National Aeronautics and Space Administration

The Earth Observer. March - April 2013. Volume 25, Issue 2.

Editor's Corner

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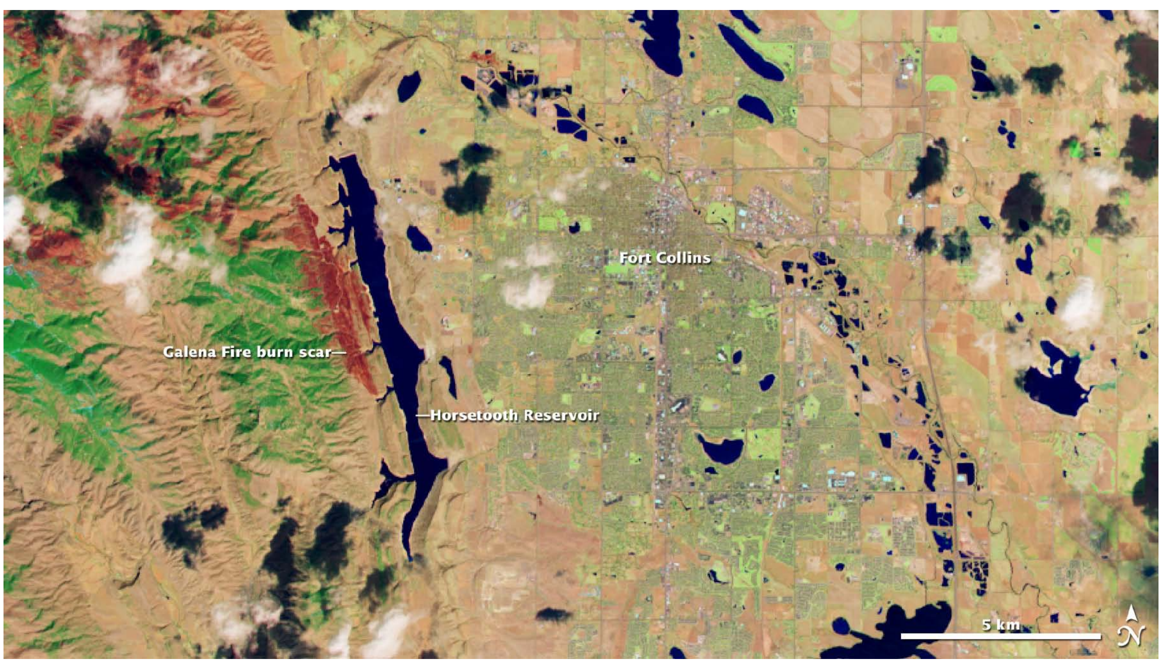
The Landsat Data Continuity Mission (LDCM) spacecraft rocketed into a clear sky on February 11, 2013 at 1:02 PM Eastern Standard Time (10:02 AM Pacific Standard Time) on an Atlas V rocket from Vandenberg Air Force Base in California. The spacecraft separated from the rocket 79 minutes after launch with the first signal received a few minutes later at a ground station in Svalbard, Norway. Recent (early-to-mid-March) activities included two successful ascent burns to raise the orbit closer to the final operational orbit of 438 mi (705 km). The final two ascent burns are planned for April. All spacecraft and instrument systems are currently performing normally. Congratulations to the entire LDCM team!

Landsat satellites have been flying since 1972, imaging the entire Earth's surface once every 16 days. Both NASA and the U.S. Geological Survey jointly manage the Landsat Program. LDCM joins Landsat 7 in orbit,

continued on page 2



On March 18, 2013, the newly launched Landsat Data Continuity Mission (LDCM) began to send back images of Earth from both of its instruments—the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). This view of Fort Collins, CO, is among the satellite's first images. It was created using data from OLI band 3 (green), band 5 (near infrared), and band 7 (short wave infrared). The city appears as a gray grid, speckled with small bodies of water (black). The Horsetooth Reservoir, a source of drinking water, lies west of the city. A red wildfire burn scar from the Galena Fire is visible just to the left of the reservoir.

The Landsat Data Continuity Mission launched on February 11, 2013, to continue the four-decade-long Landsat record of Earth's landscapes. LDCM represents an evolutionary advancement in technology from previous Landsat sensors, collecting more data daily and with greater fidelity. The imagers also include two new bands to improve the view of clouds and near-shore waters. **Credit:** U.S. Geological Survey/NASA/Earth Observatory

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In This Issue

Reminder: To view newsletter images in color, visit: *eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*

and replaces Landsat 5 in the *Morning Constellation*[1]. The LDCM spacecraft is the eighth in the satellite series and soon will be renamed Landsat 8. To learn more about LDCM's technology and performance advances, turn to page 4 of this issue. For further information, including videos of the launch and the upper stage separation from the perspective of the Atlas V *Centaur* Stage-2 rocket, please visit: *www.nasa.gov/landsat*.

We reported previously about the selection of the Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument as the first Earth Venture Instrument (EVI-1) selection[2]. Current plans call for TEMPO to launch in the 2018-19 timeframe, and for it to be the first NASA mission to "hitch a ride" into orbit onboard a commercial satellite. TEMPO will measure the concentrations of many key atmospheric pollutants over most of North America from geostationary orbit, allowing for more frequent observations than those from current pollution-monitoring satellites (e.g., Aura) in low Earth orbit that only obtain a "snapshot" once or twice a day. Europe and Korea plan to launch similar missions in approximately the same timeframe, creating the potential for the creation of a global constellation of geostationary air quality satellites. On page 10 of this issue, we feature an article giving more details about the TEMPO mission.

The Aerosol, Clouds, Ecosystems (ACE) mission, proposed by the 2007 Earth Science Decadal Survey[3], aims to build on the success of the Afternoon Constellation (a.k.a., A-Train[4]) to advance our understanding of clouds and aerosols and their impact on processes and climate. One of the key components of the proposed ACE payload is an advanced *polarimeter*—an instrument that provides unique information about aerosols and clouds relative to non-polarimetric imagers.

The concept of a space borne polarimeter goes back many decades. In fact, the original plans for the Earth Observing System called for a polarimeter—but it was later eliminated[5]. The Centre National d'Études Spatiales (CNES)—French Space Agency—flew the Polarization and Directionality of the Earth's

[1] The January–February 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 1**, p. 1] reported on the end of the Landsat-5 mission.

[2] See the November–December 2012 issue of the Earth Observer [**Volume 24**, **Issue 6**, pp. 2-3] for more on the selection of TEMPO.

[3] NRC, 2007: *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. The National Academies Press. The survey identifies ACE as a *Tier 2* mission.

[4] "A-Train" is the nickname for the *Afternoon Constellation*, a group of Earth-observing satellites operated by NASA and its international partners that closely follow one another along a similar orbital track. For more information, visit: *atrain.nasa.gov/index.php*.

[5] The Earth Observing Scanning Polarimeter was originally envisioned as flying on EOS-A1, then later planned for AM-2. We now know AM-1 as *Terra*; AM-2 was later eliminated. The evolution of EOS has been detailed in previous issues of *The Earth Observer*. A succinct summary appears in **Volume 23**, **Issue 3**, pp. 4-7.

Reflectances (POLDER[6]) instrument on PARASOL as part of the A-Train, as well as earlier missions dating back to 1996. NASA's own polarimeter mission, Glory, unfortunately failed to reach orbit in 2011. ACE polarimeter concepts represent an advancement over those previous mission technologies.

To test design technologies and retrieval capabilities, NASA recently conducted the Polarimeter Definition Experiment (PODEX) in Southern California. Three different polarimeters flew during PODEX: the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI); Research Scanning Polarimeter (RSP); and Passive Aerosol and Cloud Suite (PACS). From January 14 through February 6, instrument teams collected data during ten flights on the ER-2—a high-altitude aircraft (operating at ~65,000 ft) based at NASA's Dryden Aircraft Operations Facility. To learn more about the rationale for PODEX and to read a summary from **David Starr** [NASA's Goddard Space Flight Center—*PODEX Mission Scientist* and *ACE Study Science Lead*] please turn to page 20 of this issue.

In order to develop climate quality records of aerosols, clouds, and precipitation, there is a vital need for the active measurements that began with the A-Train and other missions to continue uninterrupted. Missions such as CloudSat and the CALIPSO[7] have done marvelous work, but both are now well beyond their design life, and with ACE not expected to fly until well into the next decade[8], there is the looming issue of a gap in observations. However, an upcoming joint European Space Agency (ESA)–Japan Aerospace Exploration Agency (JAXA) mission will provide an important partial "data bridge" between the A-Train measurements and ACE.

Selected as an Earth Explorer mission under ESA's Living Planet Programme, and scheduled for launch in 2016, the Earth Cloud, Aerosol, and Radiation Explorer mission (EarthCARE) presents an opportunity for international collaboration to continue using combined active–passive observations that the A-Train pioneered. Unlike CloudSat and CALIPSO, EarthCARE will not be part of a constellation; the passive and active instruments are all on one platform. The planned payload includes a high-spectral-resolution ultraviolet lidar, 94-GHz Doppler cloud radar, a multispectral imager, and a broadband radiometer.

To discuss the possibilities for further cooperation, the Cloudsat, CALIPSO, and EarthCARE (CCE) Science Teams gathered for a joint meeting in Paris, France, June 18-22, 2012. This was an opportunity for the teams to review important new science results obtained using CloudSat and CALIPSO—combined with other A-Train data—in order to better understand the progress on some of today's most pressing Earth science problems. To learn more about results of these discussions please see page 41 of this issue.

With the successful launch of LDCM and this issue's emphasis on future missions, field work, and interagency and international partnerships, it is a good time to reflect on the broad collaborative nature of our endeavors. NASA scientists and engineers, along with colleagues throughout the country and the world are working hard to maintain and preserve current missions and plan for the launch of future ones. There are important conversations taking place in hallways and conference rooms, and experiments taking place in laboratories and in the field, that are paving the way for the development of the next generation of observations. These conversations are not the prevue of any single agency, nation, or discipline; they are broad in scope; occur at the intersection of government, academia, and society; and involve a wide variety of participants.

In closing I wish everyone a Happy Earth Day on April 22. As of this writing, NASA is hoping to team once again with the Earth Day Network to raise awareness about our planet and to highlight various Earth science themes. The Earth Day Network will be organizing exhibits at Union Station in Washington, DC with special activities for all ages on April 6 and April 22. I encourage readers who live in, or will be visiting, the Washington, DC area to participate in these Earth Day activities or participate in activities in your own town. ■

[6] Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL) mission. Launched in 2004, PARASOL is still considered part of the "A-Train," but in December 2009 its orbit was lowered and it only intersects with the other missions occasionally.

[7] CALIPSO stands for the Cloud–Aerosol Lidar Infrared Pathfinders Satellite Observations.

[8] Current projections are that it will not launch until the early 2020s or later.

feature articles

LDCM: Continuing the Landsat Legacy

Heather Hanson, NASA's Goddard Space Flight Center/Wyle, heather.h.hanson@nasa.gov

Through more than 40 years of continuous coverage, the Landsat series of Earth-observation satellites has become a fundamental global reference for scientific issues related to land use and natural resources.

Landsat Science

The Landsat Program—a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey (USGS)—has revolutionized the way humans view and study our planet. The data series, which began in 1972, is the longest continuous record of changes in Earth's surface as seen from space. Up to recently, Landsat has been the only satellite system designed and operated to repeatedly observe the global land surface at moderate resolution.

Landsat's near-polar orbit allows virtually the entire Earth to fall within view once every 16 days, and its 185-km- (115-mi-) wide orbital swaths are broad enough for global coverage every season of the year. With a spatial resolution of 30 m (98 ft), Landsat images are detailed enough to characterize human-scale processes such as urban growth, agricultural irrigation, and deforestation.

Through more than 40 years of continuous coverage, the Landsat series of Earth-observation satellites has become a fundamental global reference for scientific issues related to land use and natural resources. For example, Landsat holds the distinction of being the only satellite record that is both long enough and consistent enough to track land-cover changes related to climate change at the scale of cities and farms. No other civilian satellite program, in our nation or in any other country, comes close to having the historical length and breadth, the continuity, and the coverage of the Landsat archive. The latest Landsat satellite—the eighth in the series—will carry on the Landsat legacy[1] for years to come.

Some of the information presented hereafter has been excerpted from Remote Sensing of Environment 122, James R. Irons [LDCM—*Project Scientist*], John L. Dwyer, and Julia A. Barsi, The next Landsat satellite: The Landsat Data Continuity Mission, 11-21, copyright 2012, doi:10.1016/j.rse.2011.08.026.

Landsat's Newest Satellite

The Landsat Data Continuity Mission (LDCM), a collaboration between NASA and the USGS, hurled into space at 10:02 AM PST (1:02 PM EST) from Vandenberg Air Force Base on February 11, 2013, aboard an Atlas-V *401* rocket. The LDCM spacecraft will be renamed Landsat 8 following a 90-day in-orbit check-out period when USGS assumes responsibility for the satellite operations and data collections.

The system consists of two major segments: the observatory and the ground system. The observatory consists of the spacecraft bus and its payload of two Earth-observing sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI and

[1] To learn more about the Landsat legacy, see the November-December 2011 issue of *The Earth Observer* [**Volume 23, Issue 6,** pp. 4-10].

Key Landsat Characteristics

- Landsat satellites provide an unparalleled record of Earth's varying landscapes.
- Landsat's 30-m (98-ft) resolution—about the size of a baseball diamond—is ideal for measuring both natural changes and human impacts on land.
- The consistency of Landsat's digital image data from sensor-to-sensor and year-to-year makes it possible to trace land-cover changes from 1972 to the present and into the future with LDCM.

TIRS jointly collect data to provide coincident images of the global land surface including coastal regions, polar ice, islands, and the continental areas. In addition, LDCM follows the same sequence of fixed ground tracks (also known as paths) as the Landsat 4, Landsat 5, and Landsat 7 satellites. This allows all of the science data from LDCM to be referenced to the same coordinate system, continuing the decades-long data record.

The spacecraft bus stores the OLI and TIRS data on an onboard solid-state recorder, and then transmits the data to ground-based receiving stations. The ground system provides the capabilities necessary for planning and scheduling the operations of the LDCM observatory and the capabilities necessary to manage and distribute the science data. The LDCM spacecraft, built by Orbital Sciences Corporation, has a design life of five years, but carries sufficient fuel for ten years of operations. The spacecraft orbits from north to south in a Sun-synchronous orbit that crosses the Equator at about 10:00 AM local time, and flies 705 km (438 mi) above Earth.

Landsat sensors enable us to see beyond what our human eyes alone can see, not only because the satellite's perspective on Earth comes from its orbit, but also because the sensors record light reflected and emitted from Earth's surface in specific infrared and visible wavelengths.

Evolutionary Advances in Technology and Performance

Landsat sensors enable us to see beyond what our human eyes alone can see, not only because the satellite's perspective on Earth comes from its orbit, but also because the sensors record light reflected and emitted from Earth's surface in specific infrared (IR) and visible (VIS) wavelengths.

The two science instruments aboard LDCM—OLI and TIRS—represent evolutionary advances in sensor technology and performance. These two instruments measure Earth's surface in the VIS, near infrared (NIR), shortwave-infrared (SWIR), and thermal infrared (TIR), at a moderate resolution between 15 and 100 m (49 and 320 ft), depending on spectral band. The distribution of energy observed across these wavelengths reveals information about Earth's reflecting and emitting surfaces. To make it possible for scientists to compare new Landsat images to Landsat images taken in the past, engineers designed LDCM to take observations in roughly the same spectral bands as previous Landsat satellites. In addition, the OLI provides two new spectral bands—one tailored especially for detecting cirrus clouds, and the other for coastal-zone observations. TIRS collects data in two additional narrow spectral bands in the thermal region, formerly covered by only one wide spectral band on Landsats 4–7, to measure Earth's thermal energy (i.e., heat).

LDCM is required to return 400 scenes per day (150 more scenes per day than required of Landsat 7) to the USGS data archive, increasing the probability of capturing cloud-free scenes for landmass observations, globally.

Operational Land Imager: Advanced Sensor Technology

The OLI advances Landsat sensor technology using an approach demonstrated by the Advanced Land Imager (ALI) sensor flown on NASA's experimental Earth Observing-1 (EO-1) satellite, launched in 2000. Earlier Landsat satellites carried *whiskbroom* sensors that employed scan mirrors to sweep the instrument's field of view across the surface swath width and to transmit light to a few detectors. The OLI, in contrast, is a *pushbroom* sensor that uses long detector arrays, with over 7000 detectors per spectral band, aligned across its focal plane to view across the swath—see *Whiskbroom vs. Pushbroom Sensors* on page 6. This pushbroom design results in a more-sensitive instrument, providing improved land surface information with fewer moving parts. Its images have 15-m (49-ft) panchromatic and 30-m (98-ft) multispectral spatial resolutions (including VIS, NIR, and SWIR) along a 185-km (115-mi) wide swath, covering wide areas of Earth's landscape while providing sufficient resolution to distinguish features like urban centers, farms, forests, and other land cover.

The OLI is designed to have a lifespan of at least five years and will detect the same spectral bands as earlier Landsat instruments [i.e., the Thematic Mapper (TM) and Enhanced Thematic Mapper-Plus (ETM+) sensors] with the exception of a TIR band. In addition to seven heritage Landsat multispectral bands (six of which have been refined), OLI adds two new spectral bands—a blue "coastal" band (band 1) and a SWIR "cirrus" band (band 9)—see **Figure 1**. These new bands will, respectively, help scientists measure water quality and help detect high, thin clouds that have previously been difficult to see in Landsat images.

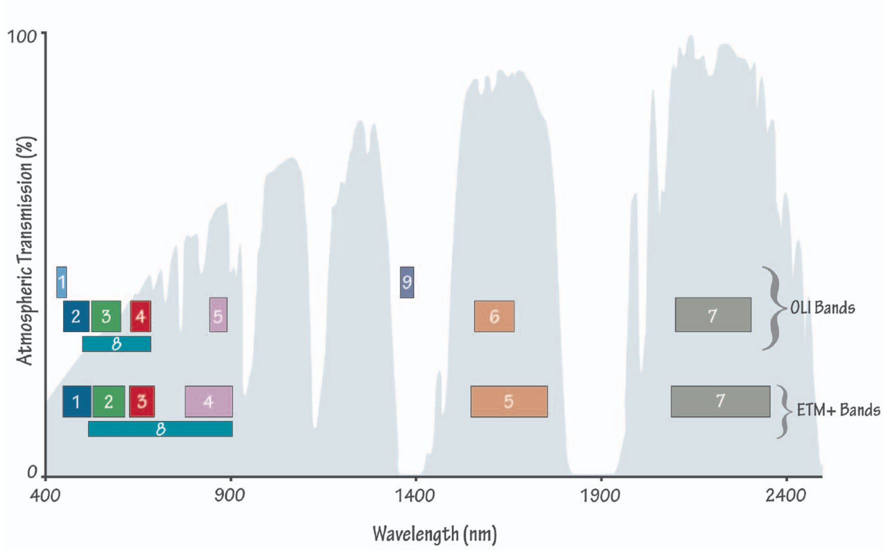
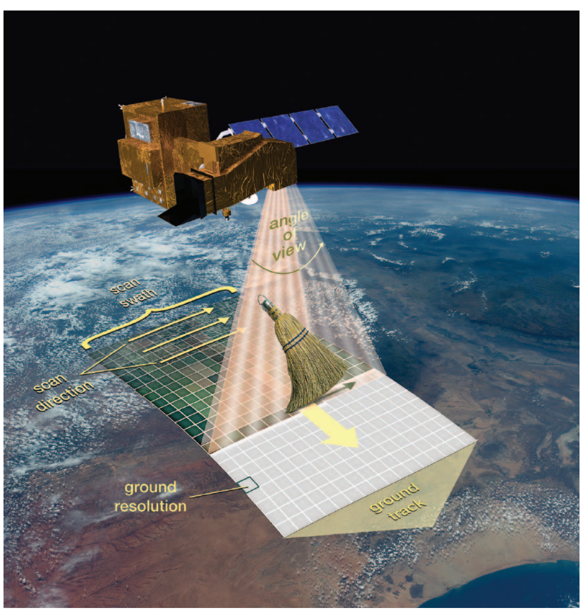


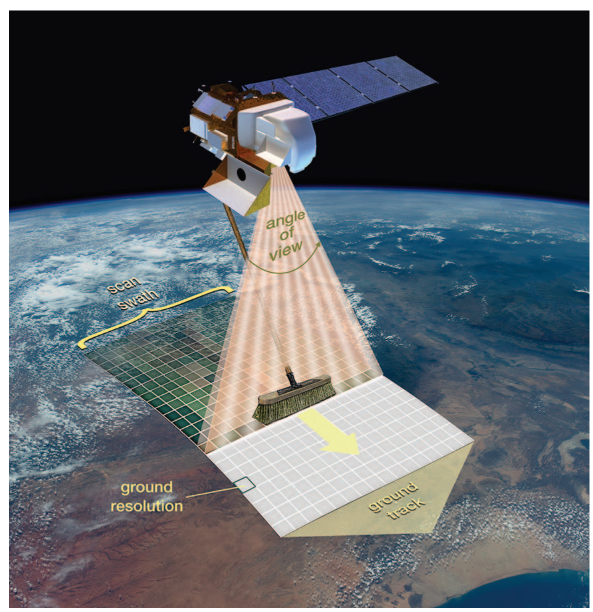
Figure 1. This graph compares the portions of the electromagnetic spectrum that Landsat 7's Enhanced Thematic Mapper-Plus (ETM+) observed [*lower row*] to the parts of the spectrum that LDCM's OLI will observe [*upper row*]. Note that OLI will detect two new spectral bands labeled 1 and 9 in the upper row.

Thermal Infrared Sensor: Thermal Band Detection

Everything on Earth emits TIR radiation—or heat. Physics tells us that the amount of emitted radiation is proportional to the object's temperature. The TIRS was added to the LDCM payload when it became clear that state water resource managers rely on the highly accurate measurements of Earth's thermal energy obtained by LDCM's predecessors—the TM on Landsat 5 and ETM+ on Landsat 7—to track how land and water are being used—see *The Value of TIRS on LDCM*.

Whiskbroom vs. Pushbroom Sensors





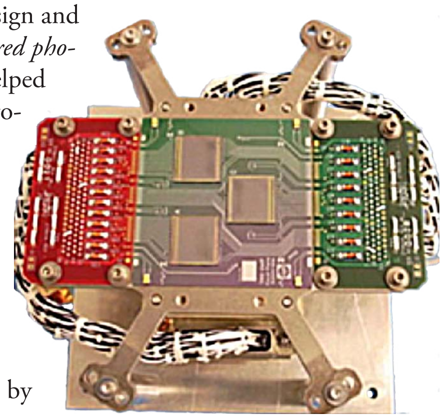
[*Left image*] Previous Landsat sensors (i.e., the Multispectral Scanner System, TM, and ETM+) used mirrors that swept back and forth, across the swath like a *whiskbroom* to collect data. This sensor design requires fast-moving parts, which are subject to wear.

[*Right image*] New technologies allow OLI to view across the entire swath at once, building strips of data like a *pushbroom*. The advantages are that pushbroom sensors require fewer moving parts and are more sensitive than whiskbroom sensors.

The Value of TIRS on LDCM

In the last ten years, a team of scientists working with the Idaho Department of Water Resources developed a method that uses Landsat data to calculate how much water was being used by agricultural fields. They used the TIR band that can measure temperature differences on the surface that correspond to water use by plants. The system, called Mapping EvapoTranspiration at High Resolution and Internalized Calibration (METRIC) uses the thermal data to calculate water use on a field-by-field basis, and is used in some form in eleven states across the Western U.S. When an earlier design of LDCM did not include a TIR band, the Western States Water Council advocated for its inclusion.

The decision, however, came late. Engineers had less than four years to design and build TIRS, so they turned to a new technology called *quantum well infrared photodetectors* (QWIPs) that NASA's Goddard Space Flight Center (GSFC) helped develop. QWIPs are made from material that is compatible with silicon processing, meaning that the same tools that facilities use to make computer chips can be used to build QWIPs. QWIPs are very reliable, uniform, and well-suited to TIRS requirements. The engineers at GSFC knew how to work with QWIPs and willingly took up the challenge to build TIRS in the short time available.



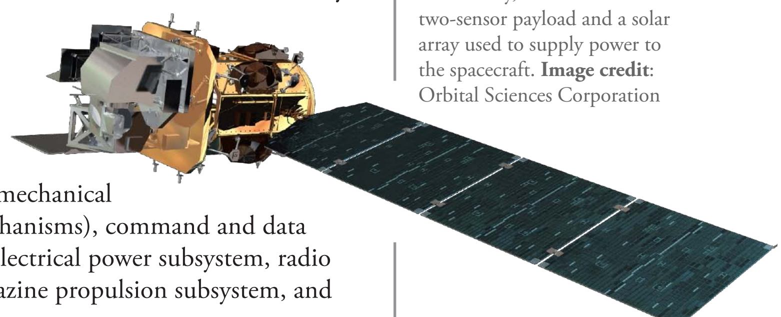
This is a photograph of the TIRS focal plane. The three squares in the center of the circuit board are QWIP arrays (see text), which are gallium arsenide semiconductor chips. Each QWIP array contains 327,680 detectors. **Image credit:** NASA

The QWIPs design operates on the complex principles of quantum mechanics. Gallium arsenide semiconductor chips trap electrons in an energy state "well" until the electrons are elevated to a higher energy state by TIR light of a certain wavelength. The elevated-energy electrons create an electrical signal that can be measured and recorded to create a digital image. Previous Landsat satellites measured land-surface temperature using a single thermal band to detect long wavelengths of light emitted by Earth. The QWIPs on TIRS, however, detect two segments of the TIR spectrum (both falling within an atmospheric transmission window) to produce better estimates of surface temperature than can be retrieved from a single thermal band. These wavelengths are well beyond the range of human vision.

Like OLI, TIRS is also a pushbroom sensor with a 185-km (115-mi) cross-track field-of-view. With a spatial resolution of 100 m (328 ft) across, the TIRS spatial resolution is deemed sufficient for water consumption measurements over fields that use center-pivot irrigation—a technique that is prevalent across the U.S. Great Plains.

A major difference between OLI and TIRS specifications is that TIRS requires only a three-year design life. This relaxation was specified to help expedite the TIRS development. The designers were able to reduce schedule requirement through more-selective redundancy in subsystem components, rather than the more-robust redundancy required for a five-year design life.

Spacecraft Design



This image depicts the LDCM observatory, which includes a two-sensor payload and a solar array used to supply power to the spacecraft. **Image credit**: Orbital Sciences Corporation

The spacecraft supplies power, orbit and attitude control, communications, and data storage for OLI and TIRS. The spacecraft consists of the mechanical subsystem (primary structure and deployable mechanisms), command and data handling subsystem, attitude control subsystem, electrical power subsystem, radio frequency (RF) communications subsystem, hydrazine propulsion subsystem, and thermal control subsystem.

All the components—except for the propulsion module—are mounted on the exterior of the primary structure. A 9.0 x 0.4 m (~29.5 x 1.3 ft) deployable solar array generates power for the spacecraft components and charges the spacecraft's 125 amp-hour nickel-hydrogen ($Ni-H_2$) battery. A 3.14-terabit solid-state data recorder provides data storage aboard the spacecraft; an Earth coverage X-band antenna transmits OLI and TIRS data either in real time or plays back from the data recorder. The OLI and TIRS are mounted on an optical bench at the forward end of the spacecraft.

Strength in Partnership

The fundamental LDCM operations concept is to collect, archive, process, and distribute science data in a manner consistent with the operation of the Landsat 7 satellite system. To that end, NASA and the USGS have well-defined roles and responsibilities to carry out the mission. NASA led the development of the spacecraft and its two-sensor payload, and was responsible for the launch. NASA also leads mission system engineering for the entire system, and therefore is the system integrator responsible for the mission assurance efforts through the in-orbit check-out period. The USGS leads the development of the ground system, and will hold responsibility for LDCM mission operations after completion of the in-orbit check-out period—approximately 90 days after launch. Mission operations include scheduling data collection along with receiving, processing, archiving, and distributing data.

The USGS program management for LDCM falls under the responsibility of the Land Remote Sensing Program within the Climate and Land-Use Change Mission Area. Responsibility for ground-system implementation and LDCM operations is assigned to the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD. EROS maintains the U.S. archive of data from all of the previous Landsat satellites—see the box, *An Invaluable Data Archive.*

An Invaluable Data Archive

The USGS Earth Resources Observation and Science (EROS) Center has carefully maintained the treasured Landsat data archive for over four decades. The archive has well over 3.5 million images of Earth, spanning the history of the Landsat program. New data from Landsat 7 are added daily, as there are regular downlinks from the spacecraft to several ground stations around the globe. In addition, new data constantly arrive from international ground station partners, who send newly acquired data in addition to their historical archives. In April 2008 the USGS announced that all archived Landsat data would be made available to the public for free. In October 2008, Landsat 7 data were made available at no cost, and in December 2008 Landsat 1–5 data were also made available at no cost. Since then, the USGS has experienced over a 100-fold increase in daily downloads (~3,000,000 images per year). In August 2009 the millionth free scene was downloaded. The following August daily downloads from EROS hit three million, and in September 2012 free downloads surpassed nine million.

Free Landsat data, paired with today's powerful computer processing capabilities, have enabled large-scale, global-change studies that in the past were too costly to conduct. The Landsat imaging dataset has led to improvements in human and biodiversity health, energy and water management, urban planning, disaster recovery, and agriculture and forestry monitoring.

Ground System

The LDCM ground system includes all of the ground-based assets needed to operate the observatory. In simple terms, the ground system performs two main functions: it commands and controls the observatory in orbit and manages and distributes the data transmitted from the observatory.

Software commands originating within the LDCM Mission Operations Center (MOC) at GSFC control the observatory. A flight operations team at the MOC operates two computer systems: the Collection Activity Planning Element (CAPE) and the Mission Operations Element (MOE). The CAPE plans science data collection by building activity requests for the LDCM imaging sensors each day, while the MOE translates the activity requests into software commands transmitted to the observatory. The Hammers Company, Inc., of Greenbelt, MD developed the MOE.

The software commands are transmitted to the observatory from the antenna of the LDCM Ground Network Element (GNE). In return, the observatory transmits data back to the GNE. The GNE is composed of three nodes, one located at Gilmore Creek, AK, another at Svalbard, Norway, and the third at Sioux Falls, SD. Each node in the GNE includes a ground station that is capable of receiving LDCM X-band data. Additionally, each station provides complete S-band uplink and downlink capabilities.

Once data are transmitted from the observatory to the GNE, the GNE sends it to the Data Processing and Archive System (DPAS), which is located at the EROS Center in Sioux Falls, SD, via the Internet. The DPAS archives the data and produces the LDCM data products for science and applications, as well as provides a data portal to the user community.

A Growing Data Record for a Growing World

Today, use of Landsat data has evolved: It is not only a fundamental data source for addressing basic science questions, but it also has come into its own as a valuable resource for decision makers in fields such as agriculture, forestry, land use, water resources, and natural resource exploration.

Over the past four decades, Landsat has also played an increasing role in diverse applications such as human population census, monitoring growth of global urbanization, and observing loss of coastal wetlands. As human populations increasingly dominate Earth's land areas, understanding changes in land cover and land use from year to year becomes increasingly important for both decision makers and human occupants of Earth. LDCM's evolutionary advances in technology and performance continue the long legacy of Landsat's invaluable data archive and will provide new perspectives of our planet for years to come.

Resources

eospso.gsfc.nasa.gov/ftp_docs/LDCM_Brochure.pdf

www.nasa.gov/landsat

ldcm.gsfc.nasa.gov

landsat.gsfc.nasa.gov

landsat.usgs.gov

svs.gsfc.nasa.gov/Gallery/Landsat

earthobservatory.nasa.gov

dx.doi.org/10.1016/j.rse.2011.08.026 ■

Q&A with Landsat Science Team Members

Why is the satellite named LDCM when the previous Landsat satellite was named Landsat 7?

LDCM was initially conceived in the late 1990s to be a public/private partnership where the data collected was not tied to a single government-owned satellite. As a result, the mission name focused on the continuity of data from various sources, rather than on a specific satellite. After this approach faltered and various mission implementation approaches were considered, it was determined that LDCM would need to be its own satellite. To be consistent with the naming convention of the other satellites in the Landsat series, the USGS will rename LDCM, Landsat 8 after the spacecraft has been checked-out in orbit—about 90 days after the launch.

Why will LDCM circle the Earth in a polar orbit?

A polar orbit allows the satellite to observe the entire globe from the northern polar region to the southern polar region and at all longitudes. As the satellite moves from pole to pole, orbiting Earth every 99 minutes, the Earth spins underneath the satellite's path, allowing the entire globe to come within view every 16 days.

Has the U.S. committed to continuing the Landsat Program after LDCM?

NASA, the USGS, the Office of Management and Budget, and the Office of Science and Technology Policy are working closely together to identify a good path forward for Landsat 9 and beyond.

NASA Ups the TEMPO on Monitoring Air Pollution

Ernest Hilsenrath, University of Maryland Baltimore County, ADNET Systems, hilsenrath@umbc.edu
Kelly Chance, Smithsonian Astrophysical Observatory, kchance@cfa.harvard.edu

If the projected 2018-2019 launch timeframe holds for TEMPO, its observations should coincide with measurements from Europe's Sentinel-4 spacecraft, planned for launch in 2019, and Korea's Multi-Purpose Geostationary Satellite (MP-GEOSAT), planned for launch in 2018. All three missions will have similar geostationary orbits and similar air quality observation objectives.

Introduction

The National Research Council (NRC) 2007 Decadal Assessment for Earth Science (Decadal Survey[1]) called for Venture class missions that are "...stand-alone using simple, small instruments/spacecraft/launch vehicles." The Assessment further stated that maintaining a steady stream of opportunities for the Earth science community to participate in innovative mission development and implementation is a key to the success of the program. One element of NASA's Venture Class program is the development of principal investigator (PI)-led spaceflight instruments, to be deployed on NASA-selected satellites to address high-value Earth science questions.

The goal for innovation is now being realized as result of the first Earth Venture Class selected Instrument (EVI-1[2]). The instrument is called the Tropospheric Emissions: Monitoring of Pollution (TEMPO), led by **Kelly Chance** [Smithsonian Astrophysical Observatory]. As PI, Chance is responsible for developing an instrument that will measure major air pollutants over Greater North America, from Mexico City to the Canadian tar sands, and from the Atlantic to the Pacific, every daylight hour. The measurements will be taken from geostationary orbit, which will enable continuous data collection over this region. A unique aspect of this mission is that the instrument will be "hosted" by a non-NASA satellite and placed into orbit on a non-NASA launch, most likely co-manifested with a commercial geostationary satellite.

The TEMPO mission builds on the science team's experience with the European Global Ozone Monitoring Experiment (GOME) and Scanning Imaging Absorption Spectrometer for Atmospheric CHartography (SCIAMACHY) missions and with the Ozone Monitoring Instrument (OMI) flying on NASA's Aura spacecraft. All of these missions measure atmospheric pollution from Sun-synchronous, polar orbit. If the projected 2018-2019 launch timeframe holds for TEMPO, its observations should coincide with measurements from Europe's Sentinel-4, planned for launch in 2019, and Korea's Multi-Purpose Geostationary Satellite (MP-GEOSAT[3]), planned for launch in 2018. All three missions will have similar geostationary orbits and similar air quality observation objectives. The three satellites will comprise a constellation for observing continental air quality and estimating transcontinental transport of pollution across the Atlantic and Pacific oceans.

TEMPO provides part of the urgently needed GEOstationary Coastal and Air Pollution Events (GEO-CAPE) atmospheric measurement[4]. In addition, TEMPO will demonstrate the use of commercially hosted payloads (described in more detail below) to accomplish NASA Earth science objectives to enable affordable earlier implementation of components of the full GEO-CAPE mission. TEMPO thus fulfills the NRC's 2012 Midterm Assessment of NASA's Implementation of the Decadal Survey, which

[1] NRC, 2007: *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.* The National Academies Press.
[2] Venture Class missions were defined in the 2007 Decadal Survey. EVI is one of three different categories of Venture Class proposals. The program was detailed in the September–October 2010 issue of *The Earth Observer* [**Volume 22**, **Issue 5**, pp. 13-18].
[3] MP-GEOSAT will involve three Korean agencies: the Korean Aerospace Research Institute (KARI,) the Korean Ocean Research and Development Institute (KORDI,) and the National Institute of Environmental Research (NIER.)
[4] The Decadal Survey proposes the Geo-CAPE mission as *Tier II* (lower) priority. This mission would provide measurements of key components of air quality and their short-term evolution, along with climate-forcing gases. In addition, it would obtain simultaneous measurements of key water quality, ocean chemistry, and ecological indicators in coastal waters, including their response to environmental change. The recommendation was to make these measurements from a dedicated platform in geostationary orbit. The launch would not occur until after 2020.

states that "The Earth Venture-class program has the added value of enabling individual university principal investigator-type missions to pursue specific science questions," and that overall, "...the program is being well implemented and is a crucial component of the Decadal Survey's objectives[5]."

The Principal Investigator is responsible for the instrument development and end-to-end data processing after Level 0 data are delivered to the Smithsonian Astrophysical Observatory. This responsibility includes data calibration, validation, and archiving at NASA. The TEMPO Science Team includes members from NASA's Langley Research Center (LaRC) and Goddard Space Flight Center (GSFC), National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), National Center for Atmospheric Research (NCAR), and a number of universities. LaRC manages the TEMPO Project. Ball Aerospace & Technologies Corporation will build, test, and calibrate the spaceborne ultraviolet (UV)/visible (VIS) spectrometer that operates in wavelengths sensitive to various atmospheric pollutants.

TEMPO thus fulfills the NRC's 2012 Midterm Assessment of NASA's Implementation of the Decadal Survey, which states that "The Earth Venture-class program has the added value of enabling individual university principal investigator-type missions to pursue specific science questions," and that overall, "...the program is being well implemented and is a crucial component of the Decadal Survey's objectives."

Science Objectives

The TEMPO science objectives result from many years of experience with requirements developed by the air quality community, using observations of pollution from Sun-synchronous, polar orbits. TEMPO's advanced capabilities over heritage instruments are designed to answer the following science questions:

- What are the temporal and spatial variations of emissions of gases and aerosols important for air quality and climate?
- How do physical, chemical, and dynamical processes determine tropospheric composition and air quality over spatial scales ranging from urban to continental, and temporally from diurnal to seasonal?
- How does air pollution drive climate forcing, and how does climate change affect air quality on a continental scale?
- How can observations from space improve air quality forecasts and assessments for societal benefit?
- How does intercontinental pollution transport affect air quality?
- How do *episodic events* (e.g., wild fires, dust outbreaks, and volcanic eruptions) affect atmospheric composition and air quality?

Each of these questions has been explored from polar orbit using data from OMI onboard Aura, SCIAMACHY on the European Space Agency's (ESA) Envisat, and the GOME instruments flown on ESA and European Organization for the Exploitation of Meteorological Satellites (Eumetsat) missions. These instruments have surveyed key atmospheric constituents that relate to air pollution and quality and include tropospheric and stratospheric ozone (O_3), which in the troposphere is a pollutant and a greenhouse gas; sulfur dioxide (SO_2); formaldehyde (H_2CO); nitrogen dioxide (NO_2); glyoxal ($C_2H_2O_2$); water vapor; cloud properties; aerosol characteristics, including aerosol optical depth (AOD); and UV-B radiation. TEMPO will also measure the same atmospheric constituents, but from geostationary orbit, thereby allowing better spatial and temporal resolutions.

The heritage satellite data have revealed how air quality changes from day-to-day and year-to-year. They have shown improvements in air quality over North America because of regulation of power plant and automobile emissions, and also have tracked recent severe pollution events originating over urban locations from Asia to North America. These observations have more recently shown the degradation of air quality with high amounts of pollution over the Canadian tar-sand oil excavation fields. An example of

[5] NRC, 2012, *www.nap.edu/catalog.php?record_id=13405*.

NO_2 data collected from OMI over the course of a year is shown in **Figure 1**. These data show urban and industrial *hot spots* that typically result from auto emissions and power plants.

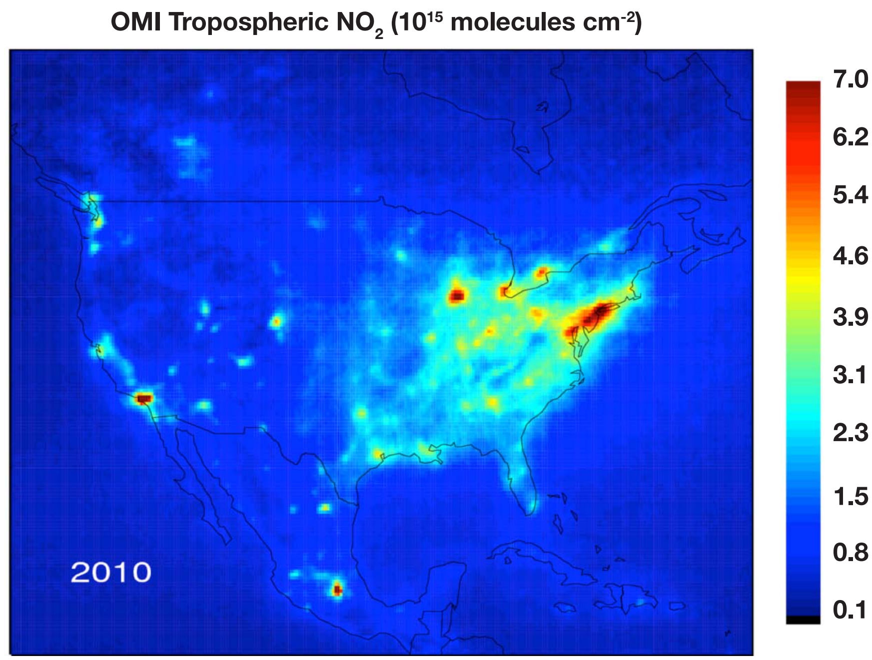


Figure 1. The OMI instrument—flown in a polar Sunsynchronous orbit—accumulated data over one year to produce the cloud-free map shown here. TEMPO's geostationary orbit will provide similar maps but at higher spatial resolution in considerably less time. OMI's spatial resolution is between 13×24 and 40×150 km^2 (~ 5×9 and 15×58 mi^2) ,while TEMPO's will be 2.5×4.0 km^2 (~1.0×1.5 mi^2) at the center of the field of regard (FoR), varying with measurement geometry for other locations. **Image credit: Lok Nath Lamsal**, [GSFC/Universities Space Research Association].

With both high temporal and spatial resolution, TEMPO data will improve emission inventories, monitor population exposure to pollution, and make possible effective emission control strategies by regulatory agencies.

Instruments flying on polar Sun-synchronous satellites observe a given location about twice per day. Instruments that observe in the UV/VIS wavelengths provide coverage only in daylight hours. On the other hand, the geostationary location of TEMPO will provide the first-of-kind capability to observe chemically active atmospheric constituents nearly continuously in daylight for given locations. Emissions that result in pollution vary strongly with weather and sunlight; therefore, pollution events occur over a broad range of temporal and spatial scales, from the rapidly varying (e.g., hourly variations in the local planetary boundary layer) to daily and longer (e.g., continental-scale transport events). Quantifying these processes requires continuous, high-spatial and -temporal-resolution measurements possible only from geosynchronous orbit. Such observations will provide crucial data to separate and quantify the effects of chemical and dynamical processes, which will enable more-accurate forecasts of pollution events.

Instrument and Mission Capabilities

Instrument

TEMPO's spectrometer design will incorporate many of the features and lessons learned from heritage spectrometers flown by Europe and the U.S. The key instrument characteristics and capabilities are:

- *Spectral range*: 290–690 nm; *Spectral sampling*: 0.2 nm; *Spectral resolution*: 0.6 nm.
- *Spatial resolution:* 2 km per pixel in the north-south direction, 4.5 km per pixel in the east-west direction at the center of the field of regard (FoR)—36.5° N, 100° W.
- *Hourly measurements* stepping east to west of the entire FoR (2.5×10^6 spectra per hour).
- *Signal/noise requirements* met at solar zenith angles less than 50° for all products—and at angles up to 70° for NO_2, clouds, and aerosols.
- *Ozone profile products* include 0–2 km O_3, free tropospheric O_3, and the stratospheric O_3 column.

TEMPO measurements will capture the high variability in the diurnal cycle of emissions and their evolving chemistry, which occurs mostly during the day. TEMPO's footprint—smaller than for previous missions measuring air quality—will resolve pollution sources at suburban scales. With both high temporal and spatial resolution, TEMPO data will improve emission inventories, monitor population exposure to pollution, and make possible effective emission control strategies by regulatory agencies.

An example of the TEMPO temporal capability is shown in **Figure 2**. The figure depicts a model calculation of column amounts of NO_2 over the course of two days based on emissions, photochemistry, and the local meteorology. Two observations from OMI over the same location are also indicated, illustrating the limitations of a polar-orbiting satellite for observing evolving time-of-day processes. The TEMPO observational period shown will be similar to the model calculations, but limited to daytime and cloud-free scenes. TEMPO's near-continuous observations will be superior to polar orbiting satellite data for verifying model predictions and likely observe features not seen in the model. It is also anticipated that data in the boundary layer will be significantly improved with TEMPO's higher spatial resolution, which is made possible by longer integration times from geostationary orbit.

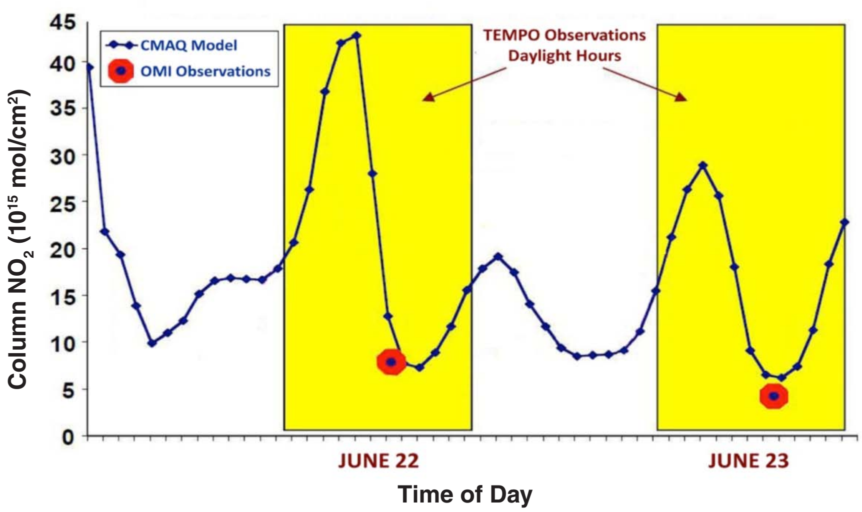


Figure 2. This graphic shows diurnal variation of NO_2 over Houston, TX, calculated from the Community Multi-scale Air Quality (CMAQ) model. The daily OMI observations, taken about 1:15 PM local time, are also shown. For this location, maximum NO_2 appears in the morning (responding to traffic congestion) with a second peak in the (evening rush-hour period). OMI data, which agree reasonably well with CMAQ output, are limited to the time period during the lull between the two rush hours. Continuous sampling by TEMPO during the daylight hours will completely overcome this sampling limitation. **Image Credit:** J. Fishman

Mission

The mission's key capabilities are listed here:

- *Geostationary location* at 100° W longitude—proposed to cover Greater North America.
- Planned *data latency* is two hours (near real-time) for air quality products developed with the EPA and NOAA.
- A *two-year operations (Phase-E) period*, driven by the cost cap. Instrument lifetime—allowing extended operations—is much greater.

TEMPO will observe the components of pollution and their source gases over all major cities and industrial areas in Greater North America (i.e., coverage similar to Figure 1). EPA has designated O_3, SO_2, NO_2, and aerosols as *criteria pollutants,* and are recognized to be harmful to health and the environment and cause property damage. Major *proxies* for air pollution include formaldehyde and glyoxal in the atmosphere, indicating the presence of non-methane volatile organic compounds (NMVOC) emissions. The short lifetime of NMVOCs make them ideal for locating the source of emissions from natural and anthropogenic processes, including biomass burning. **Figure 3** illustrates the TEMPO instrument's FoR for a one-hour measurement cycle.

Figure 3. TEMPO's FoR is outlined in green. The spread with increasing latitude is due to the projection of the FoR as seen from geostationary orbit where the satellite is over the Equator. The narrow white band is an exaggeration of TEMPO's field of view [nominally 4.5 km (~2.8 mi)], which scans from east to west over the course of an hour. The coverage from south to north will include the range from Mexico City to the Canadian tar sands. **Image Credit:** Ball Aerospace & Technology Corp.

Selecting a Host for TEMPO

By fall 2017 the TEMPO PI and science team will deliver the instrument for integration into an appropriate, yet to be determined, *host* commercial geostationary satellite. The "hosted payload" concept, under development for years by NASA as an alternative access to space, has now come to fruition with the EVI-1 solicitation issued by the Earth Science Division of NASA's Science Mission Directorate. "Commercial satellite and launch suppliers have for a long time held excess capacity, which they would like to see exploited, while NASA continued to search for low-cost opportunities for access to space to implement its Venture Class missions—and now these two needs seem to be coming together," said **Sanghamitra Dutta** [NASA Headquarters, Earth Science Division—*TEMPO Program Executive*]. While this is an unprecedented approach for access to space for NASA, it has been successfully implemented with a U.S. Department of Defense (DoD) space mission.

Fortunately, Korea and Europe plan to develop and launch their own geostationary satellites…. [with] measurement capabilities and science objectives similar to TEMPO. Therefore it will be possible, with a minimum of three geostationary satellites positioned to view Europe, East Asia, and North America, to collectively provide near-global coverage (in the Northern hemisphere).

To implement the TEMPO mission, the PI, science team, and the Earth System Science Pathfinder Program Office will generate a set of instrument accommodation and observational requirements during Phase A (ending late summer 2013), including mass; power; electrical and mechanical interfaces; and spacecraft services, including geolocation, pointing stability, contamination control, and data rate. Once the TEMPO instrument requirements are well established, NASA will release a request for proposal to select the appropriate commercial host provider. To further facilitate the hosting process, NASA is planning to participate in the Air Force's Indefinite Delivery/Indefinite Quantity (ID/IQ) Hosted Payload Solution program for a study contract to establish necessary interfaces with possible TEMPO payload hosts.

The PI-led TEMPO mission costs—capped at $90 million—must result in the delivery of an instrument, data acquisition and processing at the PI institution (i.e., Smithsonian Astrophysical Observatory), and data delivery to the NASA archive for two years of operations (Phase A through Phase D and Phase E Mission Operations and Data Analysis). The cost of integration and test of the instrument with the host platform and the cost of launch are outside of the cap. Launch vehicles for several commercial communication satellites are expected to be suitable for hosting TEMPO in the 2018-2019 launch timeframe. However, a specific launch date is not on the critical path, so NASA can opt for the best value.

International Collaboration

A single geostationary satellite views only one sector of the globe, limiting the capability to observe sources of pollution outside the instrument FoR. Fortunately, Both Korea and Europe [the European Space Agency (ESA) and Eumetsat] plan to develop and launch their own instruments to fly on geostationary satellites to measure air composition and quality in the 2017-2022 timeframe. These missions will have measurement capabilities and science objectives similar to TEMPO. Therefore, it will be possible, with a minimum of three geostationary satellites positioned to view Europe, East Asia, and North America, to collectively provide near-global coverage in the Northern Hemisphere. The synergy of contemporaneous satellite missions having similar observing capabilities and data distribution protocols will provide unique opportunities to advance understanding of the interactions between regional and global atmospheric composition in the troposphere. This would include assessments—not possible before—of emission sources, intercontinental pollution transport, and regional interactions between air quality and climate. These activities would address several *societal benefit areas* of the Global Earth Observation System of Systems (GEOSS), listed online at *www.earthobservations.org/geoss.shtml*.

In addition to TEMPO, the European Sentinel-4[6] and the Korean MP-GEOSAT[7] missions have been approved. By harmonizing these missions it is possible to improve the scientific return and societal benefit of each of the individual missions while beginning a global observing system that will be impossible for any one country to implement alone. Best efforts to cooperate on defining common requirements and data products can enable improved designs for all instruments and allow cost savings by minimizing duplication of effort. While recognizing that unique requirements likely exist for individual missions, this approach defines common objectives that build a foundation for a future integrated observing system for atmospheric composition, as envisioned in 2004 by the Integrated Global Observing System[8].

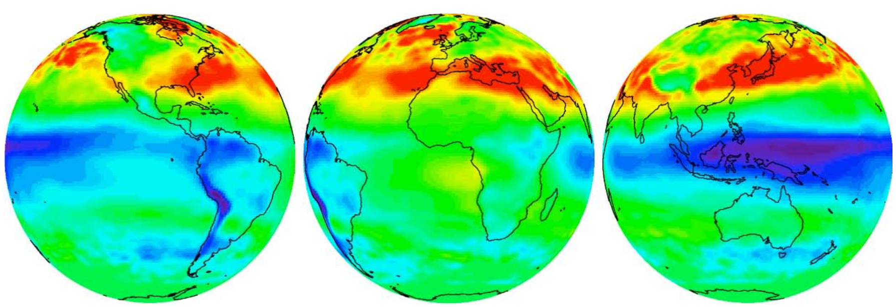


Figure 4. These images show simulation of average tropospheric ozone—an indicator of poor air quality—using data from Aura's OMI and Microwave Limb Sounder (MLS) when viewed from three geostationary positions over major continents for May-July 2008. The three geostationary missions (i.e., originated by NASA, ESA, and Korea) however, will focus on the Northern Hemisphere only. Shades of purple and blue correspond to 10-20 Dobson Units (DU) representing low ozone amounts while lighter shades correspond to 35-50 DU. Green, yellow, and red indicate high-pollution areas. **Image credit: J. Ziemke,** GSFC, and the OMI and MLS instrument and algorithm teams.

The simultaneous development of these individual missions to acquire data over Earth's major industrialized regions presents a real opportunity for international collaboration to improve the preparation for these missions and their combined capabilities within a global system. Best efforts are all ready underway to cooperate on defining common measurement requirements, retrieval algorithms, validation, data quality, and access to achieve the above goals. Consistency of data products will result in better understanding of the science, improved application capabilities, and subsequent use by regulatory agencies. The potential global coverage of the three geostationary missions, separated by roughly 120° in longitude, is depicted in **Figure 4**. Demonstrating this synergy is an ongoing effort by the Committee on Earth Observing Systems and has been described in, *A Geostationary Satellite Constellation for Observing Global Air Quality: An International Path Forward,* which can be found online at *www.ceos.org/images/ACC/AC_Geo_Position_Paper_v4.pdf*.

continued on page 35

[6] Sentinel-4 (anticipated 2019 launch) will carry the Ultraviolet-Visible-Near infrared imaging spectrometer (UVN).

[7] MP-GEOSAT (anticipated 2018 launch) will carry the Geostationary Environment Monitoring Spectrometer (GEMS).

[8] For more information, visit: *ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw159.pdf*.

feature articles

Working with NASA's HDF and HDF-EOS Earth Science Data Formats

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The Hierarchical Data Format (HDF) is the prescribed data format for standard data products derived from NASA Earth Observing System (EOS) missions. Hierarchical Data Format - Earth Observing System (HDF-EOS) is a self-describing file format for many of the data collected from EOS satellites[1,2]. HDF technologies are particularly useful when addressing management and preservation of large and complex scientific datasets such as those held by NASA's Earth Observing System Data and Information System (EOSDIS). EOSDIS provides end-to-end capabilities for managing NASA's Earth science data from various sources—e.g., satellites, aircraft, field measurements, and various other programs. NASA's EOSDIS Distributed Active Archive Centers (DAACS)—see **Table** below—process, manage, and distribute Earth science data products to a large and diverse user community. To date, over six petabytes of data have been archived in the EOSDIS data centers, with data product distribution reaching over a million end-users worldwide.

To date, over six petabytes of data have been archived in the EOSDIS data centers, with data product distribution reaching over a million end-users worldwide.

Although most of NASA's EOSDIS DAACS distribute and archive data in the HDF/HDF-EOS formats, many new users may not be familiar with how to access, manipulate, and use the data products provided in these formats. In addition, data format interoperability can be a concern since some missions and researchers will use different data formats such as NetCDF-4, which uses HDF5 as it underlying format. To address these issues, the HDF-EOS Tools and Information Center website—*hdfeos.org/zoo*—provides *comprehensive examples* of how to manipulate data in these formats and features software that facilitate interoperability between NetCDF and HDF/HDF-EOS. The examples provided at this site showcase a select range of EOS data products, associated software code, a variety of tools, and documentation that novice users can easily follow.

[1] HDF-EOS is based on the earlier released HDF4 and 5, and is uniquely designed to handle the idiosyncrasies of EOS data; it can be used to store swaths, grids, *in situ* data, instrument metadata, and browse images—all in a single file.
[2] The HDF-EOS system is now evolving beyond the EOS era; it has been adapted to manage and preserve data from the Suomi National Polar-orbiting Partnership (NPP) platform.

Table. List of NASA EOSDIS Data Centers.

Data Center	URL
Alaska Satellite Facility Synthetic Aperture Radar (SAR) Data Center [ASF SDC]	www.asf.alaska.edu
Crustal Dynamics Data Information System (CDDIS)	cddis.gsfc.nasa.gov
*Global Hydrology Resource Center (GHRC) DAAC	ghrc.nsstc.nasa.gov
*Goddard Earth Sciences Data and Information Services Center (GES DISC)	disc.sci.gsfc.nasa.gov
*Langley Research Center (LaRC) Atmospheric Sciences Data Center (ASDC)	eosweb.larc.nasa.gov
*Land Processes (LP) DAAC	lpdaac.usgs.gov
*Moderate Resolution Imaging Spectroradiometer (MODIS) Level-1 Atmosphere Archive and Distribution System	ladsweb.nascom.nasa.gov
*National Snow and Ice Data Center (NSIDC) DAAC	nsidc.org
Oak Ridge National Laboratory (ORNL) DAAC	daac.ornl.gov
*Ocean Biology Processing Group (OBPG)	oceancolor.gsfc.nasa.gov
*Physical Oceanography (PO) DAAC	podaac.jpl.nasa.gov
Socioeconomic Data and Applications Center (SEDAC)	sedac.ciesin.columbia.edu

*Asterisk denotes data centers with comprehensive examples at *hdfeos.org/zoo.*

Each of the comprehensive examples provided on the website are designed for use with one of three data analysis tools: MATLAB®[3], National Center for Atmospheric Research (NCAR) Command Language (NCL[4]), and Interactive Data Language (IDL®[5])—an IDL® example is shown in **Figure 1**.

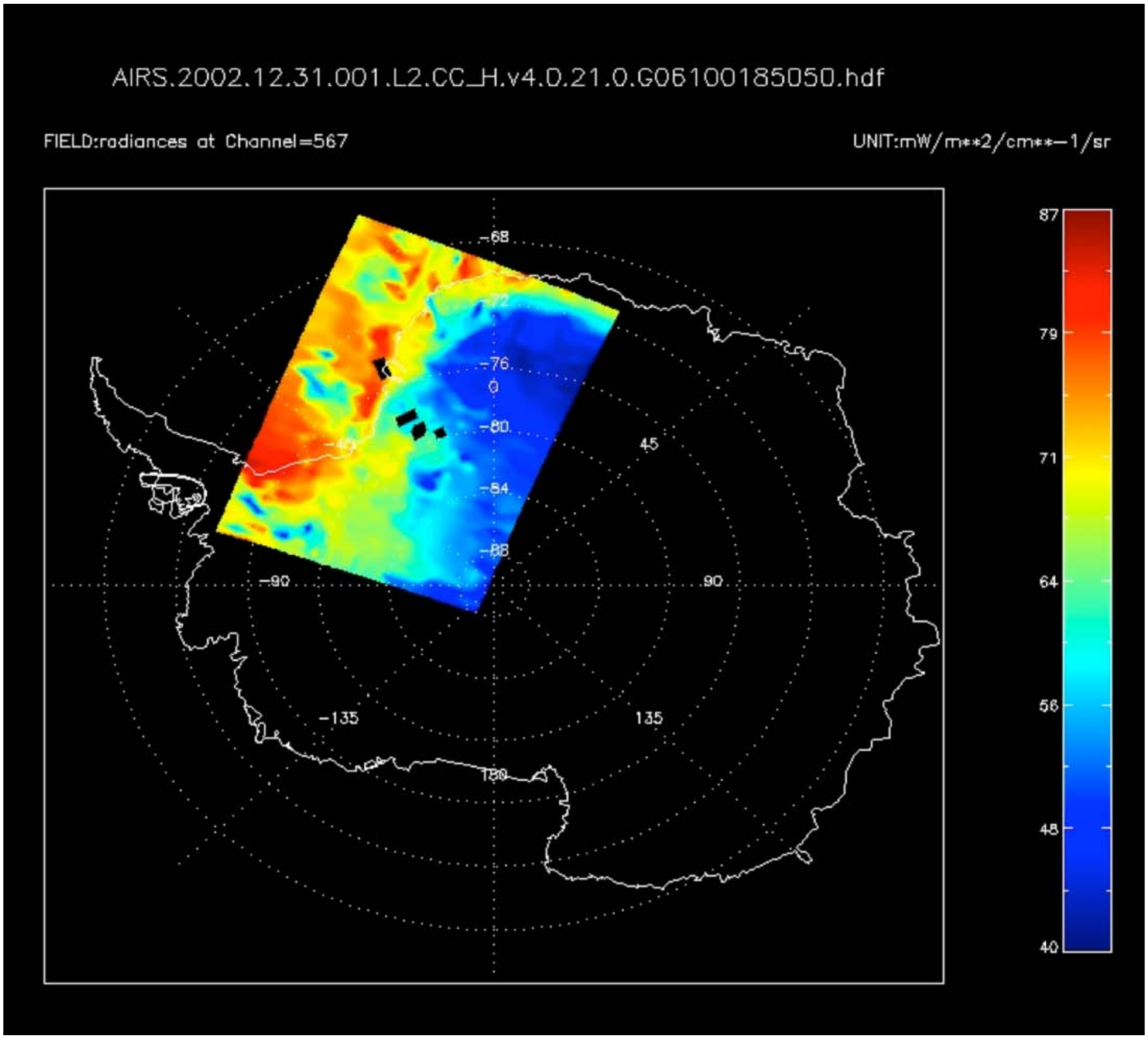

Figure 1: This image shows AIRS Level-2 (Swath) Radiance data over Antarctica, visualized using *IDL example* code to read the data file. These data can be found within the *comprehensive examples* section of the HDF-EOS Tools and Information Center website.

The website provides complete codes for accessing and visualizing many HDF/HDF-EOS products from satellites and sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS), Atmospheric Infrared Sounder (AIRS), Tropical Rainfall Measuring Mission (TRMM), Clouds and the Earth's Radiant Energy System (CERES), Multi-angle Imaging Spectroradiometer (MISR), Visible Infrared Imaging Radiometer Suite (VIIRS), and Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Other Earth-science data products, such as those derived from the Making Earth System Data Records for Use in Research Environments (MEaSUREs[6]) Program are also provided. The examples provide showcase products that are archived at and distributed by the EOSDIS data centers.

[3] MATLAB® is a high-level language and interactive environment for numerical computation, visualization, and programming. For more information, visit: *www.mathworks.com/products/matlab*.

[4] NCL is a free interpreted language designed specifically for scientific data processing and visualization. For more information, visit: *www.ncl.ucar.edu/overview.shtml*.

[5] IDL® is a scientific programming language available through EXELIS Visual Information Solutions. For more information, visit: *www.exelisvis.com*.

[6] To learn more about NASA's MEaSURES Program, please visit: *earthdata.nasa.gov/our-community/community-data-system-programs/measures-projects*

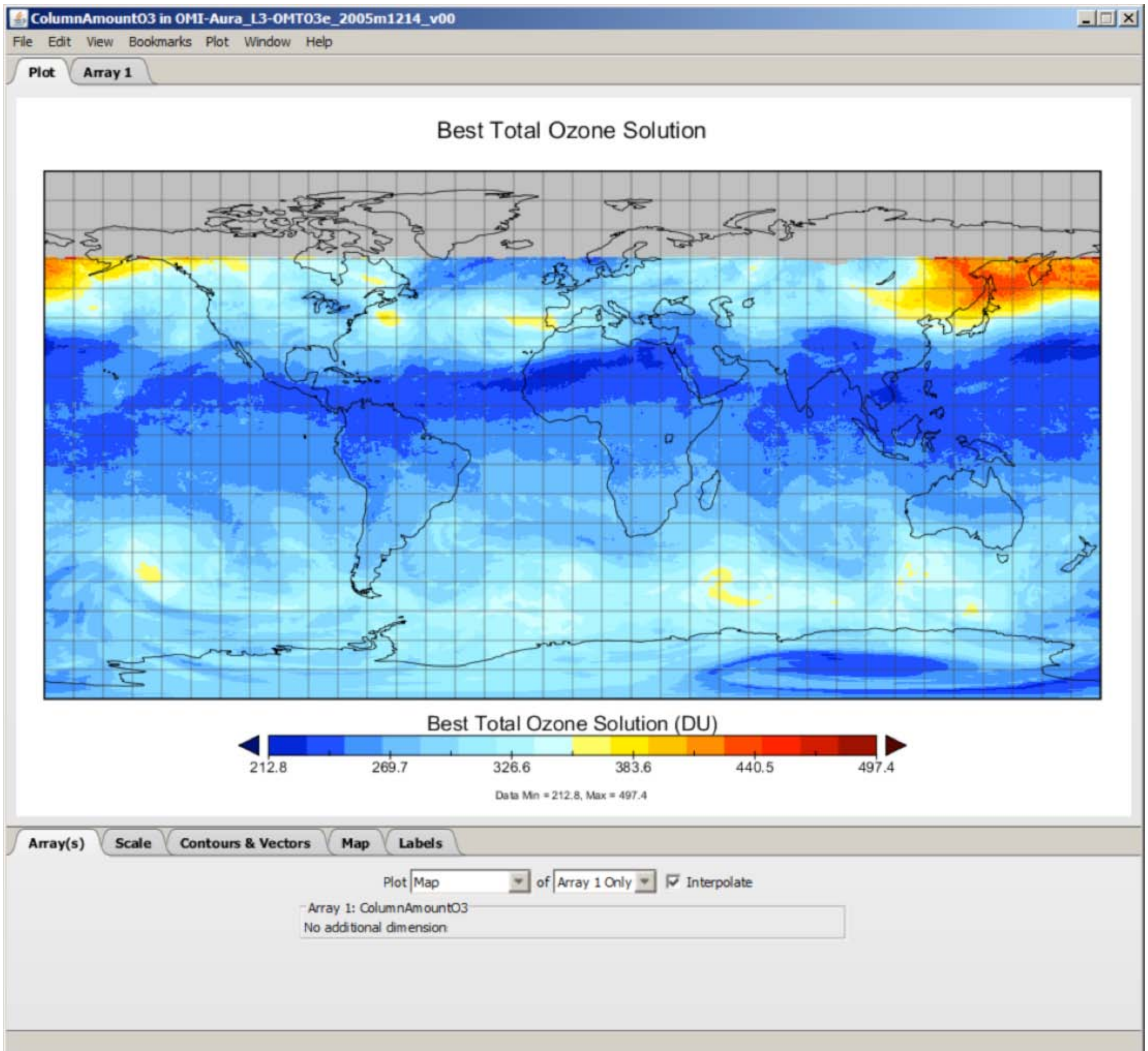

Figure 2: This image shows total ozone column data from the Ozone Monitoring Instrument (OMI) onboard NASA's Aura satellite. Data were visualized using the Panoply Data Viewer tool.

The HDF-EOS Tools and Information Center website also provides product-specific examples for accessing data via the Open-source Project for a Network Data Access Protocol (OPeNDAP[7]). The website runs a demonstration of the most up-to-date OPeNDAP server that provides many HDF/HDF-EOS data products[8]. Most products can be visualized seamlessly with OPeNDAP client visualization tools, such as Unidata's Integrated Data Viewer (IDV) and NASA's Panoply Data Viewer—as shown in the example in **Figure 2**. Users can test the demo servers at:

hdfeos.org/zoo/hdf4_handler and *hdfeos.org/zoo/hdf5_handler.*

While only two examples from the website are shown in this article, the HDF-EOS Tools and Information Center website contains many more data products and comprehensive examples. These products are diverse in organization, but there is documentation about each data product to help end-users find their way, including geolocation information, data-projection information, and a brief note about compliance with Climate and Forecast (CF) conventions required for software interoperability. For efficiency, users can quickly examine the properties of each data product before downloading and viewing the HDF data file—as shown in **Figure 3**. Such information is

[7] *OPeNDAP* is a software framework that simplifies scientific data transfer access to remote data.
[8] Some NASA data centers, such as the GES DISC, LaRC ASDC, NSIDC DAAC, and PO DAAC, already provide OPeNDAP services.

found at *www.hdfeos.org/zoo/Data_Collection/index.php* and *www.hdfeos.org/zoo/Data_Collection/hdf5index.php*.

Interested parties are advised to check the website frequently, as The HDF Group will continue to provide data product examples from new NASA missions. Please contact *eoshelp@hdfgroup.org* with suggestions on how to improve our website. ■

LP_DAAC_MOD_Summary

hdfeos.org/zoo/Data_Collection/LP_DAAC_MOD_Summary.php

HDF - EOS Tools and Information Center

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LP_DAAC_MOD

This page describes the LP DAAC MOD HDF-EOS2 and HDF4 files.

HDF-EOS2 Swath files

The swath files use dimension maps so users need to either find the corresponding geolocation HDF-EOS2 files or calculate the latitude/longitude based on dimension map parameters. The size of dimension varies in geolocation fields and data fields.
For example, for the file MOD11_L2.A2007278.0350.005.2007280073443.hdf, the dimension size of geolocation fields is 406 (Coarse_swath_lines_5km) by 271 (Coarse_swath_pixels_5km), while the dimension size of data fields is 2030 (Along_swath_lines_1km) by 1354 (Cross_swath_pixels_1km).

The following table summarizes the information collected for the Swath files:

File type	File size(avg.)	Geolocation Field	Datafield Dim. Range	CF-compliant information	Other special issues
HDF-EOS2 (Swath)	4MB	Lat/Lon = 2D	2D	Both geolocation fields and data fields have 'units' and 'long_name' attributes.	Files have dimension map.

HDF-EOS2 grid files

The projections of them are Geographic (GEO) or Sinusoidal (SNSOID). The following table summarizes the information collected for the Grid files:

File type	File size(avg.)	Number of grid	Has lat/lon	Projection	Datafield Dim. Range	CF-compliant information	Other special issues
HDF-EOS2 (Grid)	330KB -1.54GB	1 or 2	No	GEO, or SNSOID*	2D - 4D	Data fields have 'units' and 'long_name' attributes.	Some files contain objects and attributes that are added by the HDF4 APIs.

* Some software tools require extra steps to retrieve latitude and longitude for the SNSOID projection.

HDF4 files

The following table summarizes the information collected for the HDF4 files:

File type	File size(avg.)	Datafield Dim. Range	CF-compliant attributes information	Other special issues
HDF4	5MB	1D, 2D	Geo fields and some data fields have both 'units' and 'long_name' attributes.	FP_latitude and FP_longitude, which are equivalent to latitude and longitude, have unlimited dimensions (zero length in the current files).

To retrieve sample MOD files and read the detailed description of these files, please click here.

Figure 3: This figure shows an example of the descriptive information available at the HDF-EOS Tools and Information Center website, presenting metadata for sample HDF-EOS2/HDF4 and HDF-EOS5 NASA data files. This information is useful in understanding the EOS contents stored in the sample files.

PODEX Experiment to Reshape Future of Atmospheric Science

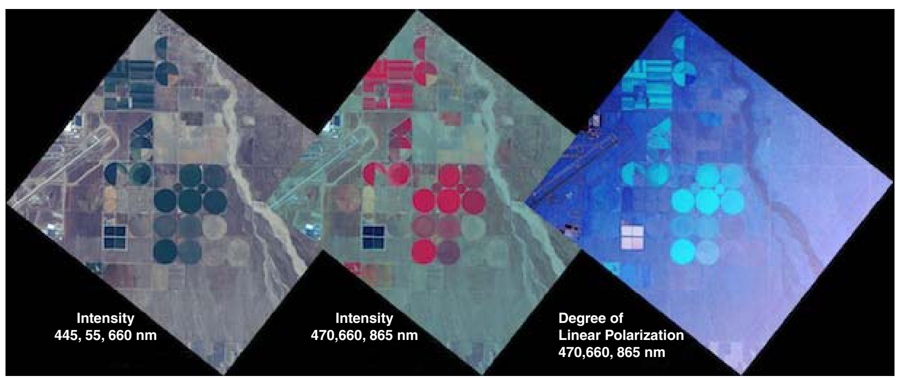
Kathryn Hansen, NASA's Earth Science News Team, kathryn.h.hansen@nasa.gov

NASA scientists and engineers are working now to lay the groundwork for the Aerosol-Cloud-Ecosystem (ACE) mission, a satellite mission proposed by the 2007 Earth Science Decadal Survey that "…will dramatically change what we can do from space to learn about clouds and aerosols," said ***David Starr*** *[NASA's Goddard Space Flight Center (GSFC), PODEX Mission Scientist and ACE science lead].*

Satellite Earth science missions don't start at the launch pad or even in orbit. They start years before, when scientists test their new ideas for instruments that promise to expand our view and understanding of the planet. NASA scientists and engineers are working now to lay the groundwork for the Aerosol-Cloud-Ecosystem (ACE) mission, a satellite mission proposed by the 2007 Earth Science Decadal Survey[1] that "…will dramatically change what we can do from space to learn about clouds and aerosols," said **David Starr** [NASA's Goddard Space Flight Center (GSFC)—*PODEX Mission Scientist and ACE Science Lead*].

To find out how the satellite's instruments should be designed, and how the data can be turned into useful information for research, three teams each developed prototype instruments that were put to the test in January 2013 during the Polarimeter Definition Experiment (PODEX) in Southern California.

Beginning on January 14 and lasting for three weeks, instrument teams collected data during ten flights on the ER-2—a high-altitude aircraft based at NASA's Dryden Aircraft Operations Facility. By virtue of its ability to operate at altitudes up to 70,000 ft (~13.2 mi), the aircraft simulates the view from space. [Most PODEX flights took place at an altitude of 65,000 ft (~12.3 mi.)]



The brightness, or intensity, and polarization of reflected light provide different information about the elements that make up a scene, apparent in this set of images collected by the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) during its maiden flight on October 7, 2010, on the ER-2 over Palmdale, CA. AirMSPI was one of three prototype polarimeters tested during PODEX. **Image credit:** JPL/Caltech, AirMSPI Team

On August 22, 2012, the ER-2 took off from Dryden Aircraft Operations Facility in Palmdale, CA. One of the instruments onboard flew during PODEX. **Image credit:** NASA/Matteo Ottaviani

The instruments that flew on the ER-2 during PODEX are a new class of *polarimeters*, an instrument that can give increasingly detailed information about aerosols and clouds based on how they rotate light—their *polarization*. Aerosols are tiny airborne particles from a variety of sources. They can stay in the atmosphere for up to a week and impact human health, cloud formation, precipitation, and Earth's radiation budget. The complex nature of aerosols has made it difficult to decipher their influence on climate.

[1] NRC, 2007: *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. The National Academies Press. The survey identifies ACE as a *Tier 2* (lower priority) mission.

As the instrument teams have demonstrated, however, there is more than one way to build a polarimeter. Three different instrument designs were tested during PODEX: the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI); Research Scanning Polarimeter (RSP); and Passive Aerosol and Cloud Suite (PACS). Respectively, the principal investigators (PI) for the instruments are **David Diner** [NASA/Jet Propulsion Laboratory], **Brian Cairns** [NASA's Goddard Institute for Space Studies], and **J. Vanderlei Martins** [University of Maryland, Baltimore County].

Two other instruments were included as part of the PODEX ER-2 payload to complement the polarimeter observations: the Cloud Physics Lidar (CPL[2]), developed at GSFC and supplied by **Matt McGill** [GSFC—*PI*], and Autonomous Modular Sensor (AMS[3]), supplied by NASA's Ames Research Center (ARC).

David Starr is Mission Scientist for the PODEX experiment. **Image credit:** NASA

David Starr has been leading airborne science campaigns since 1986. As PODEX Project Scientist, he worked with **Rich Ferrare** [NASA's Langley Research Center—*ACE Aerosol Working Group Leader*] and **Jens Redeman** [ARC] to oversee implementation of the experiment and coordinate the daily mission planning and execution with the polarimeter instrument teams. Prior to the experiment, Starr spoke with NASA's Earth Science News Team's Kathryn Hansen about the experiment and how it could reshape the next generation of atmospheric science.

During a test phase for the PODEX experiment, engineers and the crew at Dryden Aircraft Operations Facility loaded the Research Scanning Polarimeter into the "superpod," for placement under the wing of the ER-2. **Image credit:** NASA/Matteo Ottaviani

Question (Q): What is a polarimeter?

Answer (A): Traditional radiometers measure radiation intensity over a particular range of wavelengths, which are converted into products such as images of Earth's surface, clouds and aerosols. Launch of radiometers aboard NASA's Terra satellite in 1999 is, in part, what got people jazzed up about aerosols—i.e., we realized how they're blowing around the planet, then we realized the potential significance of their impact on health, clouds, Earth's radiation budget, and precipitation.

Polarimeters work in a similar way, but have the potential to provide more information about particles, such as shape and size.

Q: Why does this approach work?

A: Incoming sunlight is *unpolarized*, which means that the planes of vibration of the light waves are randomly oriented. When the sunlight interacts with Earth's atmosphere or surface, the light waves can vibrate in preferred orientations. For example, interaction with highly structured particles or objects—things like industrial soot particles, dust, vegetation, or ice crystals in a cloud—can dramatically change the polarization of reflected sunlight.

Q: What can polarimetry tell us about aerosols?

A: Aerosols are a tough problem. Unlike clouds, when looking at Earth from space you really have to look hard to see them. You're often looking at a subtle signal and that makes it hard to be quantitative and accurate. Data from MODIS are of great value, but interpretation of that data depends on educated guesses regarding the types of aerosols in a particular scene, which significantly affects the conclusions.

Polarimetry provides a way to estimate their composition from space—which has not previously been possible. With measurements that discriminate the types of aerosols that are present, we can reduce uncertainty.

[2] CPL is an airborne Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) simulator that provides definitive measurements of aerosol and cloud location in the vertical and an independent estimate of aerosol optical properties. For more information, visit: *airbornescience.nasa.gov/instrument/CPL*.

[3] AMS is an airborne scanning radiometer that acquires high-spatial resolution imagery of Earth's surface from research aircraft such as the ER-2. For more information visit: *asapdata.arc.nasa.gov/ams/*.

Q: What can polarimetry tell us about clouds?

A: Clouds composed of liquid droplets or ice crystals modulate the planet's radiation budget and directly affect climate.

For clouds composed of liquid droplets, the size and quantity of the drops determine how much solar radiation they will reflect. For example, low-level stratocumulus clouds cover vast areas of the ocean and strongly regulate how it's heated by blocking solar radiation before it gets to the ocean surface. Polarimetry measurements from various angles offer the promise of more robust measurements of droplet size, which can range in diameter from about 10-30 µm or more. Even relatively small differences in cloud droplet size can be significant for climate—because it alters cloud reflectivity, especially outside the visible spectrum.

For clouds composed of ice crystals, the radiative properties of the clouds are quite sensitive to crystal size, quantity, and shape. We learned from previous fieldwork that the size of particles in ice clouds is quite variable—spanning a large range compared to liquid clouds. Cirrus clouds, for example, can be composed of ice crystals ranging from a few micrometers to 1 mm, or greater. Consequently, different cirrus clouds may look very different to the eye. Crystal shape is also quite variable and can be complex. Because of the structure of ice crystals, it has long been known that polarimetry has a lot of promise for remote sensing of cirrus clouds and their properties.

Q: Is this new technology?

A: In the 1970s there was some discussion about polarimetry, but aerosols were not a popular remote sensing topic at the time. Kuo-Nan Liou [now at the University of California, Los Angeles], one of the fathers of atmospheric radiative transfer, previously suggested flying polarimeters to sense ice clouds because we were having a difficult time with regular radiometers. The Centre National d'Études Spatiales (CNES)—French Space Agency—flew a coarse-resolution polarimeter on the Polarization and Directionality of the Earth›s Reflectances (POLDER) satellite, and NASA flew one on the Glory satellite, which unfortunately failed to reach orbit. So, we are just opening this door—but it has a lot of potential.

The PODEX experiment is about developing polarimetry as a new area of remote sensing technology and getting it ready for space. If you look back two to six years before Terra, NASA flew simulators to prepare for the MODIS instrument and to work on algorithm development for its data from its vantage point on-board low and medium altitude research aircraft[4]. We're now trying to do that for the next generation of technology that we plan to fly in the early 2020s.

We will not simply refly Terra or Aqua here; ACE represents a major step toward new technology to reduce errors and uncertainties in aerosol and cloud observations from space.

Q: Why fly three polarimeters?

A: PODEX is an experiment to provide a basis to push each of the existing polarimeter designs to greater maturity. The data we collect will greatly facilitate algorithm development—data processing that allows us to derive geophysically relevant aerosol and cloud properties. This is where the real value of the measurements resides. For a satellite mission, we also need to be able to quickly process large volumes of data without human intervention—also a significant challenge.

Progress toward this goal will result in data we can use to address a number of key design questions for a spaceborne polarimeter. For example, how accurate do the radiance and polarization measurements need to be to achieve specified goals in accuracy for the derived geophysical parameters? How can we best achieve that accuracy? Similarly, what spatial resolution can we achieve? How many angles should be observed? How many spectral channels should be polarization capable? Which ones are optimal?

At some point we turn a corner and start building something to fly in space. What's the design? What's the impact of that design on algorithm development and data products? Right now that's all on paper.

While there are strong opinions as to the likely answers to such questions, we do not yet have sufficient observational bases to adequately confirm or deny the theoretical arguments. PODEX seeks to push this enterprise forward and ultimately to enable the optimal cost-effective design of such an instrument for the ACE mission. ■

[4] One simulator used in these studies was the Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator [MAS,] which enabled retrievals of cloud and aerosol properties that were similar to those obtained by MODIS on Terra and Aqua. For more information, visit: *airbornescience.nasa.gov/instrument/MAS.*

PODEX Field Report From David Starr

*The interview portion of this article was conducted before the PODEX campaign took place, so **The Earth Observer** asked David Starr, the PODEX Mission Scientist, if he would follow up with a statement about the recently completed campaign.*

PODEX flights occurred between January 14 and February 6, 2013, from the Dryden Aviation Operations Facility (DAOF) in Palmdale, CA. The period was chosen such that PODEX could benefit from data acquisition already planned for DISCOVER-AQ (DAQ[1]) that also operated from DAOF during this time. DAQ deployed the NASA P3 *Orion* research aircraft from NASA's Wallops Flight Facility and the NASA B-200 *King Air* from NASA's Langley Research Center (LaRC). Also associated with the DAQ deployment, an extensive network of ground sites operated in the San Joaquin Valley (SJV) during the experiment, including Aerosol Robotic Network (AERONET) sunphotometers (*aeronet.gsfc.nasa.gov*), a couple of ground-based micropulse lidars, and various *in situ* sampling systems. The P3 hosted a variety of *in situ* sensors to sample aerosols and their characteristics, as well as gas-phase-chemistry and -state measurements. The B-200 brought LaRC's High Spectral Resolution Lidar (HSRL-2), a relatively new and promising technology that provides vertical profiles of aerosol radiative and physical properties. (An HSRL-like instrument is included in the planned ACE payload.) Thus, the pairing of PODEX and DISCOVER-AQ is a "match made in heaven," with the latter providing much-needed "truth" data against which to compare retrievals of aerosol properties from the PODEX polarimeters. The addition of HSRL, critical to DAQ for profile information, was a great bonus for ACE.

While DAQ typically flew over the SJV—repeating the same coordinated pattern three times on each experiment day—NASA's ER-2 high-altitude science aircraft would overfly the valley and obtain data loosely coordinated with DAQ observations. On a few select days, the DAQ aircraft supported PODEX with flights over the nearby Pacific Ocean to obtain data for *cloud scenes*—the Earth Observing System (EOS) Project Science Office funded these additional DAQ flight hours. Excellent test cases of moderate aerosol loading (aerosol optical depths between ~0.1 and 0.25) over a *heterogeneous* surface [SJV, which has dark, light, rural, and urban surfaces] under absolutely clear skies were obtained. The heterogeneity was organized at agricultural scales, well-sampled at the native sensor resolution. Thus, these "clear" scenes with diverse land-cover backgrounds can be contrasted to very similar conditions for the same scenes when thin-to-moderate cirrus (Ci) clouds were present over the valley—a tough test for retrieval algorithms, but one necessary for a successful space-based global observing system.

Also, a remarkable case of marine stratocumulus (Sc) over the ocean was acquired to the west of San Francisco, CA. The cloud cover was nearly solid and the optical thickness sufficient to exclude significant surface influence, and without any Ci contamination. This turned out to be a difficult target to find at this time of year. We also acquired high-quality, though challenging, cases including a broken marine Sc case ("scalloped" open cell), and a Ci-over-water case, with mostly Ci over altostratus.

Other data acquisition objectives that were met included instrumented calibration targets (Rosamond Dry Lake); bright targets, including excellent snow fields in the Sierra Nevada; and Lake Tahoe (dark target). Not achieved were samples of very clean oceanic conditions beyond the coastal waters, or observation of Ci—especially relatively homogeneous cirrostratus—over dark waters without other clouds present. We may have gotten a few small bits of these, but final judgment awaits detailed analysis of the data.

Overall, the experimenters are quite pleased with the cases acquired, and therefore feel that PODEX was a very successful experiment. Analysis of the data has started, and we expect preliminary results by the end of 2013 as we progress toward robust polarimeter algorithms for the ACE instruments using these data.

[1] DISCOVER-AQ stands for Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality. It is funded through NASA's Earth Venture Program, as described in a previous issue of *The Earth Observer* [**Volume 22**, **Issue 5**, pp. 13-18].

Summary of the 2013 NASA Land Cover/Land Use Change Regional Science Meeting, South India

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Introduction

The 2013 NASA Land Cover/Land Use Change (LCLUC) Regional Science Meeting was held in South India and had three components:

- a focused workshop on water resources at the Centre for Water Resources Development and Management (CWRDM), held in Kozhikode, Kerala in India, from January 7-8, and a Land Use (LU) Transect Study from Kozhikode, Kerala, to Coimbatore, Tamil Nadu, in India[1], on January 9;
- a NASA international regional meeting, held January 10-13, at Karunya University in Coimbatore, Tamil Nadu; and
- a training workshop titled *Remote Sensing and Geospatial Technologies for Land Cover and Land Use Change Studies and Applications,* held January 14 at Karunya University.

The goal of the meeting was to discuss land cover/land use change (LCLUC) issues and impacts in the South Asia region. The meeting was organized around eight technical sessions:

1. Agricultural land-use change;
2. LCLUC-related Earth observations (missions, data, and products);
3. Atmosphere/land-use interactions (aerosols, greenhouse gases);
4. LCLUC and the carbon cycle;
5. Forests and LCLUC in mountainous areas;
6. Coastal zones and water resources;
7. Urban LCLUC; and
8. Working towards a Regional Global Observation for Forest and Land Cover Dynamics (GOFC–GOLD) South Asia Regional Information Network (SARIN) (including prospects, opportunities, and challenges).

The meeting was a joint effort of the NASA LCLUC Program; GOFC–GOLD Program; International System for Analysis Research and Training (START) Program; Monsoon Asia Integrated Regional Studies Program (MAIRS); University of Maryland College Park (UMD); Centre for Water Resources Development and Management (CWRDM) in Kozhikode, Kerala; and Karunya University, in Coimbatore, Tamil Nadu.

NASA LCLUC Workshop on Water Resources and Land Use Transect

Thirty top-level delegates from different institutes and universities in India attended the meeting in addition to twelve researchers from the U.S. **Narasimha Prasad** [CWRDM], welcomed the participants and highlighted the CWRDM water research activities.

After the welcome, **Garik Gutman** [NASA Headquarters] addressed the workshop's participants, presenting an overview of LCLUC issues in South Asia, with focus on agricultural land-cover conversion,

[1] Kerala and Tamil Nadu are two of the 28 states in India.

Water resource-focused workshop participants. **Images Credit:** All photos in this article were taken by author or other members of the LCLUC team.

Rhizophora mangle, known as the "red mangrove," near Kadalundi bird sanctuary in Kerala.

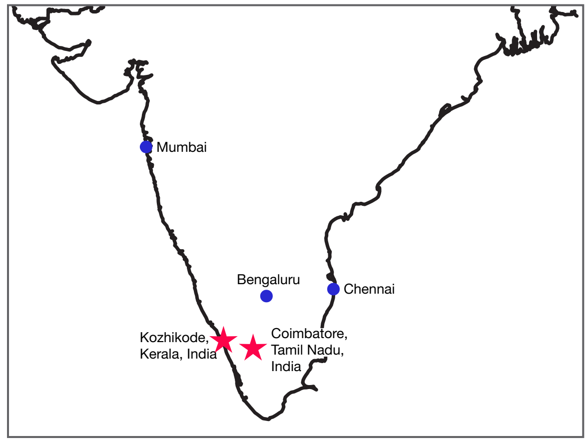
forest-cover loss, increasing urbanization, and air pollution. **Chris Justice** [UMD] stressed that much needs to be done in terms of the underpinning science of LCLUC and the linkages with global climate change in South Asia.

Some highlights from the workshop are summarized here:

- The most important LCLUC issue impacting agriculture in south India is *paddy fields* (wetlands) being converted to urban areas and/or left abandoned, with the attendant deficit in rice production.
- This *paddy conversion* is complex, and crosses economic, ecological, sociocultural, structural, and class dimensions.
- Economic return from paddy cultivation does not tend to encourage conservation—due to labor costs.
- At present, land is seen only as real estate needed for residence status, and is the safest and best investment to maximize profits.
- Coconut farming is shrinking due to the unavailability of skilled labor.
- Pollution and sedimentation from *anthropogenic* activities seriously affects aquatic systems/wetlands in South India. This requires more-stringent regulations and greater wetland protection.
- The roles of coastal vegetation and mangroves in protecting lives and property require more research to address contamination—possibly due to saline water intrusion, likely from inadequate drainage systems and poor maintenance of the well surroundings.

The CWRDM arranged several field visits to highlight local LCLUC issues and responses, including urban green park and wetlands conservation, mangrove conservation, and coastal and riparian land use management.

On January 9, participants departed for a Land Use Transect Study from Kozhikode, Kerala, to Coimbatore, Tamil Nadu, involving local scientists. The processes of urban expansion and forest degradation were quite evident during the transect study. During the transect, the participants observed forest fires in the mountains, 50 km (~31 mi) away from Coimbatore.



Coconut, arecanut, banana, and yam plantations, Kozhikode, Kerala.

Smoke from forest fires, Palakkad, Western Ghats, Kerala.

NASA International Regional Meeting

Nearly 120 participants from India attended the meeting, held January 10-13 at Karunya University in Coimbatore, Tamil Nadu. In addition, there were 18 researchers from the U.S., 3 from Nepal, 2 from Sri Lanka, and 1 each from Myanmar, Afghanistan, and Bangladesh. On January 9 top-level personnel from the Karunya University—including **E. J. James** [Karunya University—*Vice Chancellor*], the dean, department heads, and students greeted the participants with a grand welcome and reception dinner.

Thursday, January 10, 2013

International LCLUC South Asia meeting participants convened in Coimbatore, Tamil Nadu.

E.J. James, **Chris Justice**, and **Garik Gutman** each discussed the role of LCLUC generally, and in South Asia specifically. **Narasimha Prasad** summarized CWRDM workshop findings. **R.D. Singh** [National Institute of Hydrology, Roorke, India], **Olga Krankina** [Oregon State University], and **Jiaguo Qi** [Michigan State University] then followed with overview talks on water management, GOFC-GOLD regional networks, and the MAIRS network, respectively.

Chris Justice, Prasad Thenkabail [U.S. Geological Survey (USGS)], **Gumma Muralikrishna** [International Rice Research Institute, Philippines], **Wataru Takeuchi** [National Institute of Environmental Studies, Japan] and **Ruth DeFries** [Columbia University], all gave presentations during a technical session on agricultural land-use change. This material is summarized here:

- Agricultural lands are fast depleting due to urbanization in South Asia, with attendant changes in agricultural production and produce flows, leading to changes in regional dependencies.

- Cropland area, crop type, and rotations are changing across the planet, with poorly documented extent and dynamics of irrigated lands. The Group on Earth Observations-Global Agricultural Monitoring (GEO-GLAM) initiative is coordinating satellite monitoring observation systems in different regions of the world to enhance crop forecasting. **Prasad Thenkabail** has received funding from NASA's MEaSUREs[2] Program to create a new Earth Observation Global Cropland Area Database (GCAD). The project will contribute to GEO-GLAM efforts. Increased participation by South Asian scientists in the GEO-GLAM initiative was recommended.

- Spatial databases and decision support systems in South Asia in support of improved cropland inventory and monitoring using Earth-observation data are needed, as is active involvement of the Indian Space Research Organization (ISRO) and the Indian Ministry of Agriculture in the design and implementation of a GEO-GLAM data acquisition program coordinated with the Committee on Earth Observation Satellites (CEOS).

- Increasingly, extreme events are negatively affecting agricultural production in South Asia, resulting in increasing interannual production variability and the unsustainability of traditional land use practices. Mitigation and adaptation research is needed to address these issues.

- Land use studies in the region need to better integrate irrigation resources and agricultural land use.

- Several remote sensing methods are available for mapping cropping intensities for South Asian *smallholder* farming. The "best" method to map cropping intensity depends on the scale of results required.

- Drought areas are being monitored with Moderate Resolution Imaging Spectroradiometer (MODIS)-

[2] MEaSURES is an acronym for Making Earth System Data Records for Use in Research Environments.

International regional meeting participants.

based drought indices and the *Keetch–Byram Drought Index* (KBDI). In addition to these indices, coupled weather forecasting models and increased validation efforts are needed to improve drought forecasting, including crop yield estimation.

- Agricultural residue burning is one of the major issues affecting air pollution in South Asia. Better residue management practices are needed through education and extension activities in the region.
- Agricultural monitoring in India is well developed, using remote sensing technologies at a national scale. Systems continue to be enhanced for monitoring crop type, cropping intensity, etc. at finer spatial scales.

Dadhwal [National Remote Sensing Center, Hyderabad, India], **P. S. Acharya** [Department of Science and Technology, Natural Resource Data Management System, India], **Uttam Kumar** [Indian Institute of Science, India], and **Rama Nemani** [NASA's Ames Research Center] each gave presentations during a session titled *LCLUC-related Earth Observations: Missions, Data, and Products*. Conclusions from this session are summarized here:

- The lack of geospatial data sharing in South Asian countries is a major issue; coordinated policy efforts are needed to resolve this problem.
- International cooperation between NASA, ISRO, and other space agencies in the region is needed to secure satellite data continuity and to increase effective dissemination of data.
- Personnel capacity building is needed in geospatial and web-based technologies to address regional LCLUC issues.
- Development of spatial tools using free and open-source software for geospatial applications shows promise for addressing LCLUC issues.
- Data fusion methodologies are needed to address scaling issues relating to LCLUC problems.
- Department of Science and Technology/National Spatial Data Infrastructure in India is helping to build geoportals for web-based data dissemination. Interagency cooperation is needed to build decision support systems.
- NASA's Earth Exchange (NEX) provides an excellent framework for supercomputing involving large spatial datasets. Such frameworks are needed at a regional level in South Asia—otherwise, scientists need to collaborate with international partners to avail themselves of such capabilities.

Friday, January 11, 2013

Karen Seto [Yale University] presented an overview of urban LCLUC issues. **Brent Holben** [NASA's Goddard Space Flight Center (GSFC)], **Krishna Prasad Vadrevu** [UMD], and **M. M. Sarin** [Physical Research Laboratory, India] each gave presentations on aerosols and biomass burning impacts. The discussions are summarized here:

- There are many institutions, groups, and individual scientists making atmospheric, aerosol, and trace gas observations. There is a need for peer review of these datasets and for the community to collaborate on data analysis.
- There are "major issues" in reconciling *in situ* measurements of aerosols with remote-sensing-based estimates. Comparison/validation studies of satellite aerosol retrievals to surface-based measurements are needed. Local and regional studies should be encouraged to understand the uncertainty of the satellite products. Improved methodologies are needed to link remote sensing data with *in situ* measurements.
- Availability of *in situ* observations and surface-based aerosol and trace gas observations is often difficult, and assessment of uncertainty is an issue. Improved coordination is needed for temporal long-term continuity of *in situ* and ground-based aerosol and trace gas observations.
- Availability of reliable airborne observations is very limited in the South Asia region; airborne campaigns can help in understanding tropospheric chemistry.
- South Asian scientists are encouraged to establish international collaborations with well-established networks such as AERONET[3]. In that regard, AERONET would like to find an interested partner to establish a long-term observation site in southern India. Participants were encouraged to contact **Brent Holben** for details.
- Atmospherically corrected satellite data should be used when possible for LCLUC models and studies.
- Biomass burning is an important contributor of aerosols and greenhouse gas emissions in the region. Integrated campaigns are needed to address uncertainties in biomass data, combustion factors, emission factors, and aerosols.

Atul Jain [University of Illinois at Urbana Champaign], **Vinay Dadhwal** [National Remote Sensing Center, India], and **Prabir Patra** [Japan

[3] *AERONET* is short for Aerosol Robotic Network, which is a worldwide network of ground-based sun-photometers measuring aerosol concentrations and related atmospheric properties.

Agency for Marine Earth Science and Technology, Japan] gave presentations during a technical session on the carbon cycle. Session highlights are summarized here:

- South Asia is highly diverse, consisting of many different ecosystems and land use systems. Understanding carbon cycling in the region requires integrated approaches.
- Regional LCLUC impacts on the carbon cycle include deforestation, forest fires, soil carbon emissions, and agricultural change. Satellite data provide important information that can be used to study the impacts of historical LCLUC on carbon. However, more ground-based measurements are needed to validate satellite data and to further improve carbon estimates.
- Carbon emissions are not only due to LCLUC, but are also due to several environmental factors and management practices. Biogeochemical models can help in understanding carbon-cycle processes and important factors governing source/sink relationships.
- *Eddy correlation* carbon-flux measurements are being developed and conducted in India in different forest sites. Such measurements are needed throughout South Asia to better understand carbon source/sink relationships.
- There is a need to integrate top-down and bottom-up approaches to address uncertainties in carbon fluxes in South Asia.

Saturday, January 12, 2013

The day's deliberations started with **Dan Brown** [University of Michigan] presenting an overview that stressed the need for integrated models involving socio-economic variables. **Jagdish Krishnaswamy** [Ashoka Trust for Research in Ecology and the Environment, India], **Karunakaran** [Salim Ali Centre for Ornithology and Natural History, Coimbatore, India], **M.S.R. Murthy** [International Center for Integrated Mountain Development (ICIMOD), Nepal], and **Sanjay K Jain** [National Institute of Hydrology, Roorke, India] took part in a technical session that addressed forests and LCLUC in mountainous areas. Pertinent points are as follows:

- Glaciers in the Himalayan region are retreating due to climate warming combined with topographic and morphological factors. The impact of climate change on the snowmelt runoff and total stream flow of the large Himalayan rivers should be investigated, using coupled general circulation and calibrated hydrological models.
- Forest cover in India is regularly monitored using satellite remote sensing technology. Technological advances and methods have improved the product quality and reliability, but some scientists disagreed on pertinent statistics and noted that a clear definition of what constitutes a "forest" is needed.
- Greening and browning of vegetation in the mountain regions are tied to regional and global change climate drivers. Higher elevations tend to be greening, as compared to browning at mid-to-lower elevations.
- ICIMOD has been focusing various LCLUC activities in the Hindu-Kush Himalayan region and working closely with the NASA SERVIR-Himalaya[4] science applications framework. ICIMOD provides a good opportunity to foster science collaboration within the region.

Chandra Giri [USGS], **J.K. Garg** [Guru Gobind Indraprasth University, India], and **G.M.Tarekul Islam** [Bangladesh University of Engineering and Technology, Bangladesh] gave presentations during a technical session focused on land use in coastal zones and water resources. Important issues identified from this session are highlighted here:

- Statewide area statistics of wetlands in India are available. There is a need to develop similar wetland inventories (i.e., not just for mangroves) for other regions in South Asia.
- In mangrove regions, anthropogenic changes are much more significant than natural changes; thus, more attention is needed to study LCLUC drivers. Urban development and shrimp farms have been replacing mangroves in several regions of the world—including South Asia.
- Large regions in Bangladesh are flood-prone. Wetlands associated with river/floodplain systems capture and retain water, and thereby reduce the duration and severity of floods. Wetlands are being converted into built-up areas at a rapid rate, affecting both groundwater and flooding.

Yogesh Kant [Indian Institute of Remote Sensing, Dehradun] closed out the technical sessions. Important points relating to the urban presentations are summarized here:

- Urban sprawl is a major LCLUC issue in South Asian countries.

[4] Principally supported by NASA and the U.S. Agency of International Development, SERVIR is a global network of regional partners dedicated to environmental management through the integration of Earth observations and geospatial technologies.

- *Urban clusters* have become a key topic in economic, innovation, and globalization debates. The underlying socioeconomic drivers in urban clusters need more attention, as they represent agglomerate economies. Drivers and patterns of urban expansion in India are different from those in China. Urban development intensity and spatial extent can be assessed from satellite data through mapping the impervious surface distortions, which is being undertaken in a NASA LCLUC project at GSFC and UMD.

- Nighttime surface temperature can provide robust information to help understand urban heat island phenomena, whereby radiative cooling differences are maximized between urban and surrounding rural locations at night.

- In Kerala, traditional labor-intensive agriculture is becoming less economically viable; buying agricultural land and wasteland for real estate development is seen as a quick investment opportunity.

On the same day, the meeting participants took a half-day field-trip to the Attappady Valley in Palakkad district, and got first-hand experience with ecorestoration projects in the region.

Olga Krankina led a panel discussion, titled *Towards a regional GOFC/GOLD South Asia Information Network (SARIN): Prospects, Opportunities, and Challenges*. Participants included representatives from India, Afghanistan, Nepal, Myanmar, and Bangladesh. Some of the important regional science priorities mentioned during the panel discussion are highlighted here:

India

- LCLUC and water resources are a high priority area in South India. Several irrigation projects focusing on LCLUC in the Western Ghats river basin provide a good opportunity to develop underpinning science.

- Research into the links between LCLUC and climate-change studies are needed, as are studies focusing on the impact of LCLUC on human livelihoods.

- A multiyear regional science initiative is needed, complementing initial national funding and international funding. Such an initiative should include data sharing and infrastructure, including data centers focused on implementation of the initiative.

Afghanistan

- Science programs need to be built from scratch; international help is much needed. A national research priority is on land use and water resources. Research on agricultural drought and uncontrolled urban expansion is needed to help in developing of national policies.

- Extensive capacity building, education, training, and data access are needed on remote sensing and geospatial technologies.

Nepal

- There is a need to develop regionally consistent LCLUC datasets.

- Greater attention to agricultural and rangeland monitoring and management issues is needed in the mountain ecosystems that offer a number of methodological challenges to satellite-based monitoring.

- Biomass burning is a major transboundary air pollution problem; research is needed to inform both land management policy.

- Improved monitoring of forest and land cover change is needed to address threats to biodiversity in the Nepal Himalayas.

Myanmar

- Deforestation is accelerating in Myanmar; there is an urgent need for satellite-based forest monitoring at the national level.

- Similarly, the extent and impacts of biomass burning associated with slash-and-burn agriculture needs to be quantified and understood.

Bangladesh

- Training is urgently needed on remote sensing, e.g., workshops on how to access and use data. Advanced topical workshops are needed on recent science developments.

- Development of a regional science network is a priority, to include collaborative research projects; faculty, staff, student exchange programs; and data sharing.

Recommendations from the Panel on SARIN

- The panel was in full agreement that developing a major regional integrated science initiative—with a central theme of LCLUC aspects involving South Asia researchers—was a high priority; SARIN development would be an integral part of the initiative.

- International programs (e.g., GOFC–GOLD, START, MAIRS, GEO-GLAM), should be engaged as a means to strengthen the SARIN network, through science-based contributory projects. A series of SARIN planning workshops will be needed to identify, prioritize, and address local/regional scale research questions associated with such an initiative.

- Developing bilateral collaboration activities between SARIN countries and with the U.S. would strengthen regional LCLUC research and enable exchange of students and researchers.

- There is a need to strengthen capacity-building activities in SARIN countries on the use of satellite remote sensing datasets for LCLUC research.

- A regional integrated science initiative in South Asia would enable regional scientists to promote scientific data collection and dissemination activities. This would be facilitated by developing a dedicated data center.

Chris Justice ended the meeting with a summary of the most important LCLUC issues in South Asia, followed by closing remarks from **E.J. James** and **Garik Gutman**.

Sunday, January 13, 2013

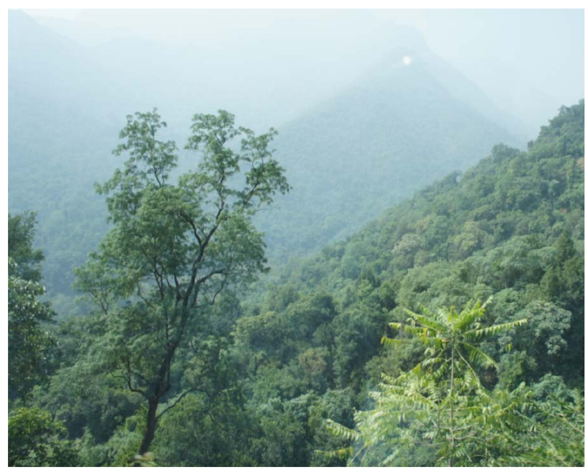
On January 13 an optional field visit was organized to Ooty (Udhagamandalam), located in the Nilgiris district of Tamil Nadu, a hill station with a range of LCLUC, including forest and eucalyptus, pine, and tea plantations—see photo on right. Many portions of the hills are preserved as natural reserve forests.

Training Workshop

The training workshop took place January 14 at Karunya University. The objective of the workshop was to introduce the latest methods, tools, and remote sensing data and products available for advanced studies of LCLUC dynamics in South Asia, with a focus on water resources, agriculture, and food security. Nearly 130 participants from different universities in India attended the highly successful training program, which was conducted by **Jiaguo Qi, Krishna Vadrevu, Atul Jain,** and **Prasad Thenkabail**.

The following topics were discussed: Fundamentals of remote sensing and geospatial technology; advanced tools, methods, and data products for land use and land cover, air pollution and applications; environmental modeling and land-use and land-cover change and its impact on biogeochemistry (carbon and nitrogen) and biogeophysics (water and thermal energy) in Asia; and data, methods, and tools for Earth observation for studies pertaining to global croplands, cropland water use, and food security.

START and UMD provided financial support for the workshop through NASA, CWRDM, Kozhikode, India, and Karunya University. The workshop agenda and presentations can be accessed at *lcluc.umd.edu/meetings.php?mid=40*. A training certificate was issued to participants who attended the training.



Fog enshrouds the forest-covered hills at Ooty (Udhagamandalam), located in the Nilgiris district of Tamil Nadu.

ASTER Science Team Meeting Report

Nina Cole, NASA/Jet Propulsion Laboratory/California Institute of Technology, nina.l.cole@jpl.nasa.gov

The forty-second Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting took place December 10-13, 2012, at the Sheraton Pasadena Hotel in Pasadena, CA.

Opening Plenary Session

H. Tsu [Japan Space Systems (J-spacesystems)—*Japan ASTER Science Team Lead*] and **M. Abrams** [NASA/Jet Propulsion Laboratory (JPL)—*U.S. ASTER Science Team Lead*] welcomed 61 U.S. and Japanese Science Team members and interested participants to the meeting. The team leaders informed attendees of the renewed Memorandum of Understanding (MOU), agreed upon by the U.S. Department of State and the Japan Ministry of State, which extends the ASTER project for seven more years.

M. Abrams opened with the latest news from NASA headquarters. He introduced **K. Thome** [NASA's Goddard Space Flight Center (GSFC)] as the new Terra Project Scientist [replacing Marc Imhoff (GSFC)] and supplied a timeline for the next Terra Senior Review in 2013. Abrams summarized ASTER science highlights, outreach activities, and recent publications. He concluded with a report on the Terra platform's fuel usage and battery status, confirming nominal spacecraft and instrument operations.

M. Kikuchi [J-spacesystems] reported on ASTER instrument status, addressing lifetime management, radiometric response, and end-of-mission (EOM) planning.

S. Hook [JPL] provided updates on the Hyperspectral Infrared Imager (HyspIRI[1]), Hyperspectral Thermal Emission Spectrometer (HyTES[2]), and Prototype Hyperspectral Thermal Infrared (TIR) Radiometer (PHyTIR[3]) activities. HyspIRI workshops are being held on an annual basis in advance of the post-2020 launch.

B. Eng [JPL] discussed the status of the Landsat Data Continuity Mission (LDCM)—the eighth in the Landsat series—scheduled to launch February 11, 2013[4].

M. Ramsey [University of Pittsburgh] reviewed Mineral and Gas Identifier (MAGI[5]) overflight activities and data analysis. Ramsey also discussed his involvement in outreach activities, including the "PhD in Residence" program funded under his ASTER award.

T. Matsunaga [National Institute for Environmental Studies (NIES)] provided an update on the Hyperspectral Imager Suite (HISUI[6]), a spaceborne instrument with hyperspectral and multispectral imagers. HISUI is the fourth spaceborne optical imager developed by the Japanese Ministry of Economy, Trade, and Industry (METI).

M. Hato [J-spacesystems] reported on ground data system (GDS) status, providing updates on observation scheduling, data processing, and product distribution. He then addressed activities planned for 2013. Level-1A (L1A) software will be updated following the termination of the shortwave infrared (SWIR) data stream, and all GDS Information Management System (IMS) users must reregister following the unification of ASTER and Phased Array type L-band Synthetic Aperture Radar (PALSAR) GDS data distribution systems.

D. Meyer [U.S. Geological Survey Land Processes Distributed Active Archive Center (USGS LP DAAC)] reviewed LP DAAC ASTER activities, including data production, distribution metrics, EOM planning, and the usefulness of application-ready ASTER products such as TerraLook.

M. Fujita [J-spacesystems] presented the Science Scheduling Support Group (SSSG) and Operations and Mission Planning (OMP) report. He reviewed the general status of ASTER scheduling and observation progress for major Science Team Acquisition Requests (STARs).

To close the plenary session, **Y. Yamaguchi** [Nagoya University] proposed two working group (WG) discussion issues: data acquisition monitoring and radiometric calibration coefficient (RCC) updates.

Working Group Sessions

Level-1/Geometric/Digital Elevation Model (DEM)

H. Fujisada [Sensor Information Laboratory Corporation (SILC)] started the session by discussing L1 software updates. Two adjustments are in progress: modifications to the L1 software to account for the suspension of SWIR data, and minor correction for the L1A+ and L1A++ tools. No appreciable problems were reported for ASTER geometric performance, instru-

[1] HyspIRI is a National Research Council (NRC) Decadal Survey *Tier II* mission, containing a visible shortwave-infrared (VSWIR) imaging spectrometer and a multispectral thermal-infrared (TIR) scanner.

[2] HyTES provides science risk reduction for HyspIRI; its first flights on an airborne platform began in July 2012.

[3] PHyTIR supplies engineering risk reduction for HyspIRI; instrument assembly will begin in 2013.

[4] **Update:** LDCM successfully launched on February 11 at 1:02 PM EST from Vandenberg Air Force Base in California.

[5] MAGI, an airborne sensor funded by NASA's Instrument Incubator Program (IIP), has 32 TIR channels.

[6] HISUI will be one of the mission instruments onboard Japan Aerospace Exploration Agency's (JAXA) Advanced Land Observing Satellite-3 (ALOS-3), scheduled for launch no earlier than 2015.

ment inter- and intra-telescope registration, or DEM accuracy. Fujisada then presented plans and improvements for the upcoming ASTER Global DEM Version 3 (GDEM V3).

R. Crippen [JPL] detailed the completion of his merged Shuttle Radar Topography Mission (SRTM)/ASTER GDEM 1-arcsecond DEM. Funded through NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program, Crippen's hybrid DEM fills voids, removes clouds and glitches, and fixes elevation and shoreline errors. The completed product will be released to the public, free of charge, at three-arc-second postings in early 2013. He also announced plans to develop a NASA Digital Elevation Model (NASA DEM)—using reprocessed SRTM data—that will be suitable for public release at 1-arcsecond postings.

D. Meyer discussed LP DAAC ASTER data production status and distribution metrics. He also reviewed the U.S. Science Team's recommendation to generate and archive all ASTER L1B and higher-level data products (HLDPs) at EOM. Meyer's talk concluded with discussions on the desirability of a L0 archive, and how to proceed with the NASA/Terra Senior Review's recommendation to include orthorectified HLDPs in the EOM archive.

Temperature-Emissivity Separation (TES)

Y. Yamaguchi presented work on the normalized difference vegetation index (NDVI)-based spatial sharpening of TIR images. Results obtained using the established thermal sharpening method (TsHARP) can be improved when the effect of spatial extent is considered.

H. Tonooka [Ibaraki University (IU)] began his series of presentations by announcing the release Version 1 of the Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J). This publicly available online database, which uses ASTER TIR data, includes all major lakes and many small water bodies in Japan. Tonooka then proposed the incorporation of a spectral emissivity ratio-based TIR snow/ice index (TSI) to enhance traditional remote sensing techniques for snow and ice. He ended by discussing the National Institute of Advanced Industrial Science and Technology's (AIST) ASTER time-series orthorectified products and IU's role in generating land-surface temperature and emissivity (LST&E) products. Comparison studies to evaluate emissivity maps generated by IU and JPL are underway.

S. Kato [NIES] reported on results derived from a Terra/Moderate Resolution Imaging Spectroradiometer (MODIS) mid-infrared (MIR) and TIR validation experiment. By coordinating a Terra overpass with the intentional burning of a wood building, researchers found that the MODIS MIR bands detected the burning area, but not the TIR bands. Using Moderate Resolution Atmospheric Transmission (MODTRAN) simulations and ASTER TIR comparisons, investigators concluded that *burning events* are detectable by high-resolution sensors at TIR bands and coarser-resolution sensors at MIR bands.

G. Hulley [JPL] detailed methodology to generate a unified high-spectral-resolution (HSR) MODIS/ASTER (MODAST) emissivity database, a NASA MEaSUREs project. Fusing ASTER Global Emissivity Mapping (ASTER-GEM) HSR data with MODIS Baseline-Fit (MODBF) V4.1 data enhances the advantages of the two products while minimizing their individual limitations. Hulley then presented an update on the MODIS-TES (MOD21) LST&E product. Developed at JPL using the ASTER TES algorithm, MOD21 will be released in 2013 with MODIS *Collection 6*.

M. Ramsey summarized the presentation that he and A. Gillespie [University of Washington] gave at the American Geophysical Union (AGU) conference in December 2012 on the variability of emissivity. *Emissivity*, which is typically taken to be constant in remote sensing, is not always immutable. Their presentation detailed two kinds of variable emissivity—*artifactual/apparent* and *natural*—and showed that each can dramatically alter the emissivity spectrum of common minerals.

A. Gillespie provided an update on a study conducted with **E. Abbott** [JPL] aimed at determining if TIR reflectivity of Earth-surface materials is a significant function of *kinetic temperature*. Though samples of field spectra and Nicolet reflectivity spectra initially suggested change, the results were not reproducible in subsequent experiments. They concluded that TIR reflectivity of common Earth-surface materials is constant at ambient temperatures.

M. Ramsey presented mineralogy analysis of the Salton Sea geothermal field using data collected with the MAGI sensor. Comparison work among MAGI data, field data, and Spatially Enhanced Broadband Array Spectrograph System (SEBASS) data is ongoing.

The session ended with two TIR Global Mapping (TGM) presentations. **M. Fujita** reviewed the current status of TGM5; **H. Tonooka** analyzed TGM5 achievements using a MOD35-based cloud assessment, and then initiated a WG discussion on future TGM plans.

Radiometric Calibration/Atmospheric Correction (RC/AC)

B. Eng provided a status update for the U.S. ASTER atmospheric correction (L2) software. Following the verification of bug fixes implemented at the LP DAAC, V3.4 will replace V3.2 as the production version, with completion expected in January 2013. Meanwhile, V3.5 is under development.

F. Sakuma [J-spacesystems] reviewed visible and near-infrared (VNIR), TIR, and SWIR onboard calibration trends; no significant changes were reported. Sakuma also presented TIR outgassing test results.

M. Kikuchi summarized ASTER instrument status. The radiometric response in the VNIR and TIR has been decreasing gradually. To prevent further deviation from the fitting curve, during the first quarter of 2013 RCC parameters for VNIR and TIR will undergo simultaneous revision from V3.12 to V.3.13. Based on the recommendation of the RC/AC WG, the VNIR RCC will remain fixed at a constant value following the RCC version update. Kikuchi also reported fault tree analysis (FTA) results for VNIR and TIR sensitivity degradation, and that inclination adjustment maneuvers (IAM) conducted in 2011 and 2012 had negligible influence on VNIR and TIR sensors. His presentation concluded with an EOM instrument action plan proposal.

A series of discussions describing field campaigns and future plans followed, including presentations by: **H. Yamamoto** and **S. Tsuchida** [Geological Survey of Japan (GSJ)/AIST], **K. Arai** [Saga University]; **H. Tonooka, S. Kato,** and **T. Matsunaga** [NIES], **T. Fukuhara** [Hokkaido University] and **T. Kouyama** [AIST], and **J. Czapla-Myers** and **S. Biggar** [University of Arizona].

Results from cross-calibration studies support the proposal to fix the VNIR RCC at a static value. **K. Arai** conducted a cross-calibration comparison study using ASTER, Enhanced Thematic Mapper Plus (ETM+), MODIS, and Multi-angle Imaging Spectroradiometer (MISR) sensors. His cross- and vicarious-calibration results showed stable gains for all VNIR bands since 1500 days after launch. While these results were in close correspondence, they differed from onboard calibration values. Because this discrepancy is increasing, he emphasized the importance of implementing a fixed RCC value. **H. Yamamoto** and **S. Tsuchida** performed ASTER–MODIS cross-calibration in conjunction with vicarious calibration to help understand the radiometric degradation trend. While cross- and vicarious-calibration results are in agreement, onboard-calibration results deviate. The WG recommends switching to a scaled calibration coefficient (SCC) and discontinuing the use of the onboard calibration degradation curve.

A. Iwasaki [University of Tokyo] discussed his investigation of the relationship between detector and preamp temperature and odd-even stripe noise.

Geology

M. Abrams relayed an ASTER Geoscience Maps of Australia Project report on behalf of **T. Cudahy** [Western Australian Centre of Excellence for 3D Mineral Mapping—*Director*]. A suite of GIS-compatible ASTER-derived mineral map products covering the entire Australian continent was released to the public at the thirty-fourth International Geological Congress (IGC) conference in August 2012. In addition to the maps' targeted use for mineral exploration, these map products can also be used for tracking desertification and assessing climate change impacts. Because mineralogy is a missing component from global resources and environment information system practices, such as the Group on Earth Observations (GEO), the WG encouraged further development of global ASTER geoscience maps.

J. Jay [Cornell University] reviewed ASTER volcano and glacier projects conducted with **M. Pritchard's** [Cornell University] group, and provided an update on the Cornell Andes Project. Thirty-five Andean volcano hotspots have been uncovered from a manual survey that included all ASTER nighttime TIR scenes collected over the region through 2010. (Prior to this study, only eight known hotspots existed in the Andean region). Jay then discussed the Cornell group's analysis of glacier velocities and elevation changes in Patagonian and southeast Alaskan icefields. Results show each icefield is thinning, and that overall mass change rates determined from ASTER DEMs agree with Gravity Recovery and Climate Experiment (GRACE) measurements.

J. Kargel reported on his combined use of ASTER data with field measurements to determine the cause of the May 2012 disaster in Seti River Basin, Nepal. Time-series analysis of data from both these sources showed that a deep-gorge rockfall might have dammed glacier meltwater drainage, creating an impoundment lake. Subsequently, a massive avalanche off Annapurna IV likely triggered the devastating flash flood. Following his fieldwork, Kargel participated in a NASA/U.S. Agency for International Development (USAID) workshop, *From Space to Village*, where he disseminated to the Nepalese public scientific findings related to the Seti River flood disaster.

J. Mars [USGS] discussed a NASA Applications Project that uses ASTER data to map hydrothermal alteration on volcanic summits. Because hydrothermally altered areas are prone to life-threatening debris flows, Mars' first 10 hazard maps will be selected from a pool of 100 mapped volcanoes, based on alteration extent and population distribution. All ASTER-derived map products, including *lahars* hazard maps and GIS shapefiles, will be available for download from the JPL ASTER Volcano Archive (AVA): *ava.jpl.nasa.gov*.

M. Ramsey's first presentation provided an update on the ASTER Urgent Request Protocol (URP) program, a rapid-response volcano-alert system. By highlighting two recent eruptions in the North Pacific—namely, Tolbachik and Chirpoi—Ramsey demonstrated the effectiveness of the URP system for acquiring, analyzing, and disseminating ASTER volcano data. Ramsey then described work, with graduate student S. Anderson [University of North Colorado], to create TIR and DEM maps of the Kizimen eruption. Ramsey (and Anderson) analyzed time-series ASTER data to document the progression of the lava flow. High-speed TIR video of active pyroclastic flows collected in the field will help validate flow-progression models.

V. Realmuto [JPL] discussed *Plume Tracker*[7] developments. The new V3.0 retrieval algorithms provide high numerical efficiency and high accuracy, ensuring optimal performance for upcoming graphic processing unit (GPU)-enabled radiative transfer (RT) modeling capabilities.

M. Urai [GSJ/AIST] reviewed the use of volcano hotspots to determine nighttime TIR geolocation accuracy. He showed results obtained over Erta Ale, located in northeastern Ethiopia, that indicate accuracy has improved with the implementation of geometric DB V3.02. On the other hand, geolocation errors persist over Erebus, located in Antarctica, indicating a latitude-dependent orthorectification issue.

P. Webley [University of Alaska Fairbanks (UAF)] discussed the importance of monitoring volcanic activity with remote sensing for aviation hazard assessment and risk reduction. He summarized UAF's Alaska Volcano Observatory suite of web tools and real-time thermal detection/alert system: *avo.images.alaska.edu/tools*.

J. Linick [JPL] introduced the newly redesigned AVA (URL listed above)—the online global volcano database of ASTER imagery. The AVA, covering all 1542 volcanoes from the Smithsonian's archive, contains over 134,000 individual granules and almost 3.5 million generated products. The new automatic data validation, ingest, and product generation process allows near-real-time AVA updates, with minimal manual intervention.

D. Pieri [JPL] provided a progress report on *in situ* gas and ash sampling activities at Turrialba Volcano in Costa Rica. Field data are combined with satellite measurements for detailed volcano-emission analysis. To conclude, Pieri presented plans for two upcoming Turrialba airborne deployments to correspond with ASTER overpasses.

Operations and Mission Planning

T. Tachikawa [J-spacesystems] presented a progress report on SWIR-off procedures. To successfully transition to *SWIR-off* mode, it will be necessary to update the following items:

- the *L1A processing algorithm,* to include dummy SWIR data (March 2013);
- the *scheduling parameter*, to reflect the change in data rate for full-mode observations without SWIR data; and
- *activity commands/sequence operations,* by turning off either the SWIR instrument or the SWIR data output to the solid-state recorder (SSR).

The full-mode data rate change may allow a 35% increase in daytime observations. The instrument team recommends turning off the SWIR data output as opposed to turning off the instrument itself.

M. Fujita analyzed ASTER observation resources and provided status updates for various STARs. The Global Mapping 5th Round (GM5) was submitted in February 2012, and will continue to acquire ASTER data globally until April 2017—or until observation rates level off. The achievement rate of nighttime TGM5 continues to be monitored with input from the TES WG. The Underserved Area (UA) STAR 2012 was submitted in June 2012, using the same areas of interest (AOI) as UA STAR 2011. Additional support STARs were submitted for Alaska, to increase collection opportunities in the region. AOIs for the next UA STAR will be generated following the release of GDEM V3. Fujita reviewed observation progress for both the Global Land Ice Measurements from Space (GLIMS) STAR 2012 and the Volcano STAR 2010. He then discussed urgent observation and field campaign success rates. To address failures caused by arbitrary shifts in the one-day schedule (ODS) end time, the ASTER Operation Segment (AOS) system was upgraded to allow operators to manually set the ODS end time. Fujita's presentation concluded with a summary of pointing-cycle resource consumption.

L. Maldonado [JPL] summarized Data Acquisition Request (DAR) user registration statistics for the lifetime of the ASTER mission. On average, 250 new DAR proposals are submitted each year.

T. Tachikawa discussed improved scheduling performance following the August 2012 adjustment of the scheduling priority parameter for cloud avoidance. Tachikawa's analysis revealed an increase in cloud-free ASTER scenes, a significant improvement in nighttime cloud avoidance, and less failure of urgent, GC, and local STARs.

K. Duda [LP DAAC] outlined L1 expedited data set (EDS) processing status, distribution metrics, and options for online access. Duda detailed new LP DAAC EDS website functionalities, including an email alert subscription service and map visualization options.

[7] *Plume Tracker* is an interactive toolkit for mapping volcanic plumes with remotely sensed multispectral TIR data.

Ecosystem/Oceanography

K. Iwao [GSJ/AIST] began by offering a summary of ASTER-related ecology research activities in Japan. He then discussed the current status of the ASTER/AIST Global Urban Area Map (AGURAM). Employing an automated method for integrating ASTER images and GIS data, AGURAM covers 3500 cities at 15-m resolution.

J. Kargel introduced a proposal requesting ASTER inputs to contribute to an in-depth biophysical survey of the Upper Seti Basin, Nepal. Year-round ASTER imaging would help improve understanding of the mass movement environment and processes, including snow avalanches, rockfalls, and debris flows.

L. Prashad [Arizona State University (ASU)] discussed ASU's 100 Cities Project and Java Mission-planning and Analysis for Remote Sensing (JMARS) for the Earth [J-Earth] activities. J-Earth updates include code integration with all JMARS products and the incorporation of *OpenStreetMap*[8] data. While the capability for users to directly import ASTER data is still under development, import is possible by processing ASTER data with *daVinci*[9] and using J-Earth as a display tool. The 100 Cities Project increased their global urban imagery holdings by obtaining all ASTER L1B, surface emissivity (AST05), and surface kinetic temperature (AST08) data for cities with populations over 500,000. The project is working with the LP DAAC to distribute these products as "Urban Bundles" with select urban-relevant datasets. Prashad concluded with examples of humanitarian remote sensing applications.

[8] Founded in the U.K. in 2004, *OpenStreetMap* is a GPS-based community project to generate editable global maps.
[9] *daVinci* is an interpreted language with vector-oriented features that works well as an image-processing tool.

G. Geller [JPL] discussed *TerraLook*[10] activities, including plans for an upcoming "TerraLook-inspired" version of Google Earth Engine.

STAR Committee

The committee heard, reviewed, and approved a new STAR proposal to support the HyspIRI preparatory aircraft campaign. Updates to the GLIMS and Volcano STARs will be forthcoming. **R. Crippen** reported that his GDEM/SRTM void-fill STAR proposal would be finalized by the end of January 2013. The STAR Committee will meet with the TES WG to discuss TGM modifications that will be required following the cessation of the SWIR data stream. The session concluded with the introduction of an action item to promote ASTER DAR and STAR capabilities.

Closing Plenary Session

All attendees reconvened to hear summaries from each WG session and to discuss issues proposed at the opening plenary. A short presentation by the instrument calibration team described their recommended actions to address VNIR response degradation, including fixing the RCC at present values so that RCC values do not deviate further from cross- and vicarious-calibration values. Attendees also discussed TGM data acquisition monitoring following SWIR data-off. Resource allocations will likely be rebalanced between day and night collections.

The meeting concluded with an announcement that the forty-third ASTER Science Team Meeting has been scheduled for June 10-12, 2013, in Tokyo, Japan. ■

[10] The *TerraLook* program provides no-cost access to ASTER and historical Landsat georeferenced *jpeg* images, along with a suite of simple visualization and analysis tools.

meeting/workshop summaries

NASA Ups the TEMPO on Monitoring Air Pollution

continued from page 15

For More Information

On degradation of air quality over the Canadian tar-sand oil excavation fields

- McLinden, C. A., V. Fioletov, K. F. Boersma, N. Krotkov, C. E. Sioris, J. P. Veefkind, and K. Yang, Air quality over the Canadian oil sands: A first assessment using satellite observations, *Geophys. Res. Lett*., **39**, L04804, doi:10.1029/2011GL050273, 2012.

On the potential of observing air quality from geostationary orbit

- Fishman, J., et al., Remote sensing of tropospheric pollution from space. *Bull. Amer. Meteor. Soc.*, **89**, 805–821, 2008.
- Fishman, J., *et al.*, The United States' Next Generation of Atmospheric Composition and Coastal Ecosystem Measurements: NASA's Geostationary Coastal and Air Pollution Events (GEO-CAPE) Mission, *Bull. Amer. Meteor. Soc.*, **93**, 1547-1566, doi:10.1175/BAMS-D-11-00201.1, 2012. ■

ESIP Federation Meeting

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Introduction

The Federation of Earth Science Information Partners (ESIP[1]) met in Washington, DC, January 8-10, 2013, for its semi-annual meeting, which was titled: *ESIP Advancing Earth Science Information: From Climate Assessment to Intelligence to Action*. Some 200 people gathered in Washington, while another 30 participated remotely—extending the conference to many who were unable to travel. The meeting was filled with many opportunities to learn from experts who utilize the Federation platform to collaborate with their peers.

Four Perspectives on the Federation

Kathy Jacobs [Office of Science Technology Policy (OSTP)—*National Climate Assessment Director*] kicked off the opening plenary presentations, and provided insights into the upcoming release of the draft National Climate Assessment Report[2]. With the Federation's broad base across federal agencies, all of which contribute to the U.S. Global Change Research Program, Jacobs's talk was the impetus for continued Federation involvement with the sustained assessment process—given its focus on *"…enhanced timely access to assessment-related data from multiple sources useful for decision making."*

Ann Bartuska [U.S. Department of Agriculture—*Deputy Undersecretary for Research, Education, and Economics* and *U.S. Global Change Research Program Principal*] provided a glimpse into the agency's Life Cycle Assessment (LCA). Digital Commons, a repository that provides open access to LCA data, provides transparent and high-quality information, and maximizes and expedites investments in sustainability research. The LCA Digital Commons provides data from a variety of U.S. federal and international sources.

Ghassem Asrar [World Climate Research Programme (WCRP), Switzerland—*Director*], spoke about his office's focus on providing reliable climate information "…for use in an increasing range of practical applications of direct relevance, benefit, and value to society." To this end, he highlighted a number of stakeholder and urgent user needs:

- "Actionable" climate information based on sound science;
- "symbiotic" relationships between providers and users of climate information to ensure climate information is timely, accessible, and easy to understand; and
- training and development of the "next generation" of scientists and decision makers who pursue and promote the use of actionable climate/environmental information.

Kit Batten [U.S. Agency for International Development (USAID)—*Global Climate Change Coordinator*] cited her agency's ongoing need for data and information that can assist on-the-ground decision makers with adaptation and mitigation practices. She cited USAID's Famine Early Warning System Network (FEWS NET) as a supported primary activity that uses historic climate data and model projections to 2025 in a downscaled fashion to assist with crop adaptation strategies.

Interagency Panel on Earth Science Data Interoperability

Building on the interagency perspectives on the Federation shared on the first day, the second day featured an interagency panel on Earth science data interoperability.

Peter Colohan [OSTP] served as moderator. Panelists included:

- **Jeff Walter** [NASA's Goddard Space Flight Center—*Earth Science Data and Information System Deputy (ESDIS) Project Manager*];
- **Jeff de La Beaujardière** [National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service (NOAA NESDIS)—*Environmental Data Management Committee Chair*];
- **Kevin Gallagher** [U.S. Geological Survey (USGS)—*Associate Director of Core Science*]; and
- **Bob Chadduck** [National Science Foundation (NSF)—*Program Manager.*]

Panelists shared their respective agency's challenges and approaches regarding interoperability. In reflecting on the importance of this panel, **Karl Benedict** [University of New Mexico's Earth Data Analysis Center—*ESIP Federation President*] noted that, "Bringing together panelists from the major federal Earth science agencies provided a great opportunity for them to share their data interoperability strategies, both with the Earth science data community that the Federation brings together, [and] with each other—as was demonstrated

[1] Hereinafter referred to as "the Federation."
[2] Following extensive review by the National Academy of Sciences and by the public, this draft report will be revised by the NCADAC and, after additional review, will then be submitted to the Federal Government for consideration in the Third National Climate Assessment (NCA) Report. To review the draft report, visit: *ncadac.globalchange.gov*.

Panel members [*left to right*] **Jeff delaBeaujardiere** [NOAA] and **Jeff Walter** [NASA].

Sara J. Graves [*left*] receives the fifth annual *Martha Maiden Award for Lifetime Achievement for Service to the Environmental Science Community* from **Martha Maiden** [*right*].

by the active question and answer session following the panel presentations and the continued conversations following the session."

Other Activities of Note

- A series of breakout sessions addressed technical, applied science, and training topics.
- The fifth annual *Martha Maiden Award for Lifetime Achievement for Service to the Environmental Science Community* was awarded to **Sara J. Graves** [University of Alabama in Huntsville].
- With a generous gift, the Foundation for Earth Science has established the *Robert G. Raskin Memorial Scholarship*. The Raskin Scholarship honors Raskin's legacy of dedication to supporting the next generation of Earth science data, technology, and informatics leaders. More information is available at *esipfed.org/Raskin*.
- The Federation's Assembly elected its slate of leaders for 2013—see *The Federation Selects Its Leaders*—on the next page.
- The Federation's Assembly approved 8 new partners, bringing its total membership to 150—see *The Federation Continues to Grow*.

The Federation Selects Its Leaders

The ESIP Federation elected new officers for 2013:

- ***President*—Karl Benedict** [Earth Data Analysis Center, University of New Mexico]
- ***Vice President*—Annette Schloss** [University of New Hampshire]
- ***Constitution and Bylaws Committee Chair*—Tamara Ledley** [TERC]
- ***Finance and Appropriations Committee Chair*—Charles Hutchinson** [University of Arizona]
- ***Partnership Committee Chair*—John Scialdone** [Socioeconomic Data and Applications Center/ Center for Interantional Earth Science Information Network, Columbia University]
- ***Data Stewardship Committee Chair*—Curt Tilmes** [U.S. Global Change Research Program/NASA]
- ***Education Committee Chair*—Roberta Johnson** [National Earth Science Teacher Association]
- ***Information Technology and Interoperability Committee Chair*—Matt Austin**, [NOAA]
- ***Products and Services Committee Chair*—Chris Mattmann** [NASA/Jet Propulsion Laboratory (JPL)]
- ***Type I*[1] *Representative*—Brian Wee** [NEON, Inc.]
- ***Type II Representative*—Emily Law** [JPL]
- ***Type III Representative*—Stefan Falke** [Northrop Grumman]

[1] The Federation is comprised of several types of partners. Type I ESIPs generally represent data centers; Type II ESIPs generally represent researchers; Type III ESIPs generally represent application developers; and Type IV ESIPs represent sponsoring agencies.

The Federation Continues to Grow

When NASA began the "working prototype" Federation in 1997, could it have imagined that 16 years later, the Federation would be alive and well—and growing! Those who remember its humble (and sometimes tumultuous) early years can marvel at how far the Federation has come. What began as an "experiment" in working together has succeeded in creating a broad-based, distributed community of practice that leverages Earth science data and information technology to work together to address common challenges.

At its 2013 winter meeting, the Federation welcomed 8 new members, swelling its ranks to 150 partners. While these members represent a wide variety of backgrounds from government (both the U.S. and abroad), academia, and the private sector (both commercial and non-profit), they are all unified behind a common commitment: *Fostering connections to make data matter*.

"This new class of members reflects the growing interest from home and abroad in the ESIP Federation," said **Karl Benedict** [University of New Mexico—*ESIP Federation President*]. "The ESIP Federation's community approach is gaining recognition for its effectiveness in tackling common technical problems facing data systems providers. The ESIP Federation's collaborative and consensus-driven model has made it the organization of choice for many seeking to advance their own work as well as that of the global Earth science data and technology community."

All of these members voluntarily choose to participate in the Federation. The fact that the Federation continues to grow each year reflects that the Federation provides a unique, dynamic, and collaborative environment that allows participants (data providers, researchers, and users) to gather and exchange information. Says Benedict: "The continued growth and diversity of ESIP Federation partners exemplifies the continued relevance of the community approach. Practitioners from across the globe value the expertise of their peers in the ESIP Federation and both gain and contribute knowledge to this dynamic network."

The newest partners to the Federation are:

- Biological and Chemical Oceanography Data Management Office (BCO-DMO) (Type I);
- Colombian Geological Survey (Type II);
- Consortium for Ocean Leadership (Type II);
- Integrated Marine Observing System (IMOS) (Type II);
- Large-Scale Scientific Information Systems (LSIS) (Type III);
- Mercury Consortium (Type III);
- Met European Research Observatory (MetEROBS) (Type II); and
- Woods Hole Oceanographic Institution (Type II).

Congratulations to these new members. More details on each can be found at *bit.ly/WoMosW*.

Information on joining the Federation, as well as a complete list of all of the Federation's current members can be found at *www.esipfed.org*.

Conclusion

The Federation's semi-annual meetings are key venues to bring together the ESIP community and its partners to exchange knowledge, learn about technology innovation, and learn important skills necessary for remaining competitive in today's research world. All meeting sessions are captured at the *ESIP Federation Commons* website[3], including session notes from breakouts and available presentations. Plans for future meetings are also announced on this site. ■

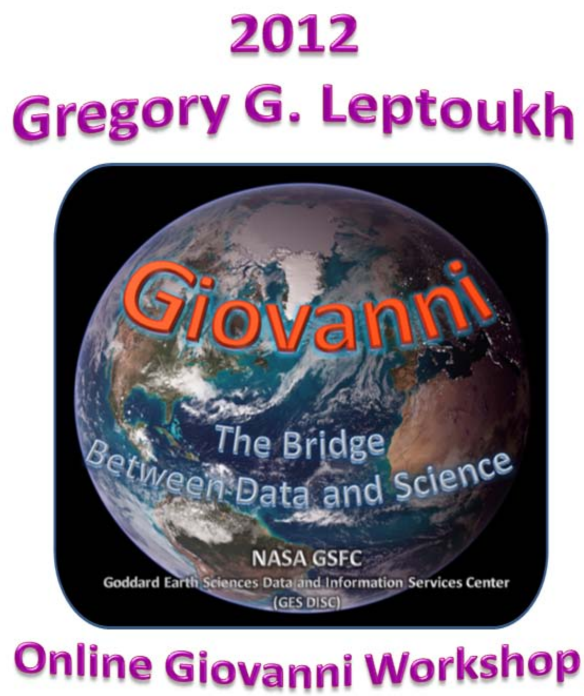
[3] To learn more, please visit: *commons.esipfed.org/schedule/Winter Meeting 2013*.

2012 Gregory G. Leptoukh Online Giovanni Workshop

James G. Acker, NASA's Goddard Space Flight Center, james.g.acker@nasa.gov

As a tribute to **Gregory G. Leptoukh**, the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) Data Manager who passed away suddenly on January 12, 2012, the GES DISC organized a workshop to highlight the scientific use of the *Giovanni*[1] data analysis system. The event took place September 23–25, 2012.

Giovanni was one of Leptoukh's main interests and significant accomplishments during his tenure at the GES DISC. He managed the development of the system, pioneered new data analysis capabilities in it, and sought collaborative use of it with researchers around the world. Because of the global reach of Giovanni and its ability to analyze global remotely sensed Earth observations from NASA satellites, it seemed appropriate to make the Giovanni workshop global as well. To facilitate the participation of scientists who had successfully and productively employed Giovanni by giving presentations on their specific research interests, the workshop adopted an online format. Presenters and participants used the online meeting environment *WebEx*[2] and conducted the meeting silently, with presenters typing their comments into the WebEx chat box as their slides were displayed. Using the chat box allowed organizers to capture verbatim narration and any question-and-answer dialogue from participants, so that they could be included with the presentations on a workshop proceedings webpage.



In all, there were 25 scientific presentations at the workshop, with scientists in six other countries participating along with many scientists in the U.S. **Steve Kempler** [NASA's Goddard Space Flight Center (GSFC)—*GES DISC Head*] and **Christopher Lynnes** [GSFC—*GES DISC Software Engineer*] took part in the workshop's opening session. Kempler welcomed all the workshop participants, and Lynnes provided a preview of the next-generation Giovanni system, *Giovanni-4*. On the third day, the workshop concluded with a roundtable discussion on using Giovanni for environmental and climate science education at the high school and undergraduate levels—described below.

Rachel Pinker [University of Maryland, College Park] described how her research group makes use of data from the Moderate Resolution Imaging Spectroradiometer (MODIS) to calculate radiative fluxes, which are primary drivers of the Earth's climate systems. **Radina Soebiyanto** [GSFC/Universities Space Research Association (USRA)] described several instances of communicable disease research using Giovanni. Her four examples were studies of malaria, dengue fever, avian influenza, and seasonal (human) influenza transmission. **Michael Wemberly** [South Dakota State University] discussed the use of various data types for malaria prediction in Ethiopia. **David Mocko** [GSFC/Science Applications International Corporation (SAIC)] discussed precipitation studies. He also described how both the North American and Global Land Data Assimilation Systems (NLDAS and GLDAS) were used to investigate several recent events, including the unusually warm winter and summer of 2011 in the U.S., the effect of hurricane Isaac on ongoing Midwest drought conditions, and the *derecho* event of June 29, 2012. **Amita Mehta** and **Ana Prados** [GSFC/University of Maryland, Baltimore County (UMBC) Joint Center for Earth Systems Technology] continued to focus on wind and precipitation, showing Giovanni precipitation data plots for several extreme rain events that contributed to dangerous flooding.

[1] Giovanni was developed by the GES DISC as a simple, intuitive way to access, visualize, and analyze vast amounts of Earth science remote sensing data—particularly from satellites—without having to download the data. Several *portals* have been created, each tailored to the specific needs of a particular Earth science research community. Giovanni includes data analysis tools for aerosols, atmospheric chemistry, atmospheric temperature and moisture, and rainfall, and can process output from assimilation models that address a wealth of atmospheric, land surface and oceanographic parameters. To find out more about Giovanni and its capabilities, please visit: *disc.sci.gsfc.nasa.gov/giovanni*

[2] The *WebEx* meeting environment was developed by Cisco Systems. See: *www.webex.com*

In the first day's evening session (morning, for residents of the Pacific Western Rim and Eastern Asia) **Paul Adams** [Fort Hays State University] discussed the Earth System Science Education Alliance (ESSEA). He described projects that employ Giovanni to illustrate particular concepts in ESSEA training "modules" he has developed. Reporting via the web from Beijing, China, **Suhung Shen** [GES DISC/George Mason University] discussed many land remote sensing data products now available in Giovanni, including remarkable 1-km- and 0.5-km-resolution land-surface-temperature- and land-cover-type data that can be used for drought research and to characterize urban heat island effects near major Chinese cities.

The second day began with **Jan Verbesselt** [Wageningen University, Netherlands] reporting on using Giovanni to apply satellite data for near-real-time disturbance monitoring. **Maksym Petrenko** [GSFC] described two results of collaborative work he had done with Greg Leptoukh—the Multi-Sensor Aerosol Products Sampling System (MAPSS) and the AeroStat aerosol data analysis system—both of which feature a Giovanni-based interface.

Sarah Strode [GSFC/USRA] used Giovanni to characterize smoke aerosols from forest fires to study the transport of the radioactive isotope cesium-137 (^{137}Cs) in the Northern Hemisphere. **Richard Hansell** [GSFC's Climate and Radiation Laboratory/UMCP Earth System Science Interdisciplinary Center (ESSIC)] focused on using Giovanni to examine dust aerosols, investigating their longwave radiative effects. He also showed some ground-based pictures of a mobile laboratory deployment in the Cape Verde Islands, which are frequently overswept by Saharan dust storms.

Eurico D'Sa [Louisiana State University] provided a detailed view of the Louisiana–Texas coast, merging Sea-viewing Wide Field-of-view Sensor (SeaWiFS) chlorophyll data from Giovanni with Quick Scatterometer (QuikSCAT) wind data from the NASA/Jet Propulsion Laboratory's Physical Oceanography DAAC (PO DAAC). **James Acker** [GES DISC] previewed Giovanni's MODIS-Aqua ocean color data anomaly analysis capability by examining ten years of Lake Michigan euphotic depth anomalies. **Tracy van Holt** [East Carolina University] provided one of the workshop's more unusual presentations, describing her work on the choices facing Chilean fishermen, who must choose to catch either the abalone-like shellfish, *loco,* or the eel-like fish, *congrio*. Holt used Giovanni to show that chlorophyll concentrations were higher offshore from river outlets that drain forest plantations. **Cecile Rousseaux** [GSFC] used the NASA Ocean Biogeochemical Model (NOBM), which she is refining with Watson Gregg [GSFC], to show a dramatic shift in the distribution of delectable (at least to zooplankton) diatoms between El Niño and La Niña conditions in the equatorial Pacific Ocean. **Zhen Liu** [Georgia Institute of Technology (Georgia Tech)] described the photochemical environment in the atmosphere above China, seeking the source of glyoxal ($C_2H_2O_2$). Liu found that the discrepancy between modeled and observed glyoxal concentrations was due to large underestimates of China's aromatic carbon emissions.

The workshop's final day began in the early morning in the U.S., as the first five presentations were given by scientists participating remotely from Europe and the Middle East. **Dimitris Kaskoutis** [Shiv Nadar University, India] described research into the atmospheric factors affecting net downward radiation in India, along with co-author **P.G. Kosmopoulos**. **Sergey Piontkovski** [Sultan Qaboos University, Oman] discussed the physical and biological oceanography of the Arabian Sea. **Sergei Sitnov** [A.M. Obukhov Institute of Atmospheric Physics] is one of Giovanni's most prolific users, and specializes in using nitrogen dioxide (NO_2) data from the Ozone Measuring Instrument (OMI) on Aura to investigate air pollution. His workshop presentation described how NO_2 concentrations vary with both location and day of the week around Moscow. **Pavel Kishcha** [Tel Aviv University, Israel] along with co-authors from that institution and JPL, looked at trends in MODIS aerosol optical depth over major cities in India and correlations with population growth. **Natalia Chubarova** [Moscow State University, Russia] followed, describing how Giovanni is an important tool for her aerosol research and environmental education curriculum.

In the next session, **Leonard Druyan** with **Matthew Fulukeza** [both from Goddard Institute of Space Studies (GISS)/Columbia University], demonstrated how data from TRMM can be used to observe propagation of convective rainfall systems over the eastern tropical Atlantic Ocean. **Charles Ichoku** [GSFC] discussed connections between environmental processes and drought in Sub-Saharan Africa. Drought in this region influences the frequency of fires, availability of water resources, health and extent of vegetative land cover, and ultimately the economic prospects and health of the human population. **Richard Kleidman** [GSFC/SSAI] described how Giovanni is used in the Applied Remote Sensing Education and Training (ARSET) program[3].

The final workshop session continued on an educational theme. **Daniel Zalles** [SRI International[4]—*Data-enhanced Investigations for Climate Change Education Project Principal Investigator*] outlined the project's

continued on page 49

[3] The ARSET program teaches professional audiences about the potential advantages and possible pitfalls of using remote sensing data.
[4] Formerly known as the Stanford Research Institute, but now referred to as SRI International.

CloudSat, CALIPSO, and EarthCARE Science Workshop

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Acknowledgement: This workshop was organized by the Institut Pierre-Simon Laplace (IPSL), Université Pierre et Marie Curie (UPMC), ESA, and CNES, in cooperation with NASA and JAXA.

Introduction

Synergistic observations obtained by the "A-Train[1]" constellation of satellites have demonstrated that *active remote sensing* observations (i.e., radar and lidar), combined with *passive remote sensing* observations[2], can provide a more comprehensive description of the three-dimensional state of aerosols and clouds than passive observations alone. Lidar observations from the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and radar observations from CloudSat have been combined with passive observations from other A-Train missions and with each other, to significantly enhance our understanding of key parameters related to Earth system processes and climate science.

To conclusively determine the impact that changes in aerosols, clouds, and precipitation are having on global climate, it will be necessary to continue these kinds of combined observations over a sufficiently long time scale. CloudSat and CALIPSO have done marvelous work, but both are now beyond their design life, and—unfortunately—current NASA plans do not call for any additional, active, space-based observations until the next decade[3]. However, the upcoming joint European Space Agency (ESA)–Japanese Aerospace Exploration Agency (JAXA) Earth Cloud, Aerosol, and Radiation Explorer mission (EarthCARE) presents an opportunity for international collaboration to continue the vitally important combined active–passive observations that the A-Train has pioneered.

Selected as an Earth Explorer mission under ESA's Living Planet Programme, EarthCARE is scheduled for launch in 2016. Unlike CloudSat and CALIPSO, EarthCARE will not be part of a constellation; the passive and active instruments are all on one platform. The planned payload includes a high-spectral-resolution UV lidar, 94-GHz Doppler cloud radar, a multispectral imager, and a broadband radiometer (in order to assess radiative effects of clouds and aerosols directly with collocated observations)—for more information, see *EarthCARE at a Glance* on page 45. In addition, there will also be opportunities for collaboration with other missions—in similar and different orbits—to allow for additional combinations of active and passive observations.

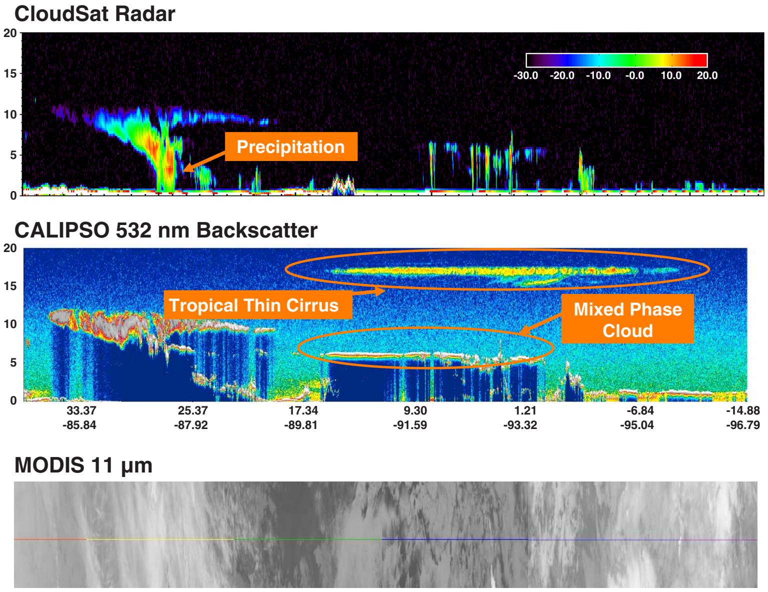
To discuss the possibilities for further cooperation, the Cloudsat, CALIPSO, and EarthCARE (CCE) Science Teams gathered for a joint meeting in Paris, France, June 18-22, 2012. This was an opportunity for the teams to review important new science results obtained using CloudSat and CALIPSO—combined with other A-Train data—and to underscore the progress on some of today's most pressing Earth science problems. Much of the progress reported is a direct result of the synergy between CloudSat and CALIPSO observations, in concert with other A-Train sensors—see **Figure** (next page). EarthCARE seeks to build upon this heritage by continuing these critical observations and extending them into the latter part of this decade.

The meeting focused on a number of topics, including new discoveries derived from the CloudSat and CALIPSO observations themselves, a focus on how the observations are improving the representation of physics in global weather and climate models, and sessions on integrated (multisensor) algorithms. The latter topic

[1] "A-Train" is the nickname for the *Afternoon Constellation*, a group of Earth-observing satellites operated by NASA and its international partners that closely follow one another along a similar orbital track. For more information, please visit: *atrain.nasa.gov/index.php*.

[2] Examples of passive observations obtained by the A-Train include water vapor measurements, from the Atmospheric Infrared Sounder (AIRS) on Aqua and Microwave Limb Sounder (MLS) on Aura; imagery, from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua; and Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL).

[3] The 2007 Earth Science Decadal Survey calls for an Aerosols, Clouds, and Ecosystems (ACE) mission (*Tier 2* priority) that would continue "A-Train-like" measurements; the mission currently is in preformulation, and is not expected to fly until 2020 or later.



The figure shows an illustration of the *synergy* of "A-Train" observations. The data here were obtained on February 5, 2007 when the A-Train passed over the Indian Ocean to the west of Southeast Asia. Shown here are the "points of view" that CloudSat's 94 GHz Cloud Profiling Radar (CPR) [*upper panel*], CALIPSO's Cloud–Aerosol Lidar with Orthogonal Projection (CALIOP) [*middle panel*], and Aqua's Moderate Resolution Imaging Spectroradiometer (MODIS)—11 µm radiances—obtained. Multiple instruments observing the same phenomena within seconds-to-minutes provide the most detailed images of the three-dimensional structure of clouds, aerosol, and precipitation that have ever been obtained and are significantly improving our understanding of these important atmospheric phenomena. **Image credit:** *CPR Data*—CloudSat data center at Colorado State University; *CALIOP Data*—NASA's Langley Research Center's Atmospheric Sciences Data Center (ASDC); *MODIS Data*—Goddard Earth Sciences Data and Information Services Center (GES DISC) at NASA's Goddard Space Flight Center (subsetted along the CloudSat ground track and sent to the CloudSat data center for processing).

included discussion of progress on EarthCARE algorithms and their evaluation based on A-Train data.

Working Group Summaries

There were four working groups (WGs) that provided a forum for more-detailed discussion of select topics of interest. Each group focused on one or more questions, as summarized here:

- **Working Group #1**: What is needed for long-term cloud and aerosol monitoring?
- **Working Group #2**: Are data being used optimally for progress in improving models?
- **Working Group #3**: What are the lessons learned from CloudSat and CALIPSO calibration/validation (cal/val) efforts to-date that could be transferred to EarthCARE?
- **Working Group #4**: What should algorithm developers be focusing on? How can the community provide continuity between the CloudSat/CALIPSO and upcoming EarthCARE lidar/radar products?

The discussions that took place during the working group sessions are summarized here. The **Table** below lists the participants in each group.

Working Group #1: Cloud and Aerosol Profiling

Clouds are one of the most fundamental components of Earth's climate; their response to *forcings*, in the form of *feedbacks*, largely determines climate sensitivity. Clouds play a dominant role in influencing Earth's energy balance, and are critical to water cycling through the system—and thus have profound influence on Earth's climate.

In view of the fundamental importance clouds play in regulating Earth's climate and the nature of their role, the unified message from the CCE teams is that the current *de facto* strategy of using passive imaging radiometers alone to provide long-term climate data records for clouds and aerosols is inadequate.

Many of the results presented at the meeting highlighted the fundamental importance of profile information available from current active instruments and important recent progress. The ability to jointly observe clouds and precipitation has been fundamental in advancing our understanding of *moist processes* and their parameterization. It is clear that active instruments provide the most direct information on the occurrence of cloud and aerosol layers, and provide our best understanding of many key cloud and aerosol properties and the processes that

Table. List of CCE Workshop Working Groups (WG) and Participants. The chair of each group (or book captain) is italicized.

WG 1	**Cloud and Aerosol Profiling**	*Graeme Stephens*, Norman Loeb, Chip Trepte, Pavlos Kollias, Robin Hogan, Jacques Pelon, Hajime Okamoto,
WG 2	**Model Evaluation**	*Richard Forbes*, Jason Cole, Johannes Quaas, Helene Chepfer, Masaki Satoh, Jonathan Jiang
WG 3	**Calibration/Validation**	*Anthony J. Illingworth*, Ulla Wandinger, Markus Rapp, Dave Winker, Jay Mace, Yuichi Ohno, Julien Delanoë
WG 4	**Current and Future Geophysical Data Products and Retrievals**	*Dave Donovan*, Howard Barker, Takashi Y. Nakajima, Jacques Pelon, Dave Winker, Simone Tanelli

shape them. A number of examples were highlighted during the meeting, demonstrating how active sensor observations of the presence of clouds, precipitation, and aerosols have led to significant progress in understanding key moist physical phenomena and the interactions between clouds and aerosols. Examples were also presented in which the active profile information exposed a number of major ambiguities in passive cloud data and their interpretation.

Thus, the observations of the A-Train era have shown that active profiling information must be the foundation for future cloud and aerosol monitoring systems—not merely optional add-ons. To this end, the WG identified the following priorities moving forward:

- Establishing continuity between CloudSat, CALIPSO, and EarthCARE, and extending the data record beyond EarthCARE;
- developing relevant support mechanisms for the science community globally, to become engaged in analysis of EarthCARE data; and
- integrating precipitation data with cloud and aerosol data more effectively in future observing systems.

Working Group #2: Model Evaluation

To improve our ability to forecast weather, advance our understanding of the present state of Earth's systems, and predict how it is likely to change in the future, data collected from missions must be integrated smoothly into relevant computer models, in a timely fashion. Thus, the objective of this WG's discussion was to assess how well that process has worked with CloudSat and CALIPSO, and how the situation might be improved as we move into the EarthCARE era and beyond.

In making its recommendations, the WG acknowledged that the kinds of improvements envisaged will require the engagement of the relatively small numerical weather prediction (NWP) and climate model development communities with the larger data and algorithm development communities, to help identify specific sources of model errors and to develop a targeted model-improvement strategy. A science-focused workshop bringing the communities together would be one practical step to facilitate this.

That said, the Model Evaluation WG made the following recommendations on the direction of the science performed with CALIPSO and CloudSat data, and on considerations for the EarthCARE mission and beyond:

- The modeling and data communities need to work more closely together, to ensure the maximum benefit of the data from CloudSat, CALIPSO, and EarthCARE.
- The modeling and data communities should actively facilitate the acceleration of general circulation model improvement using radar and lidar observations combined with passive observations.
- The modeling community needs to determine specific metrics from active, passive, and synergistic data products to constrain model projections for future climate change.
- The research community should develop innovative, synergistic analysis of active–passive data, to evaluate relationships between variables that will provide insight into physical processes, and comparisons with equivalent model relationships.
- The modeling community should perform holistic model evaluation through simulator comparisons with multiple instruments, and make comparisons with synergistic retrievals.
- The data community must provide estimates of uncertainties for satellite retrievals and model satellite simulators.
- The data community must make high-resolution data products easily available, to facilitate evaluation and improvement of high-resolution regional models and cloud-resolving models (CRMs) and statistical parameterizations.
- The satellite data community should coordinate use of consistent ancillary data in retrievals from different satellites and data products.
- The modeling community needs to perform modeling studies, to indicate what climate-change signals could be observed with active sensors.
- Near-real-time (NRT) data should be provided on a best-effort basis, to get the maximum benefit from the mission.

Working Group #3: Calibration/Validation (cal/val) Working Group

The deliberations of the cal/val WG focused on activities relevant to the active systems. There are inherent advantages in calibrating active, nadir-viewing spaceborne systems—e.g., the ability to exploit the signal returns from stable and characterizable natural "targets," such as the ocean surface or the upper atmosphere.

This group's discussion focused on cal/val of Level-1 (L-1) and -2 (L-2) products. Directly measured (i.e., L-1) quantities depend only on instrumental characteristics, and can be addressed by characterizing the instrument both on the ground and in orbit. The availability of NRT data delivery—such as is being considered for EarthCARE—means that the quality of L-1 radar reflectivity and lidar backscatter profile data can be continually monitored by comparisons with the forward-modeled values from NWP forecasts and analyses, thus providing a rapid indication of instrument malfunction.

Recommendations and their rationales for validation of L-1 products follow:

- As demonstrated with CloudSat, radar reflectivity can be calibrated using ocean-surface returns, augmented by comparisons with mobile ground radar to verify antenna pattern and pulse shape. Doppler velocity can also be calibrated using the ocean-surface Doppler return.
- Statistical reflectivity calibration is also useful, and has been successfully demonstrated by CloudSat, exploiting the existing European surface network of 94-GHz cloud radars.
- As for CALIOP, the EarthCARE Atmospheric Lidar (ATLID) molecular channel can be calibrated using lidar returns from the aerosol-free 35-40-km altitude region.
- Standard targets for calibration of the ATLID co- and cross-polar particulate channels have not been identified, but likely can be found after launch. Land surfaces and clouds are likely targets.

Recommendations and their rationales for validation of L-2 products follow:

- All L-2 products should be compared with measurements from independent techniques, with uncertainties and biases that have been quantified. For example, vertically integrated ATLID extinction profiles should be validated with column aerosol optical depth from ground-based sunphotometers.
- The ATLID aerosol-typing algorithm has been developed based on 532-nm data. There is an urgent need to establish performance of the algorithm at 355 nm.
- Contingent on overlap of the CALIPSO and EarthCare missions, the CALIOP cloud-aerosol mask can be used to evaluate the performance of the ATLID cloud-aerosol discrimination algorithm.
- Before launch, airborne 94-GHz radar and 355-nm HSRL should fly in tandem with a second aircraft measuring *in situ* aerosol and cloud properties, to provide data to test ATLID retrieval algorithms. This should be repeated after launch, with the aircraft underflying the satellite.

Working Group #4: Data Products and Retrievals

The consensus within the group was that EarthCARE data products and algorithms prepared as official ESA and JAXA products are generally appropriate. In particular, synergistic multi-instrument retrievals based on variational schemes and physically based forward modeling are considered state of the art. At the same time, the group acknowledged the contribution of the production of data products from more-established single- and multi-instrument retrievals—facilitating continuity with CloudSat and CALIPSO records. The group considered as very important the ongoing detailed simulation and algorithm intercomparison studies within the CCE community; however, they were uncertain about supporting activities for cross-agency activities.

The following recommendations emerged from the group's discussion:

- More effort should be directed toward assessment of EarthCARE capabilities regarding stratospheric clouds and aerosols.
- There is a need for close collaboration between data product developers and the climate- and weather-modeling community.
- While the information content of EarthCARE sensors is high, retrieval results will depend on prior knowledge/assumptions of clouds (in particular, ice clouds) and aerosol microphysics. Therefore, there is an ongoing need for colocated aircraft-based lidar, radar, and *in situ* measurements.
- More attention must be paid to identifying and exploiting data product synergies with products from geostationary satellites—as no other satellites would be flying in the EarthCARE orbit.
- EarthCARE should aim at implementing timely delivery of data products, so that they can contribute to forecasting air quality and identifying aerosol sources.

Conclusion

The integration of aerosol, cloud, and precipitation observations from CloudSat, CALIPSO, and the A-Train has significantly advanced our understanding of key processes that define global precipitation, aerosol influences on clouds, and the three-dimensional (3D) distribution and properties of aerosol. The profiling capability of CloudSat and CALIPSO's active instruments has added a new dimension to our study of Earth's energy balance. Indeed, a number of activities have emerged that produce different depictions of the 3D view of the energy balance; efforts to intercompare and evaluate these various products should be encouraged. Serious ambiguities in past cloud and aerosol data records have been exposed by the CloudSat/CALIPSO data, such that active sensing is now recognized as the foundational tool for developing global cloud and aerosol data records. In addition to to the improvements in observational capability that will be achieved with EarthCARE, **continuity—with EarthCARE and beyond—will be vital for monitoring key elements**

of the climate system—i.e., clouds, aerosol. The science activities of CloudSat, CALIPSO, and EarthCARE are currently highly integrated, but there is, as yet, no identified funding pathway for CloudSat/CALIPSO researchers to participate in EarthCARE after its launch. It is important that CloudSat, CALIPSO, and EarthCARE be programmatically tied together to maintain and continue this important data record.

A follow-on CCE science workshop may take place closer to or after the launch of EarthCARE. ■

EarthCARE at a Glance

Orbit Information

Type: Polar Sun synchronous
Altitude (average geodetic): *Routine orbit*—408.3 km (~253.7 mi); *Calibration/validation (cal/val) orbit*—409.7 km (~254.6 mi)
Equatorial Crossing Time: 14:00 hours (2:00 PM local time; descending node).
Inclination: 97°
Period: *Routine orbit*—5552.7 sec (~1.5 hr); *Cal/val orbit*—5554.3 sec (~1.5 hr)
Repeat Cycle: *Routine orbit*—25 days; *Cal/val orbit*—9 days

Spacecraft Specs

The satellite design is driven by the requirements to accommodate a payload of four instruments while minimizing drag—leading to a design with a trailing solar panel (see drawing)—and providing high thermo-mechanical stability in order to fulfill the required coregistration and geolocation accuracy of the instruments. It is implemented through the use of a carbon-fiber-reinforced polymer (CFRP) structure based on a central cylinder, with an upper and lower platform panel. The side panels are directly connected to the upper and lower platform and to the central cylinder via shear panels. Additional CFRP support struts support the lidar instrument optical bench interfaces. A dedicated CFRP support structure for the radar ensures good alignment towards the lidar.
Length: ~19 m (62 ft)
Mass: 1859 kg (~4098 lbs) (excl. 313 kg (~690 lbs) propellant)
Power: 1645 W (average)
Downlinks: S-Band (satellite control and monitoring), X-Band (science data)
Design Life: 3 years, including 6 months commissioning phase, plus 1 year consumables

Launch Details

Date: 2016
Location: Centre Spacial Guyanais (CSG) [Guiana Space Center] near Kourou, French Guiana
Vehicle: Soyuz as baseline

Instrument Summaries

- **ATmospheric Lidar (ATLID):** Bi-static backscatter lidar operating at 355 nm with high spectral resolution receiver that has molecular, co-polar, cross-polar particulate channels. Horizontal sampling: 290 m (~951 ft); Vertical sampling:100 m (~328 ft). Telescope footprint: <30 m (<99 ft), Field of View tilted 3° backwards to reduce specular reflection on ice clouds.

- **Cloud Profiling Radar (CPR):** 94.05 GHz nadir pointing with Doppler capability, Sensitivity: At least -35 dBZ at 20 km (~12.4 mi) height. Range resolution 500 m (~1640 ft) with 100 m (~328 ft) sampling; Horizontal sampling: 500 m (~1640 ft); Pulse Repetition Frequency: 6100-7500 Hz.

- **Multi-Spectral Imager (MSI):** Nadir *pushbroom* imager with 7 channels: 670 nm, 865 nm, 1.65 µm, 2.21 µm, 8.80 µm, 10.80 µm, 12.00 µm. Swath: 150 km (~93 mi), tilted away from sunglint; Sampling: 500 m x 500 m (~1640 x 1640 ft).

- **Broad Band Radiometer (BBR):** 2 channels: 0.2-50µm, 0.2-4µm; 3 fixed telescopes: nadir, forward (+50°), backward (-50°); Integrated pixel size: 10 km x 10 km ~(6.2 mi x 6.2 mi); Radiometric accuracy: *SW*: 2.5 W/m^2sr, *LW*: 1.5W/m^2sr.

EarthCARE ESA data products will be freely available to the worldwide research community.

CloudSat and CALIPSO Release Updated Data Products

The **CloudSat** Data Processing Center (DPC) has released to the general science community, the R04 version of the new *2C-SNOW-PROFILE* (snow particle size distribution and snowfall rate) product.

All data users are asked to review the associated documentation including the Process Description Document on the CloudSat DPC website at *www.cloudsat.cira.colostate.edu/dataSpecs.php?prodid=95*.

Although currently there are no known issues with this product, please occasionally visit the *Data Issues* page of the DPC website and familiarize yourself with any issues before using any results in publications or presentations. This page is located at: *www.cloudsat.cira.colostate.edu/dataIssues.php*. Questions concerning the product or the ordering process can be directed to the DPC at *cloudsat@ciradpc.com.*

The Atmospheric Science Data Center (ASDC) at NASA's Langley Research Center, in collaboration with the **Cloud–Aersol Lidar Infrared Pathfinder Satellite Observations (CALIPSO)** mission, announces the release of the following expedited data products:

CAL_IIR_L1_Exp-Prov-V1-12

CAL_IIR_L2_Track_Exp-Beta-V3-02

CAL_IIR_L2_Swath_Exp-Beta-V3-02

CAL_LID_L1_Exp-Prov-V3-02

CAL_LID_L2_05kmALay_Exp-Prov-V3-02

CAL_LID_L2_333mCLay_Exp-Prov-V3-02

CAL_LID_L2_01kmCLay_Exp-Prov-V3-02

CAL_LID_L2_05kmCLay_Exp-Prov-V3-02

CAL_LID_L2_05kmCPro_Exp-Prov-V3-02

CAL_LID_L2_05kmAPro_Exp-Prov-V3-02

CAL_LID_L2_VFM_Exp-Prov-V3-02

CAL_WFC_L1_125m_Exp-Prov-V3-02

CAL_WFC_L1_1Km_Exp-Prov-V3-02

CAL_WFC_L1_IIR_Exp-Prov-V3-02

New Expedited CALIPSO Lidar and Infrared Imaging Radiometer (IIR) Level-1 and Level-2, and Wide Field-of-View Camera (WFC) Level-1 data products are now available to support near-real-time weather forecasting operations and measurement field campaigns. These daily products have a processing latency of less than eight hours from the time they are received at the ground station. They use the most current attitude information and a calibration and analysis scheme based on the best available calibration, ancillary, and meteorological data. Each granule covers a 90-minute period and includes both night and day portions of the orbit. The formats of the Expedited products are identical to the Standard CALIPSO data products and are described in the CALIPSO Data Products Catalog.

The Expedited data products will be available for a period of 30 days from the day they are produced—at which time the higher-quality standard data products will be available. **Science investigations to be published in research journals should, therefore, not be based on the Expedited data products, but should instead use the Standard CALIPSO Lidar, IIR, and WFC data products, which are superior to the Expedited products.**

Information about the CALIPSO products including data availability, user documentation and quality statements, relevant links, sample read software, and tools for working with the data, etc. can be found at the following ASDC link: *eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html*.

A wide variety of Expedited and Standard browse images can be viewed at *www-calipso.larc.nasa.gov/products/lidar/browse_images/production*.

Kudos

Doug Morton from the Biospheric Sciences Lab at NASA's Goddard Space Flight Center was selected as the 2012 recipient of the National Oceanic and Atmospheric Administration's *David Johnson Award*. This award is presented by the National Space Club for innovative applications of Earth observation satellite data.

Morton was cited for his research on satellite-based monitoring of deforestation, forest degradation, and fires, including participation in a team of scientists responsible for a new seasonal fire forecast for South America based on Moderate Resolution Imaging Spectroradiometer data and sea surface temperature anomalies.

The Earth Observer wishes to congratulate Morton on this achievement.

Liftoff for Landsat Data Continuity Mission!

The United Launch Alliance (ULA) Atlas V rocket with the Landsat Data Continuity Mission (LDCM) spacecraft onboard is seen as it launches on Monday, February 11, 2013 from Vandenberg Air Force Base. LDCM is a collaboration between NASA and the U.S. Geological Survey that will continue the Landsat Program's 40-year data record of monitoring the Earth's landscapes from space.
Image credit: United Launch Alliance

NASA Satellites Find Freshwater Losses in Middle East

Alan Buis, NASA/Jet Propulsion Laboratory, alan.buis@jpl.nasa.gov
Steve Cole, NASA Headquarters, stephen.e.cole@nasa.gov
Janet Wilson, University of California, Irvine, janethw@uci.edu

A new study, using data from a pair of gravity-measuring NASA satellites, finds that large parts of the arid Middle East region lost freshwater reserves rapidly during the past decade.

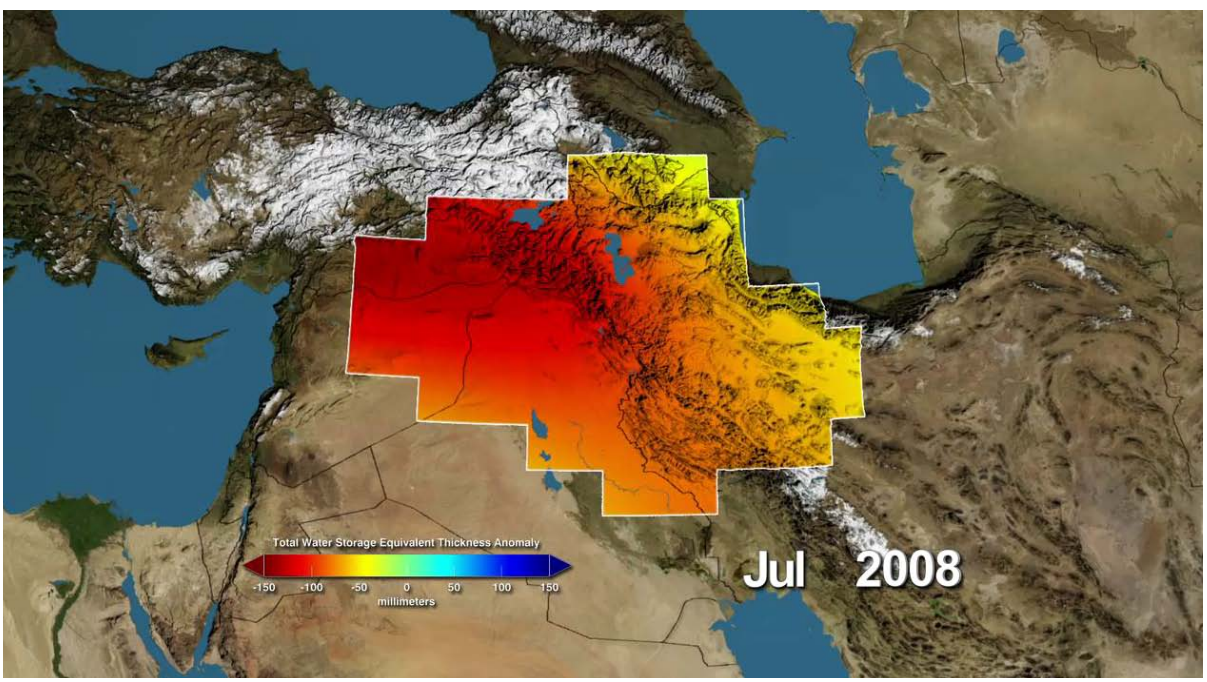
Scientists at the University of California, Irvine (UC Irvine), NASA's Goddard Space Flight Center (GSFC), and the National Center for Atmospheric Research (NCAR) in Boulder, CO, found, during a seven-year period beginning in 2003, that parts of Turkey, Syria, Iraq, and Iran along the Tigris and Euphrates river basins lost 117 million acre feet [MAF] (144 km^3) of total stored freshwater. That is almost the amount of water in the Dead Sea. The researchers attribute about 60% of the loss to pumping of groundwater from underground reservoirs.

The findings, published in the journal *Water Resources Research*, are the result of one of the first comprehensive hydrological assessments of the entire Tigris-Euphrates-Western Iran region. Because obtaining ground-based data in the area is difficult, satellite data, such as those from NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites, are essential. GRACE is providing a global picture of water storage trends and is invaluable when hydrologic observations are not routinely collected or shared beyond political boundaries.

"GRACE data show an alarming rate of decrease in total water storage in the Tigris and Euphrates river basins, which currently have the second fastest rate of groundwater storage loss on Earth, after India," said **Jay Famiglietti**, principal investigator of the study and a hydrologist and professor at UC Irvine. "The rate was especially striking after the 2007 drought. Meanwhile, demand for freshwater continues to rise, and the region does not coordinate its water management because of different interpretations of international laws."

Famiglietti said GRACE is like having a giant [extremely sensitive] scale in the sky. Within a given region, rising or falling water reserves [slightly] alter Earth's mass, influencing how strong the local gravitational attraction is. By periodically measuring gravity regionally, GRACE tells us how much each region's water storage changes over time.

"GRACE really is the only way we can estimate groundwater storage changes from space right now," Famiglietti said.



This image shows variations in total water storage from normal, in millimeters, in the Tigris and Euphrates river basins, as measured by GRACE satellites from January 2003 through December 2009. Red and orange represents drier conditions, while blue shades represent wetter conditions. The majority of the water lost was due to reductions in groundwater caused by human activities. By periodically measuring gravity regionally, GRACE tells scientists how much water storage changes over time. **Image credit:** NASA/UC Irvine/NCAR

The team calculated about one-fifth of the observed water losses resulted from soil drying up and snowpack shrinking, partly in response to the 2007 drought. Loss of surface water from lakes and reservoirs accounted for about another fifth of the losses. The majority of the water lost—approximately 73 MAF (90 km^3)—was due to reductions in groundwater.

"That's enough water to meet the needs of tens of millions to more than a hundred million people in the region each year, depending on regional water use standards and availability," said Famiglietti.

Famiglietti said when a drought reduces an available surface water supply, irrigators and other water users turn to groundwater supplies. For example, the Iraqi government drilled about 1000 wells in response to the 2007 drought, a number that does not include the numerous private wells landowners also very likely drilled.

"Water management is a complex issue in the Middle East—an area that already is dealing with limited water resources and competing stakeholders," said **Kate Voss**, lead author of the study and a water policy fellow with the University of California's Center for Hydrological Modeling in Irvine, which Famiglietti directs.

"The Middle East just does not have that much water to begin with, and it's a part of the world that will be experiencing less rainfall with climate change," said Famiglietti. "Those dry areas are getting dryer. The Middle East and the world's other arid regions need to manage available water resources as best they can."

Study co-author **Matt Rodell** of GSFC added that it is important to remember groundwater is being extracted unsustainably in parts of the United States, as well.

"Groundwater is like your savings account," Rodell said. "It's okay to draw it down when you need it, but if it's not replenished, eventually it will be gone."

For more about GRACE, visit: *www.nasa.gov/grace and www.csr.utexas.edu/grace*. ■

2012 Gregory G. Leptoukh Online Giovanni Workshop

continued from page 40

goals and accomplishments, including a streamlined Giovanni interface for use with multidisciplinary data, enhanced data information, and the project's Learning Environment.

The workshop closed with a education roundtable based on the use of Giovanni. Panelists included **Daniel Zalles, Jim Acker, Amanda Truett** [Montgomery College], **Ruth Krumhansl** [Education Development Center, Inc.], and **Bob Myers** [ESSEA]. This discussion found a distinct difference in the use of Giovanni at the high school level, where teachers have limited time to develop expertise with new technology, and the undergraduate college level, where professors can expect students to figure out how to use such a tool with less guidance, and then use it for problem-based learning. The panelists were particularly pleased that Giovanni gives both students and teachers the opportunity to work with real data, despite the uncertainties that can be introduced into the learning process through the use of such data.

Conclusion

This inaugural workshop was quite successful in highlighting the use of Giovanni for an extensive portfolio of scientific research utilizing the variety of data products the system offers. Both presenters and participants expressed their satisfaction with the system, particularly noting its ease of use, and the capability it creates to rapidly survey available data products that can be used to investigate particular research questions. Several comments from both workshop participants and readers of the online proceedings addressed potential new capabilities that they would like to see for the system. Such comments are valuable input to the development of Giovanni-4, which will continue the heritage of Giovanni in making NASA data easily accessible and eminently usable.

Greg Leptoukh envisioned Giovanni as a tool that would make NASA earth observation data more valuable to scientists by making the data easier to find and use; the research presented at the workshop named in his honor demonstrated that his vision is being constantly fulfilled by scientists around the world.

The full *Proceedings of the 2012 Gregory G. Leptoukh Online Giovanni Workshop* are available at *disc.sci.gsfc.nasa.gov/giovanni/additional/newsletters/proceedings_2012_leptoukh_Giovanni_online_workshop*. The Proceedings include each workshop presentation, accompanied by the presentations' narrative text and accompanying dialogue. ■

Landsat 5 Sets Guinness World Record For "Longest Operating Earth Observation Satellite"

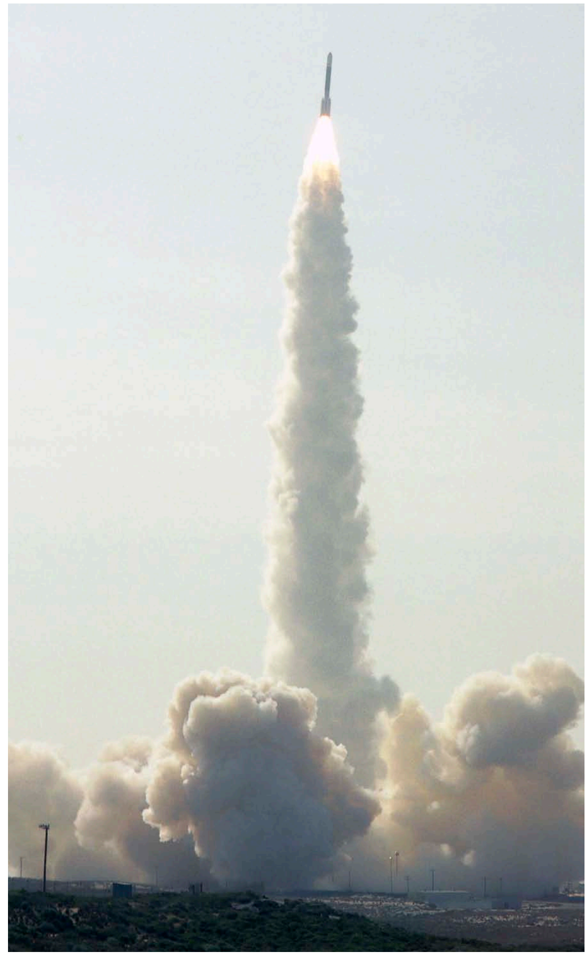
Laura Betz, NASA's Goddard Space Flight Center, laura.e.betz@nasa.gov

Landsat 5 successfully set the new Guinness World Records title for "Longest-operating Earth observation satellite" as stated in an email from Guinness World Records sent to NASA's Goddard Space Flight Center. Outliving its three-year design life, Landsat 5 delivered high-quality, global data of Earth's land surface for 28 years and 10 months.

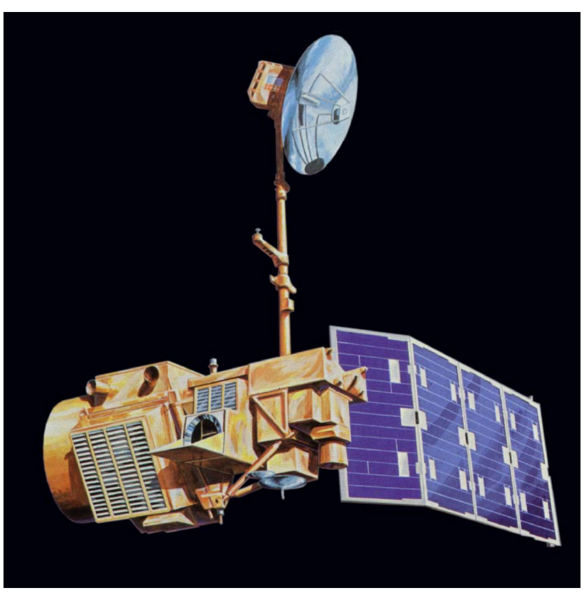
NASA launched Landsat 5 from Vandenberg Air Force Base in Lompoc, CA on March 1, 1984. Landsat 5 was designed and built at the same time as Landsat 4 and carried the same two instruments: the Multispectral Scanner System (MSS) and Thematic Mapper (TM).

Managed by the U.S. Geological Survey (USGS) as part of the Landsat Program, Landsat 5 completed over 150,000 orbits and sent back more than 2.5 million images of Earth's surface. On December 21, 2012 the USGS announced Landsat 5 would be decommissioned in the coming months after the failure of a redundant gyroscope. The satellite carries three gyroscopes for attitude control and needs two to maintain control.

"This is the end of an era for a remarkable satellite, and the fact that it flew for almost three decades is a testament to the NASA engineers who launched it and the USGS team who kept it flying well beyond its expected lifetime," said **Anne Castle**, Department of the Interior Assistant Secretary for Water and Science in a press release.



Landsat 5 taking off from Vandenberg Air Force Base, Lompoc, CA on March 1, 1984. **Image credit:** NASA/Raytheon



Artist's rendition of Landsat 5. **Image Credit:** USGS

Originally designed to be retrievable by the space shuttle, Landsat 5 was equipped with extra fuel. That extra fuel kept the satellite operating for much longer than anticipated after the space shuttle retrieval plan was thrown out[1].

Space is a harsh environment, and Landsat 5 faced more than twenty technical issues throughout its lifetime as parts gave way to wear and age. Landsat 5's USGS Flight Operations Team found engineering and operational fixes to work around the problems, which included losing batteries, star trackers, and on-board data recording capability.

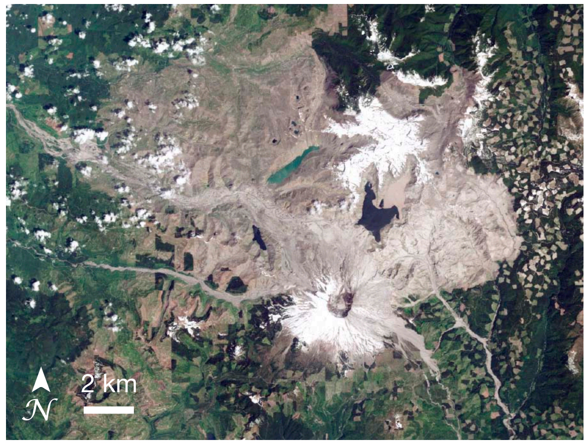
[1] To learn more about the Landsat legacy, read *Chronicling the Landsat Legacy* in the November-December 2011 issue of *The Earth Observer* [**Volume 23, Issue 6,** pp. 4-10].

"The efforts of the Landsat team were heroic. Landsat 5 could not have lasted so long without the dedication and devotion of the USGS flight operations team that overcame a number of difficult technical challenges over the last 12 years," said **Jim Irons**, Landsat Data Continuity Mission (LDCM) Project Scientist.

Not only did they keep the satellite going, said Irons, but in doing so, "Landsat 5 saved the Landsat program. This satellite's longevity preserved the Landsat program through the loss of Landsat 6 in 1993, preventing the specter of a data gap before the launch of Landsat 7 in 1999."

Today, the Landsat program continues to provide data used across the U.S. and the world for agricultural and forest monitoring and water resource management, among many other environmental applications.

NASA launched LDCM, the successor to the still operational Landsat 7 satellite, on February 11, 2013. LDCM carries two new instruments, the Operational Land Imager and the Thermal Infrared Sensor that collects data that are compatible with data from Landsat 5 and 7, and improve upon it with advanced instrument designs that are more sensitive to changes to the land surface, said Irons.

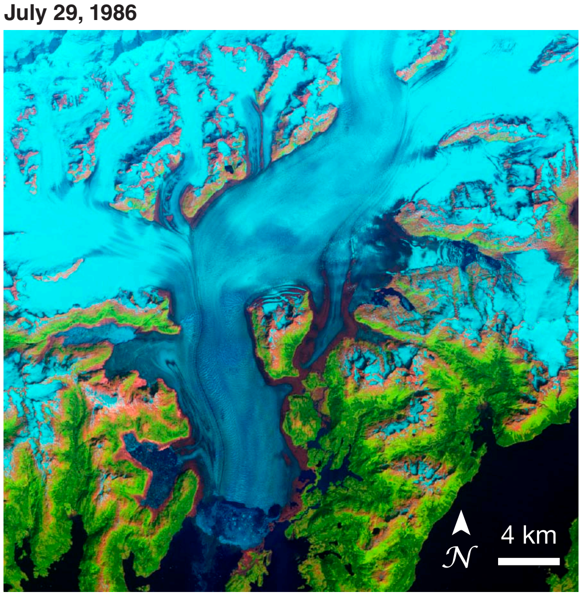


The 1980 Mount St. Helens eruption was one of the most significant natural disasters in the U.S. in the past half-century. Landsat-5 captured the extent of, and recovery from, the destruction. **Image credit:** NASA/USGS

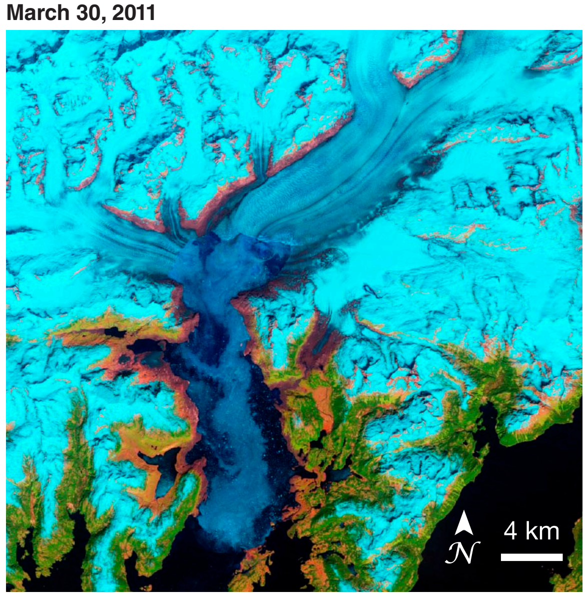
LDCM will continue the Landsat program's 40-year data record of monitoring Earth from space. Once the LDCM satellite is extensively tested and certified for its mission, it will be renamed Landsat 8 and be operated by the USGS[2]. ■

[2] To learn more about LDCM, see the article on **page 4** of this issue.

July 29, 1986



March 30, 2011



This image shows the Columbia Glacier in Alaska—one of many around the world that are vanishing. Landsat images, such as this pair, have helped scientists trace the retreat of glaciers over the last four decades. Glacier retreat is one of the most direct and understandable effects of climate change. **Image credit:** NASA/USGS

NASA Earth Science in the News

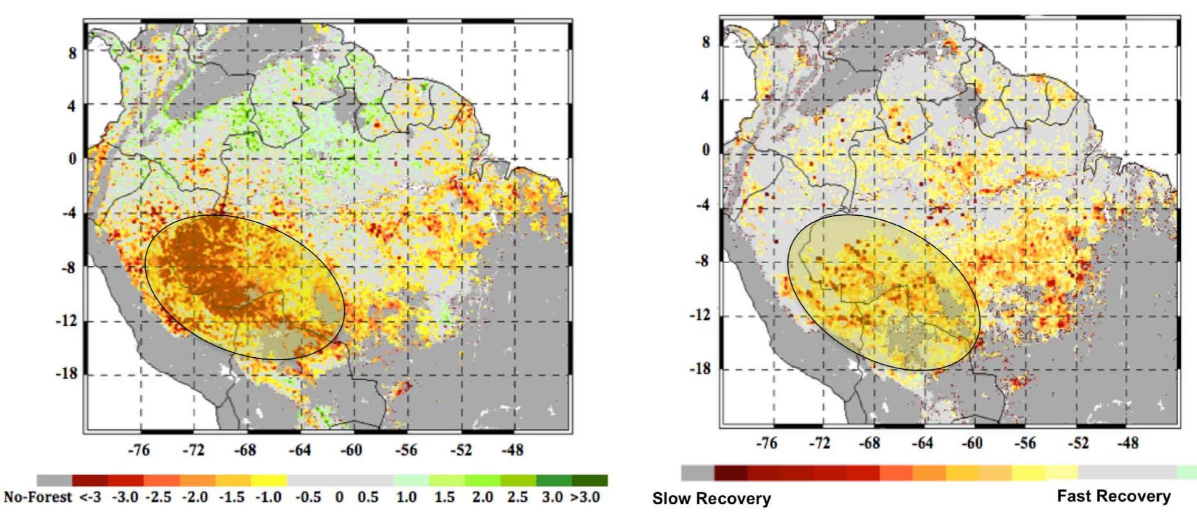
Patrick Lynch, NASA's Earth Science News Team, patrick.lynch@nasa.gov

Amazon Showing Signs Of Degradation Due To Climate Change, NASA Warns, January 13; *The Guardian.* The Amazon rainforest may be showing the first signs of large-scale degradation due to climate change. A team led by **Sassan Saatchi** [NASA/Jet Propulsion Laboratory] found that an area twice the size of California continues to suffer from a *megadrought* that began in 2005. The new study shows the severe dry spell in 2005 caused far wider damage than previously estimated, and its impact persisted longer than expected until an even harsher drought in 2010. With little time for the trees to recover between what the authors describe as a "double whammy," the analysis of 10 years of satellite microwave radar data revealed that 70 million hectares of forest have been severely affected. The data showed a widespread change in the canopy due to the dieback of branches, especially among the older, larger trees that are most vulnerable because they provide shelter for other vegetation.

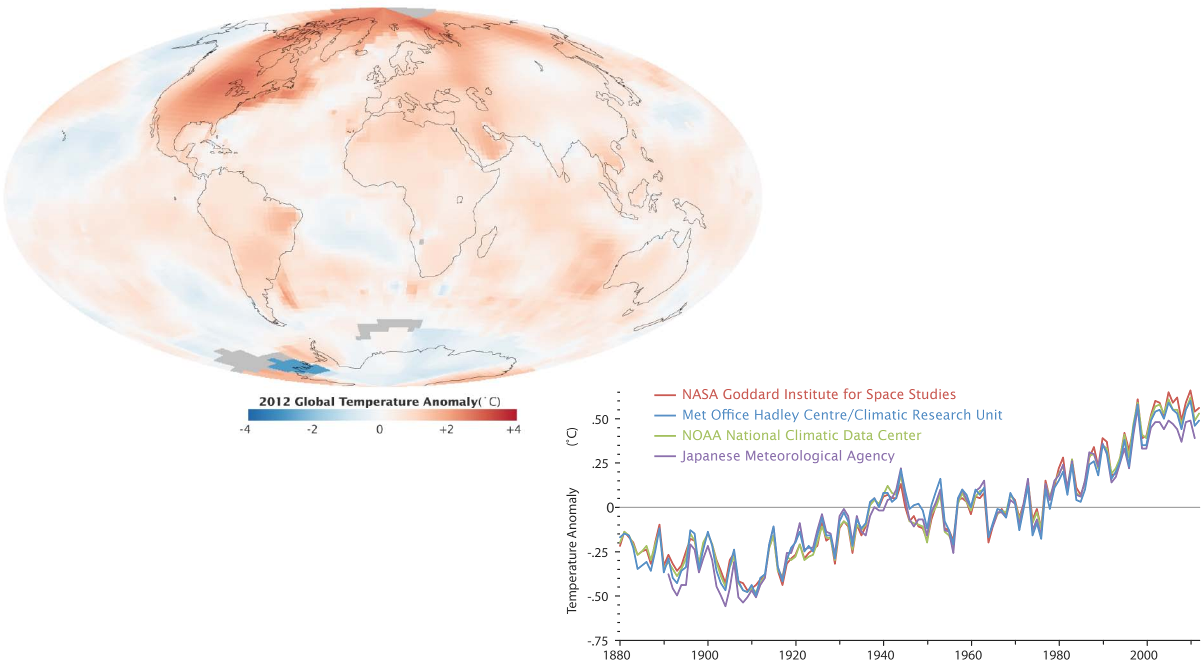
2012 Was Ninth Warmest Year On Record, Says NASA, January 15; *abcnews.com.* According to NASA climate scientists, the year 2012 was the ninth warmest globally since record keeping began in 1880, said climate scientists today from NASA. The National Oceanic and Atmospheric Administration, crunching the numbers slightly different, said 2012 was the tenth warmest year, but both agencies concurred that a warming pattern has continued since the middle of the twentieth century. "One more year of numbers isn't in itself significant," said **Gavin Schmidt** [NASA's Goddard Institute for Space Studies] in a statement. "What matters is this decade is warmer than the last decade, and that decade was warmer than the decade before. The planet is warming. The reason it's warming is because we are pumping increasing amounts of carbon dioxide into the atmosphere."

Water Leaking Into Stratosphere Could Harm Ozone, February 4; *ouramazingplanet.com.* Some of the coldest air on the planet lies over the tropics. And a new study finds that through this cold zone, more water than expected sneaks into the upper reaches of the atmosphere. Upon reaching the stratosphere, the layer of the atmosphere above the one in which we live, water vapor acts as a potent greenhouse gas and destroys the protective ozone. "Small changes in the humidity of the stratosphere are important for climate," said lead author of the study **Eric Jensen** [NASA's Ames Research Center]. The data for the study were collected during the Airborne Tropical TRopopause Experiment (ATTREX). Researchers had suspected water vapor rising into the tropopause would freeze and fall out in wispy cirrus clouds made entirely of ice crystals. In essence, they thought that the tropopause was a cold trap for water, keeping the vapor out of the stratosphere. "That turned out to be a bit of an over-simplification," Jensen said.

***Satellites Reveal Depletion Of A Vital Middle East Water Supply**, February 12; *The New York Times: Dot Earth blog.* Data from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites show a substantial decline in the volume of groundwater reserves



These images show the extent [*left image*] and recovery [*right image*] of the 2005 *megadrought* in the western Amazon rainforests during the summer months of June, July, and August as measured by NASA satellites. Red and yellow colors represent the most impacted areas. **Image credit:** NASA/JPL-Caltech/GSFC



The map here shows temperature anomalies by region in 2012. Red and blue colors show how much warmer or cooler each area was in 2012 compared to an averaged base period from 1951–1980. The graph shows yearly temperature anomalies from 1880 to 2011 as recorded by the NASA Goddard Institute for Space Studies, National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center, Japanese Meteorological Agency, and Met Office Hadley Centre in the United Kingdom. Though there are minor variations from year to year, all four records show peaks and valleys in sync with each other. All show rapid warming in the past few decades, and all show the last decade as the warmest. **Credit:** NASA's Earth Observatory

in the Tigris and Euphrates river basins between 2003 and 2009. The data show the seasonal recharge of the region's aquifers, but then there was the onset of a potent drought in 2007, followed by a persistent large drop in water amounts, 60% of which is ascribed to unsustainable rates of pumping, according to a study published in *Water Resources Research*.

Using Planes To Fix Air-Pollution Satellites, February 13; *livescience.com.* To better monitor aerosols and other pollutants, such as ozone and small particulates, NASA has launched a five-year mission called Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ). The Central Valley of California's unique pollution profile drew the attention of NASA scientists, who recently sent two research planes on swooping arcs from Bakersfield to Fresno. "Near-surface pollution is one of the most challenging problems for Earth observations from space," said **Jim Crawford** [NASA's Langley Research Center—*DISCOVER-AQ Principal Investigator*]. "To look at ground level, you still have to look through the whole atmosphere."

***Satellites See Arctic Sea Ice Decline**, February 13; *UPI.com.* Scientists report that U.S. and European satellites confirm that Arctic sea ice volume has declined 36% during autumn months, and 9% during winter months, during the last decade. Recent research has combined records of ice measurements from NASA's Ice, Cloud and Land Elevation Satellite, the European Space Agency's CryoSat-2 satellite, airborne surveys, and ocean-based sensors, NASA reported. "It's an important achievement and milestone for CryoSat-2," said study co-author **Ron Kwok** [JPL]. "It's important to know, because changes in volume indicate changes in heat exchange between the ice, ocean, and atmosphere," **Nathan Kurtz** [GSFC] said.

***NASA's Landsat 5 Satellite Sets New Guinness World Record**, February 20, *space.com.* Landsat 5 has secured a new world record title for being the longest-operating Earth observation satellite, after almost three decades in orbit. Guinness World Records sent an email confirmation to NASA's Goddard Space Flight Center, informing space agency officials of the honor, NASA officials said in a statement. Landsat 5, which launched on March 1, 1984, long outlived its initial three-year mission, and was retired recently. The satellite has circled Earth more than 150,000 times during its nearly 29 years in space, and has snapped more than 2.5 million images of the planet's surface along the way.

*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

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

Earth Day with NASA at Union Station

This year NASA has teamed with Earth Day Network to raise awareness about our planet and to highlight particular themes in Earth science. NASA's Hyperwall and Science Gallery will be on display April 22, 2013, at Union Station in Washington, DC, featuring high-definition data visualizations and captivating satellite imagery that reveal examples of world change.

Hands-on activities are planned for:

- **April 6** - STEM Science Fair
- **April 22** - Earth Day (general public invited)

Workshop: Developing and Using Assessments Aligned to Science Learning Goals

The American Association for the Advancement of Science (AAAS) *Project 2061* invites educators of all types, science specialists, assessment directors, developers, and education researchers to attend a three-day professional development experience focused exclusively on *assessment*—from high-stakes testing to classroom diagnostics—and its role in helping all students achieve important science learning goals.

Workshops will be held on:

- **May 15-17** – Early-bird registration by **April 15**;
- **August 7-9** – Early-bird registration by **July 10**; and
- **October 9-11** – Early-bird registration by **September 11**.

All workshops are $400/team member or $450 for individuals, and will be held at the AAAS Headquarters in Washington, DC. Early-bird rates are available, as are limited scholarship opportunities. For more information and to register, visit: *bit.ly/XKU35k*.

GPM Anime Challenge

Entry Deadline: April 20

Global Precipitation Measurement (GPM) mission partners from NASA and the Japan Aerospace Exploration Agency (JAXA) are holding a design challenge for participants around the world to develop an *anime* character for GPM. Participants are expected to learn about the GPM mission and science themes—including the water cycle, weather and climate technologies, and societal applications—and incorporate them into the anime character design. The winning character will star in a comic series that will teach students about GPM and precipitation science. Three age groups have been created, to which people may submit their designs: ages 13-15, 16-18, and 19 and older. For full instructions on how to submit an entry, as well as more information on GPM and contest rules, visit: *1.usa.gov/128eIsw*.

LEARN Research Experience for Middle and High School Educators

Application Deadline: April 22

The Long-term Engagement in Authentic Research at NASA (LEARN) Program at is looking for STEM educators to join a research team that will collaborate with scientists at NASA's Langley Research Center on research projects. Participants will receive training focused on atmospheric science, and will become GLOBE certified upon successful completion. Working with NASA research mentors, participants will complete on-site summer trainings for two weeks (July 8-12 and 15-19), followed by continued research through 2014 via virtual research team meetings and data presentations. A stipend is offered for participants, and educators may present proposals for travel funding to present their research at regional conferences. For more information and to apply, visit: *1.usa.gov/YT36lM*.

NASA/NICE Climate Science Research for Educators and Students Workshop – Middle and High School Educators

Application Deadline: May 1

The NASA Innovations in Climate Education (NICE) Climate Science Research for Educators and Students project (CSRES) is planning its 2013 workshop season. CSRES works with middle- and secondary-school educators and their students to develop real-world, climate-related student research projects. The workshops include science background information, as well as information on building and calibrating equipment for monitoring Earth-Sun-atmosphere interactions. In return for writing research proposals and reporting research results, participants will be able to access ongoing research support and additional equipment for collecting their own data.

The first workshop of the year will be held at Queens College in Queens, NY, near the end of June 2013. Organizers are also looking for participants to participate in online webinars and workshops. Questions about this program should be directed to Project Director **David Brooks** at *brooksdr@intesre.org*. More information about CSRES can be found at *bit.ly/tpNh4R*. ■

EOS Science Calendar

April 15–17, 2013
MODIS Science Team Meeting, Silver Spring, MD.
URL: *mcst.gsfc.nasa.gov*

April 29–30, 2013
Water Cycle Missions for the Next Decade, Baltimore, MD. URL: *www.crew-services.com/decadal/*

April 30–May 2, 2013
Terrestrial Ecology Meeting, San Diego, CA.
URL: *cce.nasa.gov/cce/meetings.htm*

May 7–9, 2013
CERES Science Team Meeting, Hampton, VA.
URL: *ceres.larc.nasa.gov/ceres_meetings.php*

June 10–12, 2013
ASTER Science Team Meeting, Tokyo, Japan.

October 7, 2013
Ocean Surface Topography Science Team Meeting, Boulder, CO.

October 23–25, 2013
GRACE Science Team Meeting, Austin, TX.
URL: *www.csr.utexas.edu/grace/GSTM*

Global Change Calendar

April 22–26, 2013
35th International Symposium on Remote Sensing of Environment, Beijing, China. URL: *www.isrse35.org*

April 15–17, 2013
Joint Aquarius–SMOS Workshop, Brest, France.
URL: *congrexprojects.com/13c07/announcement*

May 19–24, 2013
Japan Geoscience Union International Symposium, Chiba, Japan. URL: *www.jpgu.org/meeting_e/access.html*

June 24–28, 2013
AGU Chapman Conference - Crossing the Boundaries in Planetary Atmospheres: From Earth to Exoplanets, Annapolis, MD. URL: *chapman.agu.org/planetaryatmospheres/*

July 21-26, 2013
IEEE International Geoscience and Remote Sensing Symposium, Melbourne, Australia. URL: *www.igarss2013.org*

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Greenbelt, MD 20771

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The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 610, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available in color on the World Wide Web at *eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*. Black and white hard copies can be obtained by writing to the above address.

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

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Printed on Recycled Paper

NP-2013-2-004-GSFC