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Editor's Corner

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Noting that *"…humankind's understanding of the material nature of our world is grounded… in our knowledge of chemistry…"*, the United Nations has designated 2011 as the International Year of Chemistry (IYC). The American Chemical Society (ACS) is working together with professional societies worldwide to raise public awareness of the fundamental importance of chemistry. According to an ACS publication the activities will range *"…from science cafés in Cape Cod to chemistry shows in Sydney, Australia, to undergraduate competitions in Beirut, Lebanon, to museum displays in Athens, Greece."* Twenty-three nations around the world have sponsored chemistry-related activities. NASA is an active participant in IYC. On page 19 of this issue of *The Earth Observer*, we feature an article that discusses IYC and presents a sampling of NASA's many activities related to chemistry. The article places particular emphasis on our Earth Science investigations, but also reminds us that chemistry underlies

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On May 14, 2011, the U.S. Army Corps of Engineers opened the Morganza Spillway in an attempt to ease flooding along the Mississippi River in Louisiana. The decision was made to protect the heavily populated areas and infrastructure around the ports of Baton Rouge and New Orleans. The decision is not without cost, however, to the thousands of people who were likely to lose homes and farms within the flood plain downstream.

On May 15, the Advanced Land Imager (ALI) on NASA's Earth Observing-1 (EO-1) satellite captured this image [*top*] of the Morganza Floodway. The image was acquired at 11:20 AM Central Daylight Time, one day after the spillway was partially opened. The lower photo was taken on May 14 by the Army Corps, several hours after water began streaming onto the floodway.

The flood control structure, or spillway, includes 125 gates, 11 of which had been opened as of noon on May 16. In the satellite image, the white pixels near the spillway are whitewater churned up by the flow through the gates.

The satellite image shows various shades of water, reflecting the different loads of muddy sediment churned up from the bottom; darker areas might also reflect deeper water. Past the spillway, water is more readily apparent along the levee on the south and east side of the floodway, suggesting that there are fewer trees and perhaps lower elevations in those areas. The floodway was last opened in 1973—the first and only time it was used before 2011.

Image Credit: NASA Earth Observatory. Photograph courtesy Team New Orleans, U.S. Army Corps of Engineers.

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In This Issue

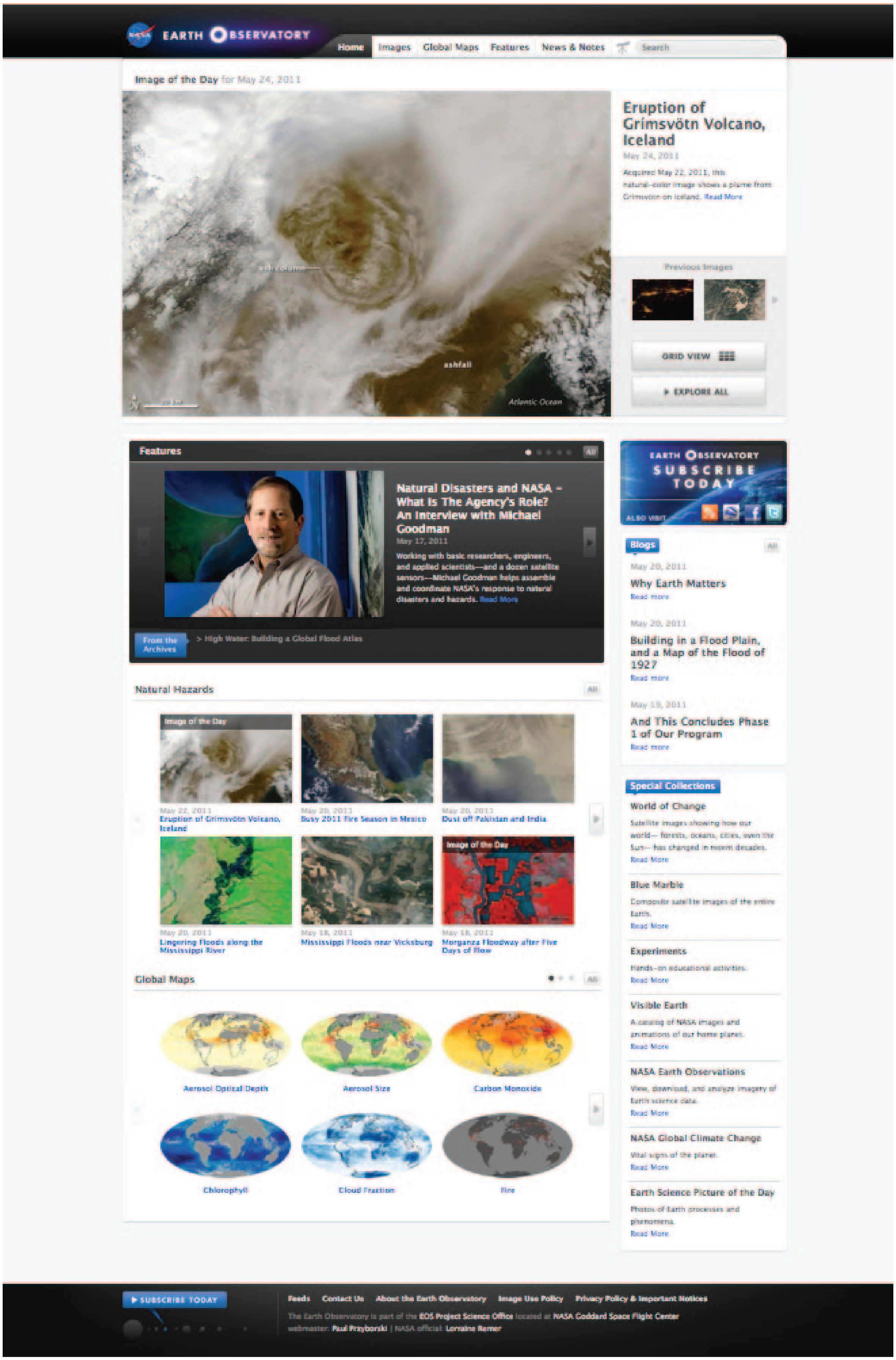
Reminder: To view newsletter images in color, visit: *eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*

much of what we do at NASA. Many of the remote sensing techniques that NASA routinely uses to study the composition of Earth, the Solar System, and the Universe are essentially applied chemistry.

This issue also contains the second of two *Perspectives on EOS* articles from **Ghassem Asrar**—see page 4. (Asrar's first article appeared in our March–April issue.) Asrar actively participated in EOS (as a Science Program Manager, Program Scientist, and Associate Administrator), and brings us recollections from those days at NASA as well as a unique perspective on EOS and how it fits into our overall Earth observing capabilities. This part of the article focuses on the historical challenges of incorporating new technology into the EOS Program and how these new innovations created opportunities for the evolution of NASA's Earth observing capabilities beyond EOS. Collectively, these two articles offer insight on how EOS came to be in the form it is today and provide lessons-learned for the implementation of the next generation of Earth observing satellites. I would once again like to thank Asrar for taking time from his current duties as director of the World Climate Research Progamme (WCRP) to provide his recollections and perspective.

We are rapidly approaching the launch of NASA's Aquarius instrument on the Argentinian Satélite de Aplicaciones Científicas (SAC)-D spacecraft. The mission was developed under the Earth System Science Pathfinder Program (similar to Cloudsat, CALIPSO and GRACE) and is currently scheduled to lift off from Vandenberg Air Force Base on June 9 on a *Delta II* rocket. Once in orbit Aquarius/SAC-D will map the concentration of Sea Surface Salinity, i.e., dissolved salt at the ocean's surface. The science community is eager to have this new measurement capability, which when combined with existing Sea Surface Temperature measurements will allow for determination of the density-driven circulation of the surface waters of the ocean. Scientists will investigate how this circulation is tied to changes in rainfall and evaporation, the melting and freezing of ice, and examine its effect on climate variability. To learn more about Aquarius/SAC-D refer to the news article on page 36. We hope to provide more coverage of the launch in our July–August issue.

The Earth Observatory (EO) has completed another redesign of their signature website—*earthobservatory.nasa.gov* [*see screenshot on page 3*]. The new design better highlights the imagery and feature stories on the site, and offers readers a chance to browse more images at first glance. It also improves the capacity for new functionality in the future. The Earth Observatory is NASA's primary outlet for communicating Earth Science through the publication of images and articles. The EO Group publishes more than 850 images and captions every year, and its work is regularly featured on major television networks, print news outlets, and a vast array of blogs. ■



Screenshot of the newly redesigned Earth Observatory Home Page feature articles

The Enduring Legacy of the Earth Observing System Part II: Creating a Global Observing System—Challenges and Opportunities

Ghassem R. Asrar, Director of the World Climate Research Progamme, GAsrar@wmo.int

***Editor's Note:** Asrar shared with us his perspectives on a number of topics of interest to the Earth Science community. **The Earth Observer** has arranged his remarks into two parts. **Part I** appeared in our March–April issue and focused on the efforts that the EOS Program made from its earliest days to establish a broad, interdisciplinary, multi-generational, and international community. **Part II** appears in this issue and focuses on the challenges associated with integrating new technology into the EOS Program and how NASA has turned those challenges into opportunities as it plans and implements the Earth observing system of the future—i.e., the post-EOS era.*

Ghassem Asrar currently serves as the World Climate Research Programme (WCRP) Director. Prior to this, he had a long tenure at NASA that dates back to 1987. Asrar moved to NASA Headquarters in December 1987 as a distinguished visiting professor and served as the NASA Remote Sensing Science and Hydrology Program Manager. In 1992, he became a NASA civil servant and assumed the role of EOS Program Scientist. In 1998 he was appointed Associate Administrator for the former Earth Science Enterprise. Following the Agency's transformation in 2004 he became Deputy Associate Administrator for the Science Mission Directorate. Asrar was a key player in the development of EOS from the beginning; he led an international science team responsible for promoting and guiding the EOS development. It was during his tenure that NASA successfully launched the first series of EOS satellites and developed the EOS Data and Information System (EOSDIS)—a comprehensive data and information system for managing the wealth of information resulting from these missions. While at Headquarters, Asrar also helped to articulate NASA's vision for Earth Science in the 21st century, a vision he continues to pursue with his current endeavor as director of the WCRP.

Before joining NASA, Asrar combined his interest and expertise in research with his keen desire to educate the next generation of Earth system scientists. Upon completing his PhD at Michigan State University, he worked for about a decade in academia as a research associate and professor. Asrar has published more than 100 peer-reviewed papers and edited several reference and text books with a focus on biosphere-atmosphere interactions and remote sensing methodologies. He established the NASA Earth System Science Fellowship and the New Investigators Postdoctoral Programs both of which continue to this day. These programs have supported and trained over 1000 young scientists globally.

During the *Terra@10* celebration at the American Geophysical Union's (AGU) fall meeting in December 2009, **Steve Platnick** approached Asrar on behalf of *The Earth Observer* and asked if he would be willing to share his reflections on the legacy of EOS over the past 20 years as part of our periodic *Perspectives on EOS* series. Asrar agreed and we are pleased to present Part II of his report below.

The Risk of Not Risking: The EOS Flight Hardware Concept Evolves

The EOS flight hardware that actually ended up in orbit looks very different from what was originally envisioned. The very first discussions (pre-EOS) proposed having three large platforms in space that could be serviced by the Space Shuttle[1]—similar to how the Hubble Space Telescope has been serviced on five separate occasions.

However, as the EOS plans developed and the program began to take shape, the idea of servicing was deemed not worth the risk. Instead, identical copies of each platform would

[1] **Dixon Butler** shared his reflections on the planning of what was known as *System Z* (that laid the groundwork for EOS) in the September–October 2008 issue of *The Earth Observer* [**Volume 20**, **Issue 5**, pp. 4-7].

Ghassem R. Asrar

be launched every five years to obtain the desired 15-year mission lifetime; although, the platforms would be designed to allow for servicing if technology became available. When EOS got its *New Start* in 1990, the mission elements included two large platforms (EOS-A and EOS-B) carrying a total of 30 instruments. These instruments would be supplemented by a dedicated Synthetic Aperture Radar mission, as well as the National Oceanic and Atmospheric Administration (NOAA), European, and Japanese polar platforms. At that time, plans called for EOS-A and EOS-B to be launched aboard a *Titan IV* rocket.

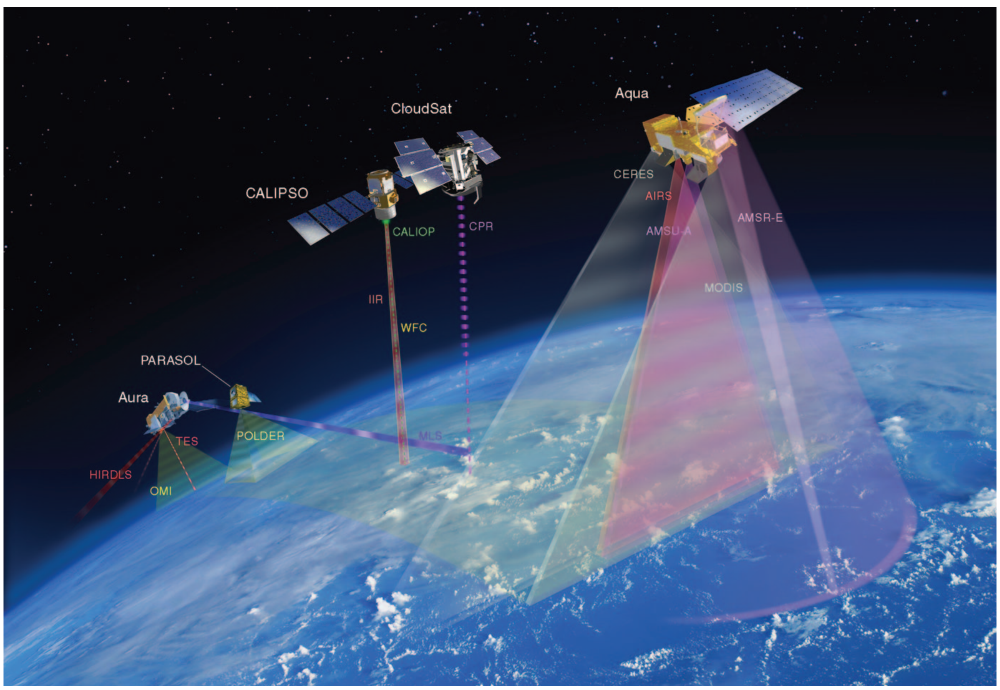
In essence, EOS sought to combine both the unique capabilities of a highly innovative research and development program, and the longevity and replacement capabilities of an operational system. This was a good idea in theory, but certain aspects of it were difficult to implement in practice. For example, since so many instruments would be collocated on the same platform, it meant that the lowest maturity and longest-lead technology would set the pace for launching the missions—and for the marching army of engineers and scientists associated with all the projects involved. In order to achieve the desired operational capabilities, the satellites in the series would need to be launched on a tight timetable (originally every five years; later to every six) to avoid gaps in the time series of measurements. There arose a legitimate concern that if there was an onorbit failure of any one instrument or any of the associated technology, there would not be time to: 1) understand the root cause(s) of the failure; or 2) come up with a viable alternative before the next scheduled launch in the series.

EOS sought to combine both the unique capabilities of a highly innovative research and development program, and the longevity and replacement capabilities of an operational system. This was a good idea in theory, but certain aspects of it were difficult to implement in practice.

EOS was being promoted as a multi-decadal Earth-observing program, yet it came under increasing scrutiny for not having a technology evolution plan for the entire life of the program. At the time, the program administrators defended their plan (i.e., flying multiple copies of the same instruments and spacecraft) by arguing that this was the best way to obtain the "continuity of measurements" stability and simultaneity needed to detect and measure subtle changes in Earth's atmosphere, cryosphere, oceans, and terrestrial ecosystems over decades. They argued that the measurement concepts proposed, and those ultimately selected, were cutting-edge technologies to begin with and we should not introduce any more risks to the EOS Program. To them, allowing for new technology infusion would simply introduce an unnecessary source of uncertainty to measurement continuity.

The independent evaluators, especially the technology-savvy individuals and organizations involved, had a different point of view. They believed it was extremely shortsighted to freeze technologies based on what was available in the late 1980s for flights that would not happen until the late 1990s–early 2000s timeframe, and expected to last a few decades. They argued this would lead to many missed opportunities to adopt new and emerging technologies into EOS that might result in greater performance and perhaps, lower costs. They also believed that allowing new technology, could lead to other ways of obtaining the "continuity of measurements" that was desired for EOS. The group suggested that a combination of smaller satellites placed in complimentary orbits (i.e., the *formation flying* and *constellation* concepts first introduced by the Frieman Engineering Review Committee in 1991[2]) could fulfill the EOS simultaneity and continuity requirements. These smaller satellites would also help to reduce the risks associated with having so many instruments on two large platforms.

A few years later, during my tenure as Associate Administrator, Dan Goldin was the NASA Administrator and continued to ask the same questions that had been raised during the reviews[3]. Goldin clearly did not favor the large platform approach to EOS, once derisively referring to it as *Battlestar Galactica*. This led to the innovative idea of *formation flying* Landsat 7 and a technology demonstrator satellite known as Earth Observing-1[4] that eventually became known as the Morning Constellation[5], and later, the formulation of the Afternoon Constellation[6] (a.k.a., the "A-Train"). The international Committee on Earth Observing Satellites (CEOS) now promotes the *constellation* concept as the basis for future planning and coordination among the space-faring nations worldwide. Carefully designed *formation flying* offers a more-flexible, low-cost, low- risk approach for achieving the continuous, simultaneous, calibrated, global measurements required for studies of climate change.



The A-Train satellites flying in formation. The deployment of *constellations* of satellites, like the A-Train, has allowed the EOS Program to obtain continuous, simultaneous, calibrated, global measurements of the Earth without having all of the instruments co-located on a single large platform.

In light of these realities, during the early 1990s, the original EOS flight hardware concept evolved considerably. The program homed in on global climate change as its primary focus, and the idea of having two large platforms was abandoned in favor of having six different missions. Included among these were the intermediate-sized EOS-AM, EOS-PM, and EOS-CHEM platforms. Also included were smaller missions dedicated to Aerosols (EOS-AERO), Ocean Color (EOS-COLOR), and Altimetry (EOS-ALT). Some instruments originally selected were removed; others were de-

[2] **Greg Williams'** article (in Footnote #7) includes mention of the Frieman committee's recommendations—see p. 7.

[3] Goldin had actually proposed a similar concept to the *formation flying* concept described below to some NASA officials around the time of the EOS Announcement of Opportunity in 1988 (he was with TRW aerospace company at the time) but the proposal was deemed infeasible.

[4] The EO-1 satellite was later used as the basic architecture for the Global Precipitation Measuring (GPM) Core satellite.

[5] In addition to Landsat 7 and EO-1, the Morning Constellation now includes Terra and the Argentinian Satellite de Aplicaciones Cientifico-C (SAC-C) satellite.

[6] The A-Train currently includes the NASA missions Aqua, Aura, CloudSat, and the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Operations (CALIPSO). The French Polarization and Directionality of the Earth's Reflectance (PARASOL) mission was originally part of the A-Train but is now drifting out of the constellation. The Japanese Global Change Observation Mission for Water (GCOM-W1) and NASA Orbiting Carbon Observatory (OCO-2) missions plan to join the constellation in the future.

layed indefinitely. At first, the idea of launching a series of virtually identical missions to ensure a 15-year mission lifetime was maintained—although there were now provisions for having some instruments superseded (i.e., replaced by a more-advanced version on the later flights) or flying only once. The thinking was, the new configuration would be less expensive to launch (requiring smaller launch vehicles than the *Titan IV*) and less risky since the instrumentation would be spread out over several different platforms.

Over the next few years, continued cuts to the EOS budget and political opposition necessitated further reviews of the proposed EOS Program, and the flight hardware continued to evolve to try and achieve the maximum science possible on the reduced budget and to incorporate new technologies where possible. The planned payload of EOS-AM, EOS-PM, and EOS-CHEM was subjected to intense scrutiny and changed several times. Eventually the idea of multiple copies of the same satellite was abandoned; *formation flying* had the potential to achieve the same result with far less cost and risk. The AM-1, PM-1, and CHEM-1 missions were eventually renamed Terra, Aqua, and Aura[7] respectively.

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Similarly, if we traced the "family tree" of EOS-ALT we would see that it eventually split into two separate missions that would eventually become known as the Ice, Clouds, and land Elevation Satellite (ICESat) [with the Geoscience Laser Altimeter] and the joint NASA–French Centre National d'Études Spatiales (CNES) Jason-1 and Ocean Surface Topography Mission (OSTM)/Jason-2 missions [a radar altimeter]. EOS-AERO was to fly the Stratospheric Aerosol and Gas Experiment (SAGE-III) five times, but that eventually morphed into pursuing "flights of opportunity". SAGE-III has flown on the Russian METEOR 3M mission; another copy was developed to fly on the International Space Station (ISS)[8]. The EOS-COLOR concept was achieved with the flight of the Sea-viewing Wide Field-of-view Sensor on the Orbview-2 spacecraft.

Infusing New Technology Into EOS: The ESSP and NMP Programs

In response to the technology concerns/risks that were raised during the many reviews of EOS, NASA developed the Earth System Science Pathfinder (ESSP) Program. The goal of ESSP was to create smaller, Principal Investigator-led, satellite missions with focused science objectives that could be deployed quickly and cost less than the larger platforms. They also developed a technology development and on-orbit demonstration called the New Millennium Program (NMP). Both of these programs provided greater opportunities for involvement of scientists, engineers, and technology advocates in the NASA Earth Science Program. The emphasis on technology development and demonstration also provided a venue for the Earth Science Program to establish its own technology development, adoption, and demonstration. This has had a major positive influence on future-generation missions that were selected or are being considered by NASA and other world-wide national programs today.

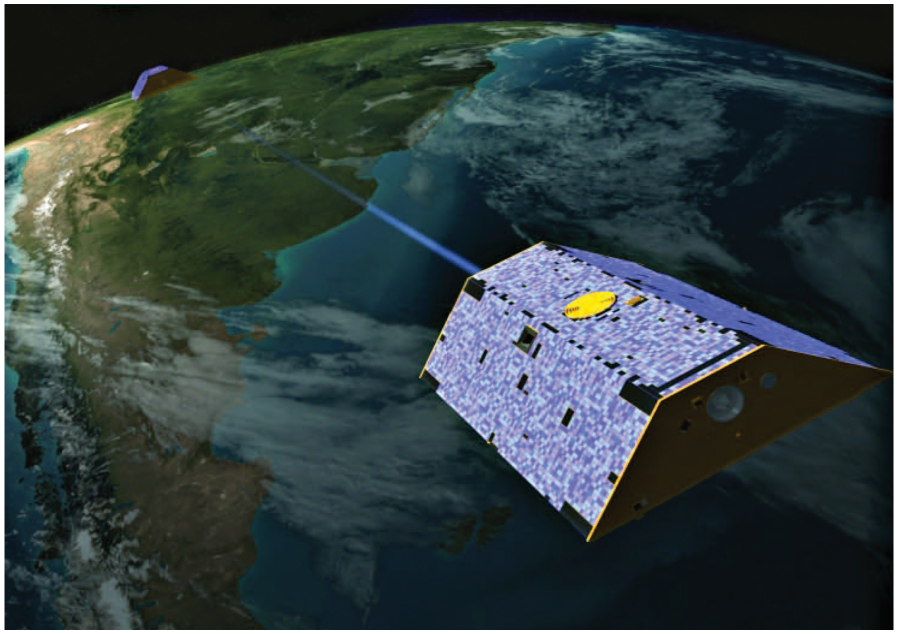
One can cite seminal discoveries and major breakthroughs afforded by the missions funded under these programs[9]. They also brought to EOS and the NASA Earth Sci-

[7] **Greg Williams'** article in the March–April 2009 issue of *The Earth Observer* [**Volume 21**, **Issue 2**, pp. 4-12] details how the EOS concept evolved over a series of "re"-assessments during the 1990s, eventually emerging in the form it exists today. In addition, the series of EOS Reference Handbooks are excellent resources to learn about the EOS Program Chronology, in particular the 1995 (pp. 14-23) and 1999 (pp. 15-19) editions.

[8] SAGE III was removed from the attached payload list of instruments for ISS in 2003-2004 time frame, but was returned to the list in FY11, and is now rescheduled for flight in 2014.

[9] These missions include Earth Observing 1 (EO-1) [funded under NMP]; the Gravity Recovery and Climate Experiment (GRACE), CloudSat, and CALIPSO [funded under ESSP with International partners], as well as the Quick Scatterometer (QuickScat) and the Shuttle Radar Topography Mission (SRTM).

ence Program, cutting edge capabilities such as solid-state lasers, advanced radars, photon-less remote sensing (i.e., the GRACE satellites, shown below), solid-state imaging, and a whole host of other capabilities that have enabled remote sensing of many aspects of the Earth system by several past, present, and future Earth-observing satellites.



The Gravity Recovery and Climate Experiment (GRACE) employs cutting-edge technology that was integrated into a NASA Earth Science mission developed under the Earth System Science Pathfinder (ESSP) Program.

I can now say without any reservation that if the EOS Program had simply been implemented as originally conceived, without being subjected to independent reviews and oversight of the community at large, the U.S. Administration, Congress, and some members of NASA management, the entire Earth Science community would have lost great opportunities that have been afforded by these innovations.

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No Pain No Gain: EOSDIS Comes of Age

As the flight hardware continued to evolve, so did the system that would handle all the data returned from the EOS fleet of satellites. Much like the other components of the EOS, the definition and development of the EOS Data and Information System (EOSDIS) also had its own challenges and opportunities as it matured—you might call them "growing pains". The evolution of EOSDIS has been thoroughly chronicled elsewhere[10] so I will simply make a few observations.

EOSDIS was originally envisioned as a centrally coordinated set of capabilities for capturing, processing, archiving, and distributing the EOS observations through a predetermined set of nodes[11]. The architecture evolved during the lifetime of the program and embraced a more *distributed* approach. EOSDIS expanded its network very creatively through the use of *three-tiered nodes* (called Type I, II, III nodes). This allowed the EOS Program to benefit from contributions of many smaller and focused nodes that brought the best of rapidly emerging information and communication technologies together with a rich mix of EOS observations to facilitate analysis, interpretation, and applications in many disciplines and economic sectors. This, in turn, helped to expand the network of EOSDIS users dramatically. In about 20 years, the number of

[10] **Rama Ramapriyan** shared his reflections on the past, present, and future of the EOS Data and Information System (EOSDIS) in the July–August 2009 [**Volume 21**, **Issue 4**, pp. 4-10] and September–October 2009 [**Volume 21**, **Issue 5**, pp. 8-14] issues of *The Earth Observer*.
[11] These nodes were to be located at NASA Centers, the USGS sponsored Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD, and the NOAA sponsored National Snow and Ice Center in Boulder, CO.

EOS data users grew from a few thousand to several million, and the public at large all around the world benefitted from all the improvements that had been implemented.

Despite the strong and negative views on EOSDIS that prevailed at that time—and to some extent, persist to the present day—the EOSDIS performance has steadily improved in terms of converting the raw signals from EOS instruments to geophysical parameters, including calibration and initial validation, and making them available to the users in a timely manner. *Data latency* improved dramatically between the launch of Terra (1999) to Aqua (2002) and Aura (2004). It took the EOS Science Teams and EOSDIS more than a year to make calibrated and initially validated data from Terra available to all users. By the time of the Aqua and Aura launches, this turn-around time was reduced to just a few months.

The EOSDIS capacity to accommodate processing the data it received in realtime from multiple satellites, while at the same time reprocessing all of the past observations using the most recent algorithms, was a major challenge; it was planned and handled superbly by all those involved. These tasks, together with managing petabytes of data, resulting from the entire EOS Program, could not have been handled through *ad hoc* mechanisms in research and development mode as was advocated in the early days of the program. We believe that EOSDIS development, as painful as it was due to its uniqueness at the time, is a major legacy contribution of the EOS Program that will serve many generations of users of its observations over the ensuing decades.

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The private sector (notably Raytheon, Hughes, Northrop Grumman), the EOS instrument teams, the Distributed Active Archive Centers (DAACs), and many other companies involved in developing this system all deserve credit for this success[12]. We could not have realized the full potential of the EOS Program without its data and information system.

Planning and Implementing the Earth Observing Satellites of the Future

About two years into my tenure as the Associate Administrator for Earth Science Enterprise, NASA recognized an urgent need to begin planning for the next phase of the EOS Program. We had just successfully launched the Landsat-7, Terra, and ACRIMSAT missions, while Aqua, ICESat, and other missions were in different stages of development. The main question in our mind was how to develop and promote the next phase of the EOS Program in the midst of the excitement and challenges faced halfway through the implementation of the first phase? We made several attempts at this, with mixed results.

Our efforts began in 1999 when we invited a small group of the Earth Science community leaders to a short meeting in Crystal City, VA to seek their advice on how to proceed. We shared with them the opportunity to develop such an initiative and promote it along with the forthcoming planetary, space-physics, and astronomy initiatives for the following decades. The general conclusion of this session was that the Earth Science community had been working very hard to realize the first phase of EOS—and still had more work ahead to complete this phase—and wanted to enjoy the fruits of their labor in their professional life for a few years before thinking about the next phase.

We later tried to use the EOS Investigators Working Group (IWG) meetings as a forum to assess the level of interest and willingness to work with NASA on planning the next phase of EOS, but the response was consistent with the outcome of the Crystal City meeting. Some community members/leaders expressed concern over the budgetary constraints and pressure that such a new initiative might impose on the full implementation and completion of the first phase of EOS. This was a valid concern,

[12] **Rama Ramapriyan's** articles on EOSDIS referenced above highlight some of these contributions.

but on the other hand, the Office of Science and Technology Policy (OSTP) and the Office of Management Budget (OMB) had made it explicitly clear that simply maintaining the *status quo* was unacceptable. Unless NASA could come up with an exciting science-focused initiative for the next phase of the EOS Program, there was serious danger that its funding would be significantly cut. This would mean it would not be possible to fully implement and operate phase one of EOS while simultaneously developing the second phase as originally conceived—i.e., simply repeating each mission/measurement-set three times to assemble a 30-year data record.

The general message to NASA and EOS was that a mere extension of what was being done as the first phase of the program, on the account of justifications used for the first phase (i.e., continuity, simultaneity of measurements), was no longer sufficient to secure funding for the future.

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In the meantime, there was significant interest and enthusiasm at the various NASA Centers—especially the Goddard Space Flight Center (GSFC), Langley Research Center (LaRC), and Jet Propulsion Laboratory (JPL)—to develop a new Earth Science initiative that would build on the solid foundation provided by the first phase of the EOS Program. Several attempts were made to jump-start such a process, mostly by focusing on unique and complimentary capabilities that would enable not only EOS science objectives, but also new science objectives based on new vantage points of space and/or new technologies. For example, some NASA scientists worked to develop high-spatial-resolution atmospheric sounding and surface imaging capabilities from geostationary orbit to allow study of mesoscale processes of the atmosphere, oceans, and coastal ecosystems. (These observations were comparable to those of Aqua, but with higher temporal resolution.) There was also an initiative to develop observation systems that could be deployed at *Lagrange libration* points to allow for a sustained and pole-to-pole view of the sunlit and moonlit parts of Earth's surface and atmosphere. The latter example resulted in the ill-fated Triana mission.

The original proposal for Triana was to place a spacecraft at the L1 *Lagrange point* (which is located between the Earth and the Moon) and provide a near-continuous view of the entire Earth and make live images available via the Internet. The hope was to both advance science and increase public awareness of the Earth itself. However, its fate became entangled in politics. Democratic leaders claimed it to be their brainchild and Republicans claimed it to be a personal project (i.e., the "dream" of then Vice President Al Gore) rather than a National initiative with its roots grounded in scientific exploration and community[13].

In view of this controversy, the mission was reformulated and given a new name—the Deep Space Climate Observatory (DSCOVR). The proposed payload included several instruments that were selected to study some aspects of atmospheric chemistry and the Earth's radiation budget, together, with several space physics instruments. The spacecraft was built very economically in record time of less than two years compared with the cost of traditional Earth and space science missions of comparable complexity. However, as of this writing, almost a decade after it was built, the spacecraft is still in storage at GSFC.

This was truly a heart-wrenching experience for the entire NASA team who worked so hard to develop, test, and get DSCOVR ready for launch from the cargo bay of the Space Shuttle—several other satellite missions had launched from the Shuttle. A decision was made, as a result of the change in U.S. Administration, to store the satellite at GSFC with the hope that logic might prevail, and that this satellite might be

[13] It is worth noting that, according to NASA historical records, this idea of having a spacecraft at the L1-point had been proposed and examined by NASA earlier, but because of the technological limitations and very high costs of access to space it had been shelved.

readied and launched at some point in the future before the lifetime of its component technologies run out[14].

Still, despite the lack of full support from the community and such political issues as DSCOVR, we had some success in convincing the NASA leadership under two different U.S. Administrations and Congresses to authorize funding and development of a subset of critical capabilities from the first phase of EOS for several future missions. These included the Jason-1 (and now its follow-on, the Ocean Surface Topography Mission (OSTM)/Jason-2) satellite as a follow-on to the very successful TOPEX–Poseidon mission, the Global Precipitation Measurement (GPM) mission as a successor to TRMM[15]. There was also an effort to create a mission that would serve to "bridge" the EOS measurements with those planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS); that bridging mission became known as the NPOESS Preparatory Project (NPP). This mission was created to ensure that there would be continuity of stratospheric ozone monitoring, land and ocean surface imaging, atmospheric sounding, and monitoring of the solar irradiance[16] between EOS and NPOESS. There was great support by both the ocean and atmospheric science disciplines for continuity of these missions, and also for the measurement of ocean-surface wind vectors as a part of the future EOS Program. This is an excellent example of building greater support for the EOS Program beyond its initial constituencies.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project [NPP] climate/weather satellite

NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Defense (DoD) formed a *tri-agency partnership* and planned to share the costs of development, launch, operation, and maintenance of NPP on a sustained ba-

[14] Both NOAA and U.S. Air Force see refurbishment of DSCOVR as potentially a cost-effective means of meeting their requirements for space weather information. However, the President's FY11 budget constraints at NOAA mean they cannot proceed as rapidly as they would like. Meanwhile, as a result of a separate action by Congress in FY09, NASA has been working to refurbish the Earth-viewing instruments on the observatory. As of this writing, if, when, and in what form DSCOVR will actually fly remains to be seen.

[15] TOPEX and TRMM were not initially a part of the EOS Program; however, because of their invaluable contributions each mission made to the study of atmospheric and oceanic processes, the EOS Program assumed responsibility for funding to support continued operation and operation beyond their initial proposed lifetime.

[16] Solar irradiance capabilities were later moved from NPP to the Glory mission.

sis beyond the planned operational lifetime of this mission. This arrangement was to continue for the NPOESS mission, which was envisioned as a successor to the combined civilian and defense operational polar orbiting meteorological satellite systems[17]. In this partnership, coordinated by an Integrated Program Office (IPO), the novel and very worthy intent was to transition the high-caliber EOS measurements and technological capabilities into the future national operational infrastructure to the benefit of the operational entities and their associated customers. This would also ensure continuity of these capabilities over multiple decades as envisioned/required by EOS.[18]

We should not forget that in the more favorable financial environment of the early 2000s, we were reminded by two U.S. Administrations and Congress that it is not practical and affordable to have two distinctly different satellite systems, one for operational weather services and one for climate monitoring. Considering how the U.S. and world financial systems have evolved since, the need for convergence of requirements for weather, climate, and total Earth system monitoring today is more urgent than ever.

Prior to beginning this partnership, several studies had been carried out to assess the pros and cons of such a convergence; they all had confirmed that the pros well outweighed the cons. These same studies had also identified some potential cost savings—although the numbers cited varied significantly based on the assumptions made in each study.

Since then, there have been many articles and opinion pieces written on this topic and by and large the post-merger views on this tri-agency partnership have been negative. Most reviews cite the governments' failure to manage properly, the risk and cost of this program. They fault the government for introducing ambitious requirements that led to major technological developments without having proper insight and involvement in managing such risks/costs in close partnership with the private sector—to which was delegated the full responsibility for implementing this program. If one takes a more objective view of the legitimate and worthy reasons behind the original NPOESS/IPO concept, however, one may conclude that this was a good idea that was not managed properly. The Government deferred too much of risks and decisions associated with them to the private sector, while the overall fiducial responsibilities remained with the Government.

Of course, things are always easier to see in hindsight; one can be a great quarterback on Monday morning after the last whistle was blown and all players and coaches have cleared the field. The fact remains that the buck stopped with those of us who had the vision for NPOESS and every intention of giving our country and the world a well-deserved set of capabilities, and we fell short. But, it is worth noting that the U.S. operational polar orbiting environmental monitoring systems have been in need of such a major overhaul for a few decades. We do hope that the new Joint Polar Satellite System partnership arrangements between NOAA and NASA (patterned after the Polar Orbiting Environmental Satellite (POES) and Geostationary Operational Environmental Satellites (GOES) management model) will succeed in providing such an urgently needed set of capabilities. We should not forget that in the more favorable financial environment of the early 2000s, we were reminded by two U.S. Administrations and Congress that it is not practical and affordable to have two distinctly different satellite systems, one for operational weather services and one for climate monitoring. Considering how the U.S. and world financial systems have evolved since, the need for convergence of requirements for weather, climate, and total Earth-system-monitoring today is more urgent than ever. Thus, the opportunity/challenge for the national and international leadership is to excel at providing the required observations and information with limited resources; this demands greater effort on the part of the current U.S. leadership and programs. To do this, it will require us to move beyond the artificial distinction of "research to operation" and toward an end-to-end approach of using "research and operation" missions to achieve our Earth and environmental observational requirements for the rest of this century and beyond.

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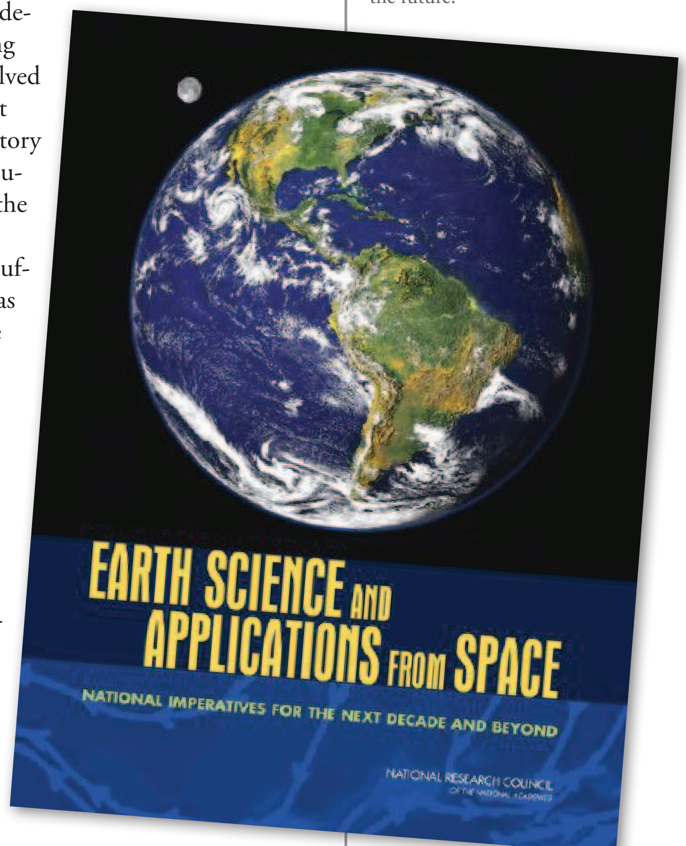
[17] In February 2010, the NPOESS partnership was dissolved. A new NASA–NOAA partnership has been created known as the Joint Polar Satellite System (JPSS). However, the "bridge" mission between EOS and JPSS still on the books, is called the NPOESS Preparatory Project (NPP), and is still scheduled for launch in October 2011.

[18] Mark Abbott shared his recollections of EOS in the mid-1990s and discussed the proposed tri-agency partnership in the September–October 2009 issue of *The Earth Observer* [**Volume 21**, **Issue 5**, pp. 4-7].

The last attempt at developing a blueprint for the "EOS of the future" resulted from a consultation with the Space Studies Board of the U.S. National Research Council (NRC), chaired at the time by Len Fisk and with Joe Alexander as its Director[19]. We reached an agreement to send a letter of request to the NRC for this study, under the auspices of the Board. The main question at the time was whether NASA should sign such a letter alone or in partnership with NOAA and the U.S. Geological Survey who had major roles to play in long-term observations of atmosphere, oceans, and land, respectively. In the end NASA sent a letter to the NRC in October 2003 to request a proposal and conduct the survey, and NOAA and USGS joined in a short while later.

This decision turned out to be quite timely, because shortly thereafter, NASA decided to embark on an ambitious activity, called the NASA Space Exploration Initiative, that initially embraced Earth, space sciences, and human exploration as major components. All concerned communities were recruited to develop their respective vision/mission priorities, including Earth Sciences. Some of the participants were also involved in the NRC's Earth Science Decadal Survey[20] study that was getting started at the time.[21] This is an interesting story in itself, but suffice to say that the Earth Science community felt very uncomfortable with this exercise because the NRC study was in its early period and had not yet had time to consult the community at large and engage in sufficient deliberation. The Space Exploration Initiative was affected adversely by the tragic loss of the Space Shuttle *Columbia* with its seven astronaut heroes and its cargo, which had included a major Earth observations experiment jointly developed by the U.S. and Israel.



The NRC Earth Science Decadal Survey report has provided a solid framework for building the Earth observing system of the future.

A Good Framework for the Future: The Decadal Survey

I believe that the NRC Earth Science Decadal Survey report provides a very good blue print to guide the evolution of the EOS Program into the future. The plan outlines a logical sequence of missions and considers the EOS requirements of continuity, calibration, and spatial and temporal coverage together with new scientific questions identified during the past decades. Of course, the proposed plan has already run into some impediments. The President's proposed FY12 budget eliminates funds for further development of two *Tier 1* (i.e., top-priority) Decadal Survey missions—the Climate Absolute Radiance and Refractivity Observatory (CLARREO) and Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)[22]. Clearly, the polarized political environment and challenging economic realities of our time will make implementing this plan more challenging than ever. On

[19] It is remarkable that about two decades after the three of us had a conversation on developing the EOS education program for NASA [see **Part I** of this article in the March–April 2011 issue of *The Earth Observer*, p. 9] we were now talking again, this time about how best to develop the strategy for EOS of the future.

[20] Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond", *National Research Council*, 2007

[21] To clarify, this was not an NRC-sponsored study, but involved the same people involved in the Earth Science Decadal Survey. Most of the team members were involved in the NRC study to ensure coordination between the two groups.

[22] For CLARREO, NASA has been directed to hold the mission in pre-formulation phase through FY16. The DESDynI lidar has been cancelled, and NASA was directed to find an international partner to contribute a space-based lidar mission. NASA was also directed to look for affordable alternatives to the DESDynI radar, though no funds were provided to do so.

the other hand, I hope this article has made clear that: 1) such challenges are nothing new; 2) the effort to overcome these challenges is worth it.

We should not forget that we also had a very good plan for the first phase of EOS that faced comparable, if not more significant, challenges that we had to overcome. But we did it! We responded to every budget cut and other directive and adjusted our ideas in light of those realities. Yes, EOS is different from what we originally planned—and in some ways, as explained above, this is a good thing. We had to sacrifice some capabilities that we had desired, but the fact remains, we now have a fleet of Earth-observing missions that are revolutionizing our knowledge of the health of our home planet and the potential impact humans have on its climate. These observations have only served to whet our appetite for what discoveries might await us in the future as we add new capabilities to our existing ones.

We had to sacrifice some of the capabilities that we had desired, but the fact remains, we now have a fleet of Earth observing missions that are revolutionizing our knowledge of the health of our home planet and the potential impact that humans are having on its climate.

As we move toward implementing the Earth Observing Program of the future, I hope we do not lose sight of lessons learned from EOS and the experience gained in implementing the program. Most of all, I hope we are committed to staying the course in pursuit of implementing these new missions. After all, the distinction between success or partial success of the program depends on how best to identify the challenges and risks associated with every single mission and to deploy creative ways to address them as early as possible, and preferably outside the timeline of mission implementation to avoid schedule delays and costs escalation. We believe this was a major factor in EOS success in the first few decades. In short, building flexibility and agility in implementing Decadal Survey missions and objectives is key to its success.

Concluding Thoughts on EOS

I wish to close with a few general remarks by restating that the EOS Program benefited greatly from contributions from a remarkable number of national and international leaders from its early days despite trial and tribulations. Had it not been for the independent reviews and a set of circumstances in major domestic (e.g., establishment of the U.S. Global Change Research Program) and international events (e.g., establishment of the International Geosphere-Biosphere Program) and initiatives (e.g., European, Japanese, and many others) throughout its lifetime, EOS would not exist as it does today. It also had the full support of the NASA senior management through multiple Administrations and Congresses. Those who have worked within the U.S. Federal Government understand and appreciate that, quite often the best and most meritorious ideas may not get the endorsement of the parent agencies. EOS was not an exception, and without the bipartisan and full support of at least three NASA Administrators and U.S. Administrations, and two major changes in leadership of the U.S. House and Senate, it would never have happened.

As stated in the Introduction to Part I of this article, there are literally thousands of individuals who played significant roles during almost three decades in making EOS a reality. As a member of the EOS team, my heartfelt thanks go to all of them. It was a personal pleasure and a great privilege to serve as the EOS Chief Scientist and the Associate Administrator for NASA Earth Science Enterprise from 1992–2004.

Geneva, Switzerland
December 2010 ■

Langley's DEVELOP Team Applies NASA's Earth Observations to Address Environmental Issues Across the Country and Around the Globe

Lauren Childs, DEVELOP National Program, Langley Research Center, Lauren.M.Childs@nasa.gov
Joseph Miller, DEVELOP National Program, Langley Research Center, Joseph.E.Miller@nasa.gov

Introduction

The DEVELOP National Program was established over a decade ago to provide students with experience in the practical application of NASA Earth Science research results. As part of NASA's Applied Sciences Program, DEVELOP focuses on bridging the gap between NASA technology and the public through projects that innovatively use NASA Earth science resources to address environmental issues. Cultivating a diverse and dynamic group of students and young professionals, the program conducts applied science research projects during three terms each year (spring, summer, and fall) that focus on topics ranging from water resource management to natural disasters.

Headquartered at Langley Research Center (LaRC), DEVELOP has grown from a small team of three students in 1998 to a national program providing over 200 internship opportunities each year. There are currently nine DEVELOP offices: Six offices are located at NASA centers—Ames Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Langley Research Center, Marshall Space Flight Center, and Stennis Space Center—and three are regional offices—Mobile County Health Department (Alabama), Wise County Clerk of Court's Office (Virginia), and the Great Lakes and St. Lawrence Cities Initiative (Illinois)[1]. DEVELOP teams conduct projects, under the guidance of science advisors from NASA and partner organizations that address national priorities and local environmental concerns, utilize NASA Earth observations, and provide end users with tools for enhanced decision making. In association with regional, national, and global partners, research is conducted to identify the widest array of practical uses for NASA data to help communities better understand environmental change over time.

DEVELOP students and staff with NASA Administrator **Charles Bolden** [*front row center*] at the 49th Robert H. Goddard Memorial Symposium on March 30th in Greenbelt, MD. **Photo credit:** Pat Izzo.

DEVELOP Activities at Langley

LaRC also hosts the largest number of DEVELOP students each year. Aligning with LaRC's core competency in atmospheric science, multiple projects have been conducted, focusing on air quality monitoring in the U.S. and around the world. LaRC DEVELOP students have also worked on numerous projects dealing with sea-level rise and storm surge along the Eastern Seaboard, including the Hampton Roads area, where LaRC is located.

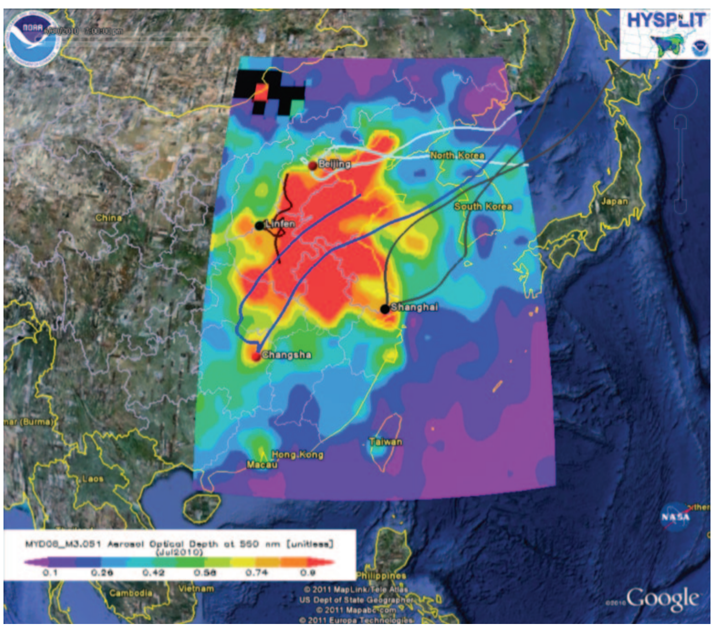
[1] *The Earth Observer* has done a series of articles on DEVELOP: March–April 2010 [**Volume 22**, **Issue 2**, pp. 7-9]; May–June 2010 [**Volume 22**, **Issue 3**, pp. 11-13]; July–August 2010 [**Volume 22**, **Issue 4**, pp. 10-12]; September–October 2010 [**Volume 22**, **Issue 5**, pp. 10-12]; November–December 2010 [**Volume 22**, **Issue 6**, pp.14-19]; January–February 2011 [**Volume 23**, **Issue 1**, pp. 4-7]; and March–April 2011 [**Volume 23**, **Issue 1**, pp. 22-25].

Air Quality Research

Since DEVELOP's inception, the LaRC DEVELOP team has conducted over a dozen different projects focused on enhanced monitoring of air quality on both local and regional scales. This research was done under the guidance of NASA atmospheric scientists at LaRC and has allowed students to learn not only about NASA's contributions to monitoring air quality through use of space-based remote sensing—such as the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission, and the Ozone Measuring Instrument (OMI) on Aura—but also airborne missions like the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites - California Air Resources Board (ARCTAS-CARB). Two recent DEVELOP Air Quality projects based out of LaRC are described below.

China Health: Monitoring aerosol changes over Eastern China using NASA Earth observations

This project took place during the Spring 2011 term, and concentrated on the evaluation of different monitoring methods of aerosol optical depth (AOD) in Linfen, China, to assist in improving air quality management. Eastern China is home to a population of approximately one billion people, concentrated in large metropolitan areas; coal provides the majority of the region's energy. Due to the large amount of aerosol emissions related to coal burning, air quality is a major concern in many cities including Linfen, the capital of the Shanxi Province. Students investigated capabilities of Aqua MODIS images and CALIPSO lidar [Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)] data to monitor aerosols. They also used NOAA's Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model to create trajectories of potential aerosol movement.



Aqua MODIS Aerosol Optical Depth (AOD) measurements and HYSPLIT trajectories displayed in *Google Earth* provide enhanced air quality monitoring and projected aerosol movement.

Despite numerous well-documented negative effects on human health, China currently has no ambient air quality standards for $PM_{2.5}$ i.e., particulate matter with particle diameter of 2.5 μm or smaller. This DEVELOP project therefore has the potential to benefit the Chinese people as well as organizations seeking to monitor air quality in China.

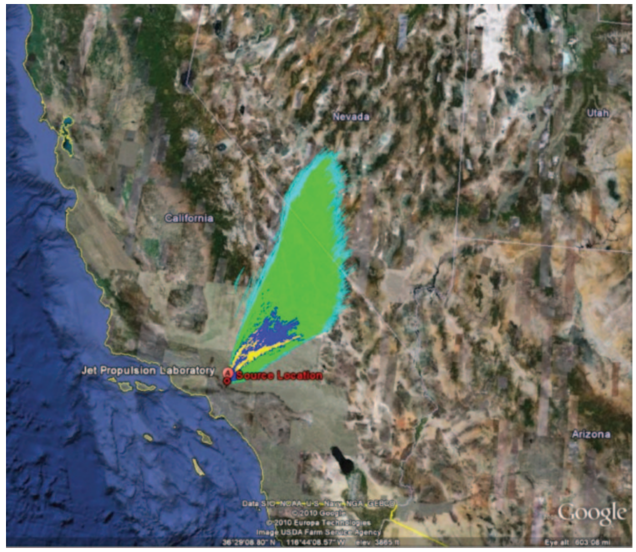
"I learned a great deal about the capabilities and limitations of satellite remote sensing in regard to measuring air quality levels. It was a good learning experience on how to conduct a research project, lead a research team, and work with students from different disciplines than my own," said **MyNgoc Nguyen** [LaRC DEVELOP/Old Dominion University—*Student & Project Co-Lead*]. "With only ten weeks to conduct the project, the team experienced the true meaning of both teamwork and flexibility."

California Natural Disasters: Using remote sensing data to assist management at Angeles National Forest

This project took place during the Summer 2010 term and sought to investigate degraded air quality levels stemming from the Angeles National Forest wildfires during the summer of 2009, as well as smoke plume trajectory modeling and associated health risks. The team utilized Terra's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and MODIS instruments, and data from the Environmental

Protection Agency's (EPA) *AirNow* system, the CARB's Air Quality and Meteorological Information System (AQMIS), as well as from ARCTAS CARB flights to observe air quality factors such as $PM_{2.5}$ levels, AOD, trace gases, and UV aerosol indices. The results obtained from this study demonstrated the feasibility and applications of NASA satellites and airborne missions for enhanced decision support to the projects partners: the U.S. Forest Service at Angeles National Forest and the South Coast Air Quality Management District. Students also investigated all aspects of the disastrous fire including fuel loading, burn extent, and impacts to public health.

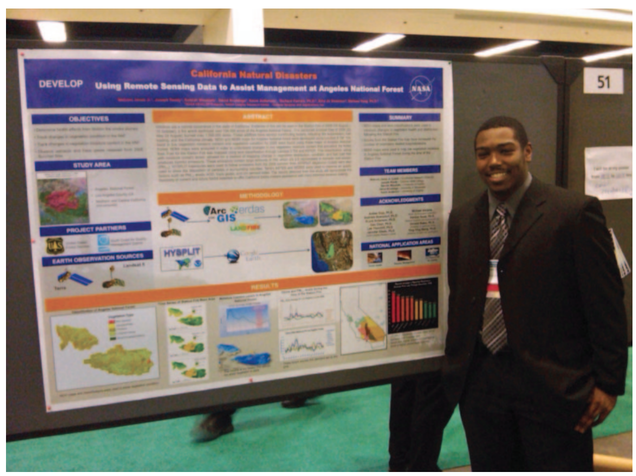
Output from the HYSPLIT Dispersion model for August 29, 2009 in *Google Earth* shows the smoke plume from the fires in Angeles National Forest spreading over the surrounding area.



Malcom Jones [LaRC DEVELOP/Christopher Newport University—*Student & Project Lead*] reported that: "using a suite of NASA's sensors to look at different aspects of the Angeles National Forest fire was extremely fascinating. Even though I am a computer engineering major, being able to work with other students and scientists in areas concerning air quality and ecological forecasting allowed me to see how I can apply my knowledge to a wide array of problems in the real world."

Sea Level Rise & Storm Surge Studies

LaRC's coastal location on the Eastern Seaboard makes sea level rise and storm surge inundation an important topic. LaRC suffered major damage from Hurricane Isabel in 2003. In response, NASA's Climate Adaptation Science Investigation (CASI) team tasked the center with investigating the effects that projected climate change could have on the center and what type of adaptations could potentially help abate impacts. Two recent DEVELOP sea-level rise and storm-surge studies based out of LaRC are described below.



Langley DEVELOP student **Malcom Jones** presents the Summer 2010 California Air Quality project poster at the American Geophysical Union (AGU) Fall 2010 Meeting in San Francisco, CA.

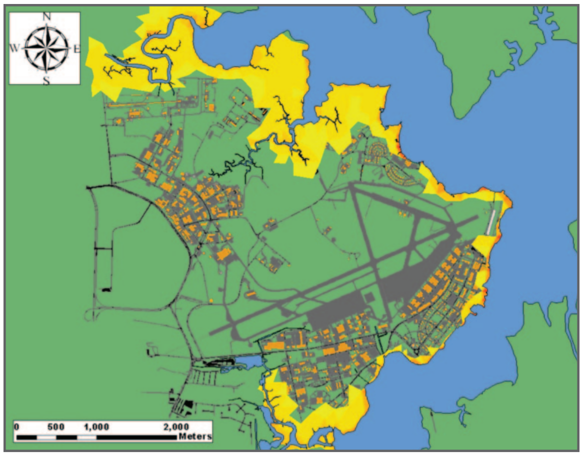
LaRC Climate Change and Adaptation: Strategies to counter predicted climate change effects on NASA Langley Research Center

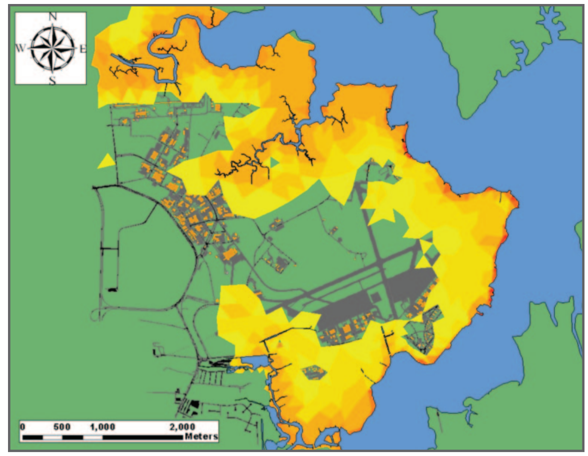
This project, taking place during the Summer and Fall 2010 terms, focused on improved storm-surge modeling and the related impact inundation could have on LaRC infrastructure, had practical application for the LaRC Science Directorate, as it allowed for improved forecasting and prioritization of assets for protection. Students gained experience with Geographic Information Systems (GIS), experience with the creation of multiple sea level rise scenarios, and practice utilizing climate models. The group was able to understand the impact storm-surge and sea-level rise could potentially have on the very buildings they were working in, making their research of even higher interest and importance.

"Analyzing tropical cyclone data has allowed us to quickly evaluate the types of storms that have affected the study area," says **Nathaniel Makar**, "As a meteorology major, this project gives me great experience **applying what I have learned in school to real world situations**." [LaRC DEVELOP/Pennsylvania State University—*Student & Project Lead*].

Outer Banks Climate: Assessing and establishing a process for understanding coastal changes in North Carolina

This project, also taking place during the Summer and Fall 2010 terms, investigated the use of NASA Earth Observing System (EOS) instruments, such as Jason-1, TOPEX/





[*Left*] Hurricane Isabel storm surge inundation at LaRC and infrastructure at risk. [*Right*] The projected impact of a storm of similar magnitude to Hurricane Isabel would have on LaRC if sea level raises by 100 cm (as some models project by 2070–2080.)

Poseidon, Landsat 5's Thematic Mapper (TM), and Terra's ASTER, to monitor North Carolina's dynamic and ever-changing Outer Banks estuarine systems. Rising sea levels and tropical cyclonic events have caused erosion and shore loss, threatening entire coastal communities. The team partnered with the North Carolina Division of Coastal Management (NCDCM) to conduct research focusing on estuarine shoreline issues, including development of shoreline identification techniques, quantification of development trends along the shoreline, shoreline movement trend analysis, and consideration of all the above within the overarching theme of sea level rise.

"The potential benefits of this investigation to our coastal program are numerous and far reaching. The implications of creating analytical procedures for remotely sensed data from NASA satellite platforms allows an exciting opportunity for North Carolina to better manage its estuarine shoreline and plan for and manage future development patterns in the context of sea level rise," said **Jeffrey D. Warren** [NCDCM—*Coastal Hazards Specialist* (*Project Partner)*]. "We are also eager to continue this work into future DEVELOP sessions to build on what I feel is groundbreaking research directly applicable to our State's coastal management efforts."

Langley DEVELOP's Summer 2010 Outer Banks Climate project team. [*Left to right*] **Dominique Norman**, **Conor Collins**, **Chelsea Burns**, **Derek Doddridge**, and **Kristin Morgan**.

Conclusion

As DEVELOP's summer term begins in early June this year, students at LaRC will continue to learn and expand their knowledge of NASA's EOS capabilities in relation to air quality and sea level rise monitoring, as well as the other six Applied Sciences national application areas. Challenged to creatively and innovatively apply NASA's satellite and airborne Earth observations to real-world issues, LaRC DEVELOP students are gaining tangible skills and knowledge that will help them in their future careers.

More information is available about the DEVELOP National Program at *develop.larc.nasa.gov/*. Information about NASA's Applied Sciences Program is available at: *appliedsciences.nasa.gov/*, and LaRC's Science Directorate at *science.larc.nasa.gov/*. ■

NASA and the International Year of Chemistry 2011

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Noting that "…humankind's understanding of the material nature of our world is grounded…in our knowledge of chemistry…", the United Nations has designated 2011 as the International Year of Chemistry (IYC). The kick-off ceremony for the IYC took place in Paris, France, in January 2011, was attended by representatives of NASA's Science Mission Directorate (SMD) and the Earth Observing System Project Science Office (EOSPSO)[1], and has been described previously in *The Earth Observer.* This article builds on the foundation laid in the previous article, and further describes the underpinnings of the IYC and the roles that chemistry plays in NASA generally, and in the Earth Sciences in particular—albeit at a summary level.

What in the world ISN'T chemistry?
*—**Unknown***

International Year of CHEMISTRY 2011

Organizational Foundations for IYC 2011

Chemistry forms the basis of just about everything we deal with on a day-to-day and long-term basis. While whole areas of study have grown up around certain types of chemicals and their related phenomena (e.g., biochemistry, geochemistry, atmospheric chemistry), these are simply a means to simplify and classify otherwise insurmountable numbers of chemical interactions. At their base, they are all "simply" *chemistry.*

The all-encompassing concepts and applications of chemistry generally led the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the International Union of Pure and Applied Chemistry (IUPAC) to organize a series of events to *"…celebrate the achievements of chemistry and its contributions to the well-being of humankind."* The goals for declaring the IYC 2011 are to:

- increase the public appreciation of chemistry in meeting world needs;
- increase interest of young people in chemistry;
- generate enthusiasm for the creative future of chemistry; and
- celebrate the role of women in chemistry[2].

The commitment to making IYC 2011 meaningful is demonstrated by the fact that twenty-three nations around the globe have sponsored chemistry-related activities. No part of the world is unrepresented in the list of events—*www.un.org/en/events/chemistry2011/.* These efforts are being undertaken by federations of chemical societies, industry, non-governmental organizations, educational and research institutions, and individuals, in addition to the organizing groups described earlier.

IYC 2011 Education and Public Outreach Activities

One of the underpinnings of the IYC 2011 is to make chemistry and its role in our society accessible and available to a wide swath of the Earth's population; this requires an intentional Education and Public Outreach (EPO) effort. According to an American Chemical Society (ACS) release, planned events include activities that range "…

[1] In the March-April 2011 issue of *The Earth Observer* [**Volume 22**, **Issue 2**, pp.16-17], **Jack Kaye** [NASA Headquarters (HQ)—*Earth Science Division Associate Director*] and **Winnie Humberson** [NASA Goddard Space Flight Center (GSFC)—*Task Lead, EOSPSO*] described the IYC Kickoff event and NASA's involvement.

[2] In particular, 2011 marks the 100^{th} anniversary of Marie Curie's receipt of the Nobel Prize in chemistry in recognition of her discovery of the elements radium and polonium.

from science cafés in Cape Cod to chemistry shows in Sydney, Australia, to undergraduate competitions in Beirut, Lebanon, to museum displays in Athens, Greece."

Globally, school students will be involved in exploring a key resource: **water**. Through the *Global Experiment,* chemical and physical water phenomena such as pH, salinity, filtration, and solar distillation will be explored and reported back to a central location for collation and dissemination.

Another global activity is called *Visualizing and Understanding the Science of Climate Change,* a program of interactive activities developed in Canada that is based on "…critically reviewed…web-based learning tools and resources…"

In the U.S., the ACS has prepared a year-long calendar entitled *365: Chemistry for Life,* which started by providing daily reference to 250 significant developments in chemistry. The public is invited to submit candidates to fill out the rest of the years entries. NASA has an opportunity to contribute to this calendar.

Similar opportunities for EPO abound and may be found by accessing the official IYC 2011 site (see *Resources,* below).

Noting that *"…humankind's understanding of the material nature of our world is grounded…in our knowledge of chemistry…",* the United Nations has designated 2011 as the International Year of Chemistry (IYC).

Chemistry under the Broader NASA Umbrella

As the Nation's "space agency" NASA's link to chemistry is fundamental, as chemical reactions are the only proven means to provide sufficient thrust to launch rockets for all the reasons we have now come to associate with space, including suborbital, Earth-orbital, Solar System exploration, and deep-space observing missions. And, while there are many new developments in thrusters for satellite station-keeping, attitude adjustment, orbital adjustment [e.g., the Variable Specific Impulse Magnetoplasma Rocket (VASIMR)], and deep-space missions [e.g., xenon ion thrusters], chemical reactions are still the standard in most such areas.

The following sections will demonstrate how chemistry further informs NASA's activities from the development of new and supportive technology and applications to research activities in space, life, and Earth Sciences. It is important to note that many of the remote sensing and *in situ* approaches that form the heart of NASA's science portfolio are basically applied chemistry. Measurement information, based on the spectral properties of chemical species, is derived from observing the response to, or emission of, radiant energy at various wavelengths (often using molecular spectroscopy techniques). **This discussion is far from all-inclusive; rather, it is meant simply to demonstrate how all-pervasive chemistry is in NASA's many activities.**

It is important to note that many of the remote sensing and in situ approaches that form the heart of NASA's science portfolio are basically applied chemistry. Measurement information, based on the spectral properties of chemical species, is derived from observing the response to, or emission of, radiant energy at various wavelengths (often using molecular spectroscopy techniques).

Basic and Applied Research in Chemistry

Once past the use of chemical energetics in bulk, NASA deals with chemistry at many levels and for many purposes ranging from research to applications. An indicator of the impact of chemistry in the NASA structure may be found at NASA's Selected Current Aerospace Notices (SCAN), part of the agency's Scientific and Technical Information (STI) service. The Chemistry SCAN page—*www.sti.nasa.gov/scan/chem-mat.html*—has entries for chemical processes and engineering, reinforced materials and fibers, chemical analysis, luminescence, photochemistry, composite materials, corrosion, metal crystals, coatings, electrochemistry, aluminum beryllium, liquid metals, steel, titanium, refractory metals, metallurgy, plastics, adhesives, ceramics, elastomers, graphite, polymers, liquid propellants, solid propellants, and more. Even without providing a one-to-one mapping of each of these topics to specifics, it should be easy to see that NASA could not do its technical work without advances in chemical science and engineering.

Chemistry in Solar System and Deep-space Exploration

NASA's planetary and other Solar System missions have heavy investments in sensors and instrumentation to examine the atmospheric and geochemical composition of the planets, comets, meteors, and asteroids that make up the Solar System—and perhaps someday, beyond. Our understanding of the mineralogy of the Moon and some asteroids is based on chemical analyses that demonstrate their largely igneous nature—similar to what is found in volcanic rocks on Earth. Spectroscopic analysis of planets in our Solar System and tenuous deep-space matter shows that these minerals are common throughout the Milky Way Galaxy. These analyses help scientists understand the processes by which large-scale matter are formed.

As an example of planetary chemistry investigations, beginning with the two Viking landers and their instrumentation packages, each successive mission to Mars has included more and more-sophisticated instrumentation to refine our understanding the Red Planet's surface chemistry. Particular emphasis on exploring the presence of water and understanding how water has created current features and possibilities for life at some point in the past. Based on the inspiring successes of past Martian lander/rover missions, the Mars Science Lander—a chemistry laboratory in its own right —currently scheduled for launch later this year, will deploy a Chemistry & Camera (ChemCam) system that uses two remote sensing instruments to provide more and more-detailed chemical analyses of rock and soil samples.

NASA's Stardust mission, launched in 1999, was designed specifically to return cometary samples for chemical analysis. The finding of *glycine*, an amino acid common in terrestrial biology, in samples from comet *Wild 2* caused great excitement. Other analyses have provided new insight on how comets form.

Farther-reaching sensors determine how elements are created in supernovae by nucleosynthesis and subsequent processing to generate organic compounds in interstellar clouds. Recent activities in the realm of spectroscopic analysis of extra-solar planetary systems have begun to focus on determining the content of the atmospheres of detected planets to see if indicators of life can be found.

Chemistry in the Life Sciences

At the interface between Solar System exploration and life science lies the relatively new discipline of *astrobiology.* Astrobiology seeks to understand the processes whereby life originated on Earth (or, possibly elsewhere, depending on the theory under discussion). These investigations are based on observed chemical and physical phenomena on Earth and elsewhere in the cosmos. The basic biochemical processes that support extant life are under discussion, with an eye toward understanding such fundamental phenomena as energy generation and use, storage and manifestation of biological information, responses to stimuli, and more. The discovery of undersea hydrothermal vents in 1977 demonstrated the presence of complex organisms and ecologies with metabolism based on chemical processes and energy sources that are unusual from what had earlier been assumed to be the basis for all life on Earth. This has provided impetus to thinking in new directions to address the question: *"What is life?"*

> Wherever we look, the work of the chemist has raised the level of our civilization and has increased the productive capacity of the nation.
> —***Calvin Coolidge***

Chemistry in life sciences research at NASA also addresses life support for human-crewed missions, whether in low-Earth orbit i.e., the International Space Station (ISS) or for planned forays back to the Moon, to asteroids, or to other planets. In all cases, chemistry is the basis for Environmental Control and Life Support Systems (ECLSS), providing air, water, and—ultimately—nutrition. (Much of life

*The discovery of undersea hydrothermal vents in 1977 demonstrated the presence of complex organisms and ecologies with metabolism based on chemical processes and energy sources that are unusual from what had earlier been assumed to be the basis for all life on Earth. This has provided impetus to thinking in new directions to address the question, "**What is life?**"*

support is currently provided from outside the system by resupply from Earth.) Means to use nominal waste produces, such as carbon dioxide and urine, are being investigated, the better to close the life system cycles by using less-complicated and lower-power equipment—but still based in chemistry. Also, there is a long history within NASA of exploring how materials found on the Moon, Mars, or other potential destinations could be used for *in situ resource utilization* to allow longer off-Earth stays by generating fuels, water, oxygen, building materials, energy sources, etc.

The ozone hole may have been the first clue of just how large and behaviorally "massive" are the Earth's systems when it comes to amelioration or mitigation of real or perceived problems caused by human activity. It also demonstrated how remote sensing could be combined with laboratory and theoretical studies to explore a real-world phenomenon—an important step in validating satellite-based remote sensing studies generally.

Other chemical research has long been underway to understand the usually deleterious effects of space travel on living systems ranging, from radiation disturbances of genetic material to the effects of microgravity on human homeostasis, plant growth and development, bacterial biochemistry, and more.

Chemistry in the Earth Sciences

The myriad articles published in past issues of *The Earth Observer* provide ample discussion of the technical and research aspects of Earth Science research; hence, no attempt to recapitulate that information will be attempted here. Rather, what follows is a sampling of NASA's space-based investigations relating to chemistry that have been, are being, or will be conducted on future missions.

Virtually everything that involves chemistry under the NASA rubric has application to the Earth Sciences. Chemical energy boosters launch our complex remote sensing observatories into orbit; chemical studies not only inform the design of spacecraft, but also ensure that the sensors on those platforms and their optics are as pristine as can be, limiting outgassing and other potential contamination*; in situ* chemical analysis are used to explore Earth's surface chemistry and geochemistry, atmospheric, and ocean chemistry; to define and follow the cycling of material through Earth's interconnected systems; and how chemicals in those systems affect and are affected by our environment. **The contributions by NASA missions to understand Earth's chemistry are manifold and far more complex than can be discussed here. The material that follows is, therefore, only a "taste" of what NASA has to offer in this area.**

The Very Air We Breathe

The air we breathe is a complex mix of chemicals in a state of constant flux. Many of the species in our atmosphere play significant roles in regulating our planet's environment at all time scales. Only by understanding these various forcings, chemical reactions, and their effects on climate can we even begin to understand what impact these chemicals have on our planet's systemic behavior.

NASA's Aura mission is probably the Earth Science mission most directly linked to chemistry—and in fact was originally referred to as EOS-CHEM. Launched in 2004, Aura is part of the wildly successful A-Train satellite constellation, and is dedicated to the study of the complex and ever-changing chemistry of our Earth's atmosphere. Measurements of various chemical species were performed with the High Resolution Dynamics Limb Sounder (HIRDLS; no longer operational), which measured the temperature and composition of the upper troposphere, stratosphere, and mesosphere; the Microwave Limb Sounder (MLS), which measures the temperature and composition of the upper troposphere and stratosphere; the Ozone Monitoring Instrument (OMI), which measures total column ozone, nitrogen dioxide, sulfur dioxide, formaldehyde, bromine monoxide, aerosol absorption.; and the Tropospheric Emission Spectrometer (TES), which measures all radiatively active molecular species in the lower troposphere.

One compound in particular has been much in the news of late because of its probable links to global temperature change. Carbon dioxide is the second-most abundant *greenhouse gas* in Earth's atmosphere, and its concentration has been steadily increasing over the industrial era. NASA's Atmospheric Infrared Sounder (AIRS) on Aqua has produced global maps of CO_2. The upcoming Orbiting Carbon Observatory (OCO-2) will produce column measurements of CO_2 that should significantly improve our understanding of regional sources and sinks of this important chemical species.

The Ozone Hole – A Mystery Solved

A key example of how basic Earth Science chemistry research has been applied to effect environmental change is the tale of the Antarctic ozone (O_3) hole (see **Figure 1).**

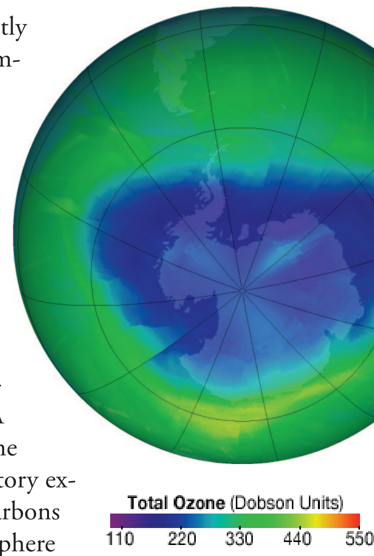

Figure 1. Antarctic Ozone Hole, September 2010. **Image courtesy:** NASA

At the beginning came the observation that ozone was being depleted in the stratosphere over the Antarctic, first from ground-based observations and later using the Total Ozone Mapping Spectrometer (TOMS), first launched on the NOAA/NASA satellite, Nimbus-7, in 1978[3]. This observation naturally raised the question: *Why?* Then came years of modeling analysis and laboratory experimentation that showed that in the presence of chlorofluorocarbons (CFCs) and bromine-containing chemicals—added to the atmosphere in abundance by our industrial society—the specific conditions in that region of the atmosphere[4] resulted in the catalytic destruction of O_3. Based on firm scientific evidence returned from NASA and other sources, the Montreal Protocols were established in 1987 (and later amended) that would phase out the use of CFCs worldwide, thereby to limit further degradation of the situation. The studies also showed how the effects of removal of such species would not be felt immediately, but that there would be a significant lag-time between cessation of input of harmful chemicals and recovery of ozone levels. The ozone hole may have been the first clue of just how large and behaviorally "massive" are the Earth's systems when it comes to amelioration or mitigation of existing or predicted problems caused by human activity. It also demonstrated how remote sensing could be combined with laboratory and theoretical studies to explore real-world phenomenon—generally an important step in validating satellite-based remote sensing studies. Such observations of the ozone hole continue today with OMI on Aura, and are now routinely used to explore other chemical aspects of the Earth's systems.

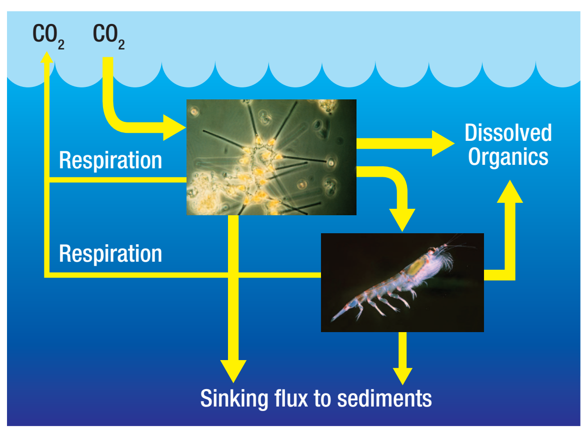

Figure 2. Oceanic Carbon Cycling. **Image courtesy:** NASA

Water – the Stuff of Life

The ionic strength of seawater derives from the presence of inorganic ions such as chlorine, sodium, magnesium, sulfur, calcium, potassium, bicarbonate, bromine, and a few other constituents. The soon-to-be-launched Aquarius/Satélite de Aplicaciones Científicas (SAC-D) mission will measure the concentration of dissolved salt at the ocean's surface. This information, combined with Sea Surface Temperature measurements from various sources—including the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua, as well as the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) on Aqua—will allow scientists to determine density of the surface water. Scientists will use these measurements to study the ocean's role in the global water cycle and how this is linked to ocean currents and climate.

[3] This was the first in a series of four TOMS instruments taking ozone measurements until 2006.
[4] Adding CFCs to the unique meteorological conditions of the Antarctic Polar Vortex turns out to be the perfect recipe for ozone loss. These conditions include extreme cold, seasonal darkness and the return of sunlight, specific wavelengths of incoming solar radiation, and the presence of ice crystals on which the chemistry could take place. The meteorological conditions are not the same in the Arctic and thus ozone loss is usually not as severe. However, in 2011 ozone loss was significant in the Northern Hemisphere: *earthobservatory.nasa.gov/IOTD/view.php?id=49874*.

Ocean chemistry is largely—but not exclusively—the domain of organic chemistry, with emphasis on biological systems. The inorganic ions and compounds also affect and are affected by *organic material*—i.e., living things ranging from the smallest (bacteria) to the largest (marine mammals). The equilibrium state of the oceans depends on maintaining a delicate balance between all these chemicals. Key to maintaining this equilibrium is the buffering capacity of the oceans, brought about by the dissolution of atmospheric CO_2 in water to produce carbonic acid and bicarbonate. The relative concentrations of these chemicals maintain the pH of the oceans in a range suitable for life. Carbon is also a major contributor to marine chemistry through—among other actions—the death and disintegration of living things, as outlined in **Figure 2**.

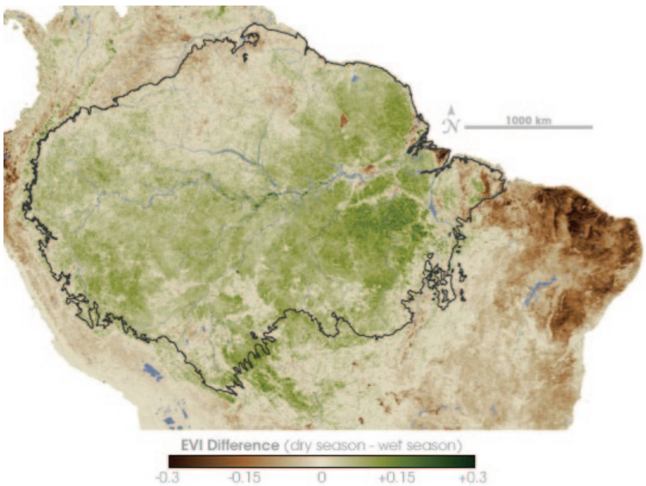

Figure 3. MODIS data for the Amazon Basin reveals something unexpected; the region is greener in the dry season than in the rainy season. **Image courtesy:** NASA Visible Earth

Measuring Dissolved Organic Matter (DOM) as well as the presence of chlorophyll in marine organisms was a key goal of NASA's Sea-viewing Wide Field-of View (SeaWiFS) mission, launched on the SeaStar spacecraft in 1997, which ended functionally in December 2010 after 13 years of superlative activity. Precursor instruments, such as the Coastal Zone Color Scanner (on the earlier-mentioned Nimbus-7 satellite), and follow-on instruments, such as MODIS on NASA's Terra and Aqua platforms, and the Visible Infrared Imager Radiometer Suite (VIIRS), planned for NPOESS Preparatory Project (NPP) and Joint Polar satellite System (JPSS)[5], have added and will add to the comprehensive chemical datasets that support our understanding of the oceans that cover some 72% of the Earth's surface, and that have significant effects on our Earth environment.

Land Biology and Chemistry

Chemistry on the land areas of the Earth is also of significant interest, as organic compounds (*via* the presence of chlorophyll) are used to determine the health of ecosystems and crops, and the geochemical composition of the Earth's surface. For the former, satellite-based measurements of the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) are used, similar to measurements of ocean-based chlorophyll fluorescence—*see* **Figure 3**. The Advanced Very High Resolution Radiometer (AVHRR) launched on several NASA-NOAA missions, as well as MODIS and Landsat have been linchpins for ecosystem studies.

For the latter, the Japanese Advanced Spaceborne Thermal and Emission Radiometer (ASTER) on Terra has provided significant data to allow better understanding of surface chemistry and its relation to land surface processes, the composition of volcanic gas plumes, and more. Localization and spread of fires—whatever the origin—help scientists understand contributions to atmospheric composition, both chemical and physical, for aerosols.

NASA: A World-class Chemistry Agency

Certainly, within NASA's various communities and constituencies, chemistry plays many roles. The ubiquity of chemistry-related activities can almost make such efforts invisible; for those who are practitioners of the chemical sciences it is a day-to-day ef-

[5] **Note on nomenclature**. The precursor to the Joint Polar Satellite System (JPSS) is a bridge-mission known as the NPOESS Preparatory Project (NPP). The National Polar-orbiting Operational Environmental Satellite System (NPOESS) was the name of the joint NASA–NOAA–DOD satellite program until February 2010, when the civilian and military elements were separated, whereupon the name of the NASA–NOAA element was changed to JPSS.

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We Can See Clearly Now: ISS Window Observational Research Facility

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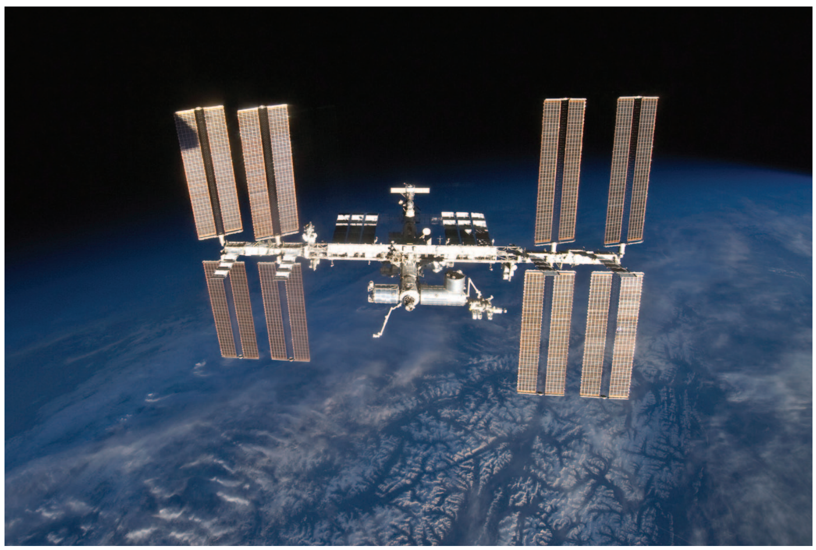
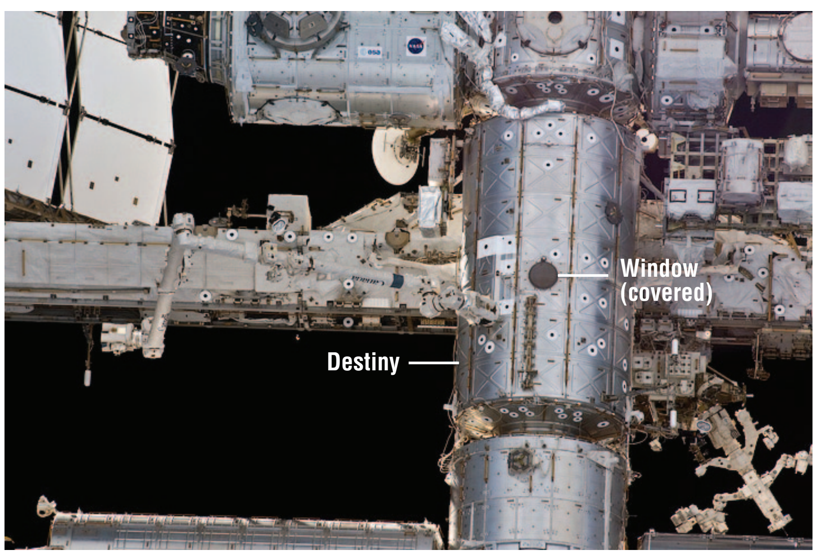
Like a human who just went through laser vision correction, the International Space Station (ISS) recently got a clearer view of our world. The improved view is opening up new vistas for students in American classrooms.

The Window Observational Research Facility (WORF) was delivered to the ISS in April 2010 on the STS-131 mission of Space Shuttle Discovery. It was installed and prepped on the *Destiny* Laboratory over the past year, and includes the highest-quality optics ever flown on a human-occupied spacecraft.





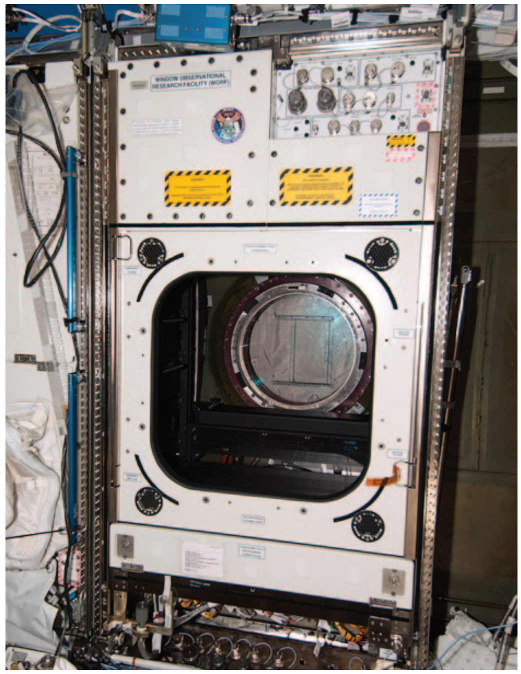
The International Space Station [*top*] and the *Destiny* Laboratory [*bottom*]. **Credit:** Astronaut photograph S131-E-011050 [*top*], taken on April 17, 2010. Astronaut photograph S130-E-012258 [*bottom*], taken on February 20, 2010

The arrival of the WORF has allowed astronauts to permanently remove a protective non-optical "scratch pane" on the window, which had often blurred images. The WORF also provides a highly stable mounting platform to hold cameras and sensors steady, while offering power, command, data, and cooling connections. With the WORF, the high-quality optics of the *nadir-viewing window*—looking "straight down" towards the Earth—are now fully utilized for the first time since *Destiny* was launched in 2001.

"Optically speaking, the scratch panes limited the resolution that could be obtained with spectral imagers or cameras," said former astronaut **Mario Runco**, who was part of the design and development teams for the WORF now serving as the lead for spacecraft window optics and window utilization at NASA's Johnson Space Center. "With the WORF finally in place, we can now make full use of the investment in an optical quality window for Earth Science and observation."

The subject of the first test image from the WORF was British Columbia's snow-capped mountains and coastline in western Canada. The image, [shown on the next page] captured with a 50-mm lens on January 17, 2011, features an area just north of Vancouver Island—centered at 51.8° N latitude and 127.9° W longitude—covering an area approximately 124 mi (200 km) x 83 mi (134 km). Calvert Island is visible at image left, and the glaciers of the Heiltskuk

Ice Field in the Coast Mountains are visible at image right. In between the two are Oweekeno Lake and inlet.



The Window Operational Research Facility on the International Space Station provides a stable mounting platform to hold cameras and sensors, while offering power and data connections. **Credit:** Astronaut photograph S131-E-008619, taken on April 10, 2010

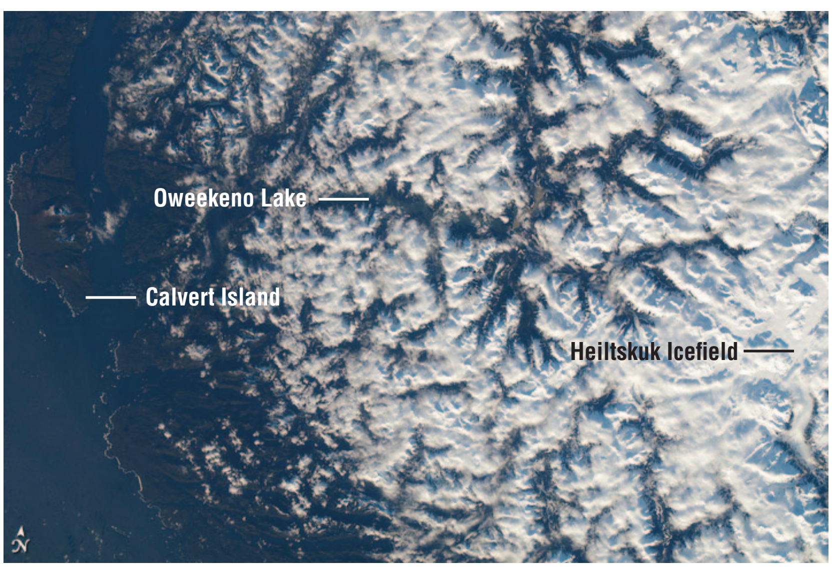
While it is not a particularly unique image, it is notable for the clarity and sharpness of ground features even though it was taken with a wide-angle lens. It is a significant improvement from similar imagery acquired through the *Destiny* lab window when the non-optical-quality pane was in place.

The image was taken to test the control computer and camera associated with the EarthKAM payload—an educational outreach project that allows middle school students to remotely take pictures of their home planet from the unique perspective of the space station—220 mi (354 km) above the Earth's surface.

"We are very excited to have a new camera system that appears to be functional and taking incredible images," said **Karen Flammer** [University of California, EarthKAM Manager, San Diego, CA].

EarthKAM

Following the British Columbia test images, Parkview Montessori in Jackson-Madison County, Tennessee, and Public School 229–Dyker in Brooklyn, New York acquired the first student images from EarthKAM. Teacher **Vickie LeCroy's** students at Parkview plan to study landforms such as islands, mountains, and deserts in the EarthKAM image they obtained of Mexico. Dyker teacher **Camille Fratantoni** and her students plan to enrich their studies of Earth Science and learn more about NASA missions.



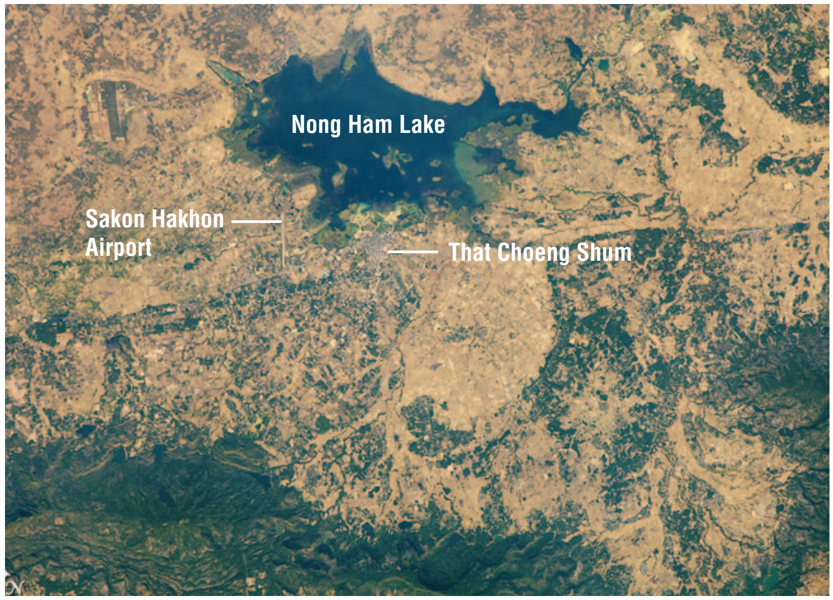
The first EarthKAM image from WORF: the Coast Mountains of British Columbia. (EarthKAM image 9362, Taken on January 17, 2011.)

After the first two days, EarthKAM ground controllers worked with Expedition 26 astronaut **Cady Coleman** to swap from a 50-mm (focal length 1.4) lens to a 180-mm (focal length 2.8) lens, in order to capture images with finer detail. Soon students from 146 participating schools captured 1,023 more images (1,562 total).

"The clarity and level of detail is captivating," said **Brion Au**, EarthKAM payload developer. "Never before in the history of EarthKAM have images of this quality been possible."

An image of That Choeng Shum, Thailand—taken on January 21, 2011—demonstrates the clarity of images taken through the *Destiny* lab window and WORF. The view is so crisp that details such as the stripes [about 18 ft (6 m) wide] on the Sakon Hakhon runway are faintly visible.

Photograph and zoomed enlargement of That Choeng Shum, Thailand. **Credit:** EarthKAM Winter 2011 Mission Image 59371



The new combination of the *Destiny* lab window and the WORF adds to the space station's capabilities as a remote-sensing platform for Earth Science. It enables the operation of high-resolution cameras and multi- or hyperspectral imagers within the pressurized environment of the ISS. And the WORF/Optical Window tandem also can be used for research and applications in fields such as geology, volcanology, meteorology, oceanography, coastal ocean management, ranch and forestry management, and disaster assessments and management.

In this capacity, the ISS can be used not only as a test bed for new instruments, but as an operating location for current sensor technology without the space environment and platform design requirements necessary for "free-flying" orbital sensors.

Currently, both the EarthKAM and the ISS Agricultural Camera (ISSAC) are onboard the ISS. EarthKAM is operational now, while ISSAC will become operational in the spring of 2011, when both payloads will conduct simultaneous but independent operations—the first time multiple payloads would be operational in the WORF for Earth Science. ■

Complete Set of ASTER Level-1B Data Available

All 11 years of ASTER Level-1B data over the U.S. and Territories have been made available by the Land Processes Distributed Active Archive Center (LPDAAC). Users may browse, search, and download their product(s) of interest from several sites. The U.S. Geological Survey's (USGS) Earth Explorer (EE) client at *earthexplorer.usgs.gov* is the newest. The first step is to register for a free account. Then click on the "Data Sets" tab, expand "NASA LPDAAC Collections", and select ASTER. Next use the search criteria to choose location and time periods. The data are also available from the Warehouse Inventory Search Tool (WIST), USGS Global Visualization Viewer (GLOVIS), and the LPDAAC Data Pool.

The "Human Satellite" Returns to Earth

Piers Sellers has been selected to serve as the Deputy Director of the Sciences and Exploration Directorate at Goddard Space Flight Center (GSFC)—effective June 6, 2011. Sellers began his career at GSFC where he worked as a researcher from 1982–1996 and worked on global climate problems—particularly those involving interactions between the biosphere and the atmosphere—and was involved in: 1) constructing computer models of the global climate system; 2) satellite data interpretation; and 3) conducting large-scale field experiments in the U.S., Canada, Africa, and Brazil. He served as the first Project Scientist for the Terra mission (then called AM-1) during the period 1991–1996, and has over 70 refereed journal publications, including 30 first author papers, and two first author papers in *Science*.

Sellers joined the U.S. astronaut corps in 1996 and flew on space shuttle missions to the International Space Station (ISS) in 2002 and 2006, carrying out six spacewalks; he flew another mission to the ISS in 2010 during which he operated the shuttle's robotic arm. In between flights, he served as a liaison in Russia, as the branch head of the ISS Operations branch that looks after all astronauts training to fly on ISS, and as an Extravehicular Activity instructor.

Sellers was born and educated in the U.K.: Cranbrook School in Kent, Edinburgh University for a degree in Ecology, and Leeds University for a PhD in Biometeorology.

The Earth Observer would like to welcome Sellers (who has referred to himself as "the human satellite") back to *terra firma*.

Blog Log

Nicole Miklus, formerly NASA Goddard Space Flight Center

Blog introductions modified from text on the Earth Observatory website and featured blogs; images are also from the Earth Observatory website (*earthobservatory.nasa.gov/blogs*) and featured blogs.

Welcome to another installment of the Blog Log. Here, you can learn about new blogs that feature NASA Earth Science research and fieldwork, and find links to where you can access the full story. In this issue, we highlight two blogs for you to bookmark and check for updates. If you know of a blog about NASA science that perhaps deserves some attention (maybe your own!), please let us know.

MABEL: Spring 2011

The Multiple Altimeter Beam Experimental Lidar (MABEL) is an Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) simulator that is being flown at high altitudes to test the satellite's measurement concept. In December 2010 MABEL flew in the nose cone of the ER-2 for five test flights out of the Dryden Aircraft Operations Facility in Palmdale, CA. In March 2011 the crew returned to Palmdale to conduct more MABEL flights—this time to test a new set of filters that allows the simulator to fly during daylight hours. This "shakedown" mission includes flights over different terrain types to assess MABEL's performance. To enable data comparisons, some flight paths follow established routes for *Operation IceBridge*. **Kelly Brunt**, a NASA scientist who works on the ICESat-2 mission and flight planning for MABEL, writes about the test flights at: *earthobservatory.nasa.gov/blogs/fromthefield/category/mabel-2011/*.

MABEL awaits placement in the nose cone of the ER-2.

The ER-2, on the runway, just prior to takeoff.

Operation IceBridge: Arctic 2011

Operation IceBridge (OIB) is a six-year NASA field campaign to complete the largest ever airborne survey of Earth's polar ice. *IceBridge* began in March 2009. Previous *Blog Logs* have referenced blogs that chronicled these first flights and the Arctic 2010 campaign. *The Earth Observer* also ran a feature article on Operation IceBridge in the May–June 2010 issue [**Vol 22**, **Issue 3**, pp. 4-7]. The Arctic 2011 (OIB 2011) campaign began in March 2011; Lieutenant Commander (LCDR) **John Woods**, a faculty member in the Oceanography Department of the United States Naval Academy (USNA), writes about his participation in OIB's Sea Ice Thickness Observation Team. Woods and his students are living at Thule Air Force Base in Greenland, and flying in NASA's P-3B aircraft to observe the collection of Arctic sea-ice data. They are part of a team that includes NASA's **Jim Yungel**, Airborne Topographic Mapper (ATM) Program Manager, and **Michael Studinger**, OIB Project Scientist. First Class Midshipmen (MIDN 1/C) **Eric Brugler**, an Oceanography major at the USNA, also contributes entries to the blog. To read more about the campaign, and to view stunning Arctic imagery, check out: *earthobservatory.nasa.gov/blogs/fromthefield/category/icebridge-arctic-2011/*.

LDCR **John Woods** and MIDN 1/C **Eric Brugler** observe sea ice conditions in the Arctic Ocean during a March 17th flight. **Photo Credit:** Jim Yungel

Moustafa T. Chahine

1935—2011

It is with deep sorrow and sadness that we report the untimely death of one of the stellar leaders of the NASA Earth-observing program, Dr. Moustafa T. Chahine, affectionately known as "Mous" to hundreds of friends and colleagues around the world.

Mous was the long-time, revered Team Leader for the Atmospheric Infrared Sounder (AIRS) on the Aqua satellite. His death on March 23, 2011, from a heart attack several hours after what had seemed to be a successful hernia surgery, is a devastating loss for the AIRS Science Team, the Aqua project, and the broader NASA Earth-observing program.

Mous was born on January 1, 1935, and grew up in Lebanon, moving to the U.S. as a teenager in 1954. Two years later he received his Bachelor of Science degree from the University of Washington, and in 1960 he received a doctorate in mechanical engineering from the University of California at Berkeley and began his career at NASA's Jet Propulsion Laboratory (JPL) at the California Institute of Technology (Caltech). Over the years, he held a variety of positions at JPL, including head of the Planetary Atmospheres Section, 1975–1978, founding Manager of the Division of Earth and Space Sciences, 1978–1984, and JPL Chief Scientist, 1984–2001.

One of Mous' primary scientific accomplishments was his 1969 development of an exact mathematical method for the inverse solution of the full radiative transfer equation. This Relaxation Method is now widely used for deriving satellite-based profiles of atmospheric temperature and composition for the atmospheres of the Earth, Venus, Mars, and Jupiter. Subsequent to his 1969 work, Mous employed both infrared and microwave data in the formulation of a multispectral approach to remote sensing in the presence of clouds. In 1980, Mous' equations were used to generate the first satellite-based global distribution of Earth's surface temperature.

Mous was the key individual behind the remarkable AIRS instrument and was the guiding force behind many major successes of the AIRS Science Team. He received his first funding for AIRS back in 1978, when he first proposed the instrument, well before the Aqua satellite was even conceived. Once the Earth Observing System (EOS) program began and AIRS was selected in 1988 as a Facility Instrument to be included on Aqua (originally known as EOS PM), Mous became the AIRS Science Team Leader and helped ensure the proper development of both the instrument and the algorithms to convert the AIRS radiance data to geophysical products. After the Aqua launch on May 4, 2002, Mous continued to lead the Science Team as the AIRS data products were developed, generated, and analyzed.

As foreseen years before by Mous, incorporation of AIRS data into forecast models has increased weather forecast skill, and Mous delighted in the positive comments made by prominent people regarding the improvements, while continuing to encourage an increase in the amount of AIRS data being incorporated. Also as foreseen by Mous, the AIRS data have proven valuable to scientific studies over a vast range of topics in Earth Sciences. Of these topics, one that Mous devoted considerable time to in recent years was the derivation of atmospheric carbon dioxide (CO_2) from the AIRS data. Mous' global CO_2 results became popular fixtures in many scientific presentations and appeared in popular media outlets as well.

Appropriately, Mous has been honored with numerous well-deserved awards, including the NASA Medal for Exceptional Scientific Achievement in 1969, the NASA Outstanding Leadership Medal in 1984, the William T. Pecora Award in 1989, the American Meteorological

Society's Jule G. Charney Award in 1991, the American Institute of Aeronautics and Astronautics' Losey Atmospheric Sciences Award in 1993, the Committee on Space Research's William Nordberg Medal in 2005, the NASA Medal for Exceptional Scientific Achievement in 2007, and the International Society for Optical Engineering's George W. Goddard Award in 2010. Mous was a Fellow of the American Physical Society, the American Meteorological Society, the British Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science, and he was a member of the prestigious U.S. National Academy of Engineering and the Society of Sigma Xi.

Mous was foremost a gentleman, a kind and caring individual who was thrilled with the successes of everyone on the AIRS team and who radiated enthusiasm for science. He has been a vital part of the EOS and Aqua communities since EOS was first conceived in the 1980s, and his presence is sorely missed.

Mous is survived by his wife Marina and his sons Tony and Steve. Our heartfelt condolences pour out to them.

[This 'in memoriam' was written by Aqua Project Scientist Claire L. Parkinson, on behalf of the Aqua Project and *The Earth Observer* staff.]

NASA and the International Year of Chemistry 2011

continued from page 24

fort. What may not be so clear is that virtually all such activities conducted under the NASA banner are mutually supportive and contributory: While NASA is colloquially referred to as the U.S. "space agency", given the cursory presentation provided here, it may also be appropriate to also list it as a world-class "chemistry agency", which makes contributions to our knowledge of chemistry not just in 2011, the International Year of Chemistry, but every year.

Acknowledgments

The author would like to thank **Terry Taylor** of the American Chemical Society and **Steve Graham** [GSFC – *EOSPSO*] for providing background information on IYC 2011.

Resources

Celebrating the International Year of Chemistry
www.un.org/en/events/chemistry2011/

International Year of Chemistry 2011
www.chemistry2011.org

Visualizing and Understanding the Science of Climate Change
www.explainingclimatechange.ca/

Global Water Experiment
water.chemistry2011.org/web/iyc

365: Chemistry for Life
iyc2011.acs.org/

NASA SCAN – Chemistry and Materials
www.sti.nasa.gov/scan/chem-mat.html

NASA Mars Exploration Program
marsprogram.jpl.nasa.gov/

Mars Science Lander ChemCam
msl-scicorner.jpl.nasa.gov/Instruments/ChemCam/

NASA Stardust Mission
stardust.jpl.nasa.gov/

Nucleosynthesis
helios.gsfc.nasa.gov/nucleo.html

NASA's Planet Quest
planetquest.jpl.nasa.gov/index.cfm

Phoenix Mars Mission
phoenix.lpl.arizona.edu/index.php

NASA Astrobiology Institute
astrobiology.nasa.gov/nai

Breathing Easy on the Space Station (2000)
science.nasa.gov/science-news/science-at-nasa/2000/ast-13nov_1/

In Situ Resource Utilization Project/Glenn Research Center
microgravity.grc.nasa.gov/Advanced/Capabilities/ISRU/

For Earth Science information related to chemistry, the reader is referred to earlier issues of *The Earth Observer,* which may be found at: *eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*

Landsat Science Team Meeting Summary

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Thomas K. Maiersperger, SGT, Inc., contractor to the USGS Earth Resources Observation and Science Center, tmaiersperger@usgs.gov, work performed under USGS contract G10PC00044
James R. Irons, NASA Goddard Space Flight Center,, James.R.Irons@nasa.gov
Curtis E. Woodcock, Department of Geography and Environment, Boston University, curtis@bu.edu

Meeting Overview

The Landsat Science Team sponsored by the U.S. Geological Survey (USGS) and NASA met in Mesa, AZ, from March 1-3, 2011. The team met in Mesa so that they could receive briefings and tours of the Landsat Data Continuity Mission (LDCM) spacecraft that is being developed by Orbital Sciences Corporation in nearby Gilbert, AZ.

Tom Loveland and **Jim Irons** [USGS and NASA Goddard Space Flight Center (GSFC), respectively—*Landsat Science Team Co-chairs*] opened the ninth meeting of the Landsat Science Team. They stated that the primary focus of the meeting was the in-depth review of LDCM development status, but that Landsat 5 and 7 activities and future Landsat missions would also be discussed. Loveland commented that the meeting marked the beginning of the final year of the team but that the USGS plans this year to issue a request for proposals to continue the team for an additional five years. Irons noted that the LDCM development is on schedule, and that all major systems are in the integration and test phase of their development. He also mentioned that Bill Ochs has left his position as the LDCM Project Manager to lead the NASA James Webb Space Telescope and that Phil Sabelhaus now leads LDCM. The team offered a round of applause in recognition of Bill's outstanding leadership and commitment to science.

Curtis Woodcock [Boston University—*Landsat Science Team Leader*] concluded the opening session by reminding everyone of the major Landsat accomplishments achieved over the previous four years (e.g., no-cost Landsat data, global archive consolidation, Sentinel-2[1] coordination, Landsat science products, and LDCM progress). He then challenged the team to focus their attention on bigger accomplishments over the next five years.

Meeting presentations are available at: *landsat.usgs.gov/science_LST_mar1_3_2011.php*

USGS Landsat Science and Development

Matt Larsen [USGS—*Associate Director for Climate and Land Use Change*] introduced himself to the team and described the recent USGS realignment. The USGS is now organized into mission areas. Land Remote Sensing and Landsat activities are part of the Climate and Land Use Change Mission that Larsen leads. Larsen explained the importance of remote sensing for USGS climate and land use research, and reported on efforts to stabilize the future of Landsat. The President's Fiscal Year 2012 budget includes funding to: 1) estab-

[1] Sentinel 2 is a mission under the European Space Agency's Living Planet Programme. The pair of Sentinel-2 satellites will routinely deliver high-resolution optical images globally, providing enhanced continuity of Système Pour l'Observation de la Terre (SPOT)- and Landsat-type data.

Landsat Science Team meeting participants lish a National Land Imaging Program in the Department of the Interior (DOI) and the USGS; 2) develop Landsat 9; and 3) authorize planning for Landsat 10. Future Landsat missions would be led by the USGS and developed through a NASA–USGS partnership.

Bruce Quirk [USGS—*Land Remote Sensing Program Coordinator*] led a discussion of the steps that resulted in the President's Landsat request. The National Space Policy released in mid-2010 placed operational land remote sensing responsibilities with the DOI. With the National Land Imaging Program the DOI, through the USGS, would be responsible for documenting the Federal requirements for land remote sensing data and for developing strategies to meet priority needs. Equally important, the President's budget *operationalizes* the Landsat program and authorizes the development of Landsat 9 and 10. Preliminary plans call for a Landsat 9 launch in late 2018, and Landsat 10 in 2023. Quirk said that in the coming months, USGS would be developing Landsat 9 mission requirements and identifying the key trade studies that will lead to the establishment of Landsat 9 capabilities.

The Operational Land Imager (OLI) being integrated onto the LDCM spacecraft.
Photo Credit: Ball Aerospace Technology Corporation

John Dwyer [USGS—*LDCM Project Scientist*] reviewed preliminary USGS plans to collect, analyze, and prioritize land remote sensing requirements. The plans include identification of key science and applications needs, measurements, product specifications, and services needed to make effective use of land remote sensing data and products.

Landsat Data Continuity Mission (LDCM) Status

Dell Jenstrom [GSFC—*LDCM Deputy Project Manager*] provided status on the instruments, spacecraft, and mission operations components of the LDCM project. The launch readiness date is December 1, 2012, with three months of schedule reserve. The Operational Land Imager (OLI) has completed integration and performed very well during spatial and radiometric testing. Once environmental testing is complete in June, the instrument will be shipped to the spacecraft vendor. The Thermal Infrared Sensor (TIRS) and spacecraft bus have each started integration and testing.

Betsy Forsbacka [GSFC] detailed TIRS activities and plans. Since July 2010 the focal plane array, electronics, and telescope have been completed. Other subsystems such as the cryocooler, scene-select mechanism, and main electronics box are nearly complete. Final delivery of TIRS to the spacecraft vendor is planned for December 31, 2011.

Brian Markham [GSFC] spoke about LDCM on-orbit calibration and validation considerations. The mission orbit plan is a 16-day repeat cycle with an 8-day phase shift relative to Landsat-7. The ascent plan indicates a four-day period where LDCM will underfly Landsat-7 for cross-calibration. These plans may vary depending on the operational status of Landsat-5 and -7 at LDCM launch. After launch, the OLI and TIRS instruments will undergo extensive calibration and characterization during commissioning and through operations phases.

Dave Hair [USGS—*LDCM Project Manager*] and **Doug Daniels** [The Aerospace Corporation] reported on LDCM ground systems activities. Ground Readiness Tests (GRTs) are underway; significant progress has been made in verifying critical mission operations functionality. They discussed progress on the Ground Network Element (GNE), Collection Activity Planning Element (CAPE), Data Processing and Archive Element (DPAS), and International Cooperator (IC) network.

Landsat 5 and 7 Status

Kristi Kline [USGS—*Landsat Project Manager*] and **Rachel Headley** [USGS—*Landsat Project*] provided status on the Landsat-5 and -7 spacecrafts, archive operations, and the Landsat Global Archive Consolidation (LGAC). Landsat-7 continues operating with no significant new issues. Landsat-5 also continues to collect data, but issues with the Traveling Wave Tube Amplifier require persistent monitoring. Over 170,000 Multispectral Scanner (MSS) scenes have been recovered and added to the archive. Distribution statistics show strong and increasing demand for Landsat scenes since the data became free. The archive is migrating to modern storage media, which will increase processing throughput in the future. LGAC has repatriated nearly 300,000 Landsat scenes from international stations to the U.S. archive to date.

Other Landsat-related Activities

Natalie Sexton [USGS Fort Collins Science Center] reported that results of the recent USGS Landsat survey are now available as a publication titled *The Users, Uses, and Value of Landsat and Other Moderate-Resolution Satellite Imagery in the United States – Executive Report*. The publication is available at: *pubs.usgs.gov/of/2011/1031/*.

Jeannie Allen [Sigma Space/GSFC] reviewed several aspects of NASA's Education and Public Engagement approach. These included a Landsat website redesign, establishing Landsat on *Facebook* and *Twitter*, developing new brochures, describing ongoing events and educational partnerships, and the Landsat Legacy Project[2].

Noel Gorelick [Google] spoke about Landsat data and recent progress on the *Google Earth* Engine prototype.

Peter Becker [Esri] spoke about Landsat data and recent *ArcGIS* [3] advances in raster image handling.

Sentinel-2 Discussion

Because European Space Agency representatives could not attend this meeting, **Alan Belward** [European Community Joint Research Centre—*Landsat Science Team Member*] gave a brief update on the status of Sentinel-2. The first Sentinel-2 launch is tentatively planned for 2013; it will include an optical instrument with a 13-channel multispectral imager with 10-m, 20-m, and 60-m resolution. The tentative data policy, subject to European Union approval, is to provide Sentinel-2 data for scientific purposes at no cost. The Science Team discussed areas of synergy between LDCM and Sentinel-2, including instrument cross-calibration, consistent product specifications, and coordinated acquisition planning.

LOGICAL - A Landsat Augmentation Concept

Darrel Williams [Global Science and Technology, Inc.—*Landsat Science Team Member*] described his Land Observations Globally in a Cost-effective Augmentation of Landsat (LOGICAL) concept. The LOGICAL goal is to develop a low-cost strategy for improving the frequency of Landsat-type observations. It is based on augmenting "gold standard" Landsat observations with those obtained from small satellites with lower-cost instruments that image a wider field of view. The result would be observations that, when cross-calibrated with Landsat measurements, provide multi-spectral imagery of sufficient quality to be used with Landsat for more robust global monitoring.

Science Presentations

Prasad Thenkabail [USGS] presented a knowledge-based automated cropland mapping algorithm. The algorithm is based on cropping zone, and depends on an accurate knowledge base and multiple data sources including Landsat, Moderate Resolution Imaging Spectroradiometer (MODIS), and digital elevation variables. Thenkabail demonstrated results for Tajikistan. The algorithm derived an overall accuracy of 98.9% for mapping three classes: irrigated areas, rain-fed areas, and all other land cover and land use classes.

Dirk Pflugmacher [Oregon State University] described a study of annual forest disturbance history from 1972–2010. The study leveraged recent improvements in MSS radiometry to extend earlier analyses based on Thematic Mapper (TM) data that extend back to 1972. A good correlation between MSS and TM indices exists during overlapping time periods, enabling inter-calibration of the datasets. The analysis captured both abrupt and slow disturbance in the long-time series.

Robert Kennedy [Oregon State University] spoke about moving towards attribution of change agents using Landsat time series information. While simplified pixel-level temporal trajectories can detect vegetation changes, the attribution of change agents to the trajectories was conceptualized as a fundamentally patch-based problem. Kennedy presented a methodological framework to: 1) generate patches from the pixel-based information; 2) utilize patch metrics and process knowledge to aid attribution; and 3) validate the results.

Mike Wulder [Canadian Forest Service] presented the results of two research projects that used Landsat time series imagery. The first project used time series data to identify salvage harvesting activity within recently burned sites. The second project focused on the productive capacity of boreal forest ecosystems after disturbance. Wulder found that both harvested and burned areas were recovering and had gross primary productivity similar to undisturbed samples.

[2] The Landsat Legacy Project conducts oral history interviews with members of the Landsat alumni. Together with an ongoing literature search, the project is unearthing interesting and useful information about the development and maintenance of the Landsat program over its 30+ year history.

[3] ArcGIS is a suite consisting of a group of geographic information system (GIS) software products produced by Esri. *www.esri.com/software/arcgis/index.html*

Landsat Products Development

Curtis Woodcock reviewed the impetus and focus for developing an expanded suite of Landsat products. He stated that expanding the range of successfully implemented products would significantly enhance the impact and relevance of the Landsat Program. Initial efforts should focus on enabling products such as surface reflectance, surface temperature, and cloud masks. Later, the focus can shift to higher-level science products such as land cover, land cover change, leaf area index, and albedo.

Jeff Masek [GSFC—*Landsat Project Scientist*] underscored these points when he summarized outcomes of the Landsat Science Team November 2010 products workshop, held in Boston, MA.

John Dwyer followed up with a discussion of USGS plans for Landsat science products. The initial USGS priorities dovetailed with Science Team recommendations, including surface reflectance, surface temperature, land cover, and leaf area index. **Tom Loveland** provided details of the global land cover strategy that includes quantifying annual land cover components (e.g., percent trees, shrubs, herbs, water, and barren), and periodic land cover type maps.

John Schott [Rochester Institute of Technology] described progress in developing a land surface temperature product for Landsat, with the goal of delivering the methodology and software to USGS for implementation. Currently, the approach is being defined and tested for North America. In year two, the algorithms will be refined, extended globally, and evaluated. After refining and validating the global algorithms, the final tools will be delivered to USGS.

Chengquan Huang [University of Maryland College Park] presented the use of MODIS data to assess global Landsat surface reflectance products. Huang showed that operational quality assessments of Landsat surface reflectance products were feasible during the MODIS era. A suite of tools has been developed and is available for performing automated quality checks. For the post-MODIS era, Visible Infrared Imager Radiometer Suite (VIIRS) data might be used in replacement.

Future Meetings

The next meeting of the Landsat Science Team will be held at the USGS Earth Resources Observation and Science Center (EROS) near Sioux Falls, SD, from August 16-18, 2011. The meeting will emphasize the science accomplishments achieved during the five-year term of this Landsat Science Team. ■

AMSR-E Level-2A Brightness Temperatures Now Available Through LANCE

The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) Science Investigator-led Processing System (SIPS) and Global Hydrology Resource Center Distributed Active Archive Center (GHRC DAAC) are pleased to announce that we have integrated a new Level-2A (L2A) Brightness Temperature algorithm into our Land Atmosphere Near-real-time Capability for EOS (LANCE) processing systems. Developed at Remote System Systems (RSS), these much improved *Version 11* brightness temperatures, as well as the corresponding Level-2B (L2B) and Level 3 (L3) daily derived products, are available for FTP (registration required) from our LANCE servers at: *ftp://lance1.nsstc.nasa.gov/ops/* and *ftp://lance2.itsc.uah.edu/ops/*.

This new Near-Real-Time (NRT) L2A algorithm is comparable to the *Version 11* L2A algorithm currently used to process standard data products at the AMSR-E SIPS. We are seeing only very small differences (less than 1 K in most cases) in the data produced by the new NRT *Version 11* algorithm compared to the *Version 11* standard data product algorithm. The primary difference between the new *Version 11* NRT L2A code and the L2A science code used in the SIPS for generating research-quality L2A brightness temperatures is that the NRT algorithm uses static rather than dynamic calibration.

We will continue to evaluate the *Version 11* NRT data during the next year and document our findings on the AMSR-E SIPS LANCE website at: *lance.nsstc.nasa.gov/*.

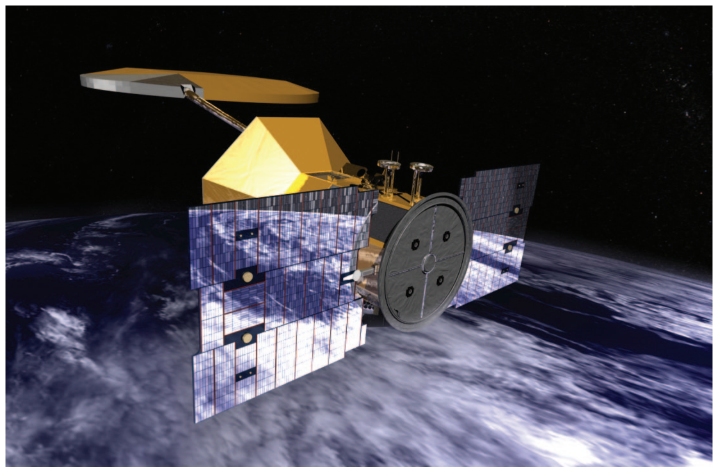
More information about LANCE AMSR-E near real-time data and other LANCE elements [including the Advanced Infrared Sounder (AIRS), Ozone Monitoring Instrument (OMI), Microwave Limb Sounder (MLS), and Moderate Resolution Imaging Spectroradiometer (MODIS)] are available at: *lance.nasa.gov/*.

NASA's Aquarius: The Water Bearer Flies Soon

Melissa Quijada, NASA Goddard Space Flight Center, melissa.z.quijada@nasa.gov

With more than a few stamps on its passport, NASA's Aquarius instrument on the Argentinian Satélite de Aplicaciones Científicas (SAC)-D spacecraft will soon embark on its space mission to "taste" Earth's salty ocean.

After a journey of development and assembly through NASA facilities, a technology center in Bariloche, Argentina, and testing chambers in Brazil, the Aquarius is just about ready to fly. The instrument, set to measure the ocean's surface salinity, recently made the final leg of its transcontinental journey from São José dos Campos, Brazil, to California's Vandenberg Air Force Base for final integration and testing before its scheduled launch on June 9, 2011.



An artist's rendering of Aquarius/SAC-D deployed in orbit.

Aquarius will map the concentration of dissolved salt at the ocean's surface, information that scientists will use to study the ocean's role in the global water cycle and how this is linked to ocean currents and climate. Sea surface temperature has been monitored by satellites for decades, but it is both temperature and salinity that determine the density of the surface waters of the ocean. Aquarius will provide fundamentally new ocean surface salinity data to give scientists a better understanding of the density-driven circulation; how it is tied to changes in rainfall and evaporation, or the melting and freezing of ice; and its effect on climate variability.

"The ocean is essentially Earth's thermostat. It stores most of the heat, and what we need to understand is how do changes in salinity affect the three-dimensional circulation of the ocean," said **Gene Feldman**, Aquarius Ground System and Mission Operations Manager at NASA's Goddard Space Flight Center (GSFC). The development of the Aquarius mission began more than 10 years ago as a joint effort between GSFC and NASA's Jet Propulsion Laboratory (JPL). In 2008, GSFC engineers completed the Aquarius microwave radiometer instrument, which is the key component for measuring salinity from space.

"The radiometer is the most accurate and stable radiometer built for sensing of Earth from space. It's a one-of-a-kind instrument," said **Shannon Rodriguez-Sanabria**, a microwave communications specialist at GSFC.

JPL built Aquarius' scatterometer instrument, a microwave radar sensor that scans the ocean's surface to measure the effect that wind speed has on the radiometer measurements. The radiometer and scatterometer instruments, along with an 8.25 x 10 ft elliptical antenna reflector and many other systems, have been integrated at JPL to form the complete Aquarius instrument. A number of other instruments aboard the SAC-D spacecraft are contributions from Argentina, France, Canada, and Italy.

In June 2009 Aquarius was flown via a U.S. Air Force cargo jet to San Carlos de Bariloche, Argentina—a destination known for its blue lakes and verdant mountains—to be integrated with Argentina's SAC-D spacecraft. A year later, the fully assembled spacecraft and all the instruments—now referred to as the *Aquarius/SAC-D Observatory*—were shipped to Brazil. There, engineers began a nine-month campaign of alignment, electromagnetic, vibration, and thermal vacuum testing to ensure it will survive the rigors of launch and orbiting in space.

JPL will manage the Aquarius mission through the commissioning phase, scheduled to last 45 days after launch; GSFC will then manage the Aquarius instrument operations during the mission. Argentina's Space Agency [Comisión Nacional de Actividades Espaciales (CONAE)] will operate the spacecraft and download all the data collected by Aquarius several times per day. GSFC is responsible for producing the Aquarius science data products; JPL will manage the data archive and distribution to scientists worldwide.

Aquarius will collect data continuously as it flies in a near-polar orbit as it circles Earth 14–15 times each day. The field of view of the instrument is 242 mi (390 km) wide, and will provide a global map every seven days. The data will be compiled to generate more-accurate monthly averages during the planned mission lifetime of three years.

For more information about Aquarius, please visit: *aquarius.nasa.gov/*. ■

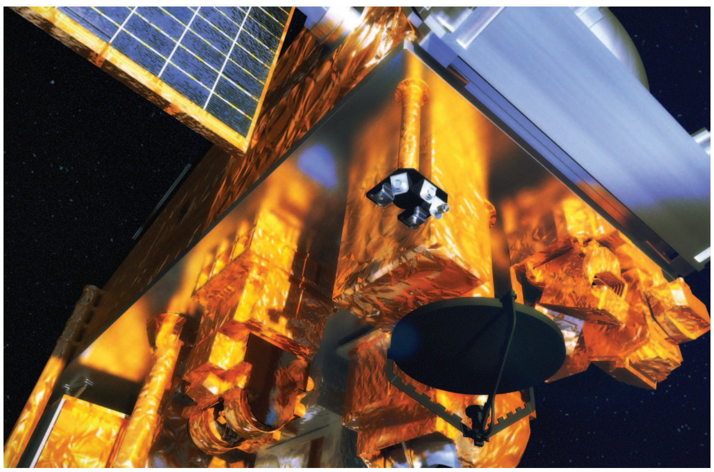
NASA Prepares Satellite for a New Era of Earth Observation

Adam Voiland, NASA's Goddard Space Flight Center, adam.p.voiland@nasa.gov

On Christmas Eve in 1968, Apollo 8 astronauts orbiting the moon used a hand-held camera to snap an ethereal photo of our cloud-speckled blue planet rising over the lunar horizon.

The photo, known as *Earthrise*, was one of the first views of Earth from deep space. It's widely credited with helping spur the global environmental movement that began to find its voice with the first Earth Day celebration on April 22, 1970.

More than four decades later, NASA's view of Earth has grown far more sophisticated. Today, a fleet of satellites —many of which are part of a project called the Earth Observing System (EOS)—constantly monitor the oceans, land surfaces, and atmosphere.



A close-up look at an artist's rendition of the NPP Spacecraft deployed in orbit.

In ways scarcely imaginable when *Earthrise* was taken, the EOS fleet has revolutionized understanding of how our planet works by helping pioneer an interdisciplinary approach to Earth Science. This approach, called *Earth systems sciences*, focuses on understanding the many components of Earth as an interconnected system rather than as independent entities. In the process, the group of EOS satellites has collected information that has led to the publication of thousands of technical papers.

To extend and build upon this legacy, NASA plans to launch a new member of its Earth-observing fleet this fall called the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project [NPP]—a minibus-sized satellite that will monitor a broad range of land, ocean, and atmospheric phenomena.

In addition to supporting operational activities, such as weather forecasting, NPP will help preserve and extend a suite of long-term measurements critical to understanding climate that began with EOS satellites launched about a decade ago. NPP is also capable of monitoring a broad range of natural and manmade disasters and contributors to global change.

Aging Flagships

Over the last decade, the three EOS flagships—Terra, Aqua, and Aura—have produced a spectacular amount of information about the environmental conditions that make life on this planet possible. Terra—the oldest—launched in 1999, Aqua in 2002, and Aura in 2004.

The three flagships have monitored phenomena ranging from wildfire smoke and volcanic ash plumes, to phytoplankton blooms and red tide outbreaks, to oil spills and rainforest deforestation. In addition, many EOS sensors have detected trends of global change: retreating ice sheets, rising sea levels, and increasing surface temperatures.

Yet parsing out the extent to which these observed changes reflect long-term climate change caused by human activity—as opposed to fleeting fluctuations due to natural climate variations—remains a complex and thorny problem for scientists. To answer it, high-quality, global satellite records significantly longer than a decade are needed.

"The EOS satellites have built a spectacular foundation, but they won't last indefinitely," said **Steve Platnick**, EOS Senior Project Scientist at NASA's Goddard Space Flight Center (GSFC). All three of the flagships have surpassed their six-year mission life spans. Terra is going into its 11th year on orbit, and certain instruments and pieces of hardware have started to degrade. Eventually, all three satellites will run out of fuel, despite the resilience of their hardware.

"When you're dealing with climate, by definition you're working with long-time scales," said NPP Deputy Project Scientist **Christina Hsu**, an aerosol specialist based at GSFC. "We've started building a whole set of databases in the last decade, and gaps in them would prove huge obstacles to understanding what's happening with the climate and why."

A Bridge Mission

NPP, like its flagship predecessors, will be placed in an orbit that passes over the poles. The satellite will fly about 512 mi (824 km) above the surface and complete about 14 orbits per day. A polar orbit makes it possible for NPP sensors to monitor all parts of the surface at least once per day. In contrast, geostationary satellites, which are primarily used to study changing weather patterns hour-by-hour, orbit high over the equator and cannot observe the poles or all sides of the planet.

Although some earlier NASA satellites have flown just one science sensor, NPP will carry five, similar to Terra. In all, NPP sensors will retrieve 24 key types of data about Earth including, for example, measurements of cloud and vegetation cover, ocean color, and sea and land surface temperatures.

All of NPP's 24 data products will have some bearing on global change and climate science, but a subset of them will be used for short-term weather forecasting as well. Meteorologists will use four of the 24 data products—especially measures of the vertical distribution of moisture and heat in the atmosphere—to improve forecasts.

Two of the 24 data products relate to ozone, the colorless gas that shields the planet from harmful ultraviolet radiation and which has declined in abundance over Antarctica in the last few decades. Such information will help scientists determine whether ozone depletion has reversed after ozone-depleting gases were regulated beginning in 1989.

"While the original EOS flagships were primarily climate research satellites, NPP is more of a hybrid that will serve both climate scientists and meteorologists," said NPP Project Scientist **James Gleason** at GSFC. "It stands as a bridge between EOS and the next generation of operational climate and weather satellites, which is called the Joint Polar Satellite System (JPSS)"

NPP will test a number of key instruments and data processing techniques that JPSS satellites will use in coming decades. The first of this new generation of satellites will launch no earlier than 2014.

NPP's Instruments

Of the five instruments on board NPP, the largest and most complex is an imager called the Visible Infrared Imager Radiometer Suite (VIIRS). The instrument, a follow-on to an earlier imager that flies on both Terra and Aqua, called the Moderate Resolution Imaging Spectroradiometer (MODIS), will monitor broad swaths of the land, oceans, and air.

VIIRS will provide data in 22 key parts of the electromagnetic spectrum, or bands, that will be used by scientists in a variety of disciplines. Atmospheric scientists, for example, will use certain bands to monitor clouds as well as small airborne particles called aerosols. Oceanographers, meanwhile, will use VIIRS to monitor phytoplankton and other organisms in the sea. Biologists will use it to monitor vegetation and forest cover, while ice experts will use it to track changes in the distribution of sea ice at the poles.

The other instruments are smaller and more specialized. The Ozone Mapper Profiler Suite (OMPS) will measure the total amount of ozone in the stratosphere and provide information about the distribution of ozone in lower parts of the atmosphere as well. The Clouds and Earth's Radiant Energy System (CERES) sensor, a near clone of CERES instruments that currently fly on Terra and Aqua missions, will continue a record of the amount of energy entering and exiting the top of the atmosphere.

Finally, the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) instruments will make detailed vertical profiles of atmospheric pressure, heat, and moisture—useful pieces of information for weather forecasters and climate researchers.

Data from all the instruments will be beamed once per orbit to an Arctic ground station in Svalbard, Norway and then distributed via fiber optic cables to data processing centers where much of it will be available to meteorologists and climatologists within 180 minutes.

"Linking EOS and NPP data into long-term datasets won't always be simple," cautioned **Ralph Kahn**, a climatologist based at GSFC, referring to the complex calibration and data processing techniques that will be required when NPP begins to beam data back to Earth. "There's more work to be done, but NPP represents the next step for earth and climate science."

Related Links:

High-resolution and HD-quality NPP videos, animations and stills
svs.gsfc.nasa.gov/vis/a010000/a010700/a010742/

NPP mission website
jointmission.gsfc.nasa.gov

Perspectives: Why EOS Matters
earthobservatory.nasa.gov/Features/WhyItMatters09/

The Earth Observing System Project Science Office
eospso.gsfc.nasa.gov/ ■

Time to Fly: SAGE III - ISS Prepped for Space Station

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After nine years in a clean room, an instrument that studies the Earth's atmosphere and protective ozone layer has been returned to service.

In this artist's conception, a SpaceX *Dragon* capsule prepares to dock with the International Space Station. **Image Credit:** NASA

NASA's Stratospheric Aerosol and Gas Experiment III-ISS (SAGE III-ISS) will measure ozone, water vapor, and aerosols in the atmosphere when it is attached to the International Space Station (ISS) three years from now.

The instrument is scheduled for launch in 2014 on a Space Exploration Technologies Corp. (SpaceX) rocket from NASA's Kennedy Space Center in Florida.

"It will ride in the unpressurized trunk of the rocket, and NASA will use robots to dock the instrument on the ISS—kind of like Transformers," said **Michael Cisewski**, SAGE III-ISS project manager at NASA Langley Research Center (LaRC). "We're mounting to a piece of the ISS that is going up in the next shuttle launch."

Patience Pays

SAGE III-ISS is a nearly exact replica of SAGE III Meteor-3M, sent into orbit in 2001 on a Russian satellite. SAGE III Meteor-3M went out of service five years ago when the satellite's power supply stopped working.

The new instrument was built in anticipation of being attached to the space station in 2005. A change in ISS design, however, put those plans on hold.

The instrument was stored in a Class 100 clean room in a sealed shipping container under a continuous gaseous nitrogen purge. The purge kept clean dry "air" inside the instrument.

"Now, everything is falling into place," said Cisewski.

SAGE III-ISS underwent initial testing at Langley the week of February 14, 2011, in a clean room set up in a bay with an afternoon view of the sun.

Sunspotting

The instrument was commanded to point to and lock onto the sun as if it were engaging a sunrise event over the horizon. Once locked on, the instrument's scan mirror scanned the full disk of the Sun every two seconds. It also was tested at night using the moon as a radiant source.

"It's a matter of testing SAGE III in all its operational modes, solar and lunar, then making some minor modifications," said **Patrick McCormick**, SAGE principal investigator, partnering with NASA through the Center for Atmospheric Sciences at Hampton University in Hampton, VA.

"The nice thing about SAGE III-ISS," McCormick said, "is that being a replica of a proven instrument, the risk for its refurbishment is exceedingly low. SAGE III is a solid, stable instrument."

A Pathfinder

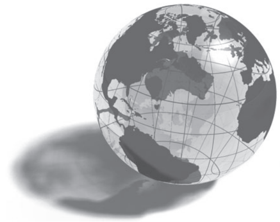
SAGE III-ISS will be among the early NASA payloads sent into space on a commercial launch vehicle known as the SpaceX F9/*Dragon*. Started in 2002 by Elon Musk, founder of PayPal and Zip2 Corporation, SpaceX has developed two launch vehicles, established a launch manifest and is funded by NASA to demonstrate delivery and return of cargo to the space station.

SAGE III-ISS will be the first instrument to measure the composition of the middle and lower atmosphere from the space station. "ISS is in the perfect orbit to do these sorts of measurements," said **Joseph Zawodny**, SAGE III-ISS project scientist at LaRC.

SAGE is one of NASA's longest running Earth-observing programs. That is significant because long-term collection of these data are necessary to understand climate change.

Previous SAGE instruments include SAGE, launched in 1979, followed by SAGE II in 1984. SAGE II gathered data for more than 20 years. The information it collected was part of the effort that led to a global ban on chlorofluorocarbons in 1987. Chlorofluorocarbons were used in air-conditioning units and aerosol spray propellants that contributed to seasonal reduction of the Earth's layer of protective ozone over the Antarctic, which has begun to recover after the chlorofluorocarbon ban.

Ball Aerospace & Technologies Corportation built the SAGE III-ISS instrument in Boulder, CO. The European Space Agency and Thales Alenia Space, headquartered in France, are providing a hexapod to keep the instrument pointing in the right direction as the ISS maneuvers in space. ■



NASA Earth Science in the News

Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

NASA Satellite Photographs San Diego County Snowfall, February 28; *The San Diego Union-Tribune.* While flying over Southern California, NASA's Terra satellite took an image that shows significant snowfall from an Arctic storm that came ashore and smacked the region with snow extending from the San Bernardino Mountains to northern Baja California.

Will Busy Twister Season Follow Wild Winter? March 1; *Our Amazing Planet/MSNBC.* Despite the slow start, tornado season jumped into action by late February and the early storms are tied to an unusually prolonged Arctic outbreak, said climatologist **Bill Patzert** (NASA JPL).

No Glory (Satellite) in Space, March 4; *The New York Times*. The loss of the Glory satellite is a setback for efforts to fill substantial gaps in the understanding of some important aspects of the climate system, and **Gavin Schmidt** (NASA GISS) posted a reflection on this mission and the larger context on *RealClimate*.

NASA's Bolden Defends Earth Science, March 4; *United Press International*. NASA Administrator **Charles Bolden** (NASA Administrator) defended NASA's Earth Science missions before a U.S. House committee, saying such projects were part of NASA's job.

EarthSky 22: Will Global Warming Cause More Rain? March 6; *EarthSky*. **Frank Wentz** (Remote Sensing Systems) uses the NASA Aqua satellite to measure water vapor in the atmosphere and explains global warming's possible effect on rainfall.

Ice Loss Accelerates in Greenland, Antarctica, NASA Study Finds, March 9; *Bloomberg.* Greenland and Antarctica's ice sheets are shrinking more quickly, suggesting United Nations projections for sea-level rise are too conservative, according to research led by **Eric Rignot** (NASA JPL).

Earth's Core ID's Natural and Human-Induced Warming, March 10; *Discovery News.* Physicists **Jean Dickey** (NASA JPL) and **Steven Marcus** (NASA JPL) and colleagues looked at variables including Earth's core, Earth's rotation, and global surface air temperature to identify a distinct trend of surface temperature warming beginning in 1930 that deviates from natural oscillations.

Richard Gross: Japan Earthquake Shortened Earth's Day 1.8 Millionths of a Second, March 18; *EarthSky*. **Richard Gross** (NASA JPL) and colleagues used seismic data showing the amount of slippage in the fault line necessary to create the Japan earthquake, in order to calculate the shift in mass inside Earth and subsequent change in Earth's rate of spin.

Robert Bindschadler: First Ever Image Mosaic of Entire Antarctica Detail, March 26; *EarthSky*. Scientists including **Robert Bindschadler** (NASA GSFC) have created a mosaic of digital images collected from space, showing the frozen continent of Antarctica in amazing detail.

A NASA Ode to a Color-Sensing Satellite, April 5; *The New York Times*. NASA has produced a video tribute—narrated by **Gene Feldman** (NASA GSFC) — to the SeaWiFS orbiting sensor, which provided vast amounts of valuable data on Earth's waters, plant life, and weather from 1997–2010.

Government Shutdown Would Put Arctic Study on Ice, April 7; *The New York Times*. A federal government shutdown would have cut short *Operation IceBridge*, a key NASA field campaign to monitor Arctic ice. **Steve Cole** (NASA HQ), **Ken Jezek** (Ohio State University) and **Jackie Richter-Menge** (Cold Regions Research and Engineering Laboratory) comment on the impacts.

Operation IceBridge, April 12; *Living on Earth*. With NASA's ice-observing satellite (ICESat) down, scientists have to travel low and slow over Greenland's glaciers to measure melting ice. Host **Bruce Gellerman** talks with science reporter **Dan Grossman**, who hitched a ride on the science plane, and also talks with NASA scientist **Lora Koenig** (NASA GSFC).

ESA–NASA Collaboration Furthers Sea-Ice Research, April 19; *Scientific American.* A carefully executed operation to validate data from CryoSat has shown what can be accomplished when ESA, NASA, and others join forces to further our understanding of how the fragile polar environment is responding to climate change; measurements from the ground and air "will create a landmark dataset to shed light on fundamental issues in remotely sensing sea ice," said **Michael Studinger** (NASA GSFC).

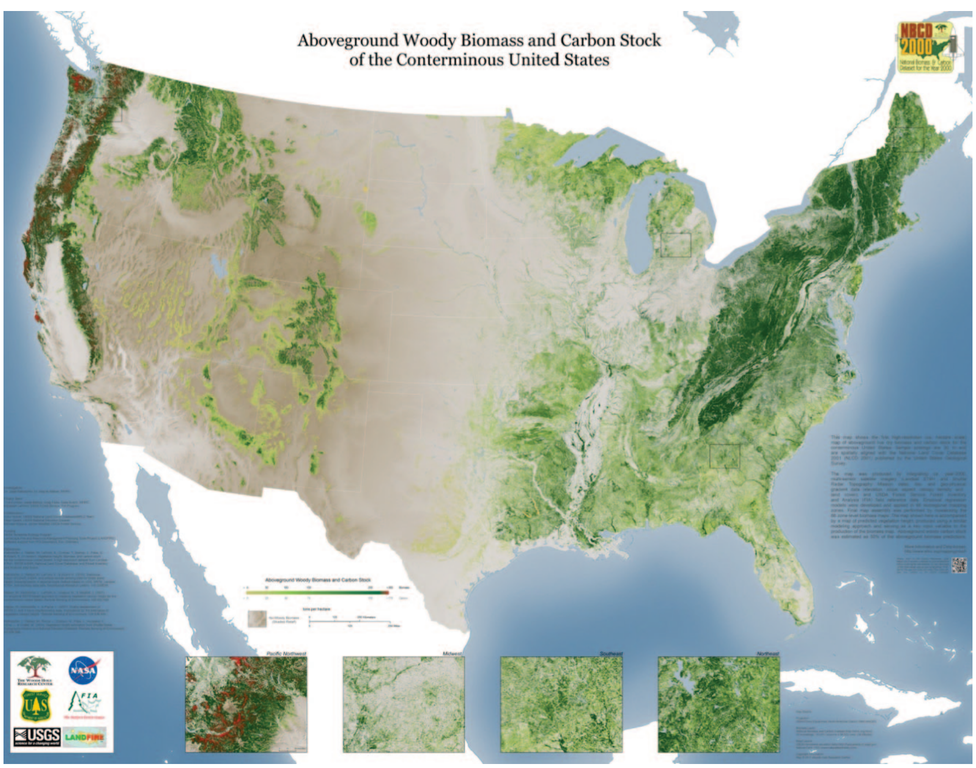
Gold-Hungry Prospectors are Tearing Down the Amazon in Peru, April 20; *Scientific American.* Using satellite imagery from NASA's Landsat 5 Thematic Mapper satellite, **Jennifer Swenson** (Duke University) and her co-researchers mapped deforestation due to mining. They found that miners in Peru are eroding the country's portion of the Amazon rainforest at an alarming rate.

One Glacier Range Found to Contribute 10 Percent of World's Melting Ice, April 20; *LiveScience.* A glacier range in the Canadian Arctic Archipelago contributed 10% of the world's melting ice from 2004 to 2009, making it a primary contributor to rising sea levels. The findings were confirmed with data from NASA's ICESat and GRACE satellites.

New Map Lets You See Forest for the Trees, April 25; *LiveScience.* Researchers used 2000-2001 data from NASA satellites and ground-based forest surveys to create the most precise representation yet of the height and coverage of U.S. forests and woodlands; the data will provide a baseline for understanding both forest resources and carbon flux. See image below.

That's Professor Global Hawk, May 2011; *Air & Space Smithsonian*. **Paul Newman** (NASA GSFC) and **Gerry Heymsfield** (NASA GSFC) comment on the first science missions using NASA's Global Hawk high-altitude unmanned aircraft.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Kathryn Hansen*** *on NASA's Earth Science News Team at khansen@sesda2.com and let her know of your upcoming journal articles, new satellite images, or conference presentations that you think the average person would be interested in learning about.* ■



Newly released map of height and coverage of U.S. forests and woodlands. To explore the zoomable, interactive map online please visit: *www.whrc.org/mapping/nbcd/index.html*. **Image Courtesy:** Woods Hole Research Center

NASA Science Mission Directorate – Science Education and Public Outreach Update

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2011 ASP Education and Public Outreach Conference

August 1–3 with special events the preceding weekend, July 30–31

The Astronomical Society of the Pacific (ASP) invites you to a national conference on science education and public outreach in conjunction with its 123rd Annual Meeting. The conference, with the theme of *Connecting People to Science*, will be held at the Tremont Plaza Hotel in Baltimore, MD. To learn more about the conference, visit: *www.astrosociety.org/events/meeting.html.* Abstract deadline April 22 (*www.astrosociety.org/events/2011mtg/abstracts.html).*

AMNH Summer Online Courses for Educators

Summer Session 2: July 4–August 14

Join *Seminars on Science* and the American Museum of Natural History, for a summer course in the life, Earth, or physical sciences. Available courses include "Earth: Inside and Out"; "The Solar System"; "Evolution"; our newest course, "Climate Change"; and more. All courses run for six weeks and are fully online. Each participant receives a CD of course resources suitable for classroom use. Affordable graduate credit is available for all courses. Register by June 20; email *semadmin@amnh.org* for more information. To register, visit: *www.amnh.org/learn/*.

Lunar Workshop for Middle and High School Educators

June 20–24; Herrett Center for Arts and Science, Twin Falls, Idaho June 27-July 1; Hinds Community College, Utica, MS.

June 27–July 1; McAuliffe-Shepard Discovery Center, Concord, N.H. July 25-29; Applied Physics Laboratory, Laurel, MD.

August 1–5; Arizona State University; Tempe, AZ.

Educators of grades 6–12 are invited to attend a workshop focused on lunar science, exploration, and how our understanding of the Moon is evolving with the new data from current and recent lunar missions. Workshop participants will learn about the Lunar Reconnaissance Orbiter (LRO) and its discoveries, reinforce their understanding of lunar science concepts, interact with lunar scientists and engineers, work with real LRO data, and learn how to bring this information to their students. For more information, to see other upcoming dates, and to register, visit: *lunar.gsfc.nasa.gov/lwe/index.html*

2011 INSPIRE Project for High School Students

Application Deadline June 30

U.S. high school students are invited to participate in NASA's Interdisciplinary National Science Program Incorporating Research Experience, or INSPIRE, through an online learning community. INSPIRE is designed to encourage students in 9–12 grade to pursue careers in science, technology, engineering and mathematics. Students and parents will participate in an online learning community with opportunities to interact with peers, NASA engineers and scientists. Students selected for the program will also have the option to compete for unique grade-appropriate experiences during the summer of 2012 at NASA facilities and participating universities. To apply and learn more, visit: *inspire.okstate.edu/index.cfm?liftoff=login.LoginForm*.

NASA's Multi-Wavelength Universe Online Professional Development Course for Middle and High School Teachers

July 11–22

Middle and High-School teachers (both pre- and in-service) are invited to register for an online professional development course sponsored by several different NASA missions exploring our Universe across the Electromagnetic Spectrum. The course is offered for academic or continuing education credit through Sonoma State University. At the conclusion of the course, participants will be able to use astronomical examples (images, phenomena, telescopes) to describe the nature of light and color in terms of the regions of the Electromagnetic Spectrum. For more information and to register, visit: *epo.sonoma.edu/multiu.php*.

ESIP Teacher Workshop-Grades 6-12

July 12–13; Santa Fe, NM

The Federation of Earth Science Information Partners (ESIP) teacher workshop is a 1.5 day event with an overall theme of Earth Science Education with an integral strand dedicated to Climate Change Education. Participating educators will learn about climate change science, climate resources, and ways to effectively communicate climate change topics. Educators are eligible to receive a $200 time and travel stipend. For more information visit: *cimss.ssec.wisc.edu/teacherworkshop/esip/*.

EOS Science Calendar

June 6–8, 2011
CloudSat/CALIPSO Science Team Meeting, Montreal, Quebec, Canada.

June 6–9, 2011
39th ASTER Science Meeting, Tokyo, Japan.

August 8–10, 2011
GRACE Science Team Meeting, University of Texas Center for Space Research. URL: *www.csr.utexas.edu/grace/GSTM/*

August 16–18, 2011
Landsat Science Team Meeting, USGS Earth Resources Observation and Science Center (EROS) Center near Sioux Falls, SD.

September 13–16, 2011
SORCE Science Meeting: Decadal Cycles in the Sun, Sun-like Stars, and Earth's Climate System, Sedona, AZ. URL: *lasp.colorado.edu/sorce/news/2011ScienceMeeting/index.html*

Global Change Calendar

June 21–24, 2011
Annual Air and Waste Management 104th Annual Conference and Exhibition, Orlando, FL. URL: *www.awma.org/ACE2011/*

June 27–July 8, 2011
XXV International Union of Geodesy and Geophysics General Assembly: Earth on the Edge: Science for a Sustainable Planet, Melbourne, Australia. URL: *www.iugg2011.com*

July 24–29
2011 IEEE International Geoscience and Remote Sensing Symposium, Vancouver, Canada. URL: *igarss11.org/*

July 10–15
Gordon Research Conference: Clouds, Aerosols, Precipitation and their Role in Climate and Climate Change, Colby College, Waterville, ME. URL: *www.grc.org/programs.aspx?year=2011&program=radclimate*

August 30–September 1, 2011
GEWEX Radiation Panel (GRP) Meeting (by invitation), Tokyo, Japan.

September 11–14, 2011
SPRS Commission VIII/WG-2 Symposium on Advances in Geospatial Technologies for Health, Santa Fe, New Mexico, USA. URL: *isprs-wg8-2.unm.edu/symposium*

September 19–22, 2011
SPIE Europe Remote Sensing 2011 Symposium, Clarion Congress Hotel Prague, Czech Republic. URL: *spie.org/remote-sensing-europe.xml*

October 24–28, 2011
World Climate Research Programme Open Science Conference, Denver, CO. URL: *www.wcrp-climate.org/conference2011/*

December 5–9, 2011
American Geophysical Union Fall Meeting, San Francisco, CA. URL: *www.agu.org/meetings/*

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