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Editor's Corner

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With the return of the Space Shuttle *Atlantis* to Kennedy Space Center on July 21 of this year, NASA's Space Shuttle Program came to an end after a highly successful 30-year run. While the shuttle was not specifically designed for Earth science observations, the link was inevitable. The shuttle was used for Earth science investigations early on—serving as a laboratory in low Earth orbit, a "launchpad," and a testbed for studying our home planet. Significant inspiration for several missions that now comprise the Earth Observing System (EOS) fleet can trace their lineage to discoveries made during shuttle missions, particularly in the areas of atmospheric chemistry and dynamics (especially ozone), atmospheric aerosols, and solar irradiance.

In this issue (see page 4) we invite you to read a unique tribute to the *Earth Observing Legacy of the Space Shuttle Program*. Space flight programs are often conceived with multiple approaches, some eventually being abandoned (the history of EOS is certainly no exception). Sometimes the most interesting stories are found down these paths not taken. In researching this article, we unearthed one such overgrown and virtually forgotten path—the ability to launch the space shuttle into polar orbit. NASA came very close to implementing this capability, and if they had, it's fair to say that some Earth observation projects would have developed differently. At the very least, NASA would have looked into the use of the space shuttle to launch and service polar orbiting Earth observing satellites. (In fact, Landsat 4 and 5 were actually designed with this capability in mind.) While it is intriguing to consider what might have been, the bulk of the article focuses on what actually was, describing the many payloads launched from the shuttle and their significant contributions to Earth science.

Last issue we gave an update on the successful launch of the Aquarius/Satélite de Aplicaciones Científicas-D (SAC-D) mission—an international partnership between NASA and Argentina's space agency [Comisión Nacional de Actividades Espaciales (CONAE)] to study Earth's Sea Surface Salinity. After completing the in-orbit

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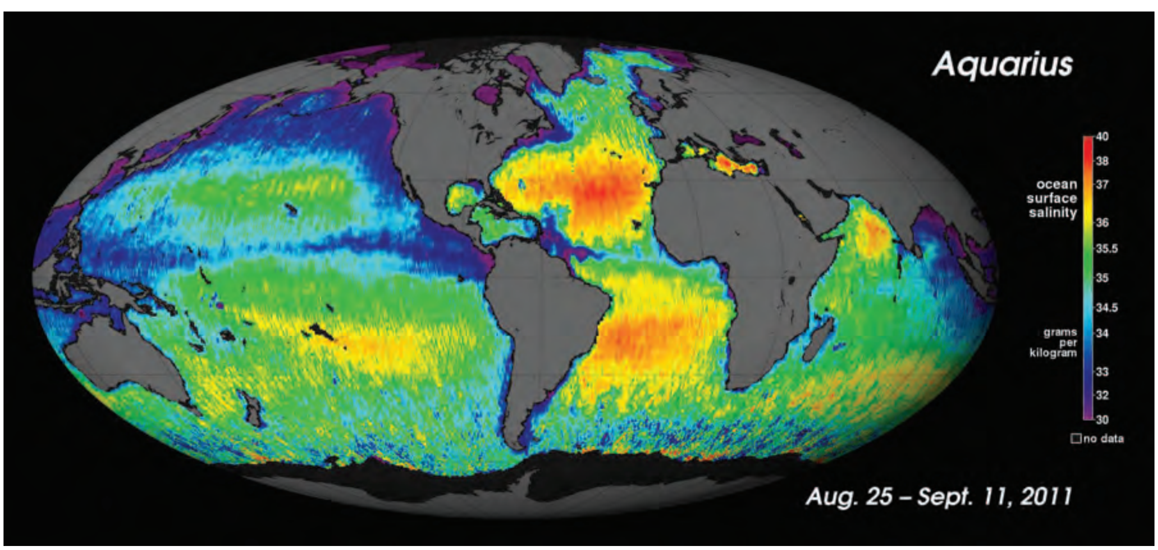

On September 22, 2011, NASA Headquarters released the first global map of the salinity, or saltiness, of Earth's ocean surface from NASA's new Aquarius instrument. The image reveals a rich tapestry of global salinity patterns and demonstrates Aquarius' ability to resolve large-scale salinity distribution features clearly and with sharp contrast. **Image credit:** NASA/GSFC/JPL-Caltech [**Editor's Note:** Our gray-scale printing lacks the detail of the color image. Please refer to the color pdf online version to view this image properly.]

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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*

checkout, the operations team began powering up the Aquarius instrument and was able to successfully deploy the antenna. The Aquarius instrument is now fully operational and in normal science mode. On September 22, 2011 NASA Headquarters released the "first light" image from Aquarius—see bottom of page 1.

"Aquarius' salinity data are showing much higher quality than we expected to see this early in the mission. Aquarius soon will allow scientists to explore the connections between global rainfall, ocean current, and climate variations." —**Gary Lagerloef** [Earth & Space Research—*Aquarius Principal Investigator*]

For more information about Aquarius/SAC-D, visit: *www.nasa.gov/aquarius* and *www.conae.gov.ar/eng/principal.html.*

We also provided an update on the status of CloudSat recovery efforts in our last issue. We refer you to the *CloudSat Update* sidebar on page 3 for the latest news.

The next Earth science mission launch will be the NPOESS Preparatory Project (NPP) satellite. Presently scheduled for launch from Vandenberg Air Force Base in California on October 25, NPP is intended to serve as a bridge to the Joint Polar Satellite System mission series[1]. All instruments are integrated on the spacecraft and the spacecraft appears healthy and ready for launch. Using legacy instrument capability from the EOS era, NPP will be the first of a new generation of Earth-observing satellites to provide data for advanced operational use as well as for research.

The newest generation of Earth science software and media specialists at NASA's Goddard Space Flight Center released the NASA Visualization Explorer—or NASA Viz—iPad app. The application brings Earth science research straight to your iPad using a unique storytelling approach. If you have an iPad, I urge you to check out this free and engaging app. For more information, see the *Announcement* on page 25.

On a related topic, NASA's *hyperwall*—our portable nine-screen video wall—traveled to Vancouver, Canada, for the 2011 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) conference. In the exhibit hall, NASA and the Japan Aerospace Exploration Agency (JAXA) shared a joint booth, both displaying large Earth science datasets on the hyperwall. The joint event showcased the longtime partnership between NASA and JAXA, and the value of international collaboration for Earth science missions.

Students from NASA's Applied Sciences Summer 2011 DEVELOP National Program presented methodologies and project results to an invited group at NASA Headquarters in August. Turn to page 18 to read an article

[1] Note on Nomenclature: The National Polar-orbiting Operational Environmental Satellite System (NPOESS) was to be a tri-agency partnership between NASA, National Oceanic and Atmospheric Administration (NOAA), and Department of Defense managed by an Integrated Program Office. In February 2010, the military and civilian partners separated and a new NASA–NOAA partnership was created called the Joint Polar Satellite System. The "bridge" mission however, has retained the name NPP.

that describes the specific projects completed at NASA's Jet Propulsion Laboratory. The majority of research projects were carried out using EOS satellite datasets. Methodologies and results are being presented to international partners including the Lake Victoria Fisheries Organization of East Africa, to help policy and decision makers establish new methodologies for studying Earth science.

Without further adieu, we invite you to turn the page and enjoy our latest issue of *The Earth Observer*. ■

CloudSat Update

On April 18, 2011 CloudSat experienced at least one additional weak battery cell anomaly (the first having occurred in December 2009), causing the system to enter into under-voltage fault protection (UV-3). From stored, automatic commands, the computer, payload and global positioning system were turned off, solar arrays positioned at +/- 40°, and the spacecraft was set spinning around the X-axis at ~5.8º per sec, ~35° from the Sun line. Multiple under-voltage trips occurred over the next several weeks. Solar, gravitational, and magnetic torques caused changes in orientation and spin rate over time. Small variations had significant impact on flight system temperatures, survival heater duty cycles, and available power.

After the UV-3 anomaly, CloudSat slowly approached Aqua. CloudSat performed a maneuver on June 18 that lowered the semi-major axis 2.6 km. As part of that maneuver on June 18, the spacecraft was re-spun and positioned in a more favorable Sun attitude. On June 24, the spacecraft control computer was powered up successfully, re-establishing sequenced control of the spacecraft. In comparison with previous attempts, the favorable solar geometry achieved during the June 18 spin-up sequence provided adequate power reserves to allow the CloudSat radar heaters to be powered on (via stored computer commands) for a large portion of the sunlight orbit. This extra heat injected into the system reduces the time survival heaters are running during eclipse and prevents the battery from being drawn down too far, avoiding under-voltage conditions.

On July 22, CloudSat executed a Sun-Point-Spin maneuver (a new *Safe Mode*), transitioning out of *Emergency Mode* for the first time since April 18. Stored commanding re-enabled torque-rod control, and over the sunlit period of the next several orbits, the torque rods slowly moved the +X axis to 20° north of the measured Sun vector and are controlling the system to that attitude to within +/- 5°. This controlled attitude provides a more stable power profile, while at the same time balancing the thermal needs of the system. Currently CloudSat is in this Safe Mode (Sun-Point-Spin). The spacecraft battery has at least two weak cells and we are learning to operate the flight system on ~10% of the pre-anomaly battery capacity.

The cloud radar remains turned off while the flight system is being reconfigured with new modes to support cloud radar operations. The cloud radar cannot be operated during eclipse; the radar must be turned on/off each orbit and spacecraft bus operation must also be limited in eclipse. This new *Daylight-Only Operations (DO-Op)* mode will be demonstrated as soon as mid-October.

CloudSat is weighing its options for a new orbit. One option is to return to the A-Train constellation, flying with Aqua and CALIPSO immediately behind CALIPSO in the location that was to have been occupied by Glory. Another option is lowering the orbit and matching Aqua's orbit plane to underfly the constellation at regular intervals. A third option is lowering the orbit significantly and precessing to a Sun-synchronous terminator orbit to formation-fly with the Aquarius mission. Graeme Stephens, the CloudSat Principal Investigator, is organizing a series of discussions with the science community to consider these options, and the CloudSat Project is studying the maneuvers to establish and maintain these options. Discussions and coordination are already underway with the Earth Science Mission Operations office and the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Operations Project, and there will also be a presentation to the A-Train Mission Operations Working Group in October. In early November, a recommendation for the future orbit will be presented to NASA Headquarters.

The Earth Observing Legacy of NASA's Space Shuttle Program

Alan B. Ward, NASA's Goddard Space Flight Center/Wyle Information Systems, alan.b.ward@nasa.gov

*When the Space Shuttle **Atlantis** touched down at Kennedy Space Center (KSC) on July 21, 2011, it marked the end of an era for NASA as its Space Shuttle Program came to an end. **The Earth Observer** is pleased to present an article that shares some of the story of how the shuttle has been used for Earth science (including an intriguing glimpse of a path not taken), and provides details about Earth science payloads that have been deployed from the shuttle over the past 30 years.*

The 11:29 a.m. EDT liftoff of shuttle *Atlantis* on July 8, 2011, marked the last time a space shuttle would climb from Kennedy's seaside launch complex to soar toward the heavens. **Image Credit:** NASA/Tony Gray and Tom Farrar

Historical Context

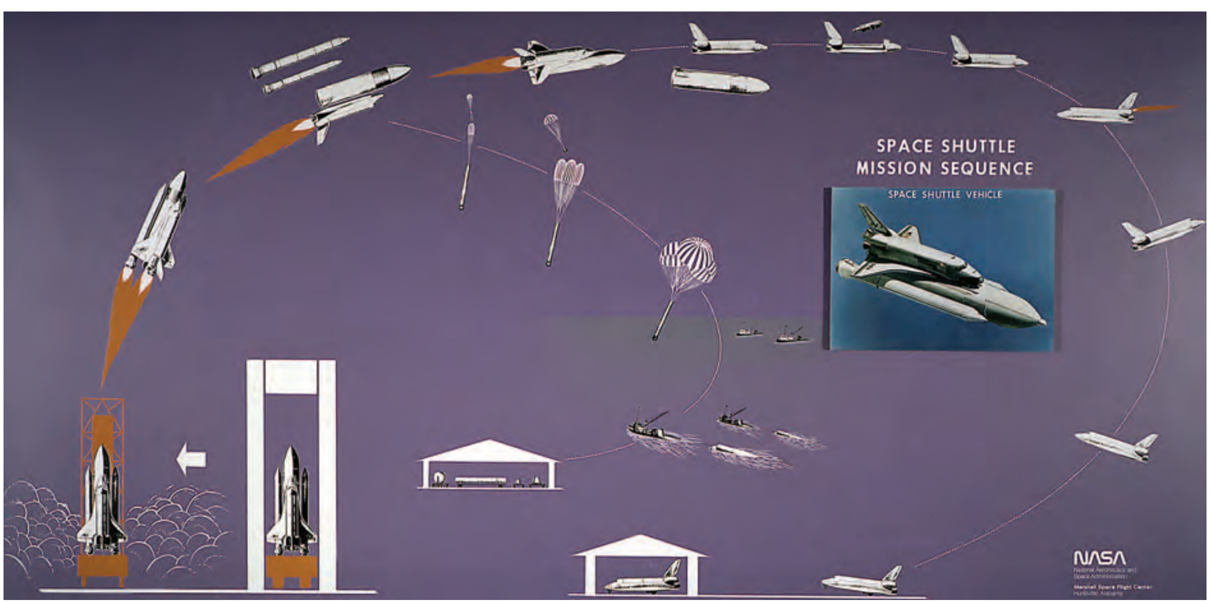
The Space Transportation System (STS)—a.k.a. the Space Shuttle—served as the U.S. government's crewed launch vehicle program from 1981–2011. The initial concepts for the shuttle program began to emerge in the late 1960s and early 1970s during the Nixon administration—as the Apollo program began to wind down. The shuttle program officially started in 1972 when President Nixon announced that the U.S. would develop a reusable space shuttle. The familiar design we ended up with—consisting of a reusable winged orbiter, reusable solid rocket boosters, and expendable external tanks—emerged from a wide array of possible designs and technologies. The shuttle was envisioned to serve as part spaceplane, part rocket-propelled pickup truck, and part orbiting launch platform.

The prototype shuttle *Enterprise*[1] rolled out in 1976 and was used to validate the technology and test the design concept. The first launch took place in 1981 when *Columbia* roared into space. There was a sense of palpable excitement as Americans returned to space for the first time since the 1975 Apollo–Soyuz mission. The initial launch went well, and many more would follow. Shuttles *Challenger*, *Discovery*, *Atlantis,* and *Endeavour*[2] would eventually join the fleet.

While the shuttle was not specifically built for Earth science applications, the link was inevitable. From early on (the first Earth science experiment flew on STS-2), Earth

[1] The original name chosen for the prototype shuttle was *Constitution*. However, in response to a huge write-in campaign from fans of the *Star Trek* television series, the White House decided to change the name to *Enterprise*.

[2] *Endeavour* was built after the loss of *Challenger* on January 28, 1986 (STS-51-L).



This diagram, from 1975, illustrates the space shuttle mission sequence. **Image Credit:** NASA scientists were intrigued by the possibilities that could be achieved using the shuttle as a low-Earth-orbit (LEO) observatory—realizing that shuttle flights could provide frequent and convenient access to LEO.

In this photo taken on September 26, 1977, during an aeronautical flight test, the Space Shuttle *Enterprise* is shown in free flight after separation from a Boeing *747* airliner modified for use as a shuttle carrier aircraft. **Image Credit:** NASA

Polar Shuttle Launches: An Intriguing Possibility for Earth Science

In the mid-1980s NASA and the Air Force pursued a plan to launch the shuttle into polar orbit from Vandenberg Air Force Base (VAFB) in California, going so far as to build a complex and to launch test flights using *Enterprise*. An inaugural launch was scheduled for July 1986—STS-62-A. NASA even made the decision to dedicate one of the orbiters—*Discovery*—for use from Vandenberg. In the end, however, shuttle launches from Vandenberg never happened. The *Challenger* tragedy in January 1986 put a kibosh on all these plans and ended what had been a controversial program from the start; to learn more, see ***Polar Shuttle Launches: The Path Almost Taken*** on page 6.

Though primarily conceived of for use by the Air Force, the possibility of polar shuttle launches drew great interest from the Earth science community. Polar orbits can allow full global coverage on a regular basis, and are often used for Earth mapping, data acquisition from Earth observation and reconnaissance satellites, and from some weather satellites. The earliest concepts for the Earth Observing System (EOS)—originally called *System Z*—envisioned having several large polar-orbiting platforms in LEO that would be launched from the shuttle and subsequently *serviced* by shuttle flights in a manner not unlike what was done for the Hubble Space Telescope[3]. Indeed, the Landsat 4 and 5 satellites were designed with extra fuel capacity so that their orbit might be lowered to allow re-servicing from a polar-orbiting shuttle—see ***What Might Have Been: Landsat Reservicing Missions***[4].

What Might Have Been: Landsat Reservicing Missions.

Landsat 4 and 5 (launched in 1982 and 1984 respectively) were designed with expanded fuel capacity so that their orbit might be lowered to allow servicing from a shuttle launched into polar orbit. Since the Vandenberg launches never happened, the extra fuel was not used for its intended purpose. However, the fuel has not gone to waste, as it allowed both satellites to function well beyond their designed lifetime. As of this writing, Landsat 5 is still providing valuable observations of Earth's land surface some 27 years after launch!

When the polar launches were canceled in the aftermath of the *Challenger* explosion, the idea of reservicing the EOS platforms from the shuttle quickly lost momentum. By 1990, using an unmanned Titan *IV* rocket had become accepted as the baseline launch vehicle[5]. The community would seek to obtain the continuity of measurements needed for climate change studies through launch of a series of overlapping missions spread across 15 years. Initially, the idea was to have two large polar-orbiting platforms supplemented by some smaller missions, but the concept continued to evolve throughout the 1990s in the face of budgetary and political realities. In the end, what emerged was a fleet of three, midsized "flagship" missions, supplemented by smaller, more-focused missions. Such an approach has proven less expensive and more flexible than earlier concepts, and still achieves essentially the same science results that would have come if the instruments were on a single large platform[6].

*The earliest concepts for the Earth Observing System (EOS)—originally called **System Z**—envisioned having several large polar-orbiting platforms in LEO that would be launched from the shuttle and subsequently **serviced** by shuttle flights in a manner not unlike what was done for the Hubble Space Telescope.*

[3] **Dixon Butler** has told the story of this interesting chapter in the "prehistory" of EOS in the September–October 2008 issue of *The Earth Observer* [**Volume 20**, **Issue 5**, pp. 4-8].

[4] This historical anecdote came from Landsat Data Continuity Mission Project Scientist Jim Irons during an EOS project scientists' meeting on July 1, 2011.

[5] Moore, III, Berrien, 1995: Global Change, the Earth Observing System, and Change. *The State of Earth Science from Space: Past Results, Future Prospects*, G. Asrar and D. J. Dokken, Eds., American Institute of Physics, 63-64.

[6] **Ghassem Asrar** describes the "evolution" of the EOS Concept in the May–June 2011 issue of *The Earth Observer*. [**Volume 23**, **Issue 3**, pp. 4-14]. Asrar also references a number of other previous articles in the *Perspectives on EOS* series in his article that may be informative.

Polar Shuttle Launches: The Path Almost Taken

In the early days of the Space Shuttle Program there was a desire (primarily from the Air Force) to have the capability to launch shuttles into polar orbit. A debate arose about whether it should be done from KSC or from VAFB. Polar-orbit launches must travel north or south after liftoff, and do not benefit from vectorial contributions from Earth's rotational speed of over 850 mph (1,368 km/h) at this latitude. Thus, they require considerably more energy than the typical eastward launch. While it would have been possible to achieve this orbit from KSC, it would have been more challenging, as there are major population centers located both north and south of KSC, and attaining polar orbit from Florida would require huge energy-inefficient maneuvers to avoid them. These maneuvers would require more fuel and would therefore reduce the payload capacity of the shuttle by 30%. There were other concerns about polar launches from KSC, such as having to fly over the state of South Carolina and having to release the external tank over Canada or Russia instead of over the expanse of the unaffiliated Atlantic Ocean.

In 1972 Space Launch Complex Six (SLC-6) at VAFB—a.k.a. *Slick Six*—was chosen as the site to construct a Western Shuttle Launch Complex for Air Force shuttle launches. One of the reasons SLC-6 was chosen was because it had originally been designed to launch the Titan *III* rocket in support of the later-cancelled Manned Orbiting Laboratory. This meant that the site already had some of the infrastructure in place that was needed to facilitate manned spaceflight, and thus could be more easily modified to accommodate shuttle launches. An entire complex was constructed and stood ready for use; the Space Shuttle *Enterprise* was used to test out the complex—see photos. The pictures looks almost surreal, but the complex actually existed in the mid-1980s.

Modification of SLC-6 to support polar missions turned out to be more problematic and expensive than what was originally anticipated. The SLC-6 launch site was the subject of controversy long before the *Challenger* disaster; budget, safety, and political considerations all came into play. Still, despite criticism, plans

Image Credit: U.S. Air Force

progressed and testing continued. The inaugural polar-orbit shuttle launch (dubbed STS-62-A or STS-1V) from VAFB was planned for October 15, 1986.

The loss of *Challenger* on January 28, 1986, hastened the demise of *Slick Six* as a shuttle launch site. The shuttle fleet was grounded after the disaster, and the inaugural launch cancelled. The program was scaled back over the next couple of years, and eventually put into "mothballs." The Air Force officially terminated the Shuttle program at VAFB on December 26, 1989. The *Challenger* disaster highlighted the danger of relying too heavily on the shuttle for satellite launches. The investigation that took place in the aftermath of the disaster also unearthed a number of other serious safety and budgetary concerns that helped seal the fate of the launch site at VAFB. Polar orbit would have to be attained using unmanned launches—e.g., Titan *IV* (proposed), Atlas *II-AS*, and Delta *II*.

It is interesting to speculate what would have happened had *Challenger* and her crew not been lost on that fateful January morning, and STS-62-A had actually launched as planned. Suffice it to say that the history of Earth science observations from space could have been quite different.

Image Credit: U.S. Air Force/TSGT James R. Pearson

A Laboratory, a "Launchpad," and a Testbed for Studying Our Home Planet

While the EOS that exists today is radically different in design than those original concepts that would have been deployed and serviced from the shuttle, the Space Shuttle Program has still had a profound influence on the development of EOS. The shuttle provided numerous opportunities that enabled scientists to study Earth from new perspectives. Shuttles served as platforms for observation and sensor calibration, engineering test beds, satellite launchpads, and platforms for Earth imaging. Significant inspiration for EOS began with discoveries made during shuttle missions, particularly in the areas of atmospheric chemistry and dynamics (especially for ozone), atmospheric aerosols, and solar irradiance. As the Earth science team at NASA's Johnson Space Center likes to say: ***Every shuttle mission is a mission to planet Earth***.

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While that is certainly true, there have been certain flights that were particularly germane to Earth science applications. The table, below includes short descriptions of the **major** payload experiments conducted, and the satellites and instruments deployed from the shuttle during its 30-year history.

Shuttle Flight	Orbiter	Launch Date	Payload[1]
STS-2	Columbia	11/10/1981	SIR-A, MAPS
STS-3	Columbia	03/22/1982	*OSS-1* (SUSIM[2])
STS-6	Challenger	04/04/1983	TDRS-A
STS-9*	Columbia	11/28/1983	*Spacelab-1* (ACRIM, SOLSPEC, SOLCON, SUSIM)
STS-41-G	Challenger	10/05/1984	SIR-B, MAPS, ERBS, (SAGE-II)
STS-51-B*	Challenger	04/29/1985	ATMOS

STS-51-L	Challenger	01/28/1986	TDRS-B**
STS-26	Discovery	09/29/1988	TDRS-C
STS-29	Discovery	03/13/1989	TDRS-D
STS-43	Atlantis	08/02/1991	TDRS-E
STS-48	Discovery	09/12/1991	UARS
STS-45*	Atlantis	03/24/1992	ATLAS-1
STS-52	Columbia	10/22/1992	LAGEOS-2
STS-54	Endeavour	01/13/1993	TDRS-F
STS-56*	Discovery	04/08/1993	ATLAS-2, CRISTA-SPAS-1, (MAHRSI)
STS-59	Endeavour	04/09/1994	*Space Radar Lab-1*
STS-64*	Discovery	09/09/1994	LITE
STS-68	Endeavour	09/30/1994	*Space Radar Lab-2*
STS-66*	Atlantis	11/03/1994	ATLAS-3
STS-70	Discovery	07/13/1995	TDRS-G
STS-72	Endeavour	01/11/1996	SLA
STS-85*	Discovery	08/07/1997	CRISTA-SPAS-2, (MAHRSI), *TAS* (ISIR, SLA, SOLCON)
STS-87	Columbia	11/19/2007	*SOLSE-1*
STS-99*	Endeavour	02/11/2000	SRTM
STS-107	Columbia	01/16/2003	*FREESTAR* (MEIDEX, SOLCON, *SOLSE-2*)

Table: List of shuttle missions that have flown major Earth science payloads.

[1] The *ITALICIZED* payloads are defined in the **NOTES** below. Items grouped in (PARENTHESES) were the parts of these payloads related to Earth science and are detailed in the **PAYLOAD DESCRIPTIONS** that appear below.
[2] Items listed separately in (PARENTHESES) were part of a larger payload but have separate **PAYLOAD DESCRIPTIONS** below.
* The payloads described here were deployed on flights of the European Space Agency's *Spacelab* facility.
** The TDRS-B satellite was lost in the *Challenger* disaster.

NOTES on Payloads

- *OSS-1* — This was a payload sponsored by NASA's Office of Space Science and Applications to demonstrate the feasibility of conducting scientific research from the shuttle. The SUSIM instrument described below made its maiden flight on this mission.
- *Spacelab*-1 — This was the inaugural flight of the ESA's *Spacelab* facility. Several of these instruments would fly again as part of ATLAS-1 payload described below.
- *Space Radar Laboratory-1 and -2*—The two experiments (three instruments) that made up this payload were MAPS and SIR-C/X-SAR, described below.
- *SOLSE-1* and *-2* — The Shuttle Ozone Limb Sounding Experiment consisted of the SOLSE and LORE instruments, both described in a single entry below.
- *TAS* —Technologies Applications and Science was a "Hitchhiker" payload flown as part of the Shuttle Small Payloads Project that consisted of eight experiments. Among them, SOLCON, ISIR, and SLA had Earth science applications and are described below.
- *FREESTAR* — The Fast Reaction Experiments Enabling Science, Technology, Applications, and Research payload contained six experiments, of which MEIDEX, SOLCON, and *SOLSE-2* pertained to Earth science; these are described below.

PAYLOAD DESCRIPTIONS[7]

Atmospheric Chemistry, Aerosols, and Ozone

Atmospheric Laboratory for Applications and Science (ATLAS-1, -2, and -3)
STS-45, 56, and 66

Originally planned for flight on 10 shuttle missions[8] but later truncated to three, all but one of the instruments that made up the Atmospheric Laboratory for Applications and Science payload were mounted on one or more *Spacelab* pallets in the shuttle's cargo bay[9]. These flights were early efforts of NASA's *Mission to Planet Earth*—the former name for NASA's Earth Science Division—to study the Earth as an integrated *system*, with particular emphasis on detecting changes in the Sun and the composition of the middle atmosphere, and determining what impact those changes have on Earth's climate. While each ATLAS payload was different in terms of its instruments and specific objectives, there were seven "core" instruments that were the same for all the ATLAS flights[10]. These were the:

- Atmospheric Trace Molecule Spectroscopy (ATMOS);
- Millimeter-wave Atmospheric Sounder (MAS);
- Solar Ultraviolet Spectral Irradiance Monitor (SUSIM);
- Solar Constant Sensor (SOLCON);
- Active Cavity Radiometer Irradiance Monitor–II (ACRIM-II);
- Solar Spectrum Measurement (SOLSPEC); and
- Shuttle Solar Backscatter Ultraviolet Spectrometer (SSBUV).

ATLAS-1 was the largest ATLAS payload, taking up two *Spacelab* pallets (and the igloo module) in the shuttle's cargo bay, and equipped with a complement of 14 experiments. ATLAS-1 had a broader focus than the later flights. Beyond the "core" payload, ATLAS-1 deployed seven other instruments, some of which had previously flown as part of the *Spacelab-1* payload[11].

- Atmospheric Lyman Alpha Emissions (ALAE)
- Imaging Spectrometric Observatory (ISO)
- Atmospheric Emissions Photometric Imaging (AEPI)
- Space Experiments with Particle Accelerators (SEPAC)
- Far Ultraviolet Space Telescope (FAUST)
- Infrared Spectrometer ("Grille")
- Experiment of the Sun Complementing the ATLAS Payload and for Education–II (ESCAPE-II)

ATLAS-2 focused more on the relationship between the Sun's energy output and Earth's middle atmosphere, and how these factors affect the ozone layer. STS-56 has the distinction of being one of several shuttle missions that launched at night. This particular nighttime liftoff was planned so that ATLAS's ozone monitoring instruments would be in the proper position to collect observations over the Arctic during early spring—i.e., immediately after the long, dark, cold Polar winter, when ozone loss in the Arctic reaches peak levels. ATMOS-2 was comanifested with the CRISTA-SPAS-1 payload, described below.

ATLAS-3 built on the legacy of its predecessors, making the first detailed measurements from the shuttle of the Northern Hemisphere's middle atmosphere in late fall. This flight took place when the Antarctic ozone hole was beginning to recover; it allowed scientists to study possible effects of the ozone hole on mid-latitudes, the way Antarctic air recovers, and how the northern atmosphere changes as the winter season approaches.

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[7] This section contains some material that was taken directly from other websites and adapted and edited slightly for use in this context. See the list of **Related Links** as the end of this article for a representative summary of the sites referenced.

[8] Conducting the ten flights as originally planned would have allowed the "core" ATLAS instruments to collect data throughout an entire solar cycle. Nevertheless, the three flights covered a range of different observations.

[9] The exception was SSBUV, which was enclosed in two *Get Away Special* canisters mounted on the shuttle's payload bay.

[10] Each "core" instrument listed here is described in greater detail in the descriptions below.

[11] While several of these are germane to studies of the upper atmosphere and Sun, they are not described herein. The reader is referred to the link listed below on ATLAS for more information on these missions.

Atmospheric Chemistry, Aerosols, and Ozone

Atmospheric Trace Molecule Spectroscopy Experiments (ATMOS)
STS-45, 51-B, 56, and 66

ATMOS flew on four flights—including the three flights of the ATLAS experiment described above—and was used to examine the chemistry and composition of the middle atmosphere using a modified Michelson interferometer. This experiment marked the first time that several critical atmospheric trace gases were detected and measured from space. The data were also used to create profiles of more than 30 atmospheric constituents between 6–93 mi (10–150 km). The information was used to validate instruments that flew on UARS (described below) as well as Aura.

Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere—Shuttle Palette Satellite (CRISTA-SPAS-1 and -2)
STS-66 and 85

Deployed and retrieved from the shuttle's payload bay, the German-built CRISTA-SPAS satellite consisted of three telescopes and four spectrometers that scanned the Earth's limb and measured infrared emissions (between 4–71 µm) of the atmosphere. CRISTA was the primary payload mounted on the Shuttle Pallet Satellite; the payload was designed to explore the variability of the atmosphere and to provide measurements to complement those being obtained by the Upper Atmosphere Research Satellite (described below). The data from CRISTA had very high resolution in all three spatial dimensions—well beyond any other instrument at that time—which allowed scientists to trace the movement of trace gases in Earth's middle atmosphere and to infer details about the dynamic processes taking place—e.g., winds, wave interaction, and turbulence.

Lidar in Space Technology Experiment (LITE)
STS-64

LITE was the first use of a lidar in space. The LITE instrument operated for 53 hours, over an 11-day period in September 1994. The experiment obtained measurements of the vertical structure of clouds and aerosols from the Earth's surface through the middle atmosphere, including cloud layering, storm systems, dust and smoke clouds, pollutants, forest burning, and surface reflectance. The data returned from LITE were foundational in the development of subsequent space lidar missions, such as the Ice, Cloud, and land Elevation Satellite (ICESat), as well as the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO).

Measurement of Air Pollution from Satellites (MAPS)
STS-2, 41-G, 59, and 68

MAPS measured the distribution of carbon monoxide (CO) in the middle troposphere to evaluate CO sources and chemistry, and to evaluate the seasonal and interannual variation of this key atmospheric trace gas. The MAPS measurements provided scientists with the first database of near-global, mid-tropospheric CO concentrations. These unique measurements helped scientists understand how readily the atmosphere could cleanse itself of pollutants such as CO. In addition, the MAPS measurements helped scientists to better understand both how far pollutants travelled from their source areas and the size of the sources. The MAPS data presented the first evidence of the strong impact that the seasonal burning in the Southern Hemisphere had on the total abundance of CO in the troposphere.

Atmospheric Chemistry, Aerosols, and Ozone

Mediterranean Israeli Dust Experiment (MEIDEX)
STS-107

MEIDEX was a contribution to the FREESTAR payload from Tel Aviv University and the Israeli Space Agency[12]. The primary mission was to study the properties of desert dust, monitor its transport, and determine its impact on energy balance and atmospheric chemistry, with possible links to weather forecasting. The primary focus was the Mediterranean Sea and adjacent areas. As a result of data returned from the experiment, scientists now have a better understanding of the makeup of aerosols over the Mediterranean and what impact they may have on cloud formation and precipitation. MEIDEX also sought to study electrical phenomena in the upper atmosphere known as *transient luminous events*—seen above the cloud tops of enormous thunderstorms and classified as "sprites" and "elves" depending on size, shape, and duration. The experiment yielded a wealth of new information about these phenomena as well; the findings served as a benchmark for future investigations.

Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI)
STS-66 and 85

MAHRSI was an instrument flown on the CRISTA-SPAS satellite that was developed specifically to measure the vertical density profiles of hydroxyl (OH) radicals and nitric oxide (NO) in the middle atmosphere and lower thermosphere from 52° S – 62° N latitude at heights of 24–72 mi (40–120 km). The data returned led to the first complete global maps of OH in the atmosphere. MAHRSI was successfully flown for a second time in August 1997 under conditions that extended the geographical coverage to 72° N latitude and local solar time coverage through the afternoon hours.

Millimeter-Wave Atmospheric Sounder (MAS)
STS-45, 56, and 66

The MAS instrument flew on the three ATLAS missions and measured atmospheric trace gases in the upper troposphere [water vapor (H_2O), ozone (O_3), and carbon monoxide (CO)], stratosphere [O_3 trend detection, chlorine monoxide (ClO), and H_2O), and mesosphere [O_3, H_2O, and CO]. The data from MAS allowed scientists to get a clearer picture of how these trace gases were distributed in the upper atmosphere and were compared with those obtained from similar instruments, such as the Microwave Limb Sounder on the Upper Atmosphere Research Satellite (described below). MAS data had the distinct advantage of not being impacted by the presence of atmospheric aerosols inserted into the atmosphere in the aftermath of the eruption of Mount Pinatubo in 1991.

Shuttle Solar Backscatter Ultraviolet Experiment (SSBUV)
Eight flights between 1986–1996

Having flown eight times between 1989–1996, SSBUV holds the distinction as being one of the shuttle's most durable "frequent flyers"—this includes the three flights of the ATLAS experiment (described above). The shuttle provided a unique platform in space for calibrating other ozone-monitoring instruments. SSBUV was returned to Earth and carefully calibrated between each flight so that it could be used as a baseline to check the accuracy of other instrument measurements. This capability helped scientists to achieve a very accurate ozone record, which has been crucial for determining the success of international agreements such as the Montreal Protocol of 1987. Also, although the flights were intermittent, SSBUV did help confirm ozone depletion at an altitude of 28 mi (45 km)—i.e., where chlorine chemistry is most active. The calibration techniques were also extended to international ozone-monitoring instruments.

[12] Despite the tragic end to the STS-107 mission, most of the data from MEIDEX (and the other FREESTAR experiments) were either transmitted prior to the accident that destroyed the orbiter as it reentered Earth's atmosphere or, in at least one case, was salvaged during the recovery operation.

Atmospheric Chemistry, Aerosols, and Ozone

Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE)
STS-87 and 107

Together, these two instruments comprised the Shuttle Ozone Limb Sounding Experiment, which was to test new techniques for measuring how ozone varied with altitude. Both instruments observe light scattered by the limb of Earth. **SOLSE** measured atmospheric ozone between 19–31 mi (30-50 km) while **LORE** measured between 9–22 mi (15–35 km). Results from these experiments revealed that limb sounding was a viable technique for measuring the vertical distribution of ozone. These experiments demonstrated the capability of the limb instrument planned for the Ozone Mapping and Profiler Suite that will be flown on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (scheduled for launch on October 25, 2011) and the Joint Polar Satellite System.

Stratospheric Aerosol and Gas Experiment (SAGE-II)
STS-41-G

The second of four SAGE instruments built, SAGE-II was launched from the shuttle[13] as part of the Earth Radiation Budget Satellite (ERBS) described below. SAGE was designed to monitor the chemical composition of Earth's atmosphere, specifically the ozone layer and aerosols in the lower atmosphere through the use of a technique called *solar occultation* that measures attenuated sunlight through the atmosphere, and then ratios that measurement with a sunlight measurement without atmospheric attenuation, i.e., before a sunset and after a sunrise as experienced by the satellite. Using the bright Sun as a source provides the technique with a very high signal-to-noise ratio and, therefore, a vertical resolution of better than 1 km. Physically, the SAGE instruments measure ultraviolet/visible energy; this is converted via algorithms to determine chemical concentrations. SAGE data have been used to study atmospheric aerosols, clouds, and O_3; H_2O (as water vapor); nitrogen dioxide; and other trace gases. SAGE-II produced measurements from October 24, 1984 – August 31, 2005—spanning nearly 21 years. This long-term dataset, with its high vertical resolution, produced data— especially ozone trend data—which were key in the international community's decision-making process that resulted in a near elimination of the use of chlorofluorocarbons in industrialized countries. With respect to its aerosol measurement capabilities, the global measurements of the effects of the 1991 eruption of the Pinatubo volcano, which produced probably the most stratospheric sulfate of any eruption of the century, allowed the study of radiation and chemical effects of aerosols on climate and chemistry. For example, heterogeneous chemistry ozone loss effects were documented, as were the cooling effects of stratospheric aerosols on surface temperature.

Upper Atmosphere Research Satellite (UARS)
STS-48

UARS, an orbital observatory with a complement of ten instruments, was designed to make the coordinated measurements necessary to understand the chemistry and dynamics of the Earth's atmosphere, particularly the protective stratospheric ozone layer. As a result of these observations, scientists have gained a better understanding of the energy input, chemistry, and dynamics of the stratosphere and mesosphere. EOS Aura continues some of the measurements initially taken by UARS—e.g., the Microwave Limb Sounder measures ozone and other molecules that are important to ozone chemistry. As the first satellite dedicated to studying the stratosphere and mesosphere, UARS focused on the processes that lead to ozone depletion, complementing the measurements of total ozone made earlier by the Total Ozone Mapping Spectrometer onboard Nimbus-7 and the Russian Meteor-3 satellites. UARS also measured winds and temperatures in the stratosphere, as well as the energy input to the Earth system from the Sun, research that is now being applied to improve Earth system models and to help scientists understand the forces behind global climate change.

[13] The original SAGE instrument launched in February 1979 on the Applications Explorer Mission-II satellite. SAGE-III launched in 2001 onboard the Russian Meteor-3M satellite. A fourth instrument, called SAGE III-ISS, is scheduled for flight on the International Space Station in 2014.

Earth Imaging

Shuttle Imaging Radar (SIR-A and -B)
STS-2 and 41-G

SIR-A was one of the first experiments ever to fly on the shuttle. It built on technology demonstrated on the SEASAT satellite in 1979, and sought to acquire radar images of a variety of different geologic regions. SIR-A collected more than 3,861,021 mi^2 (10,000,000 km^2) of imagery. These pioneering Earth imaging experiments demonstrated the ability to penetrate extremely dry surfaces to discover what lies beneath. SIR-A unearthed number of ancient river channels that had been buried beneath the sands of the Sahara for eons.

SIR-B built upon lessons learned by the SIR-A missions, and was the next step in using imaging radar for Earth observations. Despite technical difficulties encountered during the flight, SIR-B was able to obtain multiple radar images of a given target at different angles during successive shuttle orbits. After the discoveries of SIR-A , SIR-B continued to scan the Earth's vast desert regions to look for more hidden "treasures" of scientific discovery. In 1992 the data returned were used to locate the lost city of Ubar, in what is now the country of Oman on the Saudi Arabian peninsula.

Shuttle Imaging Radar-C/X-band Synthetic Aperture Radar (SIR-C/X-SAR)
STS-59 and 68

SIR-C/X-SAR was a joint effort between NASA and the Italian and German Space Agencies. The key technological leap over its predecessors (see SIR-A and SIR-B described above) was that **SIR-C** used several radar frequencies, thereby allowing studies of geology, hydrology, ecology, and oceanography. SIR-C employed a dual-frequency radar—*L-band* and *C-band*. SIR-C was the first space-based radar with the ability to transmit and receive horizontally and vertically polarized waves at both frequencies. Over 2000 personnel were deployed in the field and at sea to collect measurements of vegetation, soil moisture, sea state, snow and ice, and weather conditions during the flights of SIR-C for calibration and validation of these new radar technologies.

Both SIR-C and **X-SAR** could be operated as either standalone radars or in conjunction with each other. On its second flight, SIR-C/X-SAR was used to demonstrate a new technology from the shuttle platform, called *interferometry.* The radar was used to generate detailed three-dimensional mappings of the Earth's surface and paved the way for the Shuttle Radar Topography Mission that would follow in 2000 (see below). The two flights of SIR-C/X-SAR revealed hidden river channels in the Sahara, indicating significant historical climate change. The data were also used for volcano research, allowing researchers to safely observe these hazardous and often inaccessible areas. Change-detection algorithms allowed assessment of flooding and volcanic mudflows that occurred between the two flights.

Shuttle Radar Topography Mission (SRTM)
STS-99

SRTM was the crowning achievement of the series of radar mapping missions flown from the shuttle (see SIR-A and -B and SIR-C/X-SAR above). SRTM was an international research effort that obtained digital elevation models on a near-global scale from 56° S to 60° N, to generate the most complete, high-resolution, digital topographic database of Earth ever produced[14]. The SRTM design built upon that of the older SIR-C/X-SAR system (described above). To acquire topographic (elevation) data, the SRTM payload was outfitted with two radar antennas. One antenna was located in the shuttle's payload bay; the other—a critical change from the SIR-C/X-SAR, allowing single-pass interferometry—on the end of a 100-ft (60-m) mast that extended from the payload bay once the shuttle was in space. The technique employed is known as *Interferometric Synthetic Aperture Radar*.

[14] This distinction would hold until the release of the Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) Global Digital Elevation Model (GDEM) in 2009.

Measuring Radiant Energy

Active Cavity Radiometer Irradiance Monitor–II (ACRIM-II)[15]
STS-45, 56, and 66

When NASA began to study Earth as a system, one of the questions that needed to be resolved was: *How much of the observed global warming can we attribute to changes in the Sun's output?* The data returned from the series of Active Cavity Radiometer Irradiance Monitor (ACRIM) instruments have helped to resolve the Sun's contribution to climate change and improve accuracy of computer models used to predict future climate change[16]. ACRIM measured the total amount of the Sun's energy reaching Earth—called *total solar irradiance* (TSI). The ACRIM that flew on the shuttle was essentially identicial to the ACRIM-II instrument that was flying simultaneously on UARS (described below).

Atmospheric Laboratory for Applications and Science (ATLAS-1, -2, and -3)
STS-45, 56, and 66

See description under **Atmospheric Chemistry, Aerosols, and Ozone,** above. The data returned from the three ATLAS flights also made significant contributions to our understanding of how changes in the output of the Sun could impact climate.

Earth Radiation Budget Satellite (ERBS)
STS-41-G

Studying Earth's climate in detail requires understanding Earth's *radiation budget*— think of it as a "ledger." Other, less-significant sources aside, this consists of compiling the energy Earth receives from the Sun on one side and the energy it releases to space on the other. Even a small shift in the planet's radiation budget could have profound impacts on climate. ERBS was constructed to monitor Earth's radiation budget and, remarkably, did so for over two decades[17]. ERBS consisted of two separate instruments: the ERBE scanner (three detectors for longwave, shortwave, and total radiation, respectively) and a non-scanning device (with five different detectors). ERBS was one of three satellites that, together, comprised the Earth Radiation Budget Experiment (ERBE)[18]. The SAGE-II instrument (described above) was also deployed on ERBS.

Infrared Spectral Imaging Radiometer (ISIR)
STS-85

Flown as part of the TAS payload, ISIR tested new technologies for making cloud observations. The radiometer measured the temperature of cloud tops; it also collected over 60 hours' of data on a variety of cloud, land, and ocean scenes. The results from this experiment were instrumental in leading to the development of more-compact, cheaper, and more reliable spaceborne infrared imagers.

Solar Constant Experiment (SOLCON)
STS-9, 45, 56, 66, 85, and 107 [19]

SOLCON-3 flew on the three ATLAS flights, and as part of the TAS and FREESTAR payloads. The experiment was designed to measure the solar constant and to identify variations during a solar cycle to better understand global climate changes on Earth. This kind of information is of fundamental importance for climate change studies. The Royal Meteorological Institute of Belgium managed the instrument; NASA's Earth Science Division (then referred to as *Code Y*) sponsored SOLCON's flights on the shuttle.

[15] This instrument was originally called the Active Cavity Radiometer Module (ACR).
[16] ACRIM-I flew on the Solar Maximum spacecraft in 1980; ACRIM-II was one of the instruments on UARS (described above); ACRIM-III is part of EOS, and was the primary payload of the ACRIMSAT mission launched in December 1999.
[17] The ERBS scanner detectors stopped operating in 1989, five years after launch; the so-called "non-scanner" detectors operated until 2005.
[18] The second ERBE instrument flew on the NOAA-9 satellite that launched in January 1985; the third flew onboard the NOAA-10 satellite that launched in October 1986.
[19] SOLCON actually flew on several additional shuttle flights, but those payloads are not included herein as they focused more on the realm of heliophysics, rather than Earth observations.

Measuring Radiant Energy

Solar Spectrum Measurement (SOLSPEC)
STS-9, 45, 56, and 66

SOLSPEC was a French-built instrument that flew several times, including all three flights of ATLAS. Similar to ACRIM, SOLPSEC measured TSI, but it used slightly different measurement techniques. SOLSPEC consisted of three spectrometers that detected ultraviolet (180–370 nm), visible (350–900 nm), and infrared (800–3000 nm) wavelengths respectively; there was also an onboard calibration device.

Solar Ultraviolet Spectral Irradiance Monitor (SUSIM)
STS-3, 9, 45, 56, and 66

The Sun is the primary driver of Earth's climate. In order to understand and properly model the upper atmosphere or climate systems, scientists need to know how light is distributed across the solar spectrum and also monitor changes in the concentration of incoming solar particles. Data returned from SUSIM were very helpful in answering these questions. The instrument was flown as part of five shuttle payloads: OSS-1, Spacelab-2, and all three ATLAS flights. After each flight, the instrument could go back to the laboratory for calibration, updates, and refurbishment, which meant that every flight built on the lessons learned from the previous ones. In September 1991, an identical copy of the SUSIM instrument was launched on UARS, allowing for intercomparison of the two instruments.

Other Payloads of Note

Laser Geodynamic Satellite-2 (LAGEOS-2)
STS-52

LAGEOS-2[20] was launched from the shuttle's payload bay. The satellite has no instruments *per se*; it is a simple, extremely dense aluminum sphere covered with tiny reflectors. Scientists could flash a pulse of laser light from the ground to the satellite to measure the *geoid*—a map of the shape of Earth's surface. The LAGEOS satellites provided a permanent reference point in a very stable orbit for such precision Earth-dynamics measurements as crustal motions, regional strains, fault motions, polar motion and Earth-rotation variations, solid-Earth tides, and other kinematic and dynamic parameters associated with earthquake assessment and alleviation.

Shuttle Laser Altimeter (SLA)
STS-72 and 85

The SLA flights used the space shuttle platform to demonstrate (and in the second flight, to fine-tune) what was—at that time—state-of-the-art laser remote sensing technology for geodetic surface altimetry of land, vegetation and ice that would be used in future EOS missions. The altimeter emitted 1064-nm laser pulses and studied the echoes returned to determine the shape of land surfaces and vegetation canopies at meter scales (vertically) and with geodetic precision. Millions of laser pulses were analyzed to produce a database that has proven very useful for scientific study, including publications. The discoveries made during the two SLA missions also supported the development of the algorithms for ICESat and the proposed Vegetation Canopy Lidar mission—selected as an Earth System Science Pathfinder mission but ultimately canceled. SLA was the first Earth-orbital lidar to demonstrate one-meter vertical accuracy topographic remote sensing and direct detection of vegetation canopy structure.

[20] LAGEOS-2 was a follow-on to the LAGEOS-1 satellite, launched in 1976. There were plans for a LAGEOS-3, but they never materialized. However, the data returned from NASA's Gravity Probe B mission have provided essentially the same information that flying the three LAGEOS satellites in formation would have.

Other Payloads of Note

Tracking and Data Relay Satellites (TDRS A, B, C, D, E, F, G)
STS-6, 51-L, 26-R, 29-R, 43, 54, and 70

While not Earth observing missions themselves, the TDRS launches are included here because they serve as critical communications links that enable Earth science and other missions. The TDRS system (TDRSS) is a constellation of satellites that provides communications, tracking, telemetry, data acquisition, and command services essential to shuttle flights and other low-Earth-orbital spacecraft such as the Hubble Space Telescope, the Compton Gamma Ray Observatory, UARS, the Cosmic Background Explorer, the Extreme Ultraviolet Explorer, TOPEX-Poseidon, Landsat missions, and many more. The first seven TDRS satellites launched onboard the shuttle, although TDRS-B was lost in the *Challenger* disaster (STS-51L) in 1986.

The Most Important Payload

Perhaps the most important "payload" that flew on every STS mission was comprised of the human crew, the astronauts. While capabilities onboard the shuttle couldn't observe the planet continuously for months or years (the way a satellite could), crews could conduct specific, intensive, targeted Earth observations while in orbit. There are some things, no matter how sophisticated our technology becomes, that only living beings can see and do.

For most of the Space Shuttle Program, each crew was trained to visually recognize between 25–50 locations of interest to the Earth science community. Sometimes, natural events added to the target list for a given mission; other times, the astronauts' well-trained eyes spotted unexpected beauty and surprises. The myriad astronaut photographs (both film and digital) taken over the past 30 years on STS missions have been used for studies of large-scale synoptic atmospheric, coastal, and geologic phenomena[21]. Quite often, these photos provided vital clues that alerted scientists to phenomena worthy of further investigation on future shuttle flights or with the electronic "eyes" in orbit that continuously observe Earth.

Reflecting on the Shuttle's Earth Science Legacy

In a recent book, titled *Wings In Orbit*[22] **Jack Kaye**, Associate Director for NASA's Earth Science Division, summarized the shuttle's contribution to Earth science as follows:

The Space Shuttle played a significant role in the advancement of Earth System Science. It launched major satellites that helped revolutionize our study of the Earth. Its onboard experiments provided discoveries and new climatologies never before available…it provided for multiple flight opportunities for highly calibrated instruments used to help verify results from operational and research satellites... Shuttle flights provided for on-orbit demonstration of techniques that helped pave the way for subsequent instruments and satellites…The shuttle [also] enabled international cooperation…The shuttle provided launch capability for Earth science-related experiments to the International Space Station...Finally, the shuttle provided outstanding education and outreach opportunities.

Concluding Remarks

We do not tend to think of the shuttle as having an Earth science focus. Indeed, we have shown how, owing to fateful events and decisions in the early days of EOS, most of our Earth science payloads shifted away from shuttle involvement. This observation notwithstanding, the Space Shuttle Program has played an important role in helping to enable the Earth Observing program that exists today. Several of the key technologies employed by Earth Observing satellites in orbit now (or those planned for the near future) can trace their lineage to experiments first conducted on the space shuttle. It was the intent of this article to make those linkages a bit more evident.

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[21] Mike Carlowicz's article on *The Earth Observatory* website (referenced below) shows some beautiful examples of images obtained from the shuttle.

[22] *Wings in Orbit* can be viewed online at: *www.nasa.gov/centers/johnson/wingsinorbit/index.html*. The full context of Kaye's quote can be seen in **Section 5:** "Major Scientific Discoveries," p. 359.

From missions built and tested at Goddard Space Flight Center, Langley Research Center, and the Jet Propulsion Laboratory, to launches at KSC, to mission operations at Johnson Space Center, and Spacelab operations at Marshall Space Flight Center, to overall program oversight at NASA Headquarters, the Space Shuttle Program's Earth-observing efforts have had a significant impact on the entire agency. The program also included significant contributions from international partners; perhaps none of these was more important than the European Space Agency's *Spacelab* laboratory, which enabled many of the investigations described in these pages. Many of the men and women who devoted their careers over the past three decades to make Earth observations from the shuttle possible are no longer around to reap the harvest of Earth observations now flowing from the "seeds of discovery" planted during these pioneering investigations. But the seeds they planted are now bearing much fruit.

And so, as the Space Shuttle Program concludes its 30-year run and we await the next chapter in manned space exploration, the staff of *The Earth Observer* wishes to salute all of those who helped make all of these investigations possible. EOS and the entire Earth Science Division would not exist as it does today without your help!

Related Links for More Information

"Every Flight is a Mission to Planet Earth"—The Earth Observatory's Shuttle Tribute
earthobservatory.nasa.gov/Features/ShuttleRetrospective/

General Background on and History of the Space Shuttle Program
en.wikipedia.org/wiki/Space_Shuttle
en.wikipedia.org/wiki/Space_Shuttle_program

Information on Slick Six and Proposed Shuttle Launches at Vandenberg
en.wikipedia.org/wiki/Vandenberg_AFB_Space_Launch_Complex_6
blog.roderickmann.org/2011/01/vandenberg-shuttle-launch-complex/

List of Shuttle Launches
en.wikipedia.org/wiki/List_of_space_shuttle_missions

Information on Spacelab flights
en.wikipedia.org/wiki/Spacelab

Information on the ATLAS payloads
events.eoportal.org/presentations/129/11872.html

Information on Tracking and Data Relay Satellites
en.wikipedia.org/wiki/Tracking_and_Data_Relay_Satellite

Information on Many of the Payloads Referred to Above
science.nasa.gov/missions/

Acknowledgment:

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The Jet Propulsion Laboratory's DEVELOP Team Applies Earth Observations to Address Environmental Issues in the Gulf of Mexico and Louisiana Coastal Wetlands

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As part of NASA's Applied Sciences Program (ASP), DEVELOP focuses on bridging the gap between NASA-developed technology and the public through projects that innovatively use NASA Earth science resources to address environmental issues.

Introduction

The DEVELOP National Program was established over a decade ago to provide high school, undergraduate, and graduate students with experience in the practical application of NASA Earth science research results. As part of NASA's Applied Sciences Program (ASP), DEVELOP focuses on bridging the gap between NASA-developed technology and the public through projects that innovatively use NASA Earth science resources to address environmental issues. While 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.

Under the guidance of science advisors from NASA and partner organizations, DEVELOP teams conduct projects that address national priorities and local environmental concerns, use data from NASA's Earth observations, and provide end-users with tools to enhance their decision-making process. In association with regional, national, and global partners, research is conducted to identify the widest array of practical uses for NASA-provided data to help communities better understand and, perhaps, respond to environmental change over time.

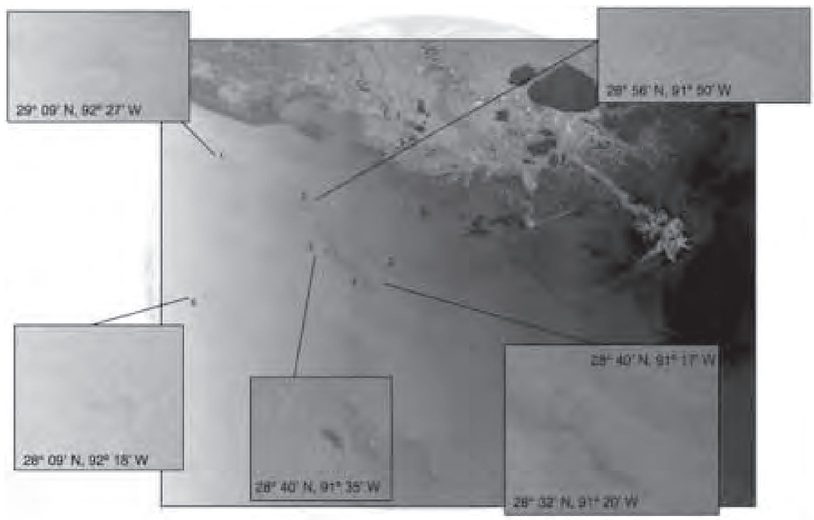
JPL DEVELOP Summer 2010 Team Members and Science Advisor, [*Left to right*] **Ian Jones**, **Katrina Laygo**, **Benjamin Holt.**

DEVELOP at NASA's Jet Propulsion Laboratory

At NASA's Jet Propulsion Laboratory (JPL) student researchers in the DEVELOP program have been using NASA's Earth science resources to address pressing environmental issues using a wide array of both satellite and airborne remote sensors. In the past year, the JPL DEVELOP team has assessed the conservation status of critically endangered species in the Gulf of Mexico, their habitats, and how prominent events—such as the 2010 Gulf of Mexico Oil Spill—may serve as a threat to such an integral part of this vital marine ecosystem.

The DEVELOP student participants come from a variety of educational backgrounds. Their major courses of study range from geography and environmental studies to public health; geotechnical engineering, urban planning, and mathematics; and experience in geographic information science and remote sensing. With such broad educational backgrounds, JPL DEVELOP participants are always searching for links between science and environmental stewardship. With direct access to NASA Earth science data and guidance from JPL scientists, students have the opportunity to study endangered species and to assess large-scale environmental impacts such as the 2010 Gulf of Mexico Oil Spill and the resulting critical effects felt across marine habitats in Louisiana wetland areas. Throughout the duration of the program, students partner with major government agencies such as the National Oceanic and Atmospheric Administration (NOAA)'s National Marine Fisheries Service (NMFS), the Department of Homeland Security (DHS), the U.S. Coast Guard (USCG), and a commercial company, Roffer's Ocean Fishing Forecasting Service. DEVELOP students delivered their research results for policy analysis and decision support to their respective partners. JPL's DEVELOP efforts have provided students and young professionals the opportunity to present at high-level conferences, such as the American Geophysical Union Annual Fall Meeting. In addition to conferences, this summer's participants had the opportunity to visit NASA's Headquarters in Washington, DC, to present active measures taken to make real change in the realm of local environmental concerns and public awareness.

Summer 2010 Gulf of Mexico Ecological Forecasting: This Synthetic Aperture Radar image details potential locations of Sargassum beds, the potential location for the home of larval Atlantic Bluefin Tuna (*Thunnus thynnus*), a critically endangered and highly prized species.



DEVELOP Activities at JPL

JPL DEVELOP participants regularly engage in research within the Oceans and Sciences Group, one of the core competencies within JPL's Earth Sciences Division. Past, current, and upcoming JPL DEVELOP teams focus on the analysis of coastal ocean data and forecasting, with students actively engaged in discussion with JPL's Group for High Resolution Sea Surface Temperature Science Team, the Gravity Recovery and Climate Experiment (GRACE) Science Team, and members of NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC).

December 2010: DEVELOP Students Presenting NASA DEVELOP Research Projects at the 2010 The American Geophysical Union Annual Meeting, [*Left to right*] **Megan Vaughan** (LaRC), **Katrina Laygo** [JPL], **Ross Reahard** [SSC], **Malcom Jones** [LaRC], **Madeline Brozen** [SSC/JPL].

The scope of their research encompasses the use of Synthetic Aperture Radar (SAR), Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) remote sensing, and an international range of satellite sensors to assess environmental issues. Particular focus has been made on studies in the Gulf of Mexico under NASA's Applied Sciences Ecological Forecasting and Disaster Applications. **Benjamin Holt** serves as the primary science advisor at JPL, and is a veteran researcher in the development of radar instrumentation to measure ocean surface currents from airborne and spaceborne platforms. His research interests include coastal oceanography circulation and its effects on biological productivity and pollutants, by using multisensor remote sensing. **Edward Armstrong** [JPL—PO.DAAC] and **Cathleen Jones** [JPL—UAVSAR Mission] also serve as science advisors for the DEVELOP team at JPL.

Decision Support Systems for Coastal and Marine Resource Management: Ecological Forecasting

Teams of undergraduate and graduate students worked during the ten-week Summer (June 2010–August 2010) and Fall (September 2010–November 2010) DEVELOP terms, conducting rapid research in NASA's Applied Science's national application area of Ecological Forecasting. The following students participated: **Jose Huerta** [California State University, Northridge], **Ian Jones** [University of California, Los Angeles], **Katrina Laygo** [University of California, Los Angeles], **Eric Burton** [University of California, Irvine], and **Samantha Roth** [California State University, Long Beach]. During the summer and fall terms, this team of students collaborated on a project titled *Gulf of Mexico Ecological Forecasting: Atlantic Bluefin Tuna Population Assessment and Managing using Synthetic Aperture Radar*. They used NASA remote sensing data to identify spawning locations for critically endangered Atlantic Bluefin Tuna (*Thunnus thynnus*) and its *Sargassum* seaweed habitat. This group also tracked the recent Gulf of Mexico Oil Spill and its potential effects on the Atlantic Bluefin Tuna and Sargassum.

JPL DEVELOP Fall 2010 Team Members **Samantha Roth** and **Eric Burton**. **Photo Credit:** Katrina Laygo

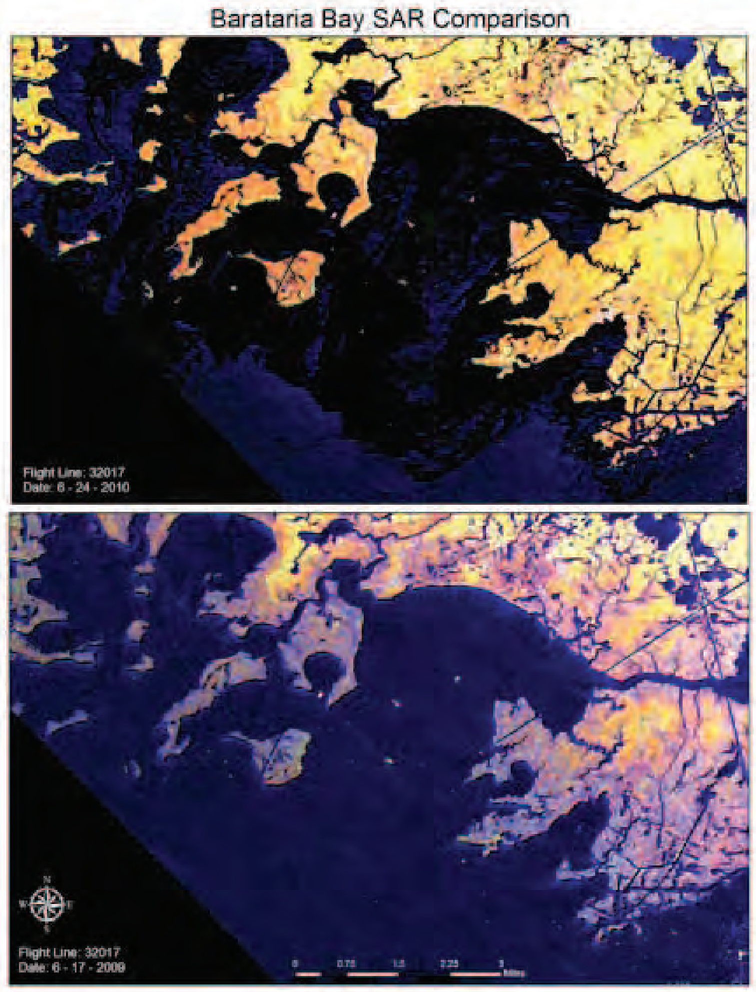
The recent oil spill disaster has had a huge impact on ecosystems in the Gulf. The implications have been enormous for marine species that thrive in the Gulf's warm water. Atlantic Bluefin Tuna, for example, are a highly politically charged, prized species, with individual fish selling for over $170,000 on sushi markets in Japan—according to National Geographic's animal species report. Managed by the International Commission for the Conservation of Tuna, Atlantic Bluefin Tuna only spawn in the Gulf of Mexico and the Mediterranean Sea.

Environmental issues, like the 2010 Gulf of Mexico Oil Spill, could threaten the pelagic brown seaweed that serves as a critical habitat for larval Atlantic Bluefin Tuna and numerous other species. Currently, assessments of Atlantic Bluefin Tuna spawning stock are highly variable. One possible way of reducing variability is to accurately identify sample areas to estimate the stocks. JPL's DEVELOP partnerships with NOAA's NMFS and Roffer's Ocean Fishing Forecasting Service were established to reduce variability of spawning stock assessments by accurately defining sample areas and costs of cruise track sampling by using NASA-derived satellite imagery and SAR data from the European Space Agency (ESA).

SAR, onboard ESA's ENVIronmental SATtellite (ENVISAT), provides two-dimensional spectra of ocean surface wave wavelength and direction. Automatic spectral measurements can improve sea forecast models and images can show the effects of other phenomena, such as internal waves, slicks, small-scale variations in wind, and modulations due to surface currents and the presence of sea ice (ESA *Earthnet* Online).

No apparent research has been used to identify Sargassum in the Gulf of Mexico; however, research has been done using SAR to identify *biogenic*—naturally occurring—and *anthropogenic*—resulting from human activities—oil slicks and ocean current features. SAR could serve as a viable alternative to optical/infrared sensors that are often impeded by cloud cover in tropical latitudes throughout the year.

Students examined the feasibility of using SAR data in identifying the patches of Sargassum and matching it to chlorophyll-*a* imagery from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), as well as imagery from ESA's Medium Resolution Imaging Spectrometer (MERIS), onboard ENVISAT. They also matched SAR data with buoy data from NOAA's National Buoy Database to correlate wind shear to Sargassum patterns. The study period for the project spanned from 2005–2010, during the Atlantic Bluefin Tuna spawning period (April–June). The students found that Sargassum beds often were several miles long and hundreds of feet wide in the northcentral and northwestern sections of the Gulf of Mexico. DEVELOP student **Ian Jones** presented this research at NASA's DEVELOP Summer 2010 Presentation at NASA Headquarters in Washington, DC, followed by a presentation at the Caltech–JPL Summer Student Seminar by **Katrina Laygo**. The project also received vital direction from JPL's DEVELOP science advisors, **Benjamin Holt** and **Ed Armstrong.**



Gulf of Mexico Oil Spill and Wetland Impact and Assessment using Polarimetric Synthetic Aperture Radar (PolSAR Data (Spring 2011): Preprocessed composite comparison of UAVSAR flight lines 32017's 2009 and 2010 data. The dark areas on the water (a suspected oil spill intrusion) in the 2010 [*top*] image are not present in the 2009 [*bottom*] image.

JPL's DEVELOP team continued outreach and collaboration with its end-users and the general public. **Katrina Laygo** and **Madeline Brozen** presented a summary of the first half of the project (Summer 2010) at the 2010 American Geophysical Union Fall Meeting in San Francisco, CA. The team reported on the research conducted during the Fall 2010 term in April at the 2011 Association of American Geographer's Annual Meeting in Seattle, WA.

Monitoring Oil in the Louisiana Coastal Wetlands: Disaster Management

Katrina Laygo, **Briton Voorhees** [California State University, Long Beach], and **Stephen LaPointe** [American Public University] worked hard during the ten-week Spring 2011 DEVELOP term, focusing on the Applied Sciences Disaster application. The research project was titled *Monitoring the Gulf of Mexico Oil Spill with Synthetic Aperture Radar (SAR) Data*. The 2010 Gulf of Mexico Oil Spill reached numerous ecologically sensitive coastal areas. This investigation extended Earth science research results to the DHS decision-making systems within the Science and Technology Directorate Division, as well as to the USCG. The goal was to develop methods using *L-band* radar returns to better characterize and quickly identify oil slicks on water and their ecological impact on vegetation.

UAVSAR is a reconfigurable polarimetric L-band SAR specifically designed to acquire airborne repeat track data for differential interferometric measurements. On June 22-23, 2010, UAVSAR flew over the Gulf of Mexico to image the spill. The airborne radar, built and managed by JPL, currently flies onboard NASA's Gulfstream-*III* aircraft from NASA's Dryden Flight Research Center in Edwards, CA.

To validate the utility of L-band data in assessing oil spill impacts, the L-band data were combined with hyperspectral data gathered from NASA's Airborne Visible/Infrared Imaging Spectrometer sensor, hyperspectral data from the Galileo Group, and *in situ* field surveys by the DHS Science Mission Directorate of Louisiana wetland sites. The research results were used for disaster management, monitoring, and mitigation.

Katrina Laygo, a recipient of the 2011 International Astronautical Federation's Youth Grants Award and an invited speaker at the International Astronautical Congress Youth Plenary, whose theme is *Next Generation Visions for Earth Observations*, will present the group's results at the 62nd International Astronautical Congress in Cape Town, South Africa, on October 6, 2011. NASA's Earth Science Division Director, **Michael Freilich**, will serve as a moderator for the plenary session.

Conclusion

The past year has developed and enhanced the relationships between students, science advisors, and informed decision-making partners in the NASA ASP application areas

NASA's DEVELOP Program Makes a World of Difference

In just ten short weeks, 140 high school, undergraduate, and graduate students conducted 25 Earth science research projects, addressing community-driven environmental issues and concerns around the world. The program—DEVELOP National Program—stems from NASA's Science Mission Directorate, Earth Science Division, Applied Sciences Program.

The program first began at NASA's Langley Research Center in 1998 with only three students; even then the local community deemed the student's efforts successful. Since then, the program has become known for its ability to bridge NASA Earth Science data and information and decision-making needs of public and private organizations.

This summer, DEVELOP participants gathered at NASA Headquarters in Washington, DC, to showcase the work they had completed over the ten-week period. The group impacted over 30 U.S. states, Puerto Rico, and other countries such as Bangladesh, Chile, Japan, Kenya, Mexico, New Guinea, Russia, and Yemen. Though the term has come to a close, many DEVELOP groups will go on to present their methodologies and new discoveries to local community centers including the Lake Victoria Fisheries Organization of East Africa, the National Oceanic and Atmospheric Administration's Marine Debris Program, the U.S. Department of Agriculture, the Smithsonian Institute's Global Volcanism Program, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the California Department of Water Resources, the Cahaba River Society in Alabama, and California's LA Conservation Corps.

Over the years the program has maintained its high-quality standards and innovative research tactics. Many attribute the success of the program to **Michael Ruiz** [DEVELOP National Program—*Program Manager*] and head mentors like **Joseph Skiles** at NASA's Ames Research Center. DEVELOP will resume this fall, with a new class of participants, who will work together on twelve projects that *develop* new ways of addressing local community concerns with NASA Earth Science data.

Take a virtual poster tour of this summer's projects at: *www.earthzine.org/summer-2011-develop-poster-session/*.

To learn more about DEVELOP National Program, visit: *develop.larc.nasa.gov/*.

of Ecological Forecasting and Disasters, opening doors to similar future studies utilizing NASA remote sensing instruments and data. By delivering new algorithms and results from research to end-users, JPL's DEVELOP group seeks to influence government and commercial management decisions and to demonstrate to the community the societal benefits of NASA Earth observations, sponsored by taxpayer dollars.

JPL's DEVELOP group has continuously sought to develop regional ecosystem assessments through the collection and analysis of Earth observation satellite and airborne data, improving habitat conservation and restoration, and enhancing the response to data needs from companies such as Roffer's Ocean Fishing Forecasting Service. The teams have addressed the environmental impacts of offshore oil and gas production along coastal wetlands for disaster management and continue to commit to public and educational outreach. These objectives have been accomplished through partnerships with communities and end-users, and in helping the public understand the importance and impacts of environmental change. Students and science advisors are currently expanding studies to include the ASP application areas of public health and air quality.

JPL DEVELOP Spring 2011 Science Advising and Team Members, [*Left to right*] **Cathleen Jones**, **Briton Voorhees**, **Katrina Laygo**, **Stephen LaPointe**, and **Benjamin Holt.**

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Reverb—The Next Generation Earth Science Discovery Tool

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After a yearlong design, development, and testing process, the Earth Science Data and Information System (ESDIS) project (Code 423) has released *Reverb*—The Next Generation Earth Science Discovery Tool. Reverb provides new ways to discover, access, and invoke NASA's Earth science data products and services.

NASA's Earth Observing System (EOS), initiated operationally with launch of the Terra platform in 1999, is a coordinated series of satellites for long-term global observations. To support data services for EOS, NASA developed the Earth Observing System Data and Information System (EOSDIS). EOSDIS is a petabyte-scale archive of and distribution system for environmental data that supports global climate change research by providing end-to-end services, ranging from instrument data collection to science data processing to full access to Earth science data. On a daily basis, EOSDIS ingests, processes, archives, and distributes over three terabytes of data from NASA's Earth Science missions, representing over 3500 data products that address a wide range of Earth science disciplines. ESDIS manages the EOSDIS science systems, including the 12 discipline-specific data centers–collocated with centers of science discipline expertise–that process, archive, and distribute data. EOSDIS provides access to both current and heritage data from satellites and aircraft, field campaigns, and socioeconomic sources.

A screenshot of the homepage for Reverb—NASA's Next Generation Earth Science Discovery tool.

Although users prefer simpler targeted search tools, in a recent survey nearly 75% of those responding indicated a need to search for multiple datasets over the same temporal or geographic range.

Reverb is the follow-on to the Warehouse Inventory Search Tool (WIST), designed with the goal of providing a user experience that enhances the existing functionality of cross-discipline data discovery and order creation available through WIST.

Like WIST, Reverb accesses the EOS ClearingHOuse (ECHO) centralized metadata catalog, and provides access to related data and services provided by EOSDIS via a service-oriented architecture between data centers and science data users.

By using Reverb, users will be able to:

- Download their data in no more than three page transitions;
- discover additional datasets that may enhance their research;
- discover and invoke services associated with their data of interest; and
- perform bulk downloads.

In addition to data discovery, Reverb will facilitate the discovery of services associated with data of interest. Based on supported standards and/or protocols, Reverb can facilitate the invocation of both synchronous and asynchronous data processing. This greatly enhances a user's ability to discover new or other data of interest, thereby making is easier to accomplish their research goals.

Reverb was developed in a fast-paced agile development process that required constant interaction between developers, data providers, and end-users. Reverb was developed and tested with newer, more-robust technologies to improve the quality and testability of the underlying code.

Although WIST is still currently available, we invite you to check out Reverb! Your feedback is appreciated. We want to continually meet and exceed your data and service discovery needs.

To access Reverb, visit: *reverb.echo.nasa.gov/reverb*.

For Reverb support, contact: *reverb-support@echo.nasa.gov*.

NASA Visualization Explorer: Earth Science From a Whole New Perspective

Science, data, and storytelling come together for the release of the new *NASA Visualization Explorer*—or NASA Viz—*iPad* app! The app, developed by software and media specialists at NASA's Goddard Space Flight Center, puts a spin on recent Earth science research topics. Designed to be a mobile, multimedia Earth science magazine, NASA Viz allows users to interact with Earth science on the go. Feature stories typically include a few high-definition videos, image stills, and supportive image descriptions.

Primarily focused on Earth science topics (e.g., atmospheric composition, climate variability and change, carbon cycles and ecosystems), the app may also include stories about the Sun, other planets in the Solar System, and exotic objects in the cosmos. Two new feature stories will be added to the app weekly, on Tuesdays and Thursdays.

"Its one-of-a-kind content is geared to the general public, students, educators… anyone interested in the natural world," says Senior Producer **Michael Starobin**, who headed the app's editorial direction.

You can download the app for free from the App Store via *iTunes*. Within minutes, you'll be able to "Meet NASA's Earth-observing Fleet," witness "India's Disappearing Water," observe an "Extreme Solar Eruption Caught on Camera," and more.

The app is only available for iPad and requires *iOS 4.3* or higher. For more information or to download the app, visit: *svs.gsfc.nasa.gov/nasaviz/index.html*.

Summary of the 39th Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting

Tetsushi Tachikawa, Earth Remote Sensing Data Analysis Center (ERSDAC), tatikawa@ersdac.or.jp

The 39th ASTER Science Team Meeting was held at the Akihabara Daibiru Building in Tokyo, Japan, from June 6-9, 2011. The members of the ASTER science team and members of teams related to the ASTER and other scientific projects attended the meeting. The status of ASTER and information on the status of future Earth-observing satellite instruments were reported on at the opening plenary presentation, which was followed by splinter sessions for each working group. The reports from each working group were presented at the closing plenary presentation.

Opening Plenary Presentation

H. Tsu [Earth Remote Sensing Data Analysis Center (ERSDAC)—*Japan ASTER Science Team Leader*] and **M. Abrams** [NASA/Jet Propulsion Lab (JPL)—*U.S. ASTER Science Team Leader*] made opening remarks, offering sympathy for the victims of the Great East Japan Earthquake that occurred on March 11, 2011. **M. Kato** [ERSDAC] presented the meeting schedule.

W. Turner [NASA Headquarters] outlined NASA's current status, which covered NASA's organization, future projects, and budget. Turner provided the updates and schedule for the NASA senior review of the ASTER project.

M. Abrams provided an update on the status of U.S. ASTER contributions. He presented information on ASTER Global Digital Elevation Map (GDEM) version 2 and observations of several natural disaster events. He also provided an introduction to the Hyperspectral Infrared Imager and the Hyperspectral Thermal Emission Spectrometer missions. Abrams reported that there were many presentations using ASTER data at the 31st European Association of Remote Sensing Laboratories Symposium that was held a week before the ASTER science team meeting.

T. Matsunaga [National Institute for Environmental Studies (NIES)] provided an update on the Hyperspectral Imager Suite. He described the mission structure, instrument/satellite performance requirements, and project timeline.

M. Kikuchi [Japan Resources Observation System and Space Utilization Organization (JAROS)—*Instrument Team*] reported on the status of the ASTER instrument. He addressed instrument lifetime management and radiometric calibration.

M. Hato [ERSDAC, Ground Data System (GDS)] reported on the status of the GDS. He gave an update on the production and distribution of GDS. He also reported on the ASTER Operation Segment (AOS) replacement plan.

D. Meyer [U.S. Geological Survey Land Processes Distributed Active Archive Center (USGS LPDAAC)] reported on the status of operations, data distribution, science activities, and development at the LPDAAC, and presented the overall validation plan for GDEM version 2.

M. Fujita [ERSDAC, Science Scheduling Support Group (SSSG)] presented the Science Scheduling Support Group/Operations and Mission Planning (SSSG/OMP) report. He described the observation status for Global Mapping and underserved observation area.

T. Tachikawa [ERSDAC] provided a brief assessment on the quality of GDEM version 2. **M. Kato** [ERSDAC] presented the results from ASTER imagery and data analysis from the March 2011 Japan earthquake.

T. Matsuzaki [Japan's Ministry of Economy, Trade, and Industry] made welcoming remarks to the participants, and explained the current status of the ASTER project in Japan.

To close the plenary session, **Y. Yamaguchi** [Nagoya University] raised issues for discussion in the working groups that included data acquisition monitoring, GDEM version 2, and updates of the radiometric calibration coefficients (RCC).

Working Group Sessions

Level 1/Geometric/Digital Elevation Model Working Group

In the first half of the session, the results from validation of the ASTER Level 1 (L1) algorithm/software were presented. No appreciable problems were found. There was discussion of geolocation error for the nighttime Thermal Infrared (TIR) data; the error will be corrected by a L1A+ software update. The second half of the session was devoted to the ASTER GDEM project. **H. Fujisada** [Sensor Information Laboratory Corporation] reported on plans for developing GDEM version 2 and beyond. **D. Meyer** presented preliminary validation reports for GDEM version 2 *beta* generated by the

USGS and National Geospatial-Intelligence Agency. **T. Tachikawa, A. Iwasaki** [University of Tokyo], **B. Crippen** [JPL], **M. Abrams,** and **R. Bindschadler** [NASA's Goddard Space Flight Center] also presented GDEM version 2 beta validation results. All reports demonstrated significant improvements for GDEM version 2 over version 1.

Radiometric Calibration/Atmospheric Correction Working Group

B. Eng [JPL] reported on the status of the atmospheric correction (L2 software) update. The instrument team reported on the results from the onboard calibration. There is a recommendation to update the radiometric database for visible near infrared (VNIR) retrievals within a year. **M. Kikuchi** and **F. Sakuma** [JAROS] presented the analysis for sensitivity degradation of VNIR and thermal infrared (TIR) retrievals. **N. Leisso** [University of Arizona], **A. Kamei** [National Institute of Advanced Industrial Science and Technology (AIST)], **H. Tonooka** [Ibaraki University] and **S. Kato** [NIES] reported on the results of field campaigns and plans for future surveys. **N. Leisso** showed the comparison of reference panels using calibration. **K. Arai** [Saga University] listed future work, including studying sensitivity degradation trend analysis, ten years of vicarious calibration reports, and recommending RCC (and biases) for users.

Temperature-Emissivity Separation (TES) Working Group

H. Tonooka presented the data from the Great East Japan Earthquake as observed by ASTER/TIR, and also reported on developing a Japanese inland water surface temperature database using ASTER/TIR. Water temperature is an important environmental factor for studying the biology of inland waters, but is either poorly monitored or not monitored at all. **H. Tonooka** and **G. Hulley** presented development status of large-scale emissivity datasets; **M. Ramsey** [University of Pittsburg] reported on initial high temperature emissivity results. **M. Fujita** presented the status of night TIR Global Mapping (TGM), and **H. Tonooka** reported on the cloud assessment update and new areas of interests (AOIs) for TGM.

Operations and Mission Planning (OMP) Working Group/Science Team Acquisition Request (STAR) Committee

At the beginning, all previous action items (AIs) were reviewed and confirmed as closed. **A. Miura** [GDS, ERSDAC] reported on the plan to replace the facilities for the AOS. **D. Meyer** reported on the status of Expedited Data Set (EDS) processing at LPDAAC and possibility of anomaly reoccurrence. **N. Cole** [JPL] reported a problem that occurs when EDS is set by night T-only mode, not S+T mode. **L. Maldonado** [JPL] proposed to raise the limitation for EDS to 20 scenes from 15 scenes per day. Investigating the possibility was agreed to, and presented as an AI. **T. Tachikawa** reported on the constraint parameters in the scheduler, which were changed in January. **M. Fujita** noted that the observation resource was increased by a scheduling parameter update, and divided appropriately. He also reviewed the status of Global Mapping 4th Round (GM 4th), TGM, and Underserved Area STAR (UA STAR). GM 4th is progressing well, and GM 5th will be discussed at the next ASTER Science Team Meeting. TGM will be nearly complete by the scheduling parameter update in January, and the fifth round will start as soon as possible. **T. Tachikawa** proposed a new UA STAR. Target areas were determined based on the stacking number for GDEM version 2. It was agreed that UA STAR version 2 will begin with approximately 2,000 AOIs, and the GDEM gap filler STAR will be prepared separately. During a STAR Committee meeting, a STAR proposal was reviewed; the working group agreed to ask the submitter whether resubmission was necessary. Global Land Ice Measurements from Space (GLIMS) STAR just arrived at SSSG, and will be put into AOS soon.

Ecosystem/Oceanography Working Group

T. Matsunaga and **G. Geller** [JPL] reviewed action items and the status of STAR. Descriptions of three projects were presented: the Science Degree Confluence Project Community Validation Tool and Global Urban Area Mapping, by **K. Iwao** [AIST]; the J-Earth 100 Cities Project, by **L. Prashad** [Arizona State University]; and Terra Look, by **G. Geller**. Seven research reports were also provided: Challenge for Peatland Management, by **K. Hirose** [Hokkaido University]; Determination of Paddy Field, by **G. Saito** [Tokyo Institute of Technology]; Estimation of Turbidity Distribution, by **Y. Sakuno** [Hiroshima University]; Relationship Between Nighttime Surface Temperature and Sky View Factor, by **S. Kato**; Application to Shallow Water Bathymetry, by **A. Kanno** [Yamaguchi University]; Satellite Remote Sensing in a Global Biodiversity Monitoring System, by **W. Turner;** and Urban Growth and Change Analysis, by **Y. Yamaguchi**.

Geology/Spectral Working Group

Descriptions of Group research activities were presented: Geologic Mapping of Southern Namibia, by **Y. Yamaguchi;** Tsunami Flood Area Estimation of the 2011 Tohoku Earthquake, by **M. Urai** [AIST]; Satellite and Airborne TIR Imaging for USGS Volcano Observatory, by **R. Wessels** [USGS]; Spectral and Thermal Behavior of Basalt Lava Flows, by **M. Ramsey**; and

continued on page 37

Advanced Microwave Scanning Radiometer for EOS (AMSR-E) Science Team Meeting

Elena Lobl, AMSR-E Science Team Manager, The University of Alabama in Huntsville, elena.lobl@nsstc.uah.edu

The National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA) hosted this year's AMSR-E Science Team meeting from June 28-29, 2011, in Asheville, NC. Because of the Mission Operations and Ground System (MOGS) meeting taking place at the same facility from June 27-28, the Science Team meeting agenda was altered, with the science presentations on the first day (June 28) and then the ground system part of the meeting on June 29. This arrangement was made so MOGS participants could attend the AMSR-E sessions. The meeting was well attended, as may be seen in the team photo on page 29. Presentations can be found online at: *www.ghcc.msfc.nasa.gov/AMSR*.

After the introduction by **Roy Spencer** [University of Alabama in Huntsville (UAH)—*AMSR-E Science Team Leader*] and **Akira Shibata** [JAXA Earth Observation Research Center—*AMSR-E Science Team Leader*], **Ramesh Kakar** [NASA Headquarters] presented an overview of current missions and those in development. Kakar assured the group that the results from the 2011 Aqua Senior Review activities would not hold any surprises for Aqua mission interests.[1]

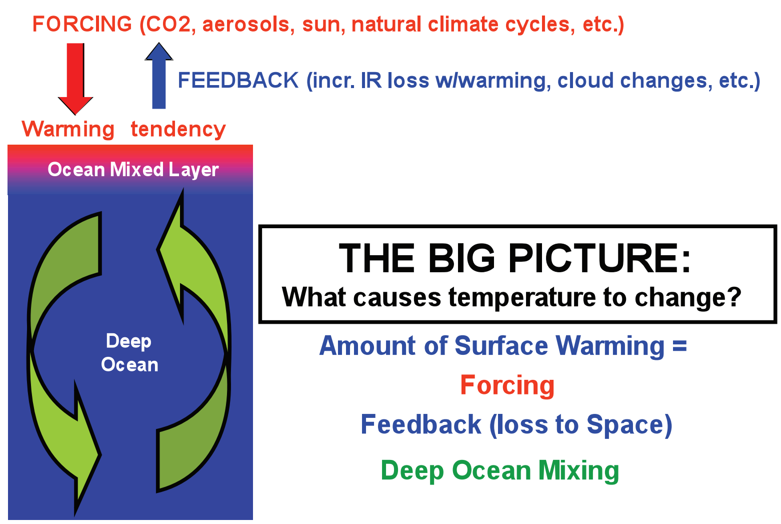

Figure 1 "Big picture" view of the atmosphere-ocean system.

John Bates [NCDC, NOAA National Environmental Satellite, Data, and Information Service (NESDIS)—*Chief of Remote Sensing Applications Division*] was the host, and presented an overview of the passive microwave data archive at NCDC. Bates discussed recent work that addresses the Special Sensor Microwave Imager Sounder (SSMIS) data quality issues, and the latest news on the upcoming availability of AMSR2 data at NCDC. (AMSR2 is the microwave imager on the Japan Aerospace Exploration Agency's (JAXA) Global Change Observation Mission-Water 1 (GCOM-W1) satellite, to be launched no earlier than February 2012.)

[1] The team subsequently has learned that the Aqua mission has been extended.

Roy Spencer addressed the connection between sea surface and deep ocean temperatures. He described the "big picture" of temperature changes in the atmosphere-ocean system, as diagrammed in **Figure 1**. Spencer concluded that, "…deep ocean temperatures will become increasingly important in order to explain surface temperature changes."

Masahiro Kazumori [Japan Meteorological Agency (JMA)] presented results from two case studies where radiances were directly assimilated into the JMA mesoscale analysis. The radiances were retrieved from total column water vapor and rain rate [from AMSR-E and TRMM Microwave Imager (TMI)] and temperature profiles (from the Advanced Television Infrared Observation Satellite). The results showed a large positive impact on the JMA numerical weather prediction system. A byproduct of this assimilation process is the detection of erroneous calibration brightness temperatures. It is expected that JMA will participate in calibration of the AMSR2 and the Global Microwave Imager to be flown on the Global Precipitation Measurement (GPM) Mission.

Akira Shibata discussed a wind speed algorithm that can retrieve products in rainy conditions. He compared his results with SeaWinds wind speeds; the comparison was not perfect. Shibata believes that the reason for this discrepancy is the presence of foam (whitecaps) on the ocean surface.

Frank Wentz [Remote Sensing Systems (RSS)] discussed the intercalibration of AMSR-E with several other microwave radiometers. Wentz concluded that the major sources of calibration error are "…specification of antenna spillover and mean hot load temperature, specification of the variation of hot load temperature with varying sun angles, and emissive antenna correction (TMI and SSMIS)." Version 7 calibrated data from

AMSR-E Science Team Meeting participants.

AMSR-E, WindSat, F13 SSMI, and F17 SSMIS can be found at the RSS website at: *ssmi.com*.

Joey Comiso [NASA's Goddard Space Flight Center (GSFC)] showed the regional variations in ice cover and ice production in the Antarctic. The scientific motivation for this study was the observed asymmetry between the Northern and Southern Hemispheres sea ice cover. The Arctic sea ice cover is declining at a rate of -13.5% per decade, whereas the Antarctic sea ice cover is increasing at a rate of greater than 1% per decade. Comiso concluded that the positive trend is mostly associated with the Antarctic circumpolar wave and the location of the ozone hole. Most of the increase in sea ice cover is taking place in the Ross Ice Sea.

Chris Kummerow [Colorado State University (CSU)] described the status of the Goddard PROFiling (GPROF) 2010 algorithm. Currently, CSU is working with the Team Lead Science Computing Facility to implement this new algorithm at the AMSR-E Science Investigator-led Processing Systems (SIPS).

Matt Lebsock [CSU] presented a comparative analysis of oceanic warm rain from AMSR-E and CloudSat. Lebsock's main conclusion was that GPROF 2010, used to calculate the AMSR-E rain rates, still misses some of the rain from shallow clouds. Further improvement to the GPROF algorithm may be needed in the future.

Ralph Ferraro [Cooperative Institute] described the improvements to the AMSR-E rain-over-land algorithm developed at the Satellite Climate Branch at NESDIS. Ferraro stressed the importance of land emissivity when trying to improve the precipitation algorithm over land. He showed some issues that came up in the International Precipitation Measurement Missions Land Surface Working Group when discussing land emissivity. His next steps to improve precipitation over land algorithms are to compare the CSU surface classification to the ones used in his algorithm, and to bring in new datasets.

Tom Wilheit [Texas A&M University] is part of the GPM Intersatellite Calibration Working Group (a.k.a., X-CAL). He reported on the latest AMSR-E activities in the X-CAL working group.

Eni Njoku [NASA/Jet Propulsion Laboratory] presented information on the status of the soil moisture algorithm, and provided an overview of the AMSR-E soil moisture standard products archived at the National Snow and Ice Data Center (NSIDC). The main conclusion was that these products are biased high, with the principal reasons being the lack of sensitivity in the 10.7-GHz channel, and erroneous modeling of the surface type. **Iliana Eva Mladenova** [U.S. Department of Agriculture's Agricultural Research Service Hydrology and Remote Sensing Lab] discussed the work she has performed in comparing existing soil moisture algorithms. The plan for improving the AMSR-E soil moisture algorithm includes using proper validation sets (ideally these would be hourly and global) and using different evaluation statistics.

Eric Wood [Princeton University (PU)] talked about the PU Land Surface Microwave Emission Model and its input datasets. Recent model developments include the use of a microwave multichannel-based vegetation optical depth; microwave 36.5-GHz total column atmospheric water vapor (V)-based surface temperature; and microwave-based mask files for snow cover, active rain, dense vegetation, and radio frequency interference. Wood plans to use this model to assess strategies for improving AMSR-E retrievals and doing a continental-scale evaluation.

Rolf Reichle [GSFC] showed an update on AMSR-E soil moisture and snow data assimilation. Reichle is part of the Global Modeling and Assimilation Office (GMAO), where he uses the Modern Era Retrospective-analysis for Research and Applications developed at the GMAO to show the positive effect of assimilating a precipitation correction and the surface soil moisture retrievals. Using assimilation of both active and passive microwave soil moisture retrievals can make further improvements. After further analysis of the AMSR-E snow water equivalent, Reichle concluded that these retrievals "…are not ready for assimilation."

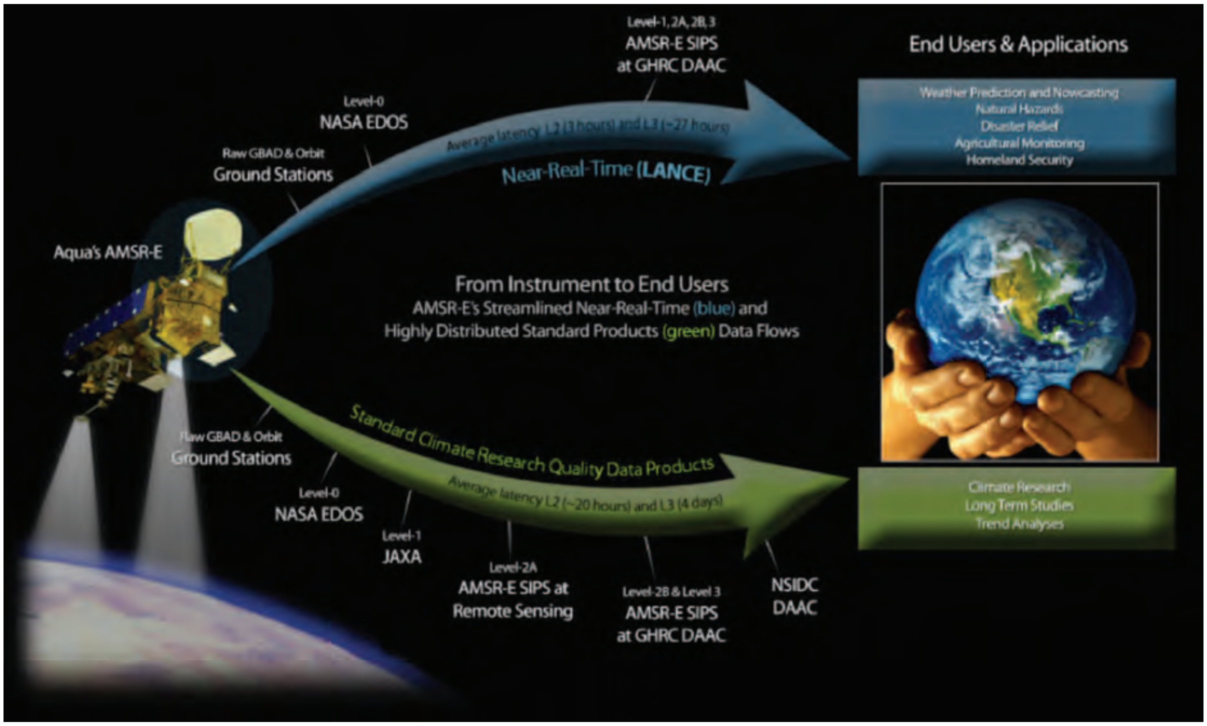

Figure 2. Two AMSR-E data flows: LANCE and the Standard Climate Research products, from Aqua/AMSR-E to the users.

Lucas Jones [Numerical Terradynamic Simulation Group, College of Forestry and Conservation and Flathead Lake Biological Station at The University of Montana] developed an algorithm using the AMSR-E channels at 18.7 and 32.8 GHz to retrieve surface air temperature (T), V, soil moisture (M_v), open water fraction (F_w), and vegetation optical depth (VOD). He now plans to reparameterize the T/emissivity/V algorithm using Integrated Global Radiosonde Archive network and external T/emissivity information, update his algorithms for simultaneous VOD and M_v estimation using T and F_w data as input, and run his algorithm with L2A swath (rather than gridded) brightness temperature (T_b) data as input.

John Kimball [Numerical Terradynamic Simulation Group, College of Forestry and Conservation and Flathead Lake Biological Station at The University of Montana] presented the status of the retrievals produced with the algorithm presented earlier by Jones. He believes that the retrievals have different technology maturity levels: Level 7 for T, VOD, and F_w; and Level 3 for M_v and V.

On Wednesday the meeting started with **Dawn Conway** [UAH] presenting the AMSR-E team leader snow cover fraction status. She also gave details about the sea ice drift product, AMSR-E's newest *beta* version product.

Kathryn Regner [Information Technology and Systems Center (ITSC) UAH] discussed the status of the AMSR-E SIPS. The important conclusion to her status was that, "Processing continues to run smoothly as we enter the tenth year of routine operations." She also described the Land Atmosphere Near-real-time Capability for EOS (LANCE) that takes place at the AMSR-E SIPS. Products can be accessed less than three hours after the observation. **Figure 2** shows the two AMSR-E data flows: LANCE and the Standard Climate Research products from Aqua/AMSR-E to the users. More information about LANCE can be found online at: *lance.nasa.gov/home/about/amsr-e-sips*.

Amanda Leon [NSIDC] reported on the status of the AMSR-E standard products, as well as the AMSR-E validation datasets. She reiterated the different paths for data access, as well as a new tool available for data viewing.

Helen Conover [ITSC UAH] introduced the project called *Instant Karma*. This tool will access provenance information for any standard product. The initial focus of the project is on sea ice processing. ITSC is collaborating with Indiana University's Data to Insight Center and the AMSR-E sea ice science team. For more information on the initial prototype of this project's results see: *instantkarmatest.itsc.uah.edu/karmabrowser/view*. Conover also presented a summary of the Passive Microwave Data Set Management Workshop. All participants—which included representatives from Earth Science Data Centers, Making Earth Science Data Records for use in Research Environments, and the Earth Science Data and Information System—found this exercise to be valuable and are recommending that other

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ESIP Federation Confronts Data Quality During Summer Meeting

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The Earth Science Information Partners (ESIP) Federation held its summer meeting in Santa Fe, NM, from July 12–15, 2011, with more than 190 participants. The ESIP Federation is a consortium of Earth science data and technology professionals representing government—NASA, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the U.S. Geological Survey (USGS), and the National Science Foundation—academia, and both commercial and not-for-profit private sectors. Initiated by NASA in 1997, the ESIP Federation provides data, products, and services to decision makers and researchers in public and private settings. The Foundation for Earth Science provides administrative and staff support to the ESIP Federation.

At this summer's meeting the group focused on the theme *Information and Data Quality*. The ESIP Federation heard from experts, practitioners, and users about many dimensions of data quality. "The ESIP Federation's community of practitioners came together to improve the flow of data from a distributed set of providers to a diverse base of users," said **Chris Lenhardt** [Oak Ridge National Laboratory—*ESIP Federation President* and *Manager, Distributed Active Archive Center for Biogeochemical Dynamics*]. "Data quality is a complex topic. The meeting approached the theme from many different angles, leveraging the many subcommunities' expertise within the ESIP Federation to gain a better understanding of the many issues at hand." The outcome from the meeting extended the approach to data quality from one historically focused on validating data integrity to including the needs of communities that use data (e.g., in terms of timeliness, usability, completeness, defensibility).

The meeting included keynote talks from **Bill Michener** [University of New Mexico—*Long Term Ecological Research* and *DataONE projects*] and **Greg Stensaas** [*USGS Earth Resources Observation and Science Center, Remote Sensing Technologies*] that surfaced the challenges presented by various communities and the need for a quality framework; it also highlighted lessons learned from large-scale investigations. A data quality plenary panel was also convened, with representatives from the modeling, science, applications development, education, and regulatory communities, each providing a glimpse into their respective requirements for quality. Beyond the plenary gatherings, the meeting offered a wide range of sessions that dealt with data quality topics that ranged from a workshop on encoding quality into International Standards Organization (ISO) 19115 metadata to domain-specific discussions in the Air Quality Working Group on specific quality needs. Session details and presentations can be found online at: *wiki.esipfed.org/index.php/July_13,_2011*.

Other meeting highlights included:

- A quality workshop on data documentation (ISO metadata);
- a cloud computing workshop and breakouts;
- a teacher workshop on climate change education;

Perspectives Panel on Data Quality. [*Left to right*] **Kerstin Lehnert** [Lamont-Doherty Earth Observatory, Columbia University], **Glenn Rutledge** [National Oceanic and Atmospheric Administration, National Climatic Data Center], **Kevin Ward** [NASA's Earth Observatory], and **Sean Fox** [Science Education Resource Center, Carleton College]. **Image Credit: Carol Meyer** [Foundation for Earth Science—*Executive Director].*

- a data preservation and stewardship track (digital identifiers, provenance, and citations); and
- service casting, semantic web, visualizations, Drupal (content management system that provides collaboration spaces for communities to work together), and energy and climate sessions focusing on alternative energy strategies.

With interest in the ESIP Federation continuing to grow, it was appropriate that new clusters formed as a result of the meeting. They are a Drupal Cluster, Climate and Forecast Cluster (NetCDF CF), and the Cloud Computing Cluster. According to President Lenhardt, "The new clusters represent the ESIP Federation's commitment to providing a venue for the community to address timely topics of interest to many practitioners across the community. Like the many clusters that came before them, the new clusters are driven by members who want to leverage the ESIP Federation's expertise in tackling emerging topics."

For more information about ESIP or meeting details, visit: *esipfed.org/*. The next ESIP Federation meeting will be held in Washington, DC, from January 4–6, 2012. ■

Advanced Microwave Scanning Radiometer for EOS (AMSR-E) Science Team Meeting

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instrument/discipline groups host similar workshops. The workshop committee is compiling a detailed report.

Hiroshi Motoi [JAXA Mission Operations System Office] provided a report on AMSR-E data processing and archiving status. Motoi showed that greater than 90% of the data are processed within three hours of its being received.

Takaaki Ishikawa [Mitsubishi Electric Corporation], discussed the AMSR-E auto gain control (AGC) status, noting that the 89-GHz channel AGC is steadily increasing. Ishikawa then presented a plan to keep the channel "alive," even with degraded resolution. The AMSR-E science team agreed with this plan, and gave JAXA the go-ahead for implementing the outlined changes.

The last two presentations were on the status of the GCOM-W1 project. **Masato Yamanashi** [JAXA – *AMSR-E Project Coordinator*] presented the GCOM-W1 schedule and stated that the launch would be no earlier than February 2012. The only payload on the satellite is AMSR2, a follow-on to AMSR-E. GCOM-W1 will enter the A-train in front of Aqua. Yamanashi also showed plans for the standard algorithms at launch, the data distribution system, the websites, and validation activities. **Keiji Imaoka** [JAXA Earth Observation Research Center] gave more details about AMSR2 and its status. The earthquake that hit northern Japan on March 11, 2011, destroyed the building where GCOM-W1 was being prepared for thermal vacuum testing. Luckily, the satellite was not damaged. It took three months to clean all satellite surfaces, and on June 13, 2011, the satellite was deemed to be back to its pre-earthquake status.

The meeting concluded with discussions about the upcoming *Aqua@10* session at the American Geophysical Fall Meeting in San Francisco, CA. ■

2011 CLARREO Science Definition Team (SDT) Meeting

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The first meeting of the recently selected Climate Absolute Radiance and Refractivity Observatory (CLARREO) Science Definition Team (SDT) was held from May 17–19, 2011, at the National Institute of Aerospace (NIA) in Hampton, VA. Approximately 40 attendees participated in the meeting, including representatives from NASA Headquarters (HQ), NASA's Langley Research Center (LaRC), NASA's Goddard Space Flight Center (GSFC), NASA's Jet Propulsion Laboratory (JPL), academia (Harvard University, University of Wisconsin, University of Miami, University of Maryland, University of Michigan, University of California at Berkeley, and Imperial College), and other federal agencies [National Institute of Standards and Technology (NIST) and National Oceanic and Atmospheric Administration (NOAA)].

2011 CLARREO Science Definition Team meeting participants.

The CLARREO SDT was selected in January 2011 in anticipation of the start of *Phase A,* following the fully successful Mission Concept Review in November 2010. However, the goals of the SDT have shifted in the aftermath of the president's proposed FY 2012 budget, which directed the team to delay implementation of the mission. The new NASA budget guidelines call for an extended *preformulation* period for CLARREO mission definition, which includes funding for the SDT. During this extended *Pre-Phase A,* the mission and science team will continue to advance the science of CLARREO while working to identify implementation options for obtaining elements of the measurement suite outside of a dedicated series of CLARREO satellites.

The primary focus of the meeting was on the presentation of recent results and the proposed research plans for each of the SDT investigators. The meeting also provided a forum for identifying opportunities for collaboration, integrating proposed studies into a Pre-Phase A science plan, and identifying studies to assist the development of alternative methods of achieving CLARREO's science goals.

Presentations from the meeting are available at the CLARREO website: *clarreo.larc.nasa.gov*.

Workshop Introduction

Dave Young [LaRC—*CLARREO Project Scientist*] welcomed the attendees, led the introduction of the new team members, and summarized the objectives of the meeting. Young identified key goals for the SDT, which included advancing CLARREO-related science, publishing science work to-date, and serving as a primary link to the external science community. He also led a discussion on team roles and guidelines for future interactions among the investigators and with the project.

Bruce Wielicki [LaRC—*Mission Scientist*] gave an overview of the current baseline plan for Pre-Phase A, which included refocusing CLARREO science and engineering on less-expensive options that address some portion of the CLARREO science goals; evaluating alternative mission options, including instruments of opportunity or large long-term aircraft instrument campaigns, international collaboration, interagency collaboration, or other mission implementations; documenting science results via peer-reviewed publications; and completing the Calibration Demonstration Systems (CDS) for infrared (IR) and reflected solar (RS) spectrometers that will be used to reduce the risk of developing these high-accuracy instruments.

Mission Concept Review (MCR) Recap

CLARREO held a successful Mission Concept Review (MCR) in November 2010 where the team presented a mission architecture concept that achieved all science objectives, satisfied all science and measurement requirements, demonstrated technical readiness, was responsive to all cost and schedule guidance, and explicitly planned for cost-effective sustainability. The mission architecture consisted of four small spacecraft: two reflected solar observatories, which include the infrared (IR) and Global Navigation Satellite System Radio Occultation (GNSS-RO) instruments, to be launched in 2017; and two observatories, to be launched in 2020.

Bruce Wielicki provided a recap of the CLARREO science presented during the MCR. He recapped the methods used to rigorously define the science and measurement requirements for the mission, and the rigorous methods used to evaluate the science value of the candidate mission architectures.

Jim Corliss [LaRC—*CLARREO Chief Engineer*] walked through the engineering design cycles that led to the design concept presented at the CLARREO MCR. Prior to the MCR, the team studied a broad range of candidate designs and worked with the science team to develop a robust framework to quantitatively assess science value vs. cost. This enabled the development of a flexible mission architecture that met all budget, schedule, and technological constraints.

Marty Mlynczak [LaRC—*CLARREO Deputy Project Scientist/IR Science Lead]* discussed the MCR conceptual designs for both the IR and GNSS-RO instruments. For the IR instrument, Mlynczak highlighted those hardware components that have matured through the Instrument Incubator Program (IIP). He summarized the Pre-Phase A plans for completing the IR CDS and testing International System of Units (SI) traceability at CLARREO accuracy levels. For the GNSS-RO, Mlynczak provided an overview of the MCR requirements and error budget. He provided updates regarding development of the JPL TriG—a GNSS precise-orbit and radio-occultation space receiver.

Kurt Thome [GSFC—*CLARREO Deputy Project Scientist/Reflected Solar (RS) Science Lead*] summarized the MCR requirements and conceptual design for the RS instrument. The design for the SOlar, Lunar for Absolute Reflectance Imaging Spectroradiometer (SOLARIS) instrument leverages existing hardware and will measure the blue channel (320–640 nm) with silicon detectors, and the red/near-infrared (NIR) channel (600–2300 nm) with mercury/cadmium/telluride (HgCdTe) detectors. Thome described the calibration approach, technology developments to improve accuracy, and progress made to-date on development of SOLARIS and the RS (CDS).

SDT Investigator Presentations

Dan Feldman [University of California-Berkeley] shared results from his RS Observing System Simulation Experiment (OSSE). Feldman simulated RS reflectance spectra for the twenty-first century based on two emission scenarios in an attempt to demonstrate the use of CLARREO to detect changes in the climate system relative to natural variability. The key result is that CLARREO spectral RS measurements will provide the means to detect change faster than existing broadband measurements. Feldman also presented the first results from a panspectral OSSE, illustrating the valuable complementarity provided by the CLARREO IR radiance and RS reflectance measurements.

Brian Soden [University of Miami] gave a brief overview of the *radiative kernel* concept that is used to simplify the method for computing climate feedbacks in climate modeling. The method compares two climate scenarios (global warming vs. a control) and computes feedbacks for each. The radiative kernel method is computationally efficient and provides insight into climate model physics. The initial analysis for CLARREO reinforced the five-year data record length targeted by the MCR design to define a reference climate state. Future plans include developing and analyzing spectrally resolved kernels for feedback and detection/attribution studies.

Peter Pilewskie [Laboratory for Atmospheric and Space Physics (LASP)] presented results from the use of scattered spectral shortwave data from the Scanning Imaging Absorption spectrometer for Atmospheric Cartography (SCIAMACHY) to define requirements and to develop methods for trend detection and attribution. Top-of-atmosphere (TOA) outgoing RS spectral radiance trends were tested using modeled simulations with known forcings, resulting in improved quantification of CLARREO requirements. These results highlight the importance of providing the entire spectral range planned for CLARREO (i.e., RS: 320–2300 nm; IR: 5–50 μm).

Zhonghai Jin [Science Systems and Applications, Inc. (SSAI)] discussed progress on using the RS spectral radiative kernel and fingerprinting for CLARREO measurements. Using observational data from Clouds and Earth's Radiant Energy System (CERES)/Moderate Resolution Imaging Spectroradiometer (MODIS) /Geostationary Operational Environmental Satellites (GOES), a set of solar spectral radiative kernels was created, pertinent to the mean reflectance and climate parameter variations over large spatiotemporal domains. These kernels provided a simple way to separate the radiative response into various dependent parameters and to test fingerprinting techniques for CLARREO.

Constantine Lukashin [LaRC] presented an overview of the CLARREO RS reference intercalibration (RI) approach. He noted that the allowable CLARREO RS *error budget* is set at 0.3% (k=2) for the spectrally integrated broadband radiance. Consequently, the uncertainty contribution from RI can be no more than 0.3% (k=2) over an 18-month time period. Lukashin evaluated multiple contributors to the RI error budget, including uncertainty of the target imager's sensitivity to polarization, errors in empirical polarization distribution models (PDMs), and sampling errors. The results of this study suggest that for well-behaved sensors (i.e., residue error 0.1% (k=1)) one can expect that using CLARREO for RI would result in imager calibration improvement to a level of 0.3% – 0.5% (k=1).

Wenbo Sun [SSAI] described his methodology for modeling polarized radiation for CLARREO intercalibration applications, which included the sensitivity of polarization to wavelength, atmospheric gas absorption, aerosols, cloud optical thickness, and incidence angle. Future work includes modeling the land surface bidirectional reflectance distribution function, studying the spectral response of polarized radiance over both ocean and land, and defining CLARREO PDM algorithm and data structure.

Jim Butler [GSFC] emphasized the importance of engaging agency and interagency missions and projects, science and user communities, and actively supporting international activities [e.g., Committee on Earth Observation Satellites (CEOS), Global Space-based Intercalibration System (GSICS)] for guidance and lessons learned from previous sensors. Butler recommended identifying potential sensors for a CLARREO intercalibration study and evaluating current RS intercalibration methodologies using lunar calibration, simultaneous nadir overpass (SNO) ratios, and observations vs. model predictions. Butler also described the potential development of an uncertainty analysis tool that could be adapted to identify and quantify pre- and post-launch CLARREO RS instrument uncertainties.

John Dykema [Harvard University] addressed the need for climate records that can be tested for systematic errors while on orbit and for high-accuracy vs. high-precision measurements. Dykema noted that if the observations have sufficient precision, then the measurements can be overlapped, but some of these attempts have been met with challenges. Dykema discussed the importance of SI-traceable measurements in understanding climate change, and the need for CLARREO to demonstrate the highest-quality accuracy traceability for the climate observing system.

Hank Revercomb [University of Wisconsin-Madison (UW)] provided an overview of CLARREO IR measurement science. He summarized the history of space-based hyperspectral IR instruments, and reviewed improvements in sampling, spectral coverage, and on-orbit traceability that CLARREO could provide for climate studies. Revercomb showed results from UW's Absolute Radiance Interferometer System and On-orbit Absolute Reference Standard, which would be used to test the interferometer on orbit.

Dave Tobin [UW] began by discussing the importance of high spectral resolution measurements for IR intercalibration. He cited results from an Atmospheric Infrared Sounder (AIRS)/MODIS radiance comparison that uncovered differences in the longwave carbon dioxide (CO_2) bands that could be nearly eliminated by the introduction of spectral shifts for the affected MODIS bands. Tobin also presented comparisons of AIRS and the European Space Agency's Infrared Atmospheric Sounding Interferometer (IASI), which revealed no noticeable trends in these data—testimony to the performance of both instruments. Tobin noted that with CLARREO, these types of comparisons could be made on a more-routine basis, improving the overall calibration of the operational IR sounders.

Bob Knuteson [UW] described his work on an IR radiance benchmark product analysis, with an emphasis on refining mission and measurement requirements using a CLARREO IR proxy dataset derived from AIRS observations. The dataset was used to characterize natural variability from 3.5–15 µm and to evaluate the sensitivity of variability to CLARREO's field-of-view diameter. Results from the CLARREO IR proxy datasets will be used to determine variability on regional scales, and to develop methods to interrogate climate models using observations.

Bill Smith [UW] presented results on developing IR retrieval algorithms for climate studies. Smith outlined the required features of climate retrieval algorithms, such as linear dependence on radiance spectra, all-sky capabilities, and independence of field-of-view size. Using a dual-regression technique that linearizes cloud and moisture dependence through classification, Smith demonstrated that the algorithm produces consistent results even when observations from several different instruments with differing characteristics are used.

Larrabee Strow [University Maryland-Baltimore County] discussed recent results from a study of the AIRS radiance record that examined radiometric stability estimates, radiance liens, and methods for combining AIRS data with IASI/Cross-track Infrared Sounder data. Strow also showed initial results on the use of reanalysis data to improve CLARREO estimates of cloud forcing and the benefits of binning the observed time series before analysis to improve climate fingerprinting.

Yi Huang [Harvard University] described a statistical approach for improving model ensemble-based multidecadal climate predictions for CLARREO measurements. Huang concluded that CLARREO measurements are well chosen for constraining ensemble prediction uncertainties and, when used together, have the potential over the next 20 years to reduce uncertainty in 50-year temperature trend predictions by as much as 50%. He also noted that the key to prediction improvement is trend measurement accuracy, which imposes a challenging requirement on most climate observing systems; this is where CLARREO finds a unique niche.

Xianglei Huang [University of Michigan] shared his work regarding the linearity of spectral radiances averaged over a large spatial domain and a long timescale. Using simulations from the European Centre for Medium-range Weather Forecasts (ECMWF) Reanalysis (ERA)-interim data, he examined the sensitivity of radiance averages to surface emissivity and spatiotemporally varying greenhouse gas and ozone profiles. Huang also discussed recent results from developing and validating spectral algorithms for deriving 10-cm^{-1} spectral flux over the full IR spectrum.

Nipa Phojanamongkolkij [LaRC] discussed the effects of uncertainty in the IR measurements on derivation of spectral fingerprint temperatures. Phojanamongkolkij also described the results of implementing a successful framework for applying fingerprinting to help define IR systematic error distribution across specified wavenumbers and scene temperatures that enable the derivation of physical parameters (e.g., water vapor feedback) and help define the IR instrument requirements.

Seiji Kato [LaRC] used Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), CloudSat, MODIS, and CERES data to derive cloud fields and model spectral radiances to examine trend detection in spatially and temporally averaged IR spectra. Kato used CERES TOA anomalies to establish baseline natural variability, produced a retrieval simulation and error estimate, and examined the effect of small-scale variability on spectral radiance differences.

Xu Liu [LaRC] discussed the advantages of using hyperspectral remote sensing data and why radiative transfer models are a key component in quantifying the relationship between satellite data and atmospheric properties. Liu also discussed climate-related parameter retrievals, and focused on the use of the principal-component-based radiative transfer models (PCRTM) as efficient tools for analyzing large quantities of hyperspectral data.

Richard Bantges [Imperial College London] discussed the feasibility and sensitivity studies his team has been working on for CLARREO, specifically looking at IR spectral signatures from satellite interferometer data, modeled clear-sky IR variability from ERA interim data, and all-sky sampling studies using Spinning Enhanced Visible and Infrared Imager (SEVIRI) data.

Stephen Leroy [Harvard University] discussed their work regarding SI traceability, information content, accuracy requirements, and sampling error using *Bayesian interpolation* for GNSS RO observations. A key result is the identification of a systematic sampling error due to sampling singularities that occur at 48° and 21° latitude (in both hemispheres), in RO coverage. The use of Bayesian interpolation greatly reduces systematic and random error, which could result in relaxation of CLARREO RO sampling requirements.

Chi Ao [JPL] presented results of uncertainty analyses for GNSS RO observations above 20 km (i.e., the stratosphere) and below 5 km (i.e., the lower troposphere). Ao discussed approaches for reducing systematic measurement errors, such as using GNSS signals to reduce ionospheric residual error and reducing random errors through vertical smoothing. Ao noted that for the stratosphere, ionospheric residual error is likely due to solar and diurnal variability, and will be most problematic for climate studies. Ao stated that a well-calibrated GPS receiver will be flown as part of the Geodetic Reference Antenna in Space (GRASP) mission, improving SI traceability for the RO instrument by providing excellent transmit antenna phase center calibration, low local multipath, and very accurate orbits.

David Doelling [LaRC] described the results of a study of spatial and temporal sampling errors from potential payload-hosting options, including the International Space Station (ISS) at a 51° orbit and Iridium at an 86° orbit. Doelling used the five-year CERES dataset and simulated orbital sampling to assess temporal sampling errors for CLARREO instruments on these platforms. Iridium provides near-global coverage, but the constellation's slow precession results in high sampling errors. The ISS provides excellent temporal sampling and unbiased annual means, but non-global coverage.

Invited External Presentations

The SDT received a briefing on two missions that share science objectives with CLARREO that were recently proposed to the European Space Agency's (ESA) Earth Explorer program. Both missions rated highly, but were not selected. CLARREO is exploring potential teaming opportunities with both groups.

Kurt Thome [GSFC]—for **Nigel Fox** [National Physical Laboratory-U.K.]—provided an overview of the Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS) mission concept. TRUTHS is designed to establish benchmark measurements in the RS domain for detecting decadal change using direct sampling and reference calibration of other sensors. Thome stated that TRUTHS is highly complementary to CLARREO and also potentially offers an opportunity for international collaboration.

Helen Brindley [Imperial College London]—for **Luca Palchetti** [Italian National Research Council]—presented an overview of the Far-infrared Outgoing Radiation Understand and Monitoring (FORUM) explorer instrument. FORUM focuses on studying the forcing/feedback effect on the climate system from atmospheric water, in the form of water vapor and clouds. FORUM provides —for the first time on a global scale from space—spectrally resolved terrestrial emissions in a broad spectral range that includes the far IR region.

Technology Presentations

Joe Rice [NIST] presented NIST's capabilities related to calibration and characterization of the CLARREO RS instrument. These capabilities include access to the Spectral Irradiance and Radiance Responsivity with Uniform Sources (SIRCUS), the Hyperspectral Image Projector (HIP), and the Absolute Spectrally Tunable Detector-Based Source.

Sergey Mekhontsev [NIST] described NIST's capabilities related to calibration and characterization of the CLARREO IR instrument. The CLARREO team continues to work with NIST to ensure that the IR instrument is designed to provide on-orbit calibration traceability at the required accuracy. CLARREO and NIST are also working to advance traceability standards in the far-IR.

Keith Murray [LaRC] provided an overview of the extensive investment in CLARREO-related technology made by NASA's Earth Science Technology Office.

Dave Young [LaRC] led a general discussion of the strategy for moving forward, including identifying critical science studies, identifying and pursuing partnership opportunities, developing communications strategy, and planning for documentation of key science results and potential mission implementation options.

Conclusion

The central goal of the CLARREO mission is to provide accurate, broadly acknowledged climate records that can be used to validate long-term climate projections that become the foundation for informed decisions on climate change mitigation and adaptation policies. Although the SDT is very disappointed that CLARREO has not been approved to proceed to Phase A, they remain collectively committed to developing cost-effective strategies to achieve this essential science objective. ■

Summary of the 39th Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER Science Team Meeting

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Thermal-infrared Imaging of Weathering and Alteration Changes on the Surfaces of Basalt Flows in Hawaii, by **E. Abbott** [JPL]. Wessels and **D. Pieri** [JPL] gave an update of GLIMS and the ASTER Volcano Archive project, respectively. Pieri reported on progress in TIR detection of persistent low-temperature eruption precursor anomalies, and on using Shannon entropy to successfully identify changes in VNIR scenes. New AIs were discussed and assigned.

Closing Plenary Session

After the splinter sessions, the groups reconvened for a closing plenary session to summarize the outcome of each working group's session. **M. Abrams** announced that the next ASTER Science Team Meeting would be held in the U.S. during the week of December 12, 2012. ■

NASA's DC-8 Flying Lab Validates Laser Instruments

Beth Hagenauer, NASA's Dryden Flight Reserach Center, beth.hagenauer-1@nasa.gov

Twenty scientists went aloft aboard NASA's DC-8 flying laboratory in late July to conduct an airborne test of four very different laser techniques for remotely measuring atmospheric carbon dioxide (CO_2) and two laser instruments that remotely measured oxygen. The DC-8 also carried two "truth" instruments—devices that are known to produce accurate data—that took air samples to be compared with the laser measurements.

The flights were part of a research campaign dubbed Active Sensing of CO_2 Emissions over Night, Days and Seasons II (ASCENDS II); these aircraft flew over central California on July 28.

The focus of this mission, which is funded by the Earth Science division of NASA's Science Mission Directorate, is the further development of laser-based Earth-observing satellite instruments designed to measure atmospheric CO_2.

"Satellite instruments start in a laboratory and mature to a point where they need to be used in the atmosphere," said DC-8 project manager **Frank Cutler** at NASA's Dryden Aircraft Operations Facility. "The cheapest way to test is first on the ground and then to get the instruments into the air for in-flight analysis.

"The DC-8 flying laboratory is often used to facilitate these assessments," Cutler added. "It is interesting to observe what an instrument that will fly on a satellite goes through to be certified for operational use."

This spectacular view of a large glacier in British Columbia, Canada, was captured from NASA's DC-8 flying laboratory during one of the ASCENDS II atmospheric sampling instrument validation flights. **Image Credit:** Natural Sciences and Engineering Research Coucil/Emily Schaller.

During an instrument-validation flight over central California, the DC-8 first flew descending and ascending spiral patterns above the Castle Airport area near Merced to take sample gas measurements with the truth instruments. The laser instruments were then flown over the airport at various altitudes up to 40,000 feet so that their data could be compared with that of the truth instruments.

The aircraft flies the instruments over different land surfaces, from snow and ice to oceans, forests, and deserts to test the surface reflectance effects on each instrument's performance. These are the same types of surfaces that a laser instrument would find when studying components of the Earth's atmosphere from space.

NASA's DC-8 flying science laboratory departs Air Force Plant 42 in Palmdale, CA, on another environmental science mission. **Image credit:** NASA/Tony Landis

Additional flights will take the aircraft over the California and Nevada deserts and offshore over the Pacific Ocean. During an early August flight to British Columbia, Canada, the instruments collected data over snowfields in mountainous regions. The aircraft will also deploy briefly to Minneapolis and St. Paul, MN, to fly over atmospheric radiation measurement sites for comparison of airborne to ground-based measurements.

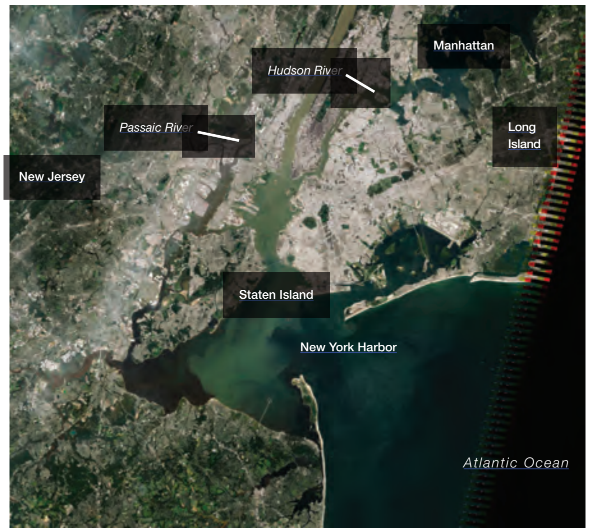
"Conducting unique flight experiments on the DC-8 is very exciting and is as close as many of us will get to being a modern day explorer," said ASCENDS II mission scientist **Edward Browell** of NASA's Langley Research Center, who has conducted more than 25 DC-8 science missions around the world since 1987.

The instrument teams are from NASA's Langley Research Center, NASA's Goddard Space Flight Center, ITT Geospatial Systems, and NASA/Jet Propulsion Laboratory. A similar ASCENDS instrument validation mission was previously flown in July 2010. ■

Landsat 5 Satellite Sees Irene-generated Sediment in New York Harbor

Mike Carlowicz, NASA Earth Observatory/NASA's Goddard Space Flight Center, michael.j.carlowicz@nasa.gov

In the wake of Hurricane Irene's heavy rains, sediment filled many rivers and bays along the U.S. East Coast. New York's Hudson River and estuary was no exception. In this true-color satellite image, pale green and tan water flows past Manhattan and mixes with the darker waters of New York Harbor and the Atlantic Ocean.



This image was acquired on August 31, 2011, when Landsat 5 viewed the coast from the Carolinas to New York. Color generally correlates with the amount and type of sediment: lighter green and tan areas have more suspended silt and sand than dark blue waters. Brown waters likely indicate more mud or leaf tannins from inland runoff; the Passaic River in New Jersey is an example.

In addition to soil and sand, flooding rivers can carry sewage, pesticides, and excess fertilizer. After Hurricane Floyd struck in 1999, scientists used similar satellite data to map flood waters in North Carolina.

Editor's Note: This article makes frequent references to colors. The full-color image can be found online: *http://eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*. To see the full Landsat 5 U.S. East Coast scene and zoom into particular areas, visit: *gigapan.org/gigapans/85783/*. ■

Immerse Yourself in NASA Science at the 2011 Fall AGU Meeting

Please plan to visit the NASA booth (# 1637) during this year's American Geophysical Union (AGU) Fall Meeting! Throughout the week we will be showing a variety of our NASA Science data images in vibrant, high-definition color on the *hyperwall*—a dynamic, nine-screen display that will serve as the centerpiece of our exhibit.

The hyperwall will be used in a variety of individual presentations to help illustrate phenomena, ideas, and examples of world change—including a presentation given by NASA's Chief Scientist, **Waleed Abdalati**. There will also be a wide range of other science presentations, demonstrations, printed material, and tutorials on various data tools and services at the booth.

This year's exhibit hall will open on Tuesday, December 6th, and will continue through Friday, December 9th. There are several different programs and missions scheduled to participate—representatives from Dryden, Ames, Jet Propulsion Laboratory, Goddard, Langley, and Wallops are expected.

Presentations will cover a diverse range of research topics, science disciplines, and programs within NASA's Science Mission Directorate. Learn about new and upcoming missions like Aquarius, NPOESS Preparatory Project (NPP), Global Precipitation Measurement (GPM), the Gravity Recovery and Interior Laboratory (GRAIL), Juno, Mars Science Laboratory Curiosity Rover, and others.

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

We hope to see you in San Francisco!

NASA Earth Science in the News

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

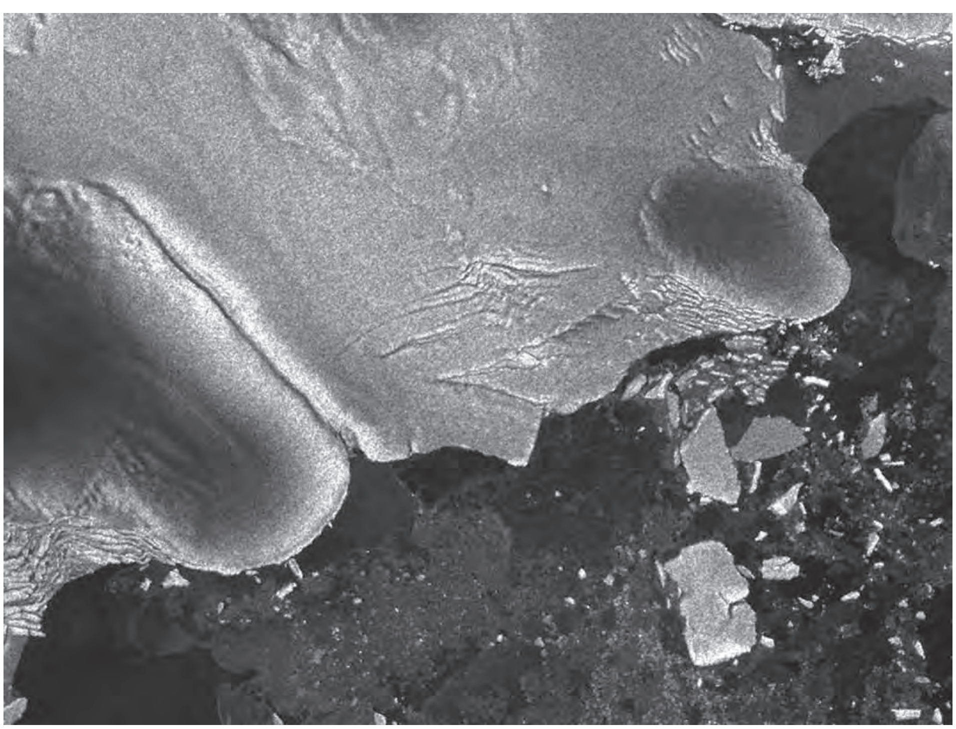
Arctic Landscape Anything But Boring, July 14; *Our Amazing Planet.* Researchers on the NASA-funded **ICESCAPE** [NASA Headquarters] mission examined *melt ponds*, the ice around them, and the waters below from late June through July. Carried by the U.S. Coast Guard Cutter *Healy*, a team of oceanographers, marine biologists, and glaciologists are investigating how changing conditions in the Arctic affect the ocean's chemical and biological makeup.

*__NASA Releases iPad App For Science Research__, July 26; *cnet.com*. A new *iPad* application that publishes two stories based on Earth science data visualization each week was reviewed extensively by technology websites. The app was created by a team at the *Scientific Visualization Studio* [NASA's Goddard Space Flight Center (GSFC)] over the past year or so, and for the time being, features only NASA Earth science, but may expand its scope in the future.

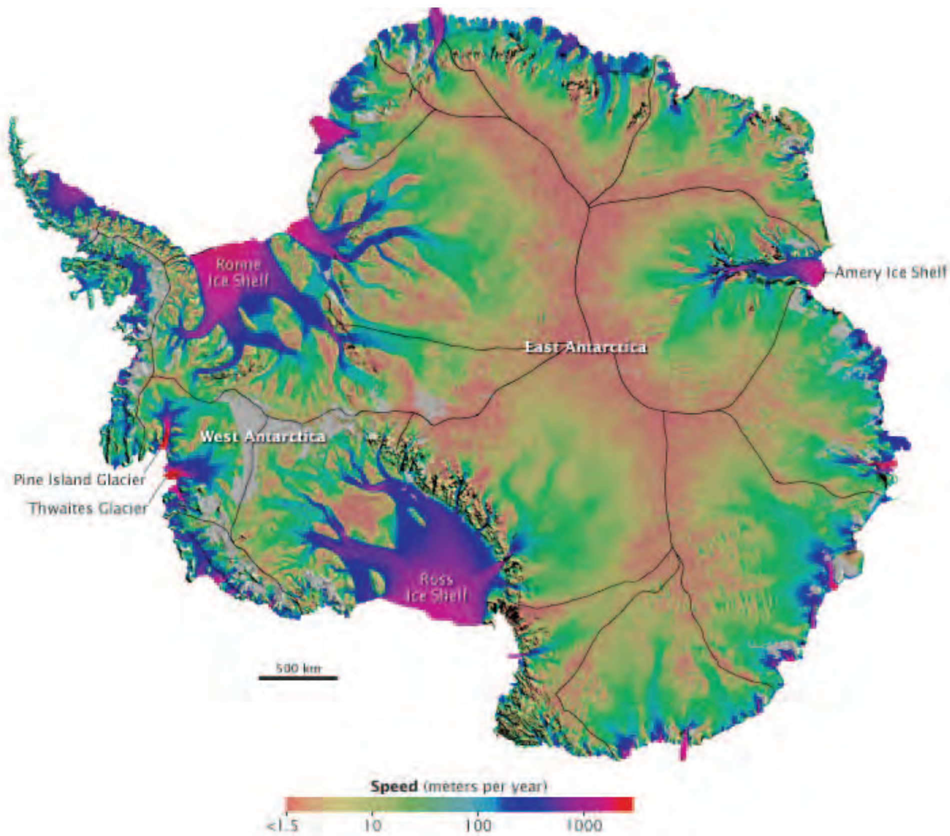
Detailed Look At Ice Loss Following Antarctic Ice Shelf Collapse, July 27; *International Business Times*. Scientists have provided the clearest account yet of how much glacial ice flows into the sea following the collapse of an Antarctic ice shelf. Glacier ice loss has increased dramatically following the collapse of Larsen A and B ice shelves. "This further demonstrates how important ice shelves are to Antarctic glaciers," said lead author **Christopher Shuman** [GSFC/University Maryland, Baltimore County).

NASA's Eyes In The Sky Study Pollution On Earth, July 29; *NPR*. The persistent problem of improving satellite measurements of air quality was targeted this summer with *DISCOVER-AQ* research flights over Baltimore, MD and Washington, DC. This *Morning Edition* featured piece quoted **Jim Crawford** and **Bruce Anderson** [Langley Research Center (LaRC)], and **Ken Pickering** [GSFC].

July 4th Was Warmest On Record, Aug. 8; *Orange County Register.* As the National Oceanic and Atmospheric Administration declared this July one of the warmest on record, **Bill Patzert** [Jet Propulsion Laboratory (JPL)] explained why California has largely been spared the scorching weather experienced in some drought-stricken states.



This satellite radar image shows icebergs floating away from the Sulzerberger Ice Shelf in Antarctica on March 16, 2011, days after the Tohoku [Japan] earthquake and tsunami occurred. Sea swell from the tsunami caused the iceberg calving. **Image Credit:** European Space Agency/ Envisat



This new view of Antarctica in motion comes from thousands of measurements between 1996–2009. **Eric Rignot** of NASA/Jet Propulsion Laboratory led the team of scientists that pieced together the data to figure out how much each section of ice moves per year.

Japan's Tsunami Rips Icebergs Double The Size of Manhattan From Antarctica, August 8; *PopularScience.com*. Cryosphere specialist **Kelly Brunt** [GSFC] and colleagues immediately began watching Antarctica after the Tohoku [Japan] tsunami in March of this year. Brunt was looking for evidence that tsunami waves could cause iceberg calving, and she found it. Her team chronicled the first direct observation of Antarctic iceberg calving caused by a tsunami, in a story that was picked up by major media outlets worldwide.

Small Volcanoes Add Up To Cooler Climate, August 13; *Sciencenews.org*. An increased level of background stratospheric aerosols over the past decade—due to volcanic activity—has dampened the warming that would have otherwise occurred during the time period, according to a paper in *Science.* The paper used data from Stratospheric Aerosol and Gas Experiment II (SAGE-II) and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and included co-authors **Jean-Paul Vernier** and **Larry Thomason** [LaRC].

Earth Isn't Getting Fatter, Scientists Confirm, August 16; *msnbc.com*. Earth's radius is changing by about 0.004 in per year, a number that is statistically insignificant and proves that our planet is not expanding. "Our study provides an independent confirmation that the solid Earth is not getting larger at present, within current measurement uncertainties," said **Xiaoping Wu** [JPL].

Simple Surface Belies Complicated Nature of California Fault, August 16; *Our Amazing Planet.* A fault that appeared straight and simple at the surface and caused a 7.2-magnitude earthquake in Mexico in 2010 was in fact warped and complicated underground, according to a team led by California Institute of Technology scientists and that included **Eric Fielding** [JPL].

Mapping Antarctic Ice In Motion, Aug. 18; *nytimes.com*. A new map that resulted from collaboration during the International Polar Year and combined data from Japanese, Canadian, and European satellites has provided the first complete map of Antarctic ice flow, said lead author **Eric Rignot** [JPL/University of California, Irvine].

* See announcement in this issue for more details.

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

NASA Science Mission Directorate – Science Education and Public Outreach Update

Theresa Schwerin, Institute of Global Environment and Society (IGES), theresa_schwerin@strategies.org
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NASA NPP Educator Launch Conference

October 24–25; Santa Maria, CA

Witness the launch of NASA's next-generation weather and Earth science mission! The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project [NPP] mission will help "bridge" the current generation of Earth-observing satellites, called the Earth Observing System (EOS), to the next-generation of operational polar-orbiting environmental satellites called the Joint Polar Satellite System (JPSS). This educational program will provide a personal tour of the NASA Mission Director Center, close-up viewing of the Delta-*II* launch vehicle before and during launch, as well as hands-on practical educator workshops and presentations from NPP investigators at NASA and the National Oceanographic and Atmospheric Administration (NOAA) principal investigators.

Registration is $75 and includes lunch and dinner, curriculum/activities, on-site transportation, materials fees, NASA T-shirt, lanyards, and Allen Hancock College training certificate. Participants are responsible for their travel and lodging costs (discounted rooms are available). For more information and to register, visit: *endeavourinstitute.org/launch_conference.html*.

MY NASA DATA Lesson 64: Evidence of Change Near the Arctic Circle – Grades 8–12

The place where global climate change is most evident is within the Arctic Circle. In this lesson, students use the Live Access Server to explore data from the Arctic, develop relationships between parameters and make conclusions based on the collected evidence. Detailed procedures and materials, vocabulary linked to an online glossary, and teacher notes are provided at: *mynasadata.larc.nasa.gov/preview_lesson.php?&passid=98*.

2011 Association of Science-Technology Centers (ASTC) Annual Conference

October 15–18; Maryland Science Center and Baltimore Convention Center, Baltimore, MD

Visit the NASA Science Education and Public Outreach Forums (exhibit hall booth #649) at the 2011 annual ASTC conference. Here, you can obtain education materials, learn about NASA Science Mission Directorate-funded education programs, and participate in in-booth activities and demonstrations. NASA HQ is also hosting a booth, along with an Astronomy and Aerospace Showcase. For more information, visit: *conference.astc.org/*.

NESTA Workshops at Fall 2011 NSTA Area Conferences

October 28, November 11, and December 9

The National Endowment for Science, Technology, and the Arts (NESTA) will be offering workshops at all three National Science Teacher's Association (NSTA) Area Conferences this fall. In addition to their traditional Share-a-Thon and Rock and Mineral Raffle, they will also be offering workshops on Earth Systems science, climate change, and geology leveraging the new program, *Windows to the Universe* (*www.windows2universe.org/*). This popular educational resource contains over 9,000 pages of content spanning Earth and space science at elementary to high school levels, as well as over 100 tested classroom activities ready for immediate use.

All of the events provide a full day of Earth science professional development, and are free with registration at the NSTA conference. Workshops will be held at the following:

- October 28; Connecticut Convention Center, Hartford, CT;
- November 11; Ernest M. Morial Convention Center, New Orleans, LA; and
- December 9; Washington State Convention Center, Seattle, WA.

For more information, and to submit to present in the Share-a-Thons, visit: *https://www.nestanet.org/cms/sites/default/files/documents/NESTA_Workshops_Fall_2011_NSTA.pdf*.

NASA Tweetup for NPP Satellite Launch

Registration Open Noon ET, September 13 until 5 p.m. ET, September 15

NASA will invite 25 of its U.S. Twitter followers to a Tweetup expected to culminate in the launch of the first of a new generation of Earth-observing satellites from Vandenberg Air Force Base in California. The event will take place from 9 a.m.–5 p.m. PT on Monday, October 24. NASA's NPP satellite is scheduled to launch between 2:48 a.m. and 2:57 a.m. on Tuesday, October 25. For more information about the Tweetup and to register, visit: *www.nasa.gov/tweetup*. ■

EOS Science Calendar

October 12–13, 2011
SMAP Applications Workshop #2, Washington, DC. URL: *smap.jpl.nasa.gov/science/workshops/*

October 13–14, 2011
LPVEx Data Coordination and User Workshop, Helsinki, Finland. URL: *lpvex.fmi.fi/*

October 19–21, 2011
Sea Surface Temperature Science Team Meeting, San Diego, CA. URL: *depts.washington.edu/uwconf/ostst2011/*

November 7–10, 2011
Precipitation Science Team Meeting, Denver, CO. URL: *pmm.nasa.gov/meetings/all/2011-pmm-science-team-meeting*

November 8–11, 2011
Sounder Science Team Meeting, Greenbelt, MD. URL: *airs.jpl.nasa.gov/meetings/science-team-greenbelt/*

Global Change Calendar

October 15–21, 2011
36th National Weather Association (NWA) Annual Meeting/7th GOES Users' Conference (GUC), Wynfrey Hotel, Birmingham, AL. NWA registration: *www.nwas.org/meetings/nwa2011/*. Contact for GUC: Kenneth Carey, *kenneth.carey@noaa.gov*, 703-610-1933, GUC registration: *directreadout.noaa.gov/GUC_VII/index.htm*

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

November 7–11, 2011
2011 IYC Ozone Symposium on Stratospheric Ozone and Climate Change, Washington, DC. URL: *www.2011-iyc-o3.org/home*

November 28–December 9, 2011
United Nations Conference on Climate Change (COP 17), Durban, South Africa. URL: *www.cop17durban.com/*

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

January 22–26, 2012
American Meteorological Society 92nd Annual Meeting, New Orleans, LA. URL: *annual.ametsoc.org/2012/*

February 16–20, 2012
AAAS Annual Meeting, Vancouver, Canada. URL: *www.aaas.org/meetings/2012/*

February 20–24, 2012
2012 Ocean Sciences Meeting, Salt Lake City, UT. URL: *www.sgmeet.com/osm2012/*

March 19–23, 2012
ASPRS 2012 Annual Conference, Imaging and Geospatial Technologies—Into the Future, Sacramento, CA. URL: *www.asprs.org/Annual-Conferences/Sacramento-2012/*

March 26–29, 2012
Planet Under Pressure 2012, London, England. URL: *www.planetunderpressure2012.net/location.asp*

May 7–11, 2012
The 44th International Liège Colloquium on Ocean Dynamics, Liège, Belgium. URL: *modb.oce.ulg.ac.be/colloquium/*

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