—see **Photo 1**. They also described how NASA works with international partners using a variety of sensors on satellites to measure ocean temperature, ocean salinity, ocean color, ocean wind speed, ocean surface topography, and sea ice extent, as well as a variety of other measurements that influence these

Photo 1. Jack Kaye discussed the different NASA satellites and sensors currently in orbit that measure ocean characteristics. **Image credit:** NASA

measurements—see **Table**. Global observations of the ocean's physical, chemical, and biological characteristics, coupled with air-, ground-, and ocean-based observations, allow scientists to address a wide range of ocean issues (including the conference's main themes). NASA Hyperwall presentations focused on the global view, environmental change over time, and assessments of how the ocean might change in the future—see **Photos 2-4**, page 12.

For example, while NASA satellites do not track *pollution* directly, ocean circulation patterns largely influence where ocean debris accumulates (e.g., the Great Pacific "garbage patch" in the central North Pacific), and sea surface height and wind (which are measured directly by NASA) determine ocean surface circulation. These measurements are also needed to run three-dimensional ocean models, which are used to track pollution (e.g., oil from spills) at the surface.

NASA Hyperwall presentations focused on the global view, environmental change over time, and assessments of how the ocean might change in the future.

With regard to ocean *acidification*, human activities are causing increased emissions of carbon dioxide (CO_2) into the atmosphere and the ocean is absorbing a significant fraction of this excess, causing CO_2 concentrations in the ocean to increase—which ultimately acidifies the ocean. Presenters explained that the second Orbiting Carbon Observatory (OCO-2), launched July 2, 2014, is the first NASA satellite dedicated to monitoring atmospheric CO_2, and it will do so with greater precision and detail than current satellite instruments. These new data will help scientists understand where CO_2 is being emitted (e.g., from power plants) and removed from the atmosphere (e.g., by the ocean), consequently allowing them to make projections of how Earth's climate might respond to these changes in the future.

On the third theme, thriving ocean *fisheries* ultimately depend on a healthy, balanced ocean. The Hyperwall presentations helped illustrate how Earth-observations by NASA and its partners allow scientists to monitor and assess ocean changes that influence ocean productivity (e.g., El Niño and La Niña), as well as the overall health of our planet. The presentations made it clear that from the tiniest of organisms (e.g., phytoplankton) to large-scale, global ocean temperatures, NASA keeps many "eyes" on our living planet.

Table. Current ocean-related satellite measurements with NASA involvement. Note: This table does not represent all ocean-related measurements, but does represent the most common.

Key Ocean Measurement	Mission(s) and Partner(s)
Sea Surface Temperature	Aqua/MODIS**, AIRS, AMSR-E (Japan) Terra/MODIS Suomi NPP/CrIS and VIIRS (NOAA)
Sea Surface Salinity	Aquarius/SAC-D (Argentina)
Ocean Surface Topography	OSTM/Jason-2 (France)
Near-Surface Winds	QuikSCAT Aqua/AMSR-E (Japan)
Sea Ice	Aqua/MODIS and AMSR-E (Japan) Terra/MODIS Suomi NPP/VIIRS (NOAA) Landsat 7 (USGS) Landsat 8 (USGS)
Ocean Color	Aqua/MODIS Terra/MODIS Suomi NPP/VIIRS (NOAA)

**Undefined Acronyms: MODIS—Moderate Resolution Imaging Spectroradiometer; AIRS—Atmospheric Infrared Sounder; AMSR-E—Advanced Microwave Scanning Radiometer for EOS; Suomi NPP—Suomi National Polar-orbiting Partnership; CrIS—Cross-track Infrared Sounder; VIIRS—Visible Infrared Imaging Radiometer Suite; OSTM—Ocean Surface Topography Mission; QuikSCAT—Quick Scatterometer; and USGS—U. S. Geological Survey.

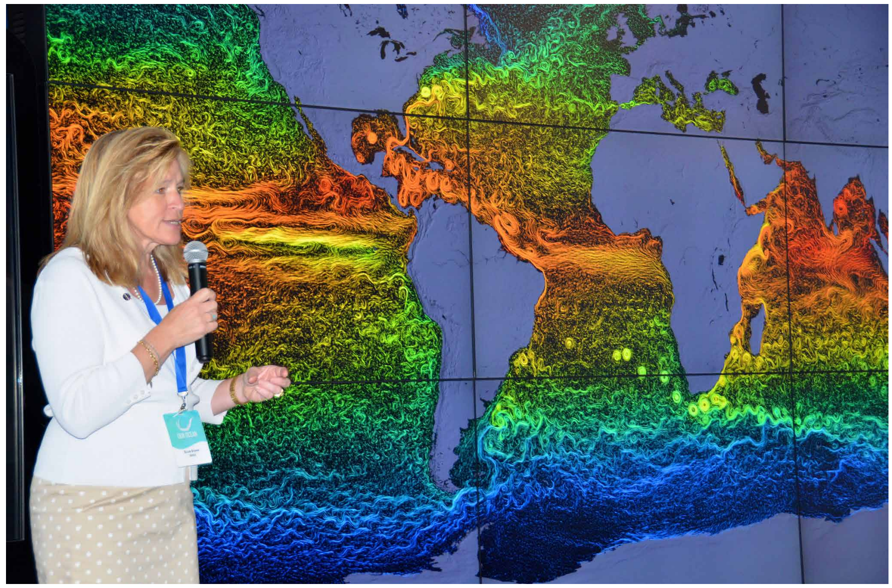


Photo 2. Ellen Stofan described how scientists use model simulations like the one pictured here—produced by the Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project—to help resolve ocean eddies and other narrow-current systems that transport heat and carbon in our ocean. **Image credit:** NASA

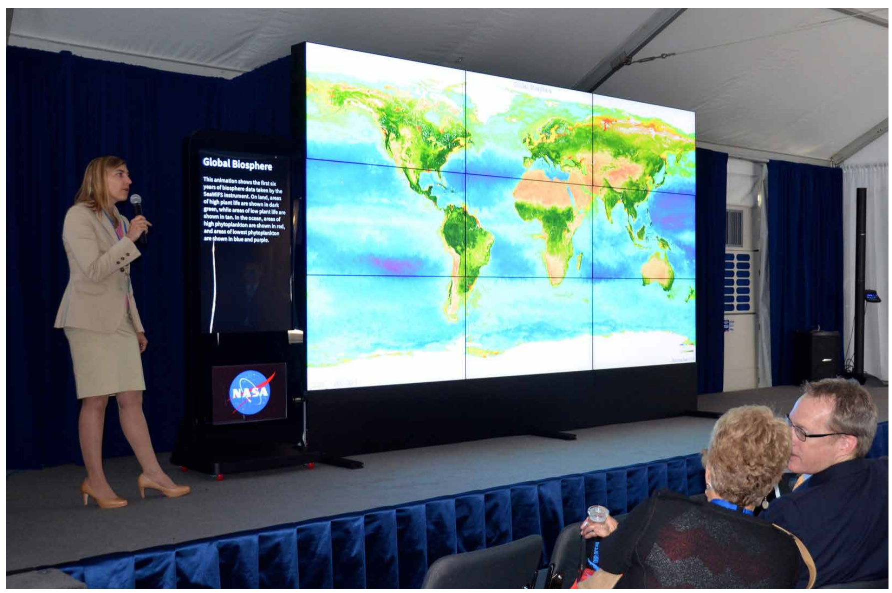


Photo 3. Paula Bontempi showed the first six years of biosphere data taken by NASA's Sea-Viewing Wide-Field-of-View Sensor (SeaWiFS). **Image credit:** NASA

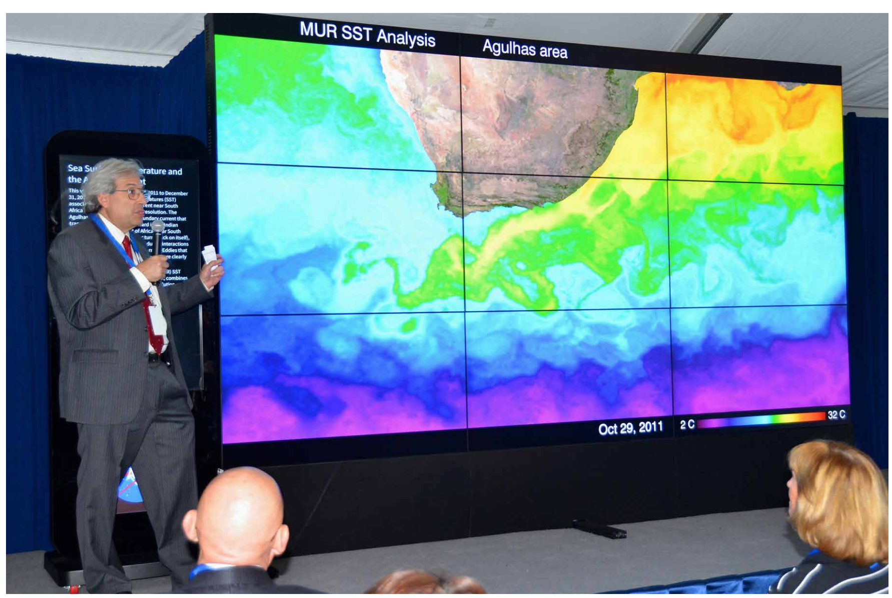


Photo 4. Michael Freilich showed the sea surface temperatures associated with the Agulhas Current near South Africa at 1-km (~0.6-mi) resolution. The Agulhas Current is a western boundary current that transports warm water southward in the Indian Ocean along the west coast of Africa. **Image credit:** NASA

Photo 5. Eric Lindstrom showed U.S. Secretary of State, **John Kerry** how winds near the ocean surface impacted the movement of marine debris associated with the 2011 Japanese tsunami as it moved across the Pacific from March 2011 to July 2012. **Image credit:** NASA

Photo 6. Leonardo DiCaprio asked questions about the visualization showing surface ocean current velocities. **Image credit:** NASA

On day two of the meeting, **John Kerry** and environmental activist and American actor and film producer **Leonardo DiCaprio** visited the Hyperwall—see **Photos 5-6**. **Eric Lindstrom** provided a guided tour of several ocean model results on the Hyperwall, revealing ocean-surface currents, circulation patterns, and how debris from the 2011 Japanese tsunami traveled across the Pacific Ocean. Kerry and DiCaprio were very intrigued by the visualizations, pointing out several features and asking questions.

The two-day meeting provided a wonderful opportunity for NASA to inform policy makers and experts about the agency's role in studying Earth's ocean. To view the collection of photos from the event, visit *www.flickr.com/photos/eospso/sets/72157645231435782*. ■

Using EOS Data to Improve Aerosol Forecasting: The International Cooperative for Aerosol Prediction (ICAP)

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Because aerosol particles can have such wide-ranging impacts, considerable efforts have been made to develop global models that simulate their distributions and properties.

Introduction

Aerosols are airborne particles and droplets so tiny that they can remain suspended in the atmosphere for long periods of time and be transported over long distances—even circumnavigating the globe. Their sources are both natural and man-made, and include windblown dust from deserts, smoke from wildfires, sulfurous particles from volcanic eruptions, and sulfurous and carbonaceous particles produced by fossil fuel combustion. Aerosols affect Earth's climate by reflecting and absorbing incoming solar radiation, and by interacting with clouds and hence changing their radiative properties and dynamics. Near Earth's surface, aerosol particles are pollutants that exacerbate air quality problems. Higher in the atmosphere, aerosols ejected from volcanoes can disrupt air traffic—as the 2010 eruption of the Eyjafjallajökull volcano in Iceland made dramatically clear.

Because aerosol particles can have such wide-ranging impacts, considerable efforts have been made to develop global models that simulate their distributions and properties. Traditionally, these aerosol models have served the climate research community, but increasingly they are taking on a role in operational, near-real-time (NRT) aerosol forecasting and decision-making activities. Applications of these NRT aerosol forecasts include providing background meteorological and chemical analyses to satellite algorithm teams and other researchers; real-time situational awareness for military, research, and civilian flight planning; and air-quality applications.

Aerosol Forecasting: Building on Weather Forecasting

The day-to-day weather forecasts now routinely relied on to make relevant decisions are ultimately drawn from at least one of several operational global-weather forecasting centers—e.g., National Centers for Environmental Prediction (NCEP) in the U.S., and the European Centre for Medium-Range Weather Forecasts (ECMWF). The models used at these centers make predictions by first specifying the initial conditions of the atmosphere at the start of their forecast run, and then propagating that state forward in time using the best available physics with the computational resources available. The initial atmospheric state used in the forecast—or *analysis*—is determined through a process called *data assimilation*, wherein the model state from a previous forecast is optimally combined with the vast number of meteorological observations made by a global network of ground-based weather stations, airborne platforms, weather balloons, and satellites. The model is then "run" forward in time—i.e., it solves the equations of fluid motion and thermodynamics relevant to atmospheric processes—to make a forecast.

Meteorological models such as these have been used operationally for decades, and they are the starting point for most operational aerosol forecasting systems. In the aerosol forecasting system a module treating the physics of aerosols is typically piggybacked onto an existing weather forecasting model—see *How an Aerosol Model Works* on page 15. The final products of either system are thus conceptually similar: In a weather model the products are the forecast temperatures, winds, precipitation, etc.; for an aerosol model the products are the forecast spatial and temporal distributions of the aerosols, as well as information about the aerosol composition (dust, smoke, etc.). For aerosols these products can be presented to the end-user in a variety of ways, such as surface mass concentrations—appropriate for air quality applications, for example—or as optical quantities, like the *aerosol optical depth*—a measure of aerosol-caused sunlight attenuation within an atmospheric column, which is easily comparable to remote-sensing observations.

Assimilating EOS Data into Aerosol Models

Just as data assimilation plays a crucial role in modern weather forecasting, it is also an important ingredient in most aerosol forecasting systems, formally bringing aerosol observations into the model to create an optimal set of initial conditions for the subsequent forecast. Several of NASA's Earth Observing System (EOS) satellite sensors lend themselves to having their data assimilated in operational aerosol forecasting systems. These include measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the Aqua and Terra spacecraft, and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) spacecraft. Of course, for them to be used in NRT aerosol forecasting applications, both the data and a proper characterization of their errors and uncertainties must be available for assimilation shortly after they are acquired.

Several of NASA's Earth Observing System (EOS) satellite sensors lend themselves to having their data assimilated in operational aerosol forecasting systems.

How an Aerosol Model Works

Typically, an aerosol model is a weather forecasting system, like the weather models described in the main text, with an additional component "module" that includes information on the physics of aerosol processes, including their sources and sinks, and representations of their chemical composition and optical properties. The integration of the weather model with an aerosol module allows the system to "solve" for the composition and spatial and temporal distributions of aerosols.

Aerosol models are built with varying degrees of sophistication. The major tropospheric aerosol species that have traditionally been forecast are dust, sea salt, black and organic carbon, and sulfates. More recent models are adding additional species, such as nitrates and secondary organic aerosols. In some systems the aerosol physics is tightly coupled with the underlying weather model—e.g., by allowing the radiative heating of aerosols to feed back on the forecast wind fields—while in other systems such processes are omitted.

Models also vary in the level of detail at which the composition and particle sizes are represented. The simplest models track only the total mass of each component species (e.g., sulfate, dust, etc.). At the other end of the complexity spectrum are models that represent the particle size distribution as a series of size *bins* (or "sections") that each have their own sets of equations. Significant detail is possible in such schemes, including how particles mix together internally and how the particle size distribution evolves as particles *coagulate*—or stick together. This complexity comes at considerable computational expense, however, and cannot easily be verified by the sorts of remote sensing observations discussed in this article. Research is under way to determine what aspects of more sophisticated models should receive highest priority for incorporation into operational aerosol forecasting models.

However, regardless of the level of sophistication of the model, important considerations include the representation of source and sink processes. For International Cooperative for Aerosol Prediction (ICAP) models, dust and sea salt typically have sources that depend on the surface wind speed, with the addition of a prescribed mask for potential dust emission locations. For anthropogenic sources (e.g., power plant emissions), prescribed inventories based on fuel use data are usually included. Biomass burning sources, on the other hand, do not have simple meteorologically based source functions and exhibit considerable day-to-day and interannual variability. A number of researchers involved in ICAP are pioneers in the operational use of satellite observations of fire and fire radiative power to derive appropriate sources for aerosols and precursors in near real-time. For all species, representation of aerosol removal (i.e., sinks) is also included in the models. Gravitational settling is most important for dust and sea salt particles, which are large and fall most rapidly out of the atmosphere, while these and other aerosol species are also removed by wet processes, e.g., scavenging in cloud droplets or washout by precipitation, and by turbulent deposition directly to the surface.

The Rapid Growth of Operational Aerosol Forecasting in the EOS Era

The development of aerosol data assimilation methodologies and NRT aerosol forecasting systems have significantly accelerated in the last decade, in part inspired by—but also crucially benefitting from—the wealth of aerosol observations available from EOS and other satellite measurements. Indeed, all existing quasi-operational aerosol models that assimilate satellite data largely depend on the two MODIS instruments, and there is considerable effort to take advantage of emerging space-based lidar datasets such as those derived from CALIOP, and soon the Atmospheric Lidar (ATLID) on the European Space Agency's (ESA) Earth Clouds, Aerosols, and Radiation Explorer (EarthCARE[1]). The earliest operational systems with assimilation capabilities were developed at the U.S. Naval Research Laboratory (NRL) and ECMWF. At the same time, the NASA Global Modeling and Assimilation Office (GMAO) runs its own quasi-operational aerosol forecast using the Goddard Earth Observing System, Version 5 (GEOS-5) model. Other center developers are developing or producing their own data assimilation programs, including the Japan Meteorological Agency (JMA), the Barcelona Supercomputing Center (BSC) in Spain, the U.K. Meteorological Office (UKMO), and—in a joint effort with NASA—NCEP. As other groups began producing aerosol forecasts, a community of model developers, data providers, and data assimilation experts began to coalesce around the particular problems associated with NRT aerosol forecasting. These diverse groups realized that they have much to learn from one another, and indeed the relatively young enterprise of operational aerosol forecasting itself has much to learn from the decades of assimilation, verification, and observability expertise within the numerical weather prediction (NWP) community.

The development of aerosol data assimilation methodologies and near-real-time aerosol forecasting systems have significantly accelerated in the last decade, in part inspired by—but also crucially benefitting from—the wealth of aerosol observations available from EOS and other satellite measurements.

ICAP—An Operational Aerosol Forecasting Community

In recognition of the growing number of operational aerosol models, and the desire to develop common practices and compatible aerosol forecast products for both research and applications, there was a community-wide desire for a discussion of best practices and data requirements for aerosol simulations and forecasting. A workshop took place in April 2010 in Monterey, CA, to assess future data capabilities and common ground between aerosol forecasting centers and data providers. This group has since become known as the International Cooperative for Aerosol Prediction, or ICAP (*icap.atmos.und.edu*).

The first workshop brought together representatives of the operational and research communities, including a number of operational NWP centers, model developers, and data providers—see **Table** on page 17 for ICAP core modeling centers and contacts. The focus of this workshop was to assess the capabilities and needs of this emerging community as related particularly to issues of aerosol observability—i.e., data product availability, timeliness, and quality. Other discussions focused on the needs for specialized products, multisensor data usage, and forecast skill and verification activities.

The first ICAP workshop in Monterey was a watershed event for this nascent community. It was the first time many of the modeling groups had met in a setting where the agenda focused on the particular problems associated with operational aerosol prediction rather than the technical discussions common at scientific meetings. Bringing the data providers together with the operational centers was another significant accomplishment, as—again—the focus of the workshop was very much geared toward practical issues related to the utility of satellite and other aerosol datasets in an operational setting.

Key to ICAP's success is its organic nature. The meetings are organized by developers. These developers do not officially speak for their agencies, and no binding agreements are made. Rather, discussions lead to community-wide consensus and ideas for future research. Further, meetings inform data providers about how the community perceives

[1] To learn more about EarthCARE, please refer to the summary of the "CALIPSO, CloudSat, and EarthCARE Science Workshop" in the March–April 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 2**, pp. 41-45]. See in particular the *EarthCARE at a Glance* sidebar on p. 45.

Table. ICAP Core Modeling Centers and Contacts

Center	Model	Contact
Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS)	Nonhydrostatic Multiscale Model/Barcelona Supercomputing Center, Chemical Transport Model (NMMB/BSC-CTM)	José Baldasano
European Centre for Medium-Range Weather Forecasts (ECMWF)	Modeling Atmospheric Composition and Climate (MACC)	Angela Benedetti
Fleet Numerical Meteorology and Oceanography Center/Naval Research Laboratory (FNMOC/NRL)	Navy Aerosol Analysis and Prediction System (NAAPS)	Douglas Westphal
Japan Meteorological Agency (JMA)	Model of Aerosol Species in the Global Atmosphere (MASINGAR)	Taichu Tanaka
NASA Global Modeling and Assimilation Office (GMAO)	Goddard Earth Observing System, Version 5 (GEOS-5)	Arlindo da Silva
NOAA National Centers for Environmental Prediction (NCEP)	NCEP Environmental Modeling System/Global Forecast System Aerosol Component (NGAC)	Sarah Lu
U.K. Met Office (UKMO)	Met Office Unified Model (MetUM)	Malcolm Brooks
ICAP Multi Model Ensemble	Combines all models	Jeffrey Reid

their products and provide feedback on how to best market their aerosol products. Ultimately, frequent interaction by ICAP participants also leads to a degree of trust between agencies, a requirement for true cooperation.

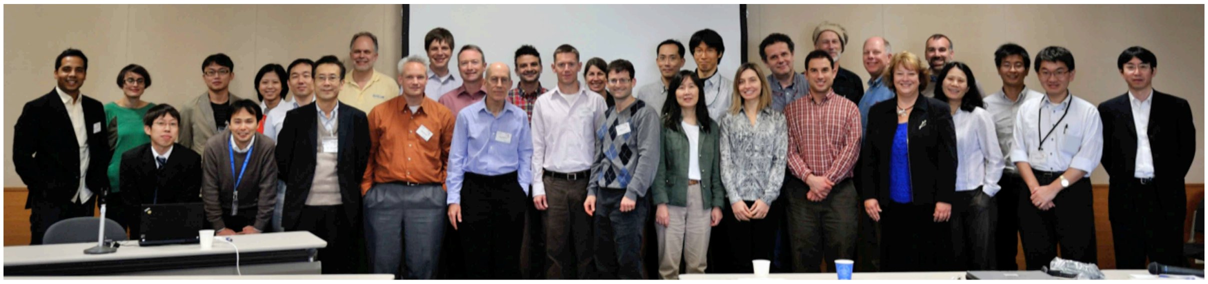
The success of the first ICAP workshop has led to several other workshops. Verification issues were the primary topic at the second workshop, held in the fall of 2010 at Oxford University, U.K. Discussion focused on the availability of suitable independent datasets for model evaluation and useful metrics for "scoring" the success of a forecast. A significant accomplishment at that meeting was an agreement between the various modeling centers to share their products (internally, at first) on a common website so that they could be easily compared—see **Figure** on page 18. This was the first time many of the products from these diverse modeling groups were plotted on the same color scale!

Ultimately, frequent interaction by ICAP participants also leads to a degree of trust between agencies, a requirement for true cooperation.

The third workshop, which took place in the spring of 2011 in Boulder, CO, focused on ensemble forecasting and data assimilation methodology. A result of this meeting was the creation of an ICAP multimodel ensemble—a consensus forecast that is the mean of the individual participating models. Experience has shown that such a consensus product can be the top performer in many verification metrics.

The fourth ICAP workshop was held at ESA's European Space Research Institute in the spring of 2012 in Frascati, Italy, with a focus on aspects of aerosol modeling itself, including representation of source and sink processes.

A fifth workshop was held in Tsukuba City, Japan, in the fall of 2013, with the focus on recent progress in aerosol observability—see photo on page 18. Significant in the fourth and fifth workshops were the presentations of existing and forthcoming satellite products from European, Japanese, and other international partners that will be available to the ICAP community for assimilation and verification activities. These presentations were a two-way exchange, where the needs of the ICAP users (e.g., low-latency of data availability in operational systems) could be communicated back to (and thereby hopefully influence) the data providers.



ICAP participants at a workshop in Tsukuba, Japan, November 2013. **Image credit:** Yuri Tachikawa, JMA

A sixth workshop is currently planned for fall 2014 in Boulder, CO, hosted jointly by NRL and the National Center for Atmospheric Research (NCAR), with a return to the verification topics discussed at the second workshop. The hope is that a set of standard verification protocols and baselines will be developed based on discussion from this gathering.

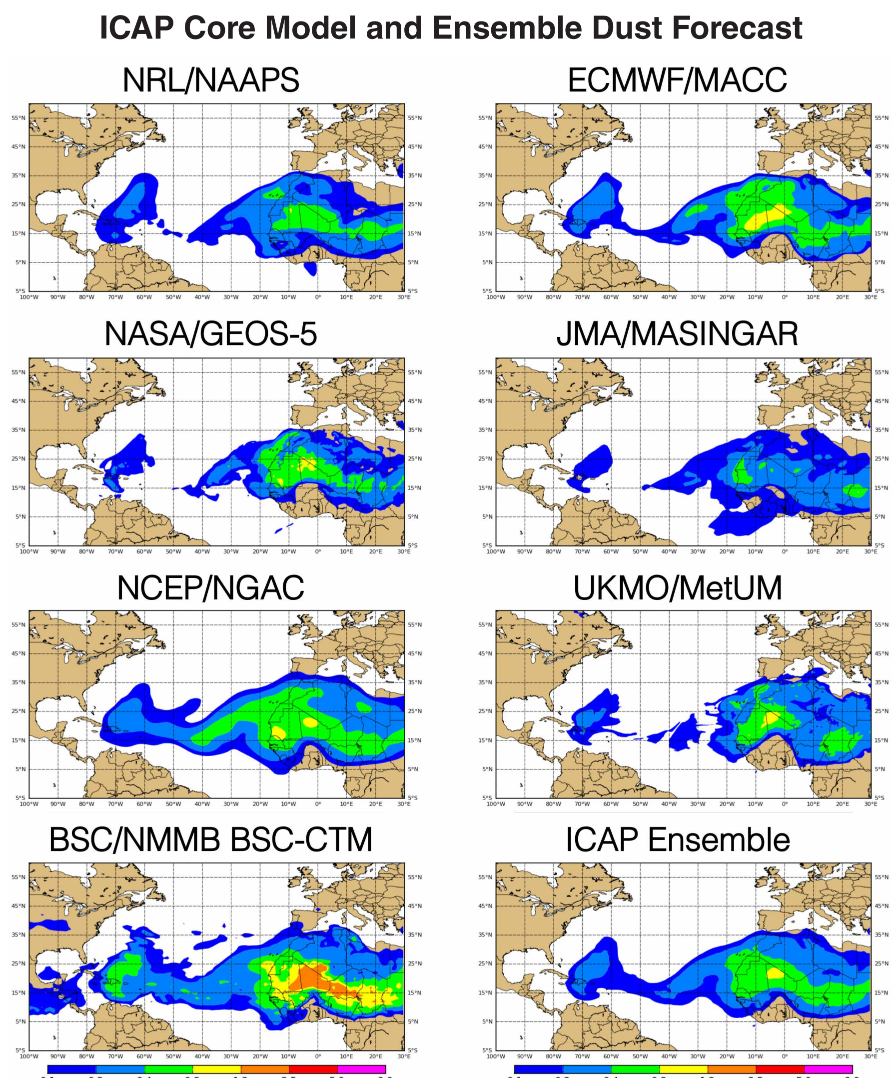


Figure. Shown here are dust forecasts for 6Z August 28, 2014 for each ICAP model (acronyms defined in Table on page 17), as well as the output from the Multi-Model Ensemble (which combines input from all models to produce a forecast). All models were initialized from their own analysis states at 0Z August 28, 2014, so what is shown is the resulting forecast for dust six hours later. The quantity plotted, indicated by the colors, is the model-calculated *aerosol optical depth* (or AOD) at a wavelength of 550 nm, which is a measure of the attenuation of incident sunlight at mid-visible wavelengths, a quantity that can be compared to retrievals made by MODIS or from ground-based sun photometers.

Moving Forward

ICAP remains a fairly young community, with the workshops still small and highly focused. The first two workshops have been documented in *Bulletin of the American Meteorological Society* (BAMS) meeting reports. The first ICAP paper, on the multimodel ensemble, has been submitted for publication and is under review in *Atmospheric Chemistry and Physics* (ACP).

Ultimately, aerosol forecasting will likely parallel the early stages of NWP, and ICAP is positioning itself to take advantage of the best practices from that community. Data standards and baselines need to be developed in a manner consistent with NWP, yet aerosol-specific challenges need to be addressed. Of importance will be the continuing dialog with satellite data developers and providers, including the community-wide encouragement of the development of innovative, timely, and freely available aerosol data products. Given aerosol forecasting's roots in the climate community, ICAP will continue to serve as a bridge between climate science and operational predictions. ■

Ultimately, aerosol forecasting will likely parallel the early stages of NWP, and ICAP is positioning itself to take advantage of the best practices from that community.

Come Explore NASA Science at the 2014 Fall AGU Meeting

Please plan to visit the NASA booth (# 2335) during the American Geophysical Union's (AGU) forty-seventh annual Fall Meeting! This year's exhibit hall will open on Monday, December 15, and will continue through Friday, December 19.

Throughout the week representatives from several different programs and missions are scheduled to give dynamic Hyperwall and Keynote presentations. Presentations will cover a diverse range of research topics, science disciplines, and programs within NASA's Science Mission Directorate, including Earth Science, Planetary Science, Astrophysics, and Heliophysics.

At the booth there will also be a wide range of other science presentations, demonstrations, printed material, and tutorials on various data tools and services.

A daily agenda will be posted on the Earth Observing System Project Science Office website—*eospso.nasa.gov*—in early- to mid-December.

We hope to see you in San Francisco!

A NASA Science presentation using the dynamic Hyperwall display during the 2012 AGU Meeting. **Image credit:** NASA

Level-1 GPM Microwave Imager and Partner Radiometer Data Release

The Goddard Earth Sciences Data and Information Services Center (GES DISC), in coordination with the Global Precipitation Measurement (GPM) mission and its Precipitation Processing System (PPS), is pleased to announce the availability of the GPM Level-1 orbital GPM Microwave Imager (GMI) and Partner Radiometer data from the GES DISC archive. The Level-1 orbital data consist of products from GMI and the partner radiometers: Tropical Rainfall Measuring Mission Microwave Imager (TMI); Advanced Technology Microwave Sounder (ATMS); Microwave Humidity Sounder (MHS); Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR); Advanced Microwave Scanning Radiometer 2 (AMSR2); and Special Sensor Microwave/Imager (SSM/I) series. The GPM GMI is used as the reference standard to ensure consistency among global precipitation retrieval and climate studies.

To learn more and to access the data, visit *disc.sci.gsfc.nasa.gov/datareleases/gpm_gmi_Level_1_data_release*.

MODIS Science Team Meeting Summary

Tassia Owen, NASA's Goddard Space Flight Center, Space Corporation, tasia.owen@nasa.gov

Introduction

Members of the Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team gathered at the Sheraton Columbia Town Center Hotel in Columbia, MD, from April 29-30, 2014. A summary of the two-day meeting is provided here. Full presentations can be found at the MODIS website at *modis.gsfc.nasa.gov/sci_team/meetings/201404/index.php*.

Day One

Paula Bontempi [HQ—*Program Scientist for the Ocean Biology and Biogeochemistry Program*] presented the *NASA Headquarters Update*, giving a brief overview of the current and anticipated budgets, and a broad discussion of current and future Earth science activities at NASA. She devoted much of her presentation to discussing the solicitation for proposals to *The Science of Terra and Aqua*, Appendix A-28 of Research Opportunities in Space and Earth Science (ROSES) 2013[1].

Jack Xiong [NASA's Goddard Space Flight Center (GSFC)] followed with an update on the operating status of the MODIS instruments on Terra and Aqua (hereafter MODIS Terra and MODIS Aqua, respectively). In both cases, the instrument and key onboard calibrators continue to operate nominally. In addition, the MODIS Characterization Support Team (MCST) has undertaken an extensive calibration effort in support of *Collection 6* (C6) and *Collection 5* (C5) Level 1B (L1B) data processing.

Alexei Lyapustin [GSFC] presented work on enhanced calibration of MODIS Collection 6 (C6+) L1B data. The C6+ L1B processing adapted the polarization correction algorithm developed by the Ocean Biology Processing Group (OBPG) and used on MODIS Terra (bands 3, 8-10). The newest version has also introduced *detrending* of MODIS on both Terra and Aqua—meaning that residual decadal trends of several tenths of one percent of reflectance in the visible–near-infrared (IR) band and errors resulting from cross-calibration of the two sensors through gain adjustment of MODIS Terra have been removed. This work was based on the Multi-Angle Implementation of Atmospheric Correction (MAIAC) analysis over Committee on Earth Observing Satellites (CEOS) desert calibration sites. This technique will be transferred to the MODIS calibration group. In addition, the C6+ L1B post-processing code (which includes polarization correction, detrending, and cross-calibration) has been provided to the MODIS Adaptive Processing System (MODAPS).

Kurt Thome [GSFC—*Terra Project Scientist*] summarized the future options for Terra in his presentation, *Terra: Aging Spacecraft and Considerations of Maintaining Mean Local Time (MLT) vs. Maintaining Altitude and Allowing MLT to Drift*. He asked for feedback from the science community to determine the best option for Terra's future to support ongoing scientific research.

Steve Ackerman [University of Wisconsin-Madison] spoke about cloud mask, cloud-top properties, and atmospheric profiles of temperature and water vapor. C6 algorithms, including cloud mask, IR cloud phase, and cloud-top properties (cloud-top temperature and pressure) have been updated and improved. Validation continues and methods of assigning uncertainty are being applied. In addition, science analysis continues through merging MODIS data with those from the High-resolution Infrared Radiation Sounder (HIRS[2]).

Steve Platnick [GSFC—*Earth Observing System Senior Project Scientist*] presented an overview of cloud optical properties and the Atmosphere Team's C6 status. Aqua Level 2 (L2) C6 reprocessing started in December 2013 with all atmosphere team products using updated reaggregated L1B 1-km files. Terra L2 reprocessing is expected to begin during the summer or fall and will use the updated MCST Terra band 5 (1.24 μm) trend artifact correction that is being readied for delivery to MODAPS. Aqua/Terra Level 3 (L3) products continue to be updated and tested, including the "Definition of Day" algorithm. Notable changes in L3 include numerous additional aerosol (*MOD04*), cloud-top (*MOD06*) and cloud optical properties (*MOD06*) statistical datasets, as well as some deletions.

Robert Levy [GSFC] summarized MODIS dark target C6 aerosol products and reviewed plans for *Collection 7* (C7). He reported about the many ways to retrieve aerosol properties from MODIS and the variety of products scientists use in aerosol research. One such product, the Dark-target Product for C6, was updated with modest changes that led to significant improvements in retrieved global aerosol research. Work towards C7 products will include corrections for urban surface bias and developing pixel-level uncertainty products.

Christina Hsu [GSFC—*Suomi National Polar-orbiting Partnership (NPP) Deputy Project Scientist*] presented an update on MODIS C6 *Deep Blue* aerosol products. C6 Deep Blue aerosol products feature improved spatial coverage and retrieval accuracy compared to C5. These improvements are possible because of the enhancements

[1] For more information, visit *cce.nasa.gov/cce/opportunities.htm.*

[2] HIRS onboard the European Organization for the Exploitation of Meteorological Satellites' MetOp-A and -B satellites. The instrument has a long international heritage, having first flown on Nimbus-6 in 1975.

made in the surface reflectance determination scheme and cloud screening as well as the use of thermal IR bands. Planning for the MODIS C7 reprocessing to implement aerosol optical depth (AOD) and aerosol forcing above cloud retrievals into the Deep Blue algorithm has started.

Eric Vermote [GSFC] discussed surface reflectance over land, noting that the surface reflectance algorithm is mature and a pathway forward has been identified. The algorithm is generic and tied to documented validated radiative transfer code, so the accuracy is traceable, thus enabling error budget calculations. In addition, the use of Bidirectional Reflectance Distribution Function (BRDF) correction enables easy cross-comparison of different sensors.

Crystal Schaaf [University of Massachusetts, Boston] reported on the V006 Daily MODIS BRDF, albedo and the Nadir BRDF-Adjusted Reflectance (NBAR) status, reporting an emphasis on quality assurance (QA) and noting improvements from the V005 MODIS product.

Kamel Didan [University of Arizona] summarized the status of the vegetation index product suite and changes in C6, noting, "All is well, with minor issues and anomalies." He also noted that C6 would be different from all previous collections due to the use of precomposited surface reflectance input data. The vegetation index product suite is now fully and independently validated with an average global error of ±5%**.**

Damien Sulla-Menashe and **Josh Gray** [both from Boston University] reported on C6 MODIS land cover and land-cover dynamics, emphasizing changes to the *MCD12* data product. The newest version now incorporates NBAR data and takes into consideration interaction between products where phenology metrics are being used as inputs to land-cover classifications and existing land cover is used to parameterize the phenology algorithm. The result is better performance in croplands, reduced bias, reduced amounts of missing data, and improved QA and control.

Dorothy Hall [GSFC] presented the C6 standard snow and ice product suite in which snow-cover algorithms were improved from C5, and new products such as cloud-gap filled snow maps and snow maps based on surface reflectance will be added. Hall also reported on some applications of C6 products for snowmelt-runoff modeling, and use of the ice-surface temperature product to detect rapid melt of sea ice that contributed to record minimum sea ice extent in the Arctic in 2012.

Simon Hook [NASA/Jet Propulsion Laboratory (JPL)] outlined the applications of land-surface temperature and emissivity products for monitoring drought, climate change, surface energy balance, urban heat islands, and atmospheric profiles. He specifically spoke about the *MOD21* land cover product and its applications compared with the M*OD11* land surface temperature product.

Day Two

Jack Kaye [NASA Headquarters (HQ)—*Associate Director for Research of the Earth Science Division*] opened the second day of the meeting by giving an update on the NASA Earth Science Program, including near-term and long-term prospects. Kaye welcomed general questions and clarifications from the audience.

Louis Giglio [University of Maryland (UMD)] gave a presentation on C6 MODIS fire products. C6 algorithm refinements have been extended to oceans and other large bodies of water, enabling detection of offshore gas flaring. These refinements also increased the ability to detect smaller fires by adjusting potential fire thresholds. In addition, the cloud mask was improved and the fire radiative power (FRP) retrieval was updated.

Ranga Myneni [Boston University] discussed research on the seasonality of Amazon forests, which concluded that wet equatorial Amazon forests do not maintain consistent structure and greenness, and exhibit a distinct light-driven seasonal cycle. His research used MODIS data in conjunction with data from many other instruments.

Charlene DiMiceli [UMD] reflected on Vegetation Continuous Fields (VCF) and the evolution through multiple spatial and temporal resolutions, stressing the value of VCF and the Leaf Area Index (LAI) in order to understand both vertical and horizontal vegetation structure on the land, enabling distinctions to be made between trees, non-tree vegetation, and bare ground, as well as phenology.

Alexei Lyapustin [GSFC] described the latest development of the MAIAC, which is based on both a time series and spatial analysis for deriving water vapor, cloud mask, aerosol optical thickness, normalized difference vegetation index, and surface BRDF and albedo. This algorithm will soon be incorporated into MODIS C6 data processing globally for the first time.

Steve Running [University of Montana] provided an update on the Evapotranspiration (MOD16) and Global Primary Production/Net Primary Production (MOD17) data products.

Compton Tucker [GSFC] summarized 33 years of nonstationary global land photosynthetic capacity observations. He showcased the improvements made in remote sensing from early days of the Television

Infrared Observation Satellite (TIROS[3]) to today's approaches, that are contributing to the Normalized Difference Vegetation Index.

Bryan Franz [GSFC] discussed remote sensing reflectance and derived ocean-color products, covering reprocessing history and current product quality, proposed chlorophyll algorithm refinement, and changes planned for the next reprocessing.

Peter Minnett [University of Miami] summarized MODIS sea-surface temperature (SST) information. MODIS SSTs are stable and accurate, but new algorithmic enhancements continue to improve accuracy—especially toward swath edges. New code is being tested for the next reprocessing cycle.

William Balch [Bigelow Laboratory for Ocean Sciences] reported on particulate inorganic carbon (PIC), noting algorithmic improvements that use cross-platform comparison of PIC and data from Terra's Multiangle Imaging Spectroradiometer (MISR) to detect *coccolithophores*—a specific type of PIC. He noted that PIC is highest at frontal boundaries and highest in January and lowest in March. Algorithm improvements continue to be made and applied to different areas of study.

Jeremy Werdell [GSFC] spoke about marine inherent optical properties (IOPs[4]) that describe the contents of the upper ocean including phytoplankton abundance and community structure, non algal suspended particles, dissolved and particulate carbon, and water clarity. IOPs provide "big picture" views to better understand the ocean's responses to climate change and thus provide useful inputs for biohydrographic models.

Ed Masuoka [GSFC] summarized MODIS Adaptive Processing System (MODAPS) status, discussing forward processing, reprocessing, and data distribution.

Robert Cook [Oak Ridge National Laboratory (ORNL)] discussed citing datasets, in the scientific literature, showing examples from the ORNL Distributed Active Archive Center (DAAC). He outlined the changes for C6, in which NASA's Earth Observing System Data and Information System (EOSDIS) will provide a registered Digital Object Identifier (DOI) for each MODIS product[5]. Cook also suggested that the MODIS Science Team should develop a citation policy for the C6 products.

Gene Feldman [GSFC] presented ocean color production and distribution from the Ocean Biology DAAC. Consolidated ocean color data are available from the ocean color website (*oceancolor.gsfc.nasa.gov*), which is being reorganized. In addition, he noted that the Sea-Viewing Wide Field-of-View Sensor Data Analysis System (SEADAS) is a free, open-source, multisensory processing, image display, and analysis tool that is available for use by the community—*seadas.gsfc.nasa.gov*.

Chris Doescher [U.S. Geological Survey (USGS)] discussed land data distribution from the Land Processes Distributed Active Archive Center (LPDAAC). All four parts of the MODIS Land Products Quality Assurance Tutorial are available from the MODIS Data Products Table webpage (*lpdaac.usgs.gov/products/modis_products_table*). A new Burned Area product (*V051*) has been released while Version 5 Land Cover Type and Land Cover Type Climate Modeling Grid have been decommissioned. The number of files distributed by the LPDAAC continues to increase.

Douglas Fowler [National Snow and Ice Data Center (NSIDC)] showcased the NSIDC's support for MODIS data through improving search tools and meeting increasing distribution demands. The NSIDC and the DAAC are working to make data more available and to assist researchers through tools such as *Worldview* (*earthdata.nasa.gov/labs/worldview*) and *The Drift* (*nsidc.org/the-drift*).

Ed Armstrong [JPL] spoke about sea surface temperature (SST) distribution from the Physical Oceanography DAAC (PO.DAAC, *podaac.jpl.nasa.gov*). MODIS Aqua/Terra SST is one of the prominent SST datasets served by the PO.DAAC and it has been integrated into many tools and web services.

James Acker [GSFC] reported on the research capabilities of *Giovanni*. The Goddard Earth Science Data and Information Services Center (GES DISC) Giovanni system enables simplified visualization of many different Earth remote-sensing and model datasets, along with several basic analytical capabilities. It includes data commonly used for ocean color, SST, aerosol optical depth (AOD), land-surface temperature, and fire pixel count. Giovanni-4 is in development and Version 4.7 has been released (*giovanni.gsfc.nasa.gov/giovanni*). Looking to the future, the Federated Giovanni will allow users to access satellite data from several collaborating DAACs and will facilitate better use of multisatellite datasets.

Conclusion

Both MODIS instruments continue to collect quality data while re-processed data products better enable scientists and researchers to utilize more precise data in their models, research, and applications. As MODIS continues to collect data, the products become more rich and meaningful with the help of the many scientists and researchers, including those who presented at the 2014 MODIS Science Team Meeting. Building on fifteen years of MODIS's rich data history would not be possible without their efforts. ■

[3] TIROS, launched in 1960, was the first successful low-Earth-orbit weather satellite.

[4] Examples include absorption and scattering coefficients.

[5] *The Earth Observer* reported on "Digital Object Identifiers for NASA's Earth Observing System" in its September–October 2012 issue [**Volume 24, Issue 5**, pp. 10-15].

Ozone-Depleting Compound Persists, NASA Research Shows

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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.

NASA research shows Earth's atmosphere contains an unexpectedly large amount of an ozone-depleting compound from an unknown source, decades after the compound was banned worldwide.

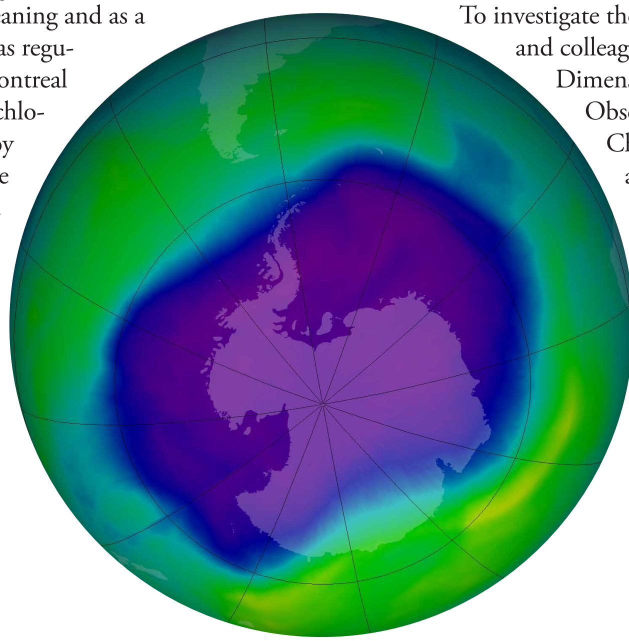
Carbon tetrachloride (CCl_4), which was once used in applications such as dry cleaning and as a fire-extinguishing agent, was regulated in 1987 under the Montreal Protocol along with other chlorofluorocarbons that destroy ozone and contribute to the ozone hole over Antarctica. Parties to the Montreal Protocol reported zero new CCl_4 emissions between 2007 and 2012.

However, the new research shows worldwide emissions of CCl_4 average 39 kilotons per year—approximately 30% of peak emissions prior to the international treaty going into effect.

"We are not supposed to be seeing this at all," said lead author **Qing Liang** [NASA's Goddard Space Flight Center (GSFC)—*Atmospheric Scientist*]. "It is now apparent there are either unidentified industrial leakages, large emissions from contaminated sites, or unknown CCl_4 sources."

As of 2008, CCl_4 accounted for about 11% of chlorine available for ozone depletion, which while not enough to alter the decreasing trend of ozone-depleting substances, is enough to puzzle scientists and regulators, who want to know the source of the unexplained emissions. For almost a decade prior to this study, there has been debate as to why the observed levels of CCl_4 in the atmosphere have declined slower than expectations, which are based on what is known about how the compound is destroyed by solar radiation and other natural processes.

"Is there a physical CCl_4 loss process we don't understand, or are there emission sources that go unreported or are not identified?" Liang said.



New research has revealed that Earth's atmosphere contains an unexpectedly large amount of ozone-depleting carbon tetrachloride (CCl_4) from an unknown source, decades after the compound was banned worldwide. Satellites observed the largest-ever ozone hole over Antarctica in 2006. Purple and blue represent areas of low ozone concentrations in the atmosphere; yellow and red are areas of higher concentrations. **Image credit**: NASA

With zero CCl_4 emissions reported between 2007 and 2012, atmospheric concentrations of the compound should have declined at an expected rate of 4% per year. Observations from the ground showed atmospheric concentrations were only declining by 1% per year.

To investigate the discrepancy, Liang and colleagues used NASA's Three-Dimensional Goddard Earth Observing System (3-D GEOS) Chemistry Climate Model and data from global networks of ground-based observations. The CCl_4 measurements used in the study were made by scientists at the National Oceanic and Atmospheric Administration's (NOAA's) Earth System Research Laboratory and NOAA's Cooperative Institute for Research in Environmental Sciences at the University of Colorado, Boulder.

Model simulations of global atmospheric chemistry and the losses of CCl_4 due to interactions with soil and the oceans pointed to an unidentified ongoing source of CCl_4. The results produced the first quantitative estimate of average global CCl_4 emissions from 2000 to 2012. In addition to unexplained sources of CCl_4, the model results showed that the chemical stays in the atmosphere 40% longer than previously thought.

The research was published online in the August 18 issue of *Geophysical Research Letters*.

"People believe the emissions of ozone-depleting substances have stopped because of the Montreal Protocol," said study co-author **Paul Newman** [GSFC—*Chief Scientist for Atmospheres*]. "Unfortunately, there is still a major source of CCl_4 out in the world."

For information on the Antarctic ozone hole, visit *ozonewatch.gsfc.nasa.gov*. ■

Snow Cover on Arctic Sea Ice Has Thinned 30 to 50 Percent

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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.

New research led by NASA and the University of Washington, Seattle, confirms that springtime snow on sea ice in the Arctic has thinned significantly in the last 50 years—by about a third in the Western Hemisphere and by half near Alaska.

The new study, published in the August 2014 issue of the *Journal of Geophysical Research*, tracks changes in snow depth over decades. It combines data from NASA's Bromide, Ozone, and Mercury Experiment (BROMEX) field campaign, NASA's Operation IceBridge flights, and instrumented buoys and ice floes staffed by Soviet scientists from the 1950s through the 1990s.

"The snow cover is like a shield that can insulate sea ice," said study co-author **Son Nghiem** [NASA/Jet Propulsion Laboratory—*BROMEX Principal Investigator*]. "In this study, we had thousands of measurements of snow depth on sea ice to thoroughly validate NASA's aircraft observations.

The researchers found that, since the Soviet period, the spring snowpack has thinned from 14 to 9 in (36 to 23 cm) in the western Arctic and from 13 to 6 in (33 to 15 cm) in the Beaufort and Chukchi seas, north and west of Alaska, respectively, despite notable uncertainty in the historical estimates. The authors speculate that delayed freezing of the sea surface may contribute to the thinning trend, as heavy snowfalls in September and October now fall onto the open ocean.

What thinner snow cover will mean for sea ice is not certain.

Study co-author **Matthew Sturm** [University of Alaska Fairbanks] takes a snow measurement on sea ice in the Beaufort Sea in March 2012 during the BROMEX field campaign. **Image credit**: U.S. Army Cold Regions Research and Engineering Laboratory

"The delay in sea-ice freeze-up could be changing the way that heat is transported in the Arctic, which would, in turn, affect precipitation patterns. That's going to be a very interesting question in the future," said first author **Melinda Webster** [University of Washington—*Oceanography Graduate Student*].

The research was supported by NASA and the U.S. Interagency Arctic Buoy Program.

For more information, visit *www.washington.edu/news/2014/08/13/snow-has-thinned-on-arctic-sea-ice*.

The full paper is online at *onlinelibrary.wiley.com/doi/10.1002/2014JC009985/abstract*.

For more information about NASA's BROMEX field campaign, visit *airbornescience.jpl.nasa.gov/campaign/bromex*.

For more information about NASA's Operation IceBridge, visit *www.nasa.gov/mission_pages/icebridge/#.VA8M3ksV1MF*. ■

NASA Begins Hurricane Mission with Global Hawk Flight to Cristobal

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NASA's unmanned Global Hawk aircraft landed at NASA's Wallops Flight Facility (WFF) on August 27 after having completed the first science flight of the third year of NASA's Hurricane and Severe Storm Sentinel (HS3) mission. This collaborative effort brings together several NASA centers with federal and university partners in an effort to better understand the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin. The goal is to investigate disturbances before they become depressions to examine how a storm forms. The mission is also looking for conditions that favor (or promote) rapid intensification of tropical cyclones.

Global Hawk 872 (number refers to its tail number) is normally based at NASA's Armstrong Flight Research Center (AFRC[1]), but will be temporarily housed at WFF for the duration of the HS3 mission—which runs through September 29. This timing corresponds to the peak of the Atlantic hurricane season that runs from June 1 through November 30. The aircraft has an 11,000-nautical-mile range and can fly for up to 26 hours, so having the Global Hawk based out of an East Coast NASA location makes accessing Atlantic tropical cyclones much easier and allows more time for science data collection than if it had to fly from the West Coast.

There are three instruments on Global Hawk 872 that are intended to study the environment around the storm. These instruments include the Scanning High-resolution Interferometer Sounder (S-HIS), Advanced Vertical Atmospheric Profiling System (AVAPS)—also known as *dropsondes*[2]—and Cloud Physics Lidar (CPL).

"The instruments are tested and then integrated onto the Global Hawk at Armstrong," said **Marilyn Vasques** [NASA's Ames Research Center (ARC)—*HS3 Project Manager*]. Before the cross-country flight, the ground operations center at WFF tested the various instruments onboard the aircraft while it was still at AFRC. "After integration and outdoor tests we conduct a Combined Systems Test on the ground as well as a test flight near AFRC before the aircraft is ready to transit," explained Vasques. Checking the performance of the instruments over that long distance while they were at a NASA center was critical to ensure they would operate correctly while in flight over Atlantic hurricanes.

The NASA Global Hawk 872 lands at 7:43 AM EDT, August 27, at the Wallops Flight Facility in Virginia following a 22-hour transit flight from its home base at the Armstrong Flight Research Center in California. **Image credit**: NASA/Brea Reeves

The first flight of the 2014 HS3 campaign was into Hurricane Cristobal, which became a hurricane late on August 25 as it was moving through the Bahamas. The Global Hawk departed AFRC on the morning of August 26 and embarked on a "lawnmower" (i.e., back-and-forth) flight pattern over Hurricane Cristobal—see **Figure 1** on page 26—while gathering data using dropsondes and the other instruments onboard. In all, there were 83 dropsondes loaded in the aircraft; two of them

[1] AFRC was formerly known as NASA's Dryden Flight Research Center. The name was changed to honor former astronaut Neil Armstrong. AFRC's Western Aeronautical Test Range has been renamed the Hugh L. Dryden Aeronautical Test Range.

[2] Dropsondes are dropped from the aircraft and measure winds, temperature, pressure, and humidity.

were dropped over the Gulf of Mexico and the other 81 over Cristobal. The Global Hawk arrived at WFF at 7:43 AM EDT on August 27, concluding its 22-hour flight.

Since arriving at WFF, the Global Hawk has flown five missions—including the one described above: It flew a second mission into Cristobal on August 28-29; followed by a flight into Tropical Storm Dolly in the Gulf of Mexico on September 2-3. On September 5-6, the Global Hawk flew to just west of the Cape Verde Islands in the eastern Atlantic to examine a disturbance that had a 10-20% chance of formation but ultimately failed to do so. Most recently, on September 11-12, the aircraft was flown into Tropical Storm Edouard the first of a series of flights in this storm as it made its way across the Atlantic.

Conducting these flights takes very careful planning. "Twice a day we hold weather briefings looking for storms or disturbances that could become tropical cyclones," said **Scott Braun** [NASA's Goddard Space Flight Center—*HS3 Principal Investigator*] who is working at WFF during the mission. "We evaluate the targets in terms of our science objectives and determine which one best addresses those objectives. We factor in stage of the life cycle of the storm, likelihood of formation or intensification, and interaction with the Saharan Air Layer, among other things."

The HS3 mission is funded by NASA Headquarters and overseen by NASA's Earth System Science Pathfinder Program at NASA's Langley Research Center. It is one of five large airborne campaigns operating under the Earth Venture program[3].

HS3 involves collaborations with partners including the National Centers for Environmental Prediction; Naval Postgraduate School; Naval Research Laboratory; the National Oceanic and Atmospheric Administration's Unmanned Aircraft System Program, Hurricane Research Division, and Earth System Research Laboratory; Northrop Grumman Space Technology; National Center for Atmospheric Research; State University of New York at Albany; University of Maryland—Baltimore County; University of Wisconsin; and University of Utah.

For more information about NASA's HS3 mission, visit *www.nasa.gov/hs3*.

For more information about an HS3 dropsonde, visit *www.nasa.gov/content/goddard/what-the-heck-is-a-dropsonde/#*.

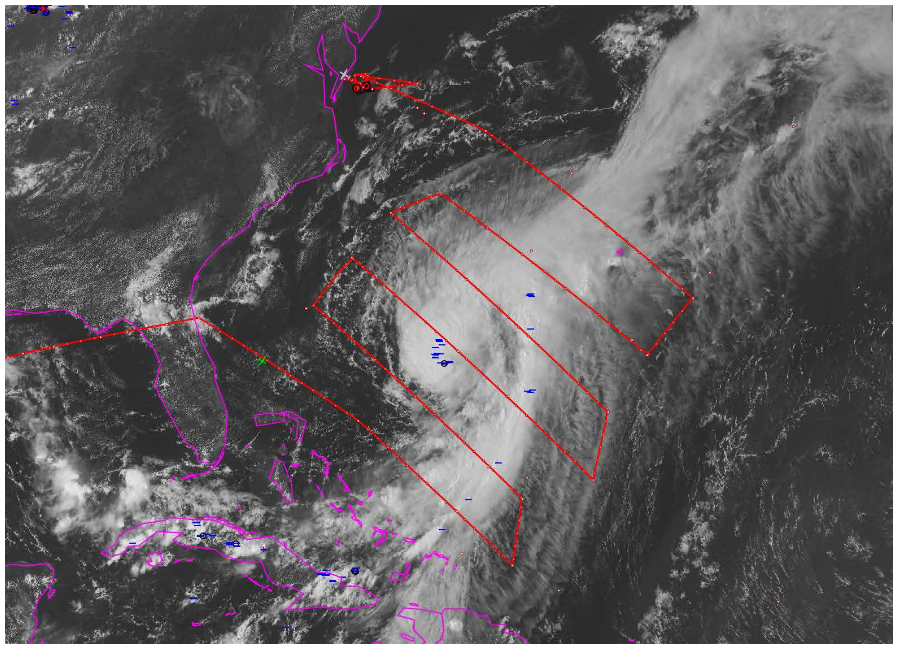

Figure 1. The Global Hawk flew this lawnmower flight pattern for its first flight over Hurricane Cristobal on August 26, 2014. **Image credit**: NASA

UPDATE as of September 12, 2014: A second Global Hawk (number 871) was also scheduled to come to WFF for the HS3 campaign, but experienced major electrical issues, and its participation had to be cancelled. It was to carry three additional instruments that would make measurements of wind and precipitation, as well as atmospheric temperature and humidity in the inner region of the storms: the High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) conically scanning Doppler radar; Hurricane Imaging Radiometer (HIRAD); and High-Altitude Monolithic Microwave Integrated Circuit Sounding Radiometer (HAMSR) microwave sounder. To mitigate the impact of the cancellation of the aircraft, HIWRAP and HIRAD are being moved to the NASA WB-57 for potential flights in the Gulf of Mexico and along the East Coast in late September to mid-October. ■

[3] To learn more about the Earth Venture program, HS3, and the other EVS-1 missions, see "NASA's Venture Continues: An Update on the EVS-1 Investigations" in the July–August 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 4, pp. 4-15**].

Smoke in Yosemite

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EDITOR'S NOTE: This article is taken from *earthobservatory.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.

People come to Yosemite National Park expecting awe-inspiring views and great camping amidst the park's granite peaks and forested lowlands. In September 2014 some visitors got much more than that.

A small wildfire had been burning in Yosemite for weeks before it suddenly quadrupled in size in early September due to strong winds and high temperatures. Park authorities needed helicopters to evacuate dozens of visitors from back-country locations on September 7, 2014, including 85 climbers airlifted from the summit of Half Dome and approximately 100 hikers picked up from campgrounds in Little Yosemite Valley. Several visitors posted photographs of the evacuation to social media sites as they were being ferried away.

On September 4, 2014, the Moderate Resolution Imaging Spectroradiometer (MODIS) captured the image of the Meadow Fire in Little Yosemite Valley shown at the bottom of this page. The photograph on the right was taken by Yosemite National Park staff on September 7, 2014. Half Dome is on the left, with a smoke plume rising from Little Yosemite Valley to its right.

Lightning first ignited the Meadow fire on July 20. For several weeks, park officials let the small, high-altitude 8000 ft (2440 m) blaze burn in order to preserve the park's natural fire patterns and because it posed no threat to public safety, according to *The Los Angeles Times*. Indeed, the fire had burned just 19 acres (ac) [8 hectares (ha)] over the first 49 days.

Then the winds surged on September 7 and the Meadow fire suddenly flared up. By September 8, the fire had charred 2582 ac (1044 ha). Though it is large enough to provoke dramatic photographs from the ground, the fire is small compared to California's largest fires. For comparison, the Happy Camp Complex fire in northern California has burned more than 99,000 ac (~40,000 ha) and was only partly contained as of the same date.

Visit *Worldview* at *earthdata.nasa.gov/data/near-real-time-data/visualization/worldview*—a satellite image-browsing tool maintained by the MODIS Rapid Response Team, to track the fires over time. ■

Image credit: Yosemite National Park

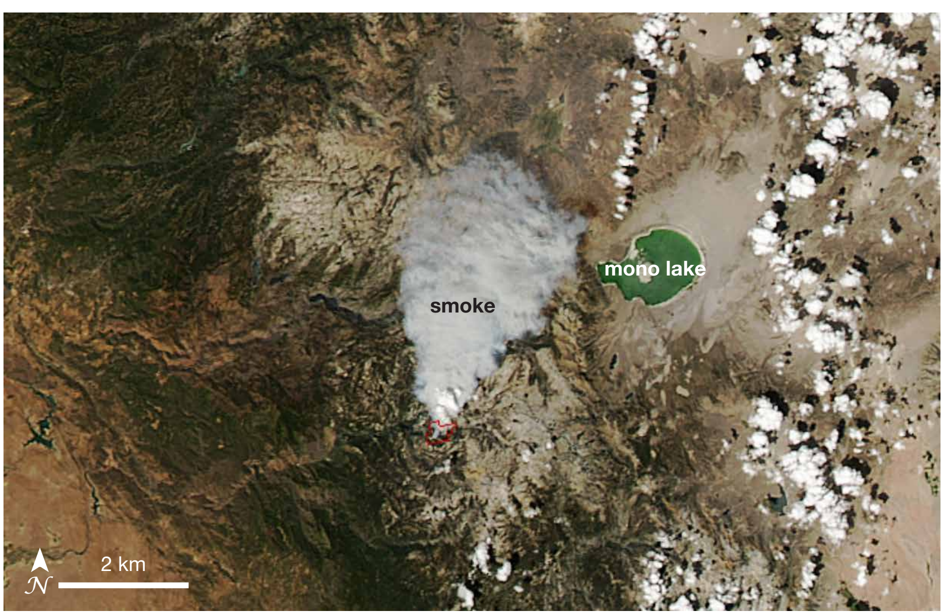


Image credit: NASA/Jeff Schmaltz

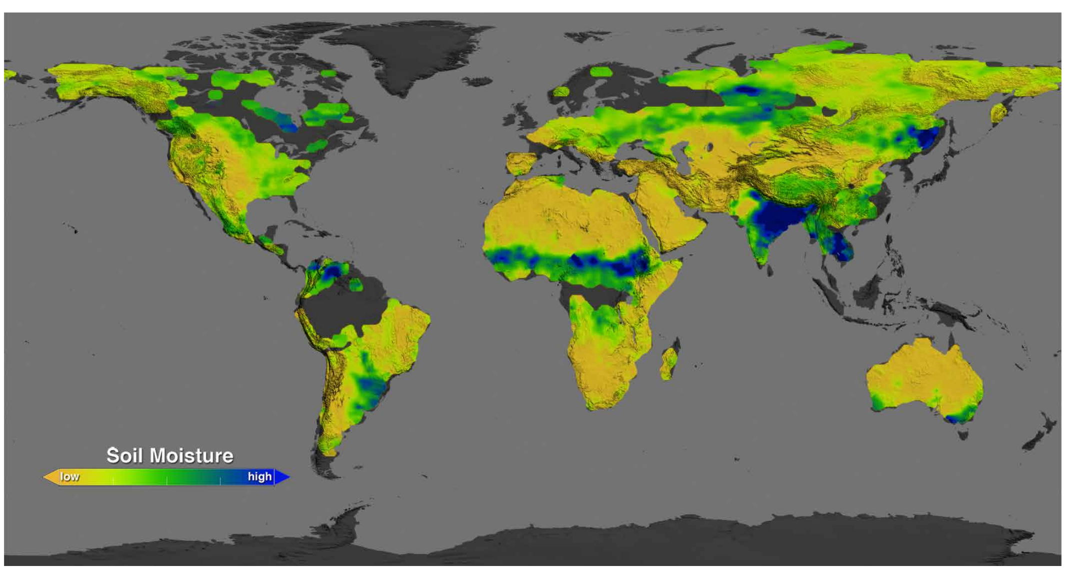
NASA Earth Science in the News

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

Human Activity Has Boosted Plant Growth Globally, NASA Data Show, July 3; *Yale Environment 360.* According to an analysis of three decades of global vegetation greenness data from satellites, the presence of people corresponds to more plant growth on a global scale. More than 20% of global vegetation change can be attributed to human activities, such as agriculture and attendant nitrogen fertilization and irrigation—rather than climate change—researchers reported in the journal *Remote Sensing*. The findings, based on NASA and National Oceanic and Atmospheric Administration (NOAA) satellite data (including data from NASA's Moderate Resolution Imaging Spectroradiometers) suggest that global climate change models, which typically do not consider land use by humans, should take into account the relatively large impact human settlements can have on vegetative cover. For example, from 1981 to 2010 areas with a human footprint saw plant greenness and plant productivity increase by up to 6%, while areas with a minimal human footprint, such as rangelands and wildlands, saw almost no change. This does not mean major cities are getting "greener;" in fact, most of the increases in growth and greenness were seen near villages and rural areas, where agriculture is more intense.

Flood Prediction in...Space? New Model Harnesses NASA Satellite Data, July 7; *NBCNews.com.* Researchers have figured out a new way to predict which rivers are most at risk of dangerous flooding. They determine flood risk by measuring how much water was stored in a river basin months ahead of the spring flood season. "Just like a bucket can only hold so much water, the same concept applies to river basins," said lead study author and Earth scientist **J.T. Reager** [University of California, Irvine]. When the ground is saturated or filled to its brim, conditions are ripe for flooding. Reager and his colleagues looked back in time using satellite data, and measured how much water was soaking into the ground before the 2011 Missouri River floods. The researchers found their statistical model strongly predicted this major flood event five months in advance. With less reliability, the prediction could be extended to 11 months in advance, the researchers said. The researchers relied on NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites to diagnose a region's flood potential. The team used GRACE data to look at all potential terrestrial water sources, including snow, surface water, soil moisture, and groundwater.

Cyclone Spying: 3-D View of Hurricane Arthur Reveals Rain Towers, July 8; *UniverseToday.com.* While 2014's Hurricane Arthur was still an active hurricane, the Global Precipitation Measurement (GPM) Core Observatory flew over the storm and captured its structure in three dimensions—see image on the front cover of this issue. This was a good test of the new satellite, launched in February, which is designed to help NASA track these Atlantic storms with better precision than before. The joint NASA-Japan Aerospace Exploration Agency mission allowed researchers to do better



This image, using data from NASA's Aquarius instrument, shows what the soil moisture conditions around the planet were like in August 2013. Brown shades represent dry areas, blue and green indicate wetter areas. **Image credit:** NASA's Scientific Visualization Studio/T. Schindler forecasting because they could track the precipitation to 1000 ft (300 m) vertically and 3 mi (5 km) horizontally. At this resolution, "Hurricane features pop out more. They're sharper, there's more clarity to the structures," stated hurricane researcher **Scott Braun** [NASA's Goddard Space Flight Center (GSFC)]. "Being able to see the structures more clearly may allow for better determination of the structure of the eye wall and rain bands, thereby providing clues about the likelihood of a storm intensifying or weakening."

Ocean-Watching Satellite Reveals Secrets of Soil, July 13; *LiveScience.com.* A satellite launched to study the salinity of the ocean is also proving helpful in understanding the land. NASA's Aquarius instrument, aboard the Argentinian Satélite de Aplicaciones Científicas (SAC)-D observatory, captured the data used to make soil moisture measurements around the globe—see image on page 28. These soil moisture maps are useful for researchers monitoring soil conditions for agriculture, as well as for those trying to understand the global water cycle. Aquarius-based data show broad regions of aridity in Africa, including the Sahara desert. Australia's interior desert is also clearly visible, with the continent's moisture concentrated along the coasts. In the U.S. and Canada, the dry west contrasts with the relatively wet south and east. Aquarius gathers data on soil moisture by detecting microwaves given off by the top 2 in (5 cm) of soil. Changes in the microwave thermal emission signals indicate different levels of moisture.

NASA Satellites Reveal Shocking Groundwater Loss in Colorado River Basin, July 24; *Associated Press.* Groundwater losses from the Colorado River basin appear massive enough to challenge long-term water supplies for the seven states in the U.S. and parts of Mexico that it serves, according to a new study that used data from NASA's satellites. Researchers from NASA and the University of California, Irvine, say their study—based on data from NASA's twin GRACE satellites—is the first to quantify how much groundwater people in the U.S. West are using during the region's current drought. Since 2004, researchers said, the Colorado River basin—the largest in the Southwest—has lost 53 million acre feet, or 17 trillion gallons, of water. That's enough to supply more than 50 million households for a year, or nearly fill Lake Mead—the nation's largest water reservoir—twice. The study found that three-fourths of those losses could be attributed to depletions in groundwater.

New CO_2 Satellite Sends First Data Back to Earth, August 13; *ClimateCentral.com.* NASA's new carbon dioxide (CO_2)-monitoring satellite just opened its eyes for the first time. Based on the initial data it is sending back to Earth, it appears to have 20/20 vision and scientists will soon have plenty more data to analyze. The satellite, named the Orbiting Carbon Observatory-2 (OCO-2) mission, was launched in July 2014 as part of an effort to better understand how carbon moves around the globe. That includes tracking human emissions from burning fossil fuels as well as natural cycles related to the growing season and ocean currents.

***Ozone-Depleting Compound Remains in our Atmosphere,** August 21; *USA Today.* It's not supposed to be up there—but it is. Our atmosphere "...contains an unexpectedly large amount of an ozone-depleting compound from an unknown source, decades after the compound was banned worldwide," reports a new NASA study. Before its use was banned in 1987 by an international treaty, the compound, carbon tetrachloride (CCl_4), was produced in large quantities to make refrigerants and propellants for aerosol cans, as a solvent for oils, fats, lacquers, varnishes, rubber waxes, resins, and as a dry cleaning agent, according to the U.S. Environmental Protection Agency. "We are not supposed to be seeing this at all," said atmospheric scientist **Qing Liang** [GSFC] and lead author of the study. "Carbon tetrachloride is not a naturally occurring compound," said Liang, "but the recent emissions could be from unknown chemical production processes, such as mixing soap and sodium hypochlorite, or soil releases of CCl_4 from old contaminated dump sites." Though this amount is not enough to halt the decreasing trend of ozone-depleting substances, the study noted that scientists want to know the source(s) of the unexplained emissions.

Front Range Air Pollution Surprises Researchers, August 29; *Associated Press.* Researchers who examined air pollution along northern Colorado's Front Range as part of NASA's Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) campaign were surprised to find out how much harmful ozone and ozone-causing chemicals are drifting into the mountains from urban and rural areas below. Ozone was found in Rocky Mountain National Park, about 60 mi (~96 km) northwest of Denver, CO, said research scientist **James Crawford** [NASA's Langley Research Center—*DISCOVER-AQ Principal Investigator].* "We view Rocky Mountain National Park as a refuge, and to learn there are days when it's not as safe as we think of it as, it's something people should know," Crawford said. Researchers gathered data from aircraft, balloons, and ground stations from the south Denver area to Fort Collins, about 60 mi (~96 km) to the north. The aircraft flights started in mid-July and ran until August 18, 2014. The scientists stressed they were in the very early stages of reviewing the data and were hesitant to offer many specifics.

*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****.*

NASA Science Mission Directorate – Science Education and Public Outreach Update

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Earth Science Week 2014—Earth's Connected Systems

Dates: October 12-18

Join us for an exploration of our dynamic Earth! This year, Earth Science Week celebrates *Earth's Connected Systems*. From land to sea, ice to sky, and everything living in between, NASA's missions study Earth's systems and help us to understand the interconnections among the components. Our 2014 website covers NASA's Earth science missions and how scientists study our home planet, educational resources about Earth's systems, videos, links to mission science information, and more. Stop by to see our schedule of upcoming events for educators and the public at *nasaesw.strategies.org*.

Want the latest information on NASA Earth Science Week activities? Follow us on *Twitter* (@NASAESW) or *Facebook* (*www.facebook.com/NASAESW*).

NASA Postdoctoral Fellowships

Deadline: November 1

The NASA Postdoctoral Program offers scientists and engineers unique opportunities to conduct research in space science, Earth science, aeronautics, exploration systems, lunar science, astrobiology, and astrophysics.

Awards: Annual stipends start at $53,500—with supplements for specific degree fields and high cost-of-living areas. There is an annual travel budget of $8000, a relocation allowance, and financial supplement for health insurance purchased through the program. Approximately 90 fellowships are awarded annually.

Eligibility: An applicant must be a U.S. citizen, lawful permanent resident, or foreign national eligible for J-1 status as a research scholar to apply. Applicants must have completed a Ph.D. or equivalent degree before beginning the fellowship, but may apply while completing the degree requirements. Fellowships are available to recent or senior-level Ph.D. recipients.

Fellowship positions are offered at several NASA centers. To obtain more information and to apply for this exciting opportunity, visit *nasa.orau.org/postdoc*.

Albert Einstein Distinguished Educator Fellowship Program

Deadline: November 20 at 5:00 PM EST

The Albert Einstein Distinguished Educator Fellowship (AEF) Program provides a unique opportunity for accomplished K-12 educators in the fields of science, technology, engineering, and mathematics (STEM) to serve in the national education arena. Fellows spend 11 months working in a federal agency or U.S. congressional office, bringing their extensive classroom knowledge and experience to STEM education program and/or education policy efforts. Program applications for the 2015-2016 Fellowship program must be submitted through an online application system.

For more information about the Fellowship Program, visit *science.energy.gov/wdts/Einstein*.

GLOBE and the Next Generation Science Standards

The Global Learning and Observations to Benefit the Environment (GLOBE) program is a worldwide hands-on, primary and secondary school-based science and educational program. Recently, the GLOBE Community developed "A Guide to Connections between the GLOBE Program and the Next-Generation Science Standards" to support schools, districts, and states in the adoption of the new national science standards. This guide connects GLOBE protocols and resources to the Next-Generation Science Standards Framework, and can be used as a resource for digital curriculum platforms.

To read the document and for more information about GLOBE and Next-Generation Science Standards, visit *www.globe.gov/teaching-and-learning/learning-standards/next-generation-science-standards*.

NASA's Climate Kids: Galleries of Change

NASA's Climate Kids presents eight galleries that show rapidly changing climate conditions on our planet. This visual tool gives individuals the opportunity to explore climate change by highlighting key areas such as weather and climate, fresh water, air, oceans, energy sources, plants and animals, and technology.

For more information, visit *climatekids.nasa.gov/search/gallery*.

SciJinks Web Comic

SciJinks is pleased to announce a new web comic series highlighting the scientific adventures of a varying cast of intrepid weather explorers. Meet Theo, a curious kid with a taste for science hijinks as he is guided by Bill, a serious-minded groundhog and mentor. Check it out at *scijinks.jpl.nasa.gov/comic1*. ■

EOS Science Calendar

October 28–31, 2014
Ocean Surface Topography Science Team Meeting, Lake Constance, Germany.
www.ostst-altimetry-2014.com

November 3–5, 2014
CloudSat/CALIPSO Science Team Meeting, Alexandria, VA.
stm.dpc.cira.colostate.edu

April 20–24, 2015
4th NASA Carbon Cycle & Ecosystems Joint Science Workshop, College Park, MD.
cce.nasa.gov/cce/meetings.htm

April 22–23, 2015
LCLUC Spring Science Team Meeting, College Park, MD.
lcluc.umd.edu/meetings.php?mid=61

Global Change Calendar

October 13–17, 2014
2014 Climate Symposium, Darmstadt, Germany.
www.theclimatesymposium2014.com

October 19–22, 2014
Geological Society of American Annual Meeting, Vancouver, BC, Canada.
community.geosociety.org/gsa2014/home

November 12–19, 2014
World Parks Congress, Sydney, Australia.
worldparkscongress.org

November 13–14, 2014
GEO-XI Plenary, Libreville, Estuaire, Gabon.
climate-l.iisd.org/events/geo-xi

December 1–12, 2014
20th Conference of Parties (COP-20), Lima, Peru.
unfccc.int/meetings/rio_conventions_calendar/items/2659.php?year=2014

December 15–19, 2014
American Geophysical Union Fall Meeting, San Francisco, CA.
meetings.agu.org

January 4–8, 2015
American Meteorological Society Annual Meeting, Phoenix, AZ.
annual.ametsoc.org/2015

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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.

To subscribe to *The Earth Observer*, or to change your mailing address, please call Cindy Trapp at (301) 614-5559, or send a message to *Cynthia.trapp-1@nasa.gov*, or write to the address above. If you would like to stop receiving a hard copy and be notified via email when future issues of *The Earth Observer* are available for download as a PDF, please send an email with the subject **"Go Green"** to *Cynthia.trapp-1@nasa.gov*. Your name and email address will then be added to an electronic distribution list and you will receive a bi-monthly email indicating that the next issue is available for download. If you change your mind, the email notification will provide an option for returning to the printed version.

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