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Editor's Corner

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After nearly 29 years in orbit, the longest operational satellite mission in history has come to an end. One of Landsat 5's three operational gyroscopes failed on November 4, 2012, and the U.S. Geological Survey (USGS) and NASA subsequently made the decision to end the mission—since control of the satellite would be impossible if another gyro fails. On January 15, the USGS's Flight Operations Team successfully executed the first in a series of maneuvers that will lower Landsat 5 from its operational orbit.

By any standard, Landsat 5 was an extraordinary success. The satellite's Multispectral Scanner (shut down in 1995, and briefly reactivated near the end of the mission) and Thematic Mapper instruments achieved an unprecedented multi-decadal record of Earth observations, helping us to gain a better understanding of land surface changes and the human impact on the planet. Landsat 5 completed over 150,000 orbits and transmitted over 2.5 million images, and its sun-synchronous low Earth orbit eventually became home to other missions. This group of satellites became known as the *Morning Constellation*—referring to their morning overpass times.

While Landsat 5 ends, current and upcoming missions continue to grow the Landsat legacy. Landsat 7, launched in 1999, continues to operate well beyond its projected five-year mission lifetime (despite a long-standing anomaly with the Scan Line Corrector). The next launch is imminent; the Landsat Data Continuity Mission (LDCM[1]) is scheduled to launch on February 11 from Vandenberg Air Force Base in southern California. Discussions are underway regarding the follow-on mission to continue this important record of Earth observations.

Meanwhile, many satellites in NASA's Earth observation fleet continue to reach well beyond their prime mission lifetime. The Solar Radiation and Climate Experiment (SORCE) celebrated the tenth anniversary of its 2003 launch on January 25. SORCE observes solar irradiance, a critical quantity needed for understanding the impact of solar variability on climate. SORCE instruments measure the solar spectral irradiance (SSI) in the ultraviolet, visible, and near/shortwave infrared as well as the total solar irradiance (TSI). SORCE has exceeded all science objectives. Most notably, SORCE's state-of-the-art Total Irradiance Monitor (TIM) instrument established a new lower TSI level near 1361 W/m^2. The mission has also developed reference SSI spectra for use in Earth's atmosphere and climate models to better understand Sun-climate changes. *"The SORCE observations have been*

[1] Following launch, the LDCM satellite will be renamed Landsat 8.

continued on page 2

This composite map of the Earth at night was assembled from data acquired by the Suomi NPP satellite in April and October 2012, and can be found online at *earthobservatory.nasa.gov/NaturalHazards/view.php?id=79765.* **Image credit:** NASA Earth Observatory image by **Robert Simmon**, using data Suomi NPP VIIRS data provided courtesy of **Chris Elvidge** from NOAA.

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critical to continue on the Sun-climate records that NASA missions helped to start back in the 1970s," says **Tom Woods** [Laboratory for Atmospheric and Space Physics, University of Colorado —*SORCE Principal Investigator*].

SORCE observed the peak of activity in Solar Cycle 23 and captured solar irradiance changes during one of the largest solar eruptions yet witnessed—the "Halloween Storm" in October 2003. Then SORCE observed continuously as solar activity declined into a prolonged, anomalously quiet minimum that lasted from 2008 to 2010. Now SORCE observations indicate a significantly lower maximum for Solar Cycle 24 (with the peak seen in November 2011) then that which was observed for cycle 23. On **page 3** of this issue we are pleased to feature an article on SORCE and some of its major accomplishments.

The Advanced Mircowave Scanning Radiometer-EOS (AMSR-E) on Aqua had its antenna stop spinning back in October 2011, most likely due to aging lubricants in the mechanism. *The Earth Observer* has periodically updated our readers on the progress of efforts to spin up the AMSR-E[2] antenna. I am happy to report that on December 4, 2012, the Japan Aerospace Exploration Agency (JAXA) operations team, together with the Aqua Flight Operations Team (FOT), safely executed "Stage 3" of the recovery effort[3] and were able to successfully achieve their rotation goal of 2 rpm. AMSR-E instrument performance is currently nominal and performance parameters (in particular, *jitter*) remain well within acceptable margins. Thus far, there appears to be no impact to the science of the other Aqua instruments. The data obtained from AMSR-E will be used for radiometric inter-comparison with the similar AMSR-2 instrument on the Global Change Observation Mission–Water (GCOM-W1) [a.k.a., *Shizuku*]. This overlap is essential for establishing data record continuity across the two missions. The plan is to have AMSR-E collect data for at least two months.

A new cloud-free view of the entire Earth at night, made with data from the Visible Infrared Imaging Radiometer Suite (VIIRS) day-night band onboard the Suomi National Polar-orbiting Partnership (NPP) satellite[4] was unveiled at a press conference during the AGU conference. Nicknamed the *Black Marble*, this new image shows the glow of natural and human-generated light sources in greater detail then ever before—see **pages 1** and **49**. Also at AGU, scientists revealed an animation showing *plant stress* from January 2010 through September 2012, using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra and Aqua satellites as well as NOAA satellites. There was also a release about the likelihood of increased wildfire activity in coming decades based on NASA data. To learn about these topics, we refer you to the news stories on **pages 44** and **46** respectively.

As usual, it is an exciting time for Earth science at NASA. We look forward to the many challenges, opportunities, discoveries, and advancements in the year to come. ■

[2] The "Editor's Corner" in previous issues of *The Earth Observer* chronicles the progress of these efforts.
[3] "Stage 1" of the recovery effort took place in February 2012; initial observations—with no rotation—were taken to test the instrument. In mid-September, "Stage 2" spin-up tests were conducted with a plan to spin up to 4 rpm (original rotation rate was 40 rpm) and then spin back down several times. The antenna did move, but there was friction; they only obtained about 1 rpm with maximum current applied.
[4] Suomi NPP is a joint NASA/National Oceanic and Atmospheric Administration (NOAA) mission.

The SORCE Mission Celebrates Ten Years

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Introduction

The Sun is the solar system's "furnace." Solar radiation carries energy to Earth and beyond, fueling planets and driving a myriad of radiative, chemical, and dynamical processes in Earth's environment that influence natural climate variability. Light at visible wavelengths carries most of the Sun's energy to Earth (82% of the total energy comes from visible wavelengths from 390 to 750 nm). On average only about 50% of the solar radiation directly reaches the surface, due to reflection and attenuation by the overlying atmosphere. Variations in solar irradiance, which occur on all time scales from seconds to centuries and longer, can only be accurately measured from space-based platforms such as SORCE. Decades-long attempts to measure the *total solar irradiance* (TSI[1]) from the ground and rockets have failed to detect the true variability: Historic satellite measurements of TSI and ultraviolet (UV) *solar spectral irradiance* (SSI) date back to 1978—see **Figure 1** (next page).

"As there is only one object in the sky on whom we utterly depend, there can be no astronomical question of more practical significance to mankind than that of the Sun's variability. To determine whether the solar constant is varying…requires long-term monitoring of both the bulk solar radiation and its terrestrially important spectral components. This assignment is not an easy one, for it demands a capability of sensing changes of no more than 0.1% in a decade, carried out over many decades. In the real world of science the greater challenge may be that of insuring the continuance of such a program."
*—**John A. "Jack" Eddy**, 1977*

Variations in solar irradiance, which occur on all time scales from seconds to centuries and longer, can only be accurately measured from space-based platforms such as SORCE.

On January 25, 2003, NASA's Solar Radiation and Climate Experiment (SORCE) spacecraft was launched into space on a Pegasus XL vehicle that carried four instruments: the Total Irradiance Monitor (TIM), Solar Stellar Irradiance Comparison Experiment (SOLSTICE), Spectral Irradiance Monitor (SIM), and Extreme Ultraviolet Photometer System (XPS). The primary objectives for SORCE are to measure important solar input to Earth's radiation budget and to relate how solar variability influences our atmosphere and climate. SORCE continues the precise measurement of TSI that began with the Earth Radiation Budget (ERB) instrument onboard the Nimbus-7 satellite in 1978 and have continued to the present with the Active Cavity Radiometer Irradiance Monitor (ACRIM) series of measurements. To learn the history of how SORCE came to be, see *The Sources of SORCE* on the next page.

This image shows the SORCE spacecraft with the solar arrays deployed during integration and testing at Orbital Sciences Corporation. **Image credit:** Orbital Sciences Corporation

[1] The *total solar irradiance* (TSI) is defined as the solar energy per unit time over a unit area perpendicular to the Sun's rays at the top of Earth's atmosphere.

Ten years of observations from SORCE's TIM and SOLSTICE instruments have extended the critical Sun-climate records of TSI and UV SSI measurements. SORCE's SIM instrument made the first continuous space-based observations of SSI at visible and infrared (IR) wavelengths, forming the basis for a new climatological record of the visible and IR SSI. SIM was designed for continuous spectral measurements through the near UV, visible, and near IR with the stability needed to determine, for the first time, true changes in SSI in these wavelengths. The XPS instrument measures high-energy UV radiation and lower-energy X-ray wavelengths. These measurements yield valuable information about the Sun's corona, solar events that impact satellite communications, and the Sun's effects on the very outermost layers of Earth's atmosphere.

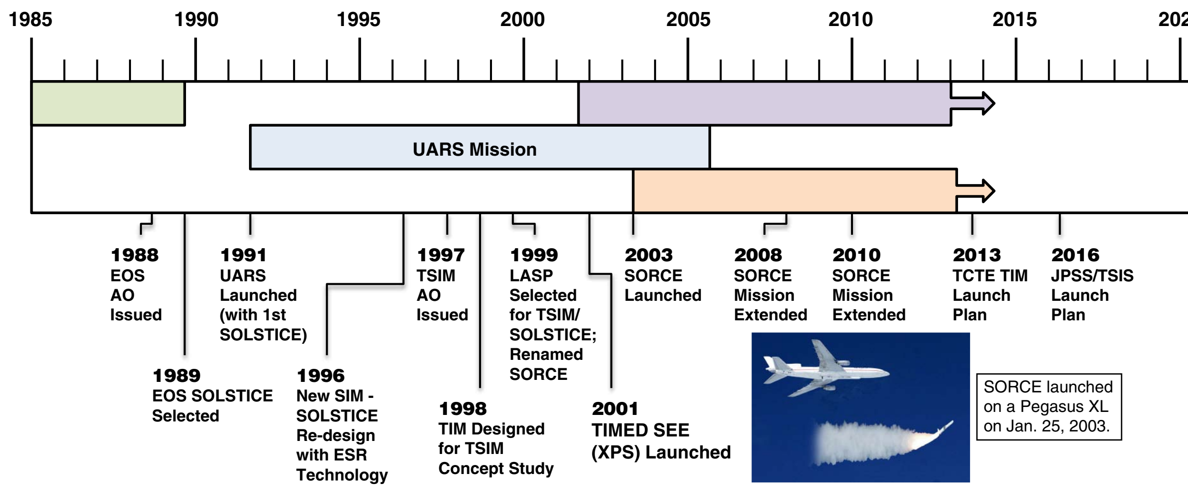


Figure 1. This timeline shows various milestones in the development of solar irradiance measurements relevant to the SORCE mission. **Image credit:** LASP/NASA

The Sources of SORCE

In early 1988 NASA issued an Announcement of Opportunity (AO) for the Earth Observing System (EOS), seeking proposals to fly instruments onboard a polar-orbiting platform—then known as EOS-A—to study Earth's systems from space. At that time, the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) was operating the Solar Mesosphere Explorer (SME), which was launched in 1981. In addition to atmospheric ozone experiments, SME carried a solar irradiance spectrometer to collect data between 115 and 300 nm. LASP had also completed the design and fabrication of the Solar Stellar Irradiance Comparison Experiment (SOLSTICE). In 1991 SOLSTICE was in its calibration phase and awaited integration to launch onboard NASA's Upper Atmosphere Research Satellite (UARS). Given this previous experience, it was quite appropriate and natural that LASP responded to the EOS AO with a proposal to provide a second-generation SOLSTICE (EOS SOLSTICE) to fly on the polar-orbiting platform.

NASA received 458 proposals in response to the EOS AO, and EOS SOLSTICE was one of the 30 Instrument Investigations selected. The NASA selection specified that SOLSTICE would become a Flight of Opportunity (FOO) and NASA's Goddard Space Flight Center would be responsible for finding an appropriate means for launch. The search seemed as if it would never end (with all possible large and small, national and international, high- and low-risk missions considered) until finally, in 1998, the small, free-flying SORCE mission that exists today began to materialize. The original NASA selection process and frequent restructuring of the EOS program during the early- and mid-1990s determined the future of the SORCE mission[1].

After launch in 1991 it became apparent that the UARS SOLSTICE technique of comparing the Sun to bright, blue stars worked very well—at the 1% accuracy level. This level of accuracy was more than adequate to determine solar variability at wavelengths below 240 nm and acceptable out to 300 nm, but provided only an upper limit at longer wavelengths. The EOS SOLSTICE needed to push this accuracy limit, so LASP developed an entirely new optical channel with a single figured prism and a miniature *electrical substitution radiometer* (ESR).

[1] Numerous articles in *The Earth Observer* have described various aspects of the evolution of the Earth Observing System from its original conceptions to its present reality. Ghassem Asrar's article in the May–June 2011 issue [**Volume 23**, **Issue 3**, pp. 4-14] includes a very-well written summary of that evolution with references to many other relevant articles.

The electronics of the new ESR were game changing, although somewhat similar to those of previous radiometers. ESR incorporated a revolutionary phase sensitive detection that improved precision by more than a factor of 10. This new channel became a separate instrument on SORCE—the Solar Irradiance Monitor (SIM).

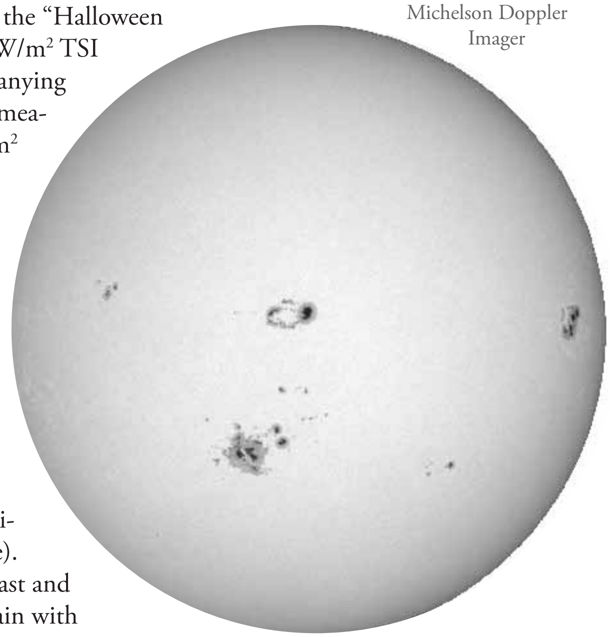
Another of the 30 EOS instruments selected in 1989 was the Active Cavity Radiometer Irradiance Monitor (ACRIM) that would measure TSI. This instrument was also relegated to the FOO category, but—unlike SOLSTICE—it fast-tracked as a small free-flyer named ACRIMSAT, and was launched in 1999. ACRIMSAT was the first of three, five-year TSI missions. To procure the second and third missions, NASA issued an AO in 1997 for a Total Solar Irradiance Monitor (TSIM). LASP was confident in its ongoing development of the ESR for SIM, and felt the phase-sensitive detection approach would provide a far-more-accurate TSI device. LASP proposed for TSIM, and was selected in 1999.

Meanwhile, throughout the 1990s the LASP extreme UV (EUV) irradiance program was becoming extremely robust. A highly successful sounding rocket program at LASP, and the Student Nitric Oxide Explorer (SNOE) and Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) missions had developed exceptional EUV photometers. An outgrowth of these programs, the X-ray Photometer System (XPS) was developed and added to the planned EOS SOLSTICE mission.

By the late 1990s EOS SOLSTICE was being studied as a possible free-flyer; the recently awarded TSIM was also considered a free-flyer. It made sense to combine the two missions into what became the SORCE mission. SORCE would combine the instruments planned for SOLSTICE and TSIM on a single platform, and operate as a principal investigator (PI)-led program with LASP as the lead institution and Gary Rottman as the SORCE PI. LASP selected Orbital Sciences Corporation (OSC) to build the spacecraft. Since launch the entire program has been on schedule. SORCE was under budget, so in 2008 the University of Colorado returned $2,997,000 to NASA after successfully completing its prime mission.

Overall SORCE Accomplishments

SORCE's state-of-the-art solar radiometers (i.e., SOLSTICE, TIM, SIM, and XPS) have successfully characterized simultaneous changes in TSI and SSI that occur in concert with the Sun's ever-changing activity. The SORCE mission began near the peak of activity in Solar Cycle 23 and captured solar irradiance changes during one of the largest solar eruptions ever witnessed—nicknamed the "Halloween Storm"—in October 2003. In addition to observing a 4-W/m^2 TSI decrease from October 18-29 and measuring the accompanying spectral changes, SORCE's TIM recorded the first direct measurement of a solar flare in TSI that increased by 0.2 W/m^2 for approximately 10 minutes on October 28.



The largest sunspots in 50 years appeared in October 2003 as part of "The Halloween Storm." **Image credit:** Solar and Heliospheric Observatory-Michelson Doppler Imager

During its ten-year mission, SORCE monitored solar irradiance continuously during the decline of solar activity into the prolonged, anomalously quiet minimum that began in 2008. Combining SOLSTICE and SIM spectral measurements during this period, along with those at shorter EUV wavelengths made by SORCE's XPS and the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) mission's Solar EUV Experiment (SEE), produced the most accurate *reference spectrum* of solar irradiance for the nominally inactive "quiet" Sun—shown in **Figure 2** (next page). This spectrum is a unique benchmark and reference for past and future solar variability. Solar activity began to increase again with the onset of a new solar cycle (Solar Cycle 24), and SORCE continues to track the solar irradiance fluctuations that are expected to peak in 2013 at a modest level. Solar Cycle 24 is exhibiting notable differences from the three prior, more active cycles for which TSI and ultraviolet SSI observations exist—and SORCE will be there to observe it as it evolves.

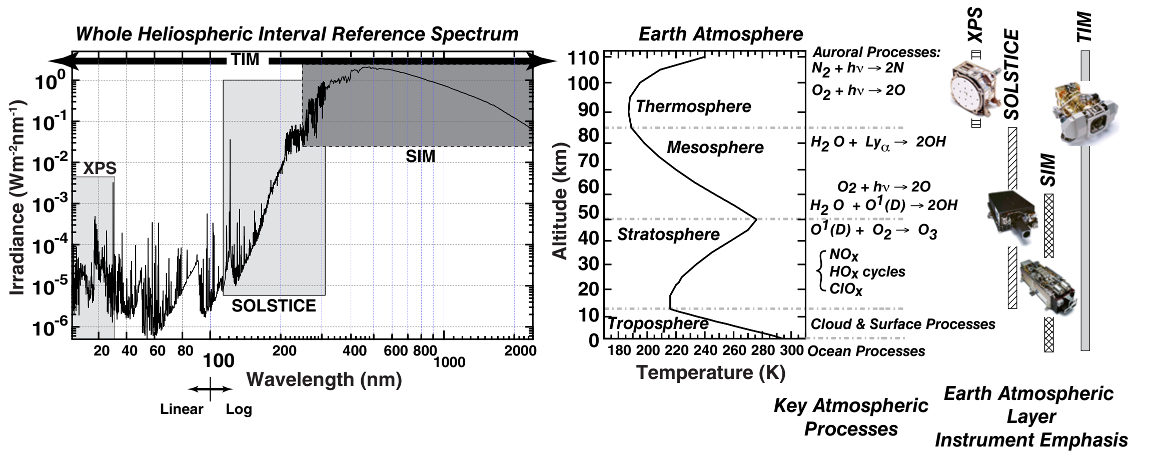


Figure 2. This figure represents a synopsis of the primary studies with SORCE data. The SORCE total and spectral radiometers measure the spectrum of the Sun and its variability daily. Solar energy establishes the structure of Earth's atmosphere through a series of key chemical reactions and thermodynamic processes. The SORCE instruments were designed to provide input for studying different layers of Earth's atmosphere and influences on climate change. **Image credit:** LASP

Results from the SORCE mission show that solar irradiance varies continuously at all wavelengths across the electromagnetic spectrum. The changes are tightly connected to solar activity, which generates both dark and bright magnetic features (*sunspots* and *faculae*[2] respectively) on the Sun's disk. These features alter the local emissions from the Sun's surface in different ways and at different wavelengths, depending on where the emissions originate within the Sun's atmosphere. Solar irradiance changes continuously as these magnetic features appear, evolve, and decay, while the Sun's rotation alters their location on the disk as seen from Earth. SORCE's measurements have characterized these changes in TSI and SSI on time scales from minutes to years. Clarifying the spectral contributions to the total irradiance variation on longer time scales of the solar cycle is underway, taking into account the wavelength-dependent changes in instrument sensitivity that are ubiquitous in space-based observations, which SORCE's instruments monitor via redundant optical channels and periodic observations of stars.

Even as the SORCE instruments have reliably and routinely tracked the Sun's irradiance, they have also recorded exciting serendipitous phenomena, detecting signatures as both Venus and Mercury transited the disk of the Sun, which each occurred twice during the mission.

As the ability to model Earth's climate and atmosphere has advanced, so too has the need for improved specification of solar irradiance inputs—as illustrated in Figure 2. Most, if not all, state-of-the-art models of Earth's climate and atmosphere, such as those used for the Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5) and the Ozone Assessment, now require the SSI—not just the total (spectrally integrated) quantity. Analysis of SORCE spectral irradiance observations and development and validation of models of spectral irradiance variability for use in global change studies is a key science objective of SORCE.

Even as the SORCE instruments have reliably and routinely tracked the Sun's irradiance, they have also recorded exciting serendipitous phenomena, detecting signatures as both Venus and Mercury transited[3] the disk of the Sun, each of which occurred twice during the mission. Additionally, the fundamental metrological scale that the SORCE instruments carried into space, traceable through careful characterization and accurate calibration to National Institutes of Standards and Technology (NIST) standards, is being transferred to other astronomical objects—e.g., stars and the Moon.

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[2] A *facula* is literally a "bright spot" on the Sun's photosphere that burns hotter than the surrounding area that often, but not always, occurs in proximity to dark (cooler) regions known as *sunspots*.

[3] For more information about how TIM observed the 2012 transit of Venus, read *SORCE/TIM Views the 2012 Transit of Venus* in the July-August 2012 issue of *The Earth Observer* [**Volume 24**, **Issue 4**, pp. 36-37].

Top Ten Achievements of the SORCE Mission

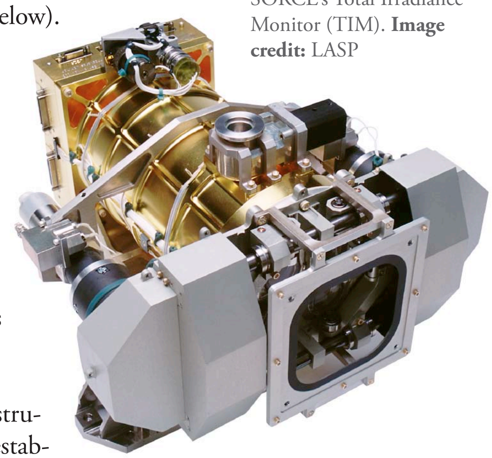
The SORCE mission has:

1. Established a new level of TSI that is 4.6 W/m^2 (0.34%) lower than prior space-based observations.
2. Acquired the first continuous measurements of SSI in the 115- to 2400-nm spectral range.
3. Defined an accurate reference spectrum of the Sun's spectral irradiance from 0.1 to 2400 nm during very quiet solar conditions.
4. Provided total and spectral irradiance inputs to the climate and atmospheric communities, and used in a wide variety of simulations and models.
5. Implemented next-generation instrumentation of spaceflight radiometers for solar irradiance monitoring, with the highest accuracy and precision yet achieved.
6. Seamlessly extended the National Oceanic and Atmospheric Administration's (NOAA's) Mg II index of chromospheric activity.
7. Acquired the first solar flare measurements in TSI, and accompanying spectral variations.
8. Advanced and validated models of the Sun's total and spectral irradiance variability.
9. Observed two Venus transits and two Mercury transits of the Sun, demonstrating exosolar planet detection capabilities and limitations.
10. Validated the white dwarf flux scale for absolute calibration of instruments for UV astronomy and made the first absolute measurement of disk-integrated lunar UV reflectance.

Top SORCE Achievements

The SORCE science team compiled a list of mission results that have been loosely organized—see *Top Ten Achievements.* While cognizant of the fact that there are many other results and details that could have been included, the consensus among the team members was that these ten are the most noteworthy achievements from SORCE's first decade in orbit.

The first five accomplishments are briefly discussed in this article (see below). A summary that includes descriptions of all ten is available at *lasp.colorado.edu/sorce/index.htm*.



SORCE's Total Irradiance Monitor (TIM). **Image credit:** LASP

#1 – Established a new level of total solar irradiance (TSI) that is 4.6 Wm^2 (0.34%) lower than prior space-based observations

The SORCE TIM extends the uninterrupted spaceborne measurements of TSI that began in 1978. Offsets between prior measurements due to instrument calibration differences have made construction of a single composite record difficult, and overlapping instruments to provide measurement continuity is imperative. The advanced design and laboratory calibrations of TIM give it an estimated uncertainty of 0.035%—more than a factor of three improvement relative to prior instruments. By virtue of its unique design and resulting accuracy, the TIM established a new baseline TSI level of the net radiative solar energy at Earth's top of atmosphere (TOA) of 1360.8 W/m^2 [0.34% (4.6 W/m^2) lower than previously measured] during the recent solar minimum[4]. This improved absolute accuracy reduces risk from a potential loss in continuity of the solar data record, although detection of solar

[4] Kopp and Lean [*Geophysical Research Letters,* **38,** L01706, 2011] describe this phenomenon.

TIM's innovative new optical design is the primary reason for its improved measurement accuracy, verified by comparisons of a ground-based TIM with international facilities at NIST and the Physikalisch-Meteorologisches Observatorium Davos (PMOD) World Radiometric Reference, as well as at LASP's newly created TSI Radiometer Facility (TRF).

trends at the levels needed for climate studies will continue to rely on TSI measurement overlap until uncertainties are reduced further.

TIM's innovative new optical design is the primary reason for its improved measurement accuracy, verified by comparisons of a ground-based TIM with international facilities at NIST and the Physikalisch-Meteorologisches Observatorium Davos (PMOD) World Radiometric Reference, as well as at LASP's newly created TSI Radiometer Facility (TRF). All prior spaceborne TSI instruments were of a configuration that was much more susceptible to internal scattered light, which caused erroneously high measurements. TRF comparisons with previous instruments help quantify the scatter in their datasets and establish the needed corrections to their measurements.

Contemporaneous measurements now report TSI values that are very similar to those that TIM first released soon after SORCE's launch. **Figure 3** shows the 34-year long TSI record and the improved measurement agreement with the currently operating instruments.

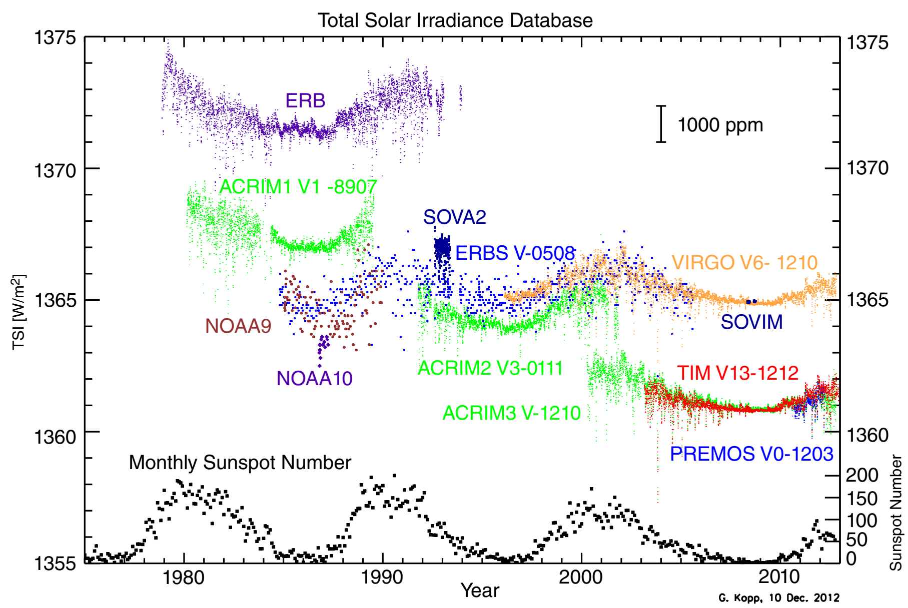
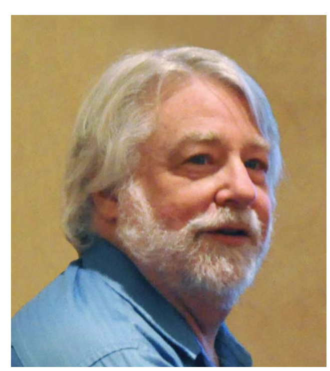


Figure 3. Having lower uncertainties than other flight TSI instruments, the TIM established a new, lower TSI value of 1360.8 W/m². Recently applied corrections for scatter—which causes erroneously high readings in other instruments—have lowered those instruments' values, and the agreement between TSI measurements is now much improved. **Image credit:** LASP

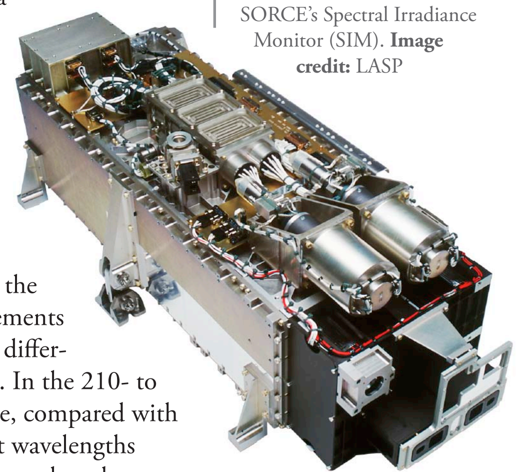
Acronyms Used in Figure: ERB = Earth Radiation Budget [onboard Nimbus 7]; ERBS = Earth Radiation Budget Satellite; ACRIM = Active Cavity Radiometer Irradiance Monitor; SOVA = SOlar VAriability experiment [onboard the Picard satellite]; VIRGO = Variability of solar Irradiance and Gravity Oscillations [onboard the SOlar and Heliospheric Observatory (SOHO)]; NOAA = National Oceanic and Atmospheric Administration; PREMOS = PREcision Monitoring Of Solar Variability [onboard Picard]; SOVIM = SOlar Variations and Irradiance Monitor [onboard the International Space Station]; TIM = Total Irradiance Monitor [onboard SORCE].

"SORCE has set a new standard of accuracy, precision, and wavelength range for the Sun's irradiance, a kind of 'climate gold standard' for the radiative forcing of Earth over the decade of the 2000's, beginning with the dramatic Halloween flares of October-November 2003, through the historically low 2008–2009 minimum of Solar Cycle 23, into the rise of Solar Cycle 24, providing a climate record likely to grow in value for Sun and Earth studies over many decades to come."
*—**Robert Cahalan** [GSFC—SORCE Project Scientist]*



#2 – Acquired the first continuous measurements of solar spectral irradiance (SSI) in the 115- to 2400-nm spectral range

SORCE's SOLSTICE and SIM have measured SSI during most of a solar cycle, and across most wavelengths. SIM also employs an innovative optical design, based on a *Fèry prism spectrometer* that both focuses and disperses light onto multiple detectors with only one optical element. The primary detector for SIM is a newly designed miniature *electrical substitution radiometer* (ESR)—see *The Sources of SORCE* sidebar on page 4—similar in concept to TIM's radiometer. Three additional photodiode detectors complement the ESR and provide a higher signal-to-noise ratio and faster response. On-orbit degradation of these detectors is corrected using the highly stable ESR. Comparisons of solar spectral irradiance measurements made by two identical (i.e., mirror-image) spectrometers, each with different solar exposure rates, establishes the prism's on-orbit degradation. In the 210- to 2400-nm range, SIM collects about 97% of the total solar irradiance, compared with spectral radiometers from earlier eras that typically measured only at wavelengths shorter than 400 nm. Thus, SIM provides a comprehensive view of wavelength contributions to solar irradiance variability. **Figure 4** shows the solar spectrum from 210 to 2400 nm measured by SIM (i.e., in orbit), and how that spectrum changes as the radiation encounters the top of Earth's atmosphere, passes through the atmosphere to the surface, and then passes through 10 m (32.8 ft) of clear ocean water.



SORCE's Spectral Irradiance Monitor (SIM). **Image credit:** LASP

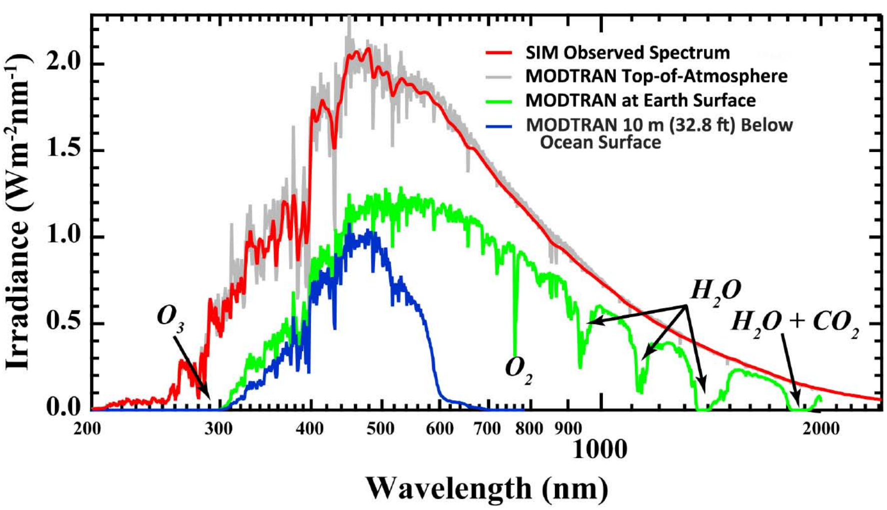
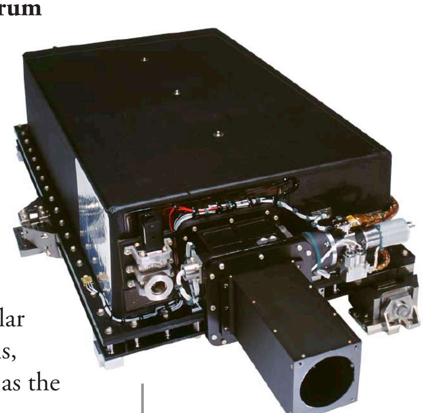


Figure 4. The solar irradiance spectrum is altered as it passes through Earth's atmosphere, and further altered by passing through water. The top red curve within the light gray curve is a SIM-observed spectrum, and the others are generated spectra generated by the MODTRAN radiative transfer model corresponding to the top of the atmosphere [*middle curve*], at the surface (equatorial, no cloud cover) and [*lowest curve*] at 10 m (32.8 ft) below the surface for clear ocean water. Also indicated are absorption bands for the major atmospheric absorbers: ozone (O_3), water (H_2O), and carbon dioxide (CO_2). **Image credit:** LASP

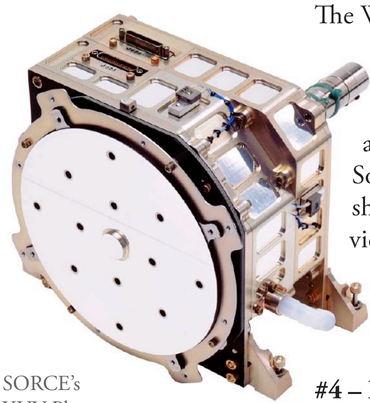
#3 – Defined an accurate solar spectral irradiance (SSI) reference spectrum

Reference spectra of the solar irradiance under different conditions of solar activity are essential physical quantities for studying solar influences on Earth's climate system and the atmospheres of Earth and other planets. For example, solar reference spectra are used as input in general circulation models of Earth's coupled atmosphere–ocean system to study long-term variations, ranging from changes due to the 11-year solar cycle to changes occurring over centuries that can affect global climate change. Solar reference spectra are also useful for establishing and validating models of solar irradiance. These models are essential for times when no solar observations are available, such as between current space-based observations, and for reconstructing solar irradiance at times prior to the space era, such as the *Maunder Minimum* period during the late seventeenth century.



SORCE's Solar Stellar Irradiance Comparison Experiment (SOLSTICE). **Image credit:** LASP

The international Whole Heliosphere Interval (WHI), which occurred from March–April 2008, was an excellent opportunity to coordinate observations with many missions (including SORCE), and to compare results for solar-cycle minimum conditions.



SORCE's XUV Photometer System (XPS). **Image credit:** LASP

The WHI campaign focused on the solar Carrington Rotation 2068 (from March 20 to April 16, 2008) and included a quiet-Sun campaign from April 10-16, 2008. During this period the average international (Zurich) *sunspot number*[5] measured only 2, and the average Penticton 10.7-cm radio flux (F10.7) was also very low at 69 (x 10^{-22} W/m^2/Hz). The "minimum" spectrum for the WHI Solar Irradiance Reference Spectra (SIRS) is for this quiet-Sun campaign—as shown in Figure 2. The SORCE SIM, SOLSTICE, and XPS instruments provided SSI measurements for WHI SIRS[6] in the wavelength ranges of 0.1 to 6 nm and 115 to 2400 nm. The EUV gap was filled with rocket measurements from the prototype Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE).

#4 – Provided total and spectral irradiance inputs to the climate and atmospheric change communities, and used in a wide variety of simulations and models

Changes in the Sun's irradiance impart an external forcing to Earth's climate and atmosphere that must be reliably specified over multiple time scales for use in simulations of global change. When IPCC AR4 was conducted, most of the general circulation climate model (GCCM) simulations included only variations in TSI to specify this natural forcing. However, physical models have now advanced, such that state-of-the-art GCCMs use SSI as an input. The most developed of these, the chemistry-climate models (CCMs), also include detailed ozone chemistry. Thus far, model simulations, including the CCMs used for the Ozone Assessment (2011) and those in progress for IPCC AR5, provide SSI variations as inputs, commensurate with those of NRL's SSI (NRLSSI) model.

The recognition that SIM measurements suggest a different scenario to describe solar variability has motivated a number of studies using climate models with alternative SSI variations.

The recognition that SIM measurements suggest a different scenario to describe solar variability has motivated a number of studies using climate models with alternative SSI variations. Most notably, those derived from the SIM observations imply much larger and differently phased variations than the NRLSSI model. Model estimates with different SSI variability show solar-cycle responses in upper-atmospheric ozone that can be compared with observations[7]. Studies of this kind are in their infancy, and ultimately require extended and validated solar and atmospheric time series for reliable conclusions. Expanding the comparison to include other key observables, like temperature and the hydroxyl radical (OH^-), and analysis of additional solar cycles will lead to a deeper understanding of the complicated role of SSI variability in Earth climate studies.

#5 – Implemented the next-generation instrumentation of spaceflight radiometers for solar irradiance monitoring with the highest radiometric accuracies and stabilities yet achieved

The TIM and SIM both utilize ESRs to measure incident sunlight power with unprecedented on-orbit accuracies and stabilities. These efficient broadband light-absorbing devices are maintained at constant temperature by electrical heaters while incident sunlight is shuttered on and off, providing radiative heating and cooling of the sensors, respectively. This modulated radiant heating must be exactly compensated for by opposing electrical heater power variations to maintain constant radiometer temperature. Precise knowledge of the electrical power to the radiometers enables measurement of the incident sunlight power with high radiometric accuracy.

While this classical measurement approach is fundamentally simple, it is nevertheless a challenge to achieve the precision and accuracy needed to unambiguously detect true solar irradiance changes. To advance these measurements, SORCE's

[5] Sunspot number is the number of sunspots on the solar disk as seen from the Earth. A plot of how it changes over time appears in Figure 2.
[6] Woods *et al.* [*Geophysical Research Letters,* **36**, L01101, 2009] provide an overview of the WHI SIRS that includes spectra from 0.1 to 2400 nm in 0.1 nm intervals.
[7] Harder *et al.* [*Geophysical Research Letters,* **36,** L07801, 2009] gives an example.

instruments incorporate the following innovative technologies, not flown on prior spaceborne radiometers.

- An absorbing surface of nickel phosphorous—a diffuse black metal with high absorptivity over a broad spectral range—enables very high efficiencies of the instruments' radiometers, while providing high thermal conductivity for improved radiometer response in addition to superior stability against exposure to solar UV and high-energy radiation.
- Phase-sensitive detection in both on-orbit instrument thermal control and in ground data processing greatly reduces sensitivities to low-frequency thermal drifts and high-frequency noise, improving the instruments' abilities to detect minuscule solar fluctuations.
- Apertures calibrated at NIST precisely define the areas over which sunlight is collected.
- TIM's optical design, with a defining aperture at the front of the instrument, allows only entry of light intended for measurement, and reduces internal instrument scatter that causes erroneously high readings in other spaceborne TSI instruments.
- SIM's Fèry prism both focuses and disperses light over a very broad wavelength range with only one optical element to reduce light losses and to improve radiometric accuracy.
- SIM's miniaturized ESRs measure signals 1000 times smaller than the TIM's, using a thermally isolated flat diamond strip bolometer in a reflective hemisphere for high efficiency.
- SIM's linear charge-coupled device at the focal plane determines the spectrometer's wavelength scale, correcting time-dependent distortions induced by thermal variations, and reducing wavelength-dependent uncertainties affecting the measurements.

Having been successfully demonstrated for spaceborne solar irradiance monitoring for the first time by SORCE, these instrument innovations will be carried into future flight programs that require high on-orbit stabilities for climate monitoring, such as the upcoming National Oceanic and Atmospheric Administration (NOAA)'s Total Solar Irradiance Sensor (TSIS) that is to be part of the Joint Polar Satellite System (JPSS).

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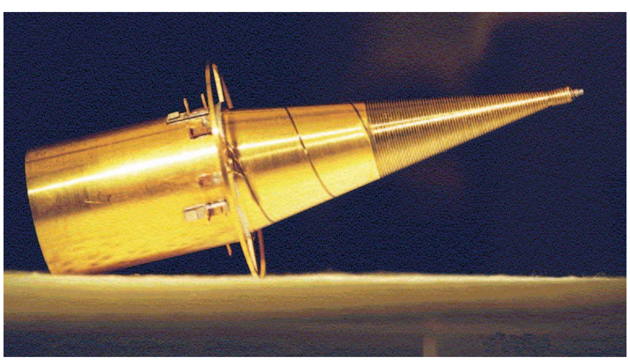
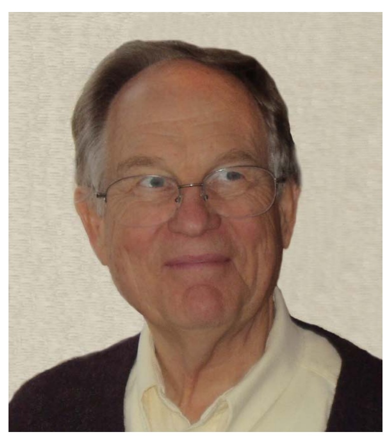


TIM's electrical substitution radiometer (ESR) has enabled SORCE to measure the solar irradiance with an improvement in precision by more than a factor of 10. **Image credit:** LASP



"When you make something 10 times more precise, then there will be 10-squared more corrections to make."

—George Lawrence's Philosophy of Metrology

"As we approach the tenth anniversary of the launch, I reflect on the more than 25 years the program has been ongoing. The success created by the true teaming of the university, government, and industry that delivered this mission within budget, on time, and fully successful in meeting the science requirements is a tremendous source of pride for myself and the more than 500 people who have been involved. I hope that this success will provide a beacon for PI-mode missions and demonstrate a way to achieve success for future missions."

*—**Tom Sparn** [LASP SORCE Project Manager]*

The Future of SORCE

SORCE's instruments and spacecraft components have performed exceptionally well during its first ten years on-orbit, and remain very healthy overall. The exception is the spacecraft battery, with aging that will eventually limit SORCE's life. Already the instruments take a "power nap" during the night side of each orbit; there are very few other options to further reduce battery loads. SORCE could potentially operate in this reduced power mode for years, but eventually the spacecraft power system will brown out and shut down critical spacecraft subsystems. With no on-board propulsion, SORCE will slowly descend due to atmospheric drag and reenter Earth's atmosphere sometime in the next decade.

SORCE operations personnel working in the LASP Mission Operations Center. **Image credit:** LASP.

The solar irradiance record will continue after the SORCE mission ends. LASP has been preparing the next generation TIM and SIM instruments. The TIM's second space flight opportunity was abruptly terminated when NASA's Glory mission failed during launch on March 4, 2011. The TIM's next flight opportunity is NOAA's TSI Calibration Transfer Experiment (TCTE), with launch aboard the Air Force STPSat-3 planned for August 2013. Advanced versions of TIM and SIM instruments have been built and are currently in calibration at LASP for JPSS, with a first launch planned for 2016. Should SORCE end before the launch of these follow-on missions, the quality of the extant solar irradiance record will degrade significantly, since maintaining the record's long-term repeatability requires overlapping sets of measurements. Every effort is being made to keep SORCE operating for as long as possible while exploring early flight options for NOAA's TIM and SIM instruments.

Conclusion

The SORCE mission has exceeded expectations in precisely and accurately measuring TSI and SSI for ten years—five more years than planned—and over a unique solar cycle. After an unusually extended period of inactivity from 2007 to 2009, Solar Cycle 24 came to life. SORCE is observing the current solar cycle maximum, which has only half the vigor of previous cycles that occurred during the space age. The Sun is offering new opportunities to study—and perhaps even to challenge—our understanding of how Earth's atmosphere and climate responds to different levels of solar activity. It is fortunate that SORCE is there to record these solar cycle changes.

SORCE's very successful mission is the product of spectacular engineering, mission operations, and management teams at LASP, OSC, and GSFC. The SORCE science team and broader international Sun and Earth communities have contributed to the remarkable science results from the mission. To commemorate SORCE's observations over one complete 11-year solar cycle, the next SORCE Science Team Meeting is being planned for January 2014 (SORCE's eleventh birthday—that is, one complete solar cycle) with focus topics concerning the key results from the mission. ■

The Sun is offering new opportunities to study—and perhaps even to challenge—our understanding of how Earth's atmosphere and climate responds to different levels of solar activity. It is fortunate that SORCE is there to record these solar cycle changes.

For more information, including an expanded article with references, visit the SORCE mission website at ***lasp.colorado.edu/sorce.***

Reflection on the SORCE Mission from the Principal Investigators

Tom Woods [LASP—PI]
Gary Rottman [LASP—Original PI]

SORCE's roots originate in an EOS proposal written in 1988 with **Gary Rottman** [LASP—*Former Principal Investigator (PI)*], **Tom Woods** [LASP—*Instrument Scientist and Current PI*], and **Tom Sparn** [LASP—*Program Manager*]. Dozens of different missions were considered in the early days of this program, all led unwaveringly by Sparn. The SORCE mission finally crystallized into a PI-led mission in 1999 and quickly accelerated from concept to reality with partners at GSFC and OSC. Launched on January 25, 2003, the SORCE mission has since exceeded all science objectives and our own personal expectations. As is common with long-term programs, there were some retirements along the way, notably TIM and ESR wizard **George Lawrence** [LASP] in 2003, PI **Gary Rottman** in 2005 (with Tom Woods then taking on the PI position), and **Ed Chang** [GSFC—*SORCE Project Manager*] in 2010. Unfortunately we also suffered the loss of our dear friend and SORCE Co-Investigator, **Julius London** [University of Colorado, Boulder] in 2009.

Gary Rottman

Tom Woods

The energy and dedication of the many SORCE team members at LASP, OSC, GSFC, and NRL have made being a member of this team a great pleasure. The goals of significantly advancing the accuracy and precision of TSI and SSI measurements were always at the forefront of any discussion about the SORCE mission, and that scientists and engineers alike shared this attitude is possibly the key ingredient for SORCE's exceptional success. We are very grateful to all of the SORCE team members for providing outstanding scientific results and new engineering capabilities for irradiance instrumentation and spacecraft technology.

We feel privileged that the SORCE mission transpired during exciting times on the Sun, with the extremely large solar storms in October-November 2003, an unusually long solar cycle minimum in 2008-2009, and interestingly low cycle maximum in 2011-2012. We are especially proud that SORCE has been able to contribute 10 years of data to the irradiance climate record that spans more than 30 years for some wavelengths. We also like to think that the late **Jack Eddy** would be equally as proud of SORCE's continuation of the solar irradiance climate record.

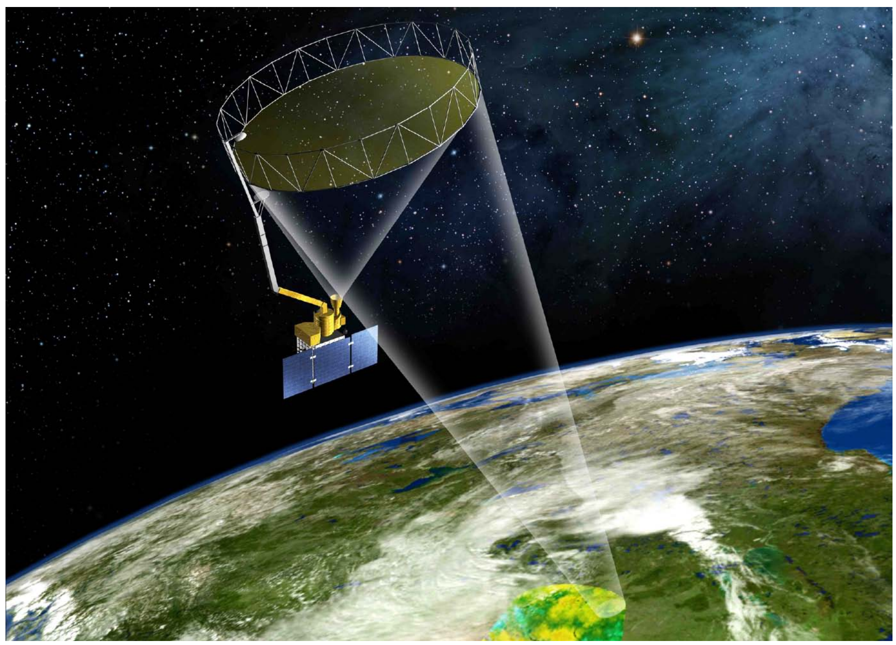
SMAP Applications Joint Mission Tutorial: Working Across Mission Boundaries to Join Thematic Applications, Observations, Mission Scientists, and End Users

Vanessa Escobar, SMAP Applications Scientist, NASA's Goddard Space Flight Center, vanessa.m.escobar@nasa.gov

SMAP has implemented a strategy that promotes applications research and engages a broad community of users in SMAP applications. This responds to recommendations of the NRC Decadal Survey report (Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Space Studies Board, National Academies Press, 2007).

Introduction

NASA's Soil Moisture Active Passive (SMAP) Mission will provide global measurements of soil moisture and freeze/thaw state with unprecedented accuracy, resolution, and coverage. Data products from the SMAP Mission will have the potential to enable a diverse range of applications, including drought and flood guidance, agricultural productivity estimation, weather forecasting, climate prediction, and improving human health and security. SMAP has implemented a strategy that promotes applications research and engages a broad community of users in SMAP applications. This



responds to recommendations of the NRC Decadal Survey report *(Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Space Studies Board, National Academies Press, 2007)*. The SMAP mission is working to promote applications research and to engage a broad community of users in its activities.

The goals of the SMAP Applications Program are to:

- promote the use of SMAP products to a community of end users and decision makers that understand the mission's capabilities and are interested in using the products in their activities;
- facilitate feedback between SMAP user communities and the mission team;
- provide information on and documentation of collaboration with different classes of users and communities; and
- design communication strategies to reach out to these new communities, including those with interests in precipitation, drought detection, agriculture, and ecosystem modeling, among others.

The SMAP Applications Program is guided by an Applications Plan that has influenced the development of communication strategies that aid in eliciting user requirements and enhancing communication between scientists and end users. Another objective of the Applications Program is to strengthen relationships between the developers and the end users and to leverage the innovation, creativity, and use of mission products. Workshops, focus sessions, and tutorials have been used to engage audiences at different levels of detail and for specific purposes defined by the mission and the application need.

Workshops are critical tools for identifying new communities and new ways that data may be used for societal benefit. *Tutorials* are meetings organized to discuss products and applications of several of NASA's decadal satellite missions. They combine application opportunities across missions and leverage innovation for how best to combine mission datasets. The tutorials provide a favorable environment to promote mission products, to explore opportunities for combining datasets from different missions and apply them to a common problem, and to find collaborators interested in developing their own product with the guidance of mission scientists.

An end-user group, such as U.S. Department of Agriculture (USDA) or the U.S. Geological Survey (USGS), hosts these meetings, but they are organized and managed by the SMAP Applications team.

Vanessa Escobar presenting on Joint mission data potential for Hydrology applications at the World Water Forum in Marseilles, France. **Image credit:** Vanessa Escobar

Joint Mission Tutorial Concept

There are significant opportunities for NASA in leveraging remote sensing products that have complementary applications and by bringing communities together to discuss applications that could use data from multiple missions. The focus behind joint observations and joint missions is not simply more data, but also to reach a broader target audience, drawing in a larger science community as well as operational users. SMAP has been actively involved in targeting a wide variety of user communities and working to elicit requirements for their applications. The success of the SMAP Applications Program is due in part to its willingness to take risks and to engage users in ways that are unique and specific to their requirements.

SMAP is the first mission to implement such a diverse Applications Plan and to implement activities such as joint mission tutorials. Through these diverse efforts, the mission has learned first-hand the value of close and personal engagement with users. The relationships developed have allowed mission scientists to have a close look at the value of soil moisture data at all scales and across a variety of agencies (both scientific and operational). Feedback from the relevant communities has also provided opportunities to expand the format for mission data delivery from a standard NASA format like HDF5 to those used more broadly by the geospatial community, such as GEOtiffs.

Early Adopters in Data Use

Joint mission tutorials have also encouraged the SMAP Mission to make data available during prelaunch phases of development. Originally, early data access was only given to a select group of users through the SMAP Early Adopters Program. This program promotes applications research to provide a fundamental understanding of how SMAP data products can be scaled and integrated into an organization's policy, business, and management activities to improve decision-making efforts. The SMAP Early Adopters are defined as *those groups and individuals who have a direct or clearly defined need for SMAP-like soil moisture or freeze/thaw data, and who are planning to apply their own resources (e.g., funding, personnel, facilities) to demonstrate the utility of SMAP data for their particular system or model*. The goal of this designation is to accelerate the use of SMAP products after launch by providing specific support to Early Adopters who commit to engage in prelaunch research that would enable integration of SMAP data in their applications.

After two rounds of selection with Early Adopters, however, the requests to use early mission data was starting to occur after every SMAP meeting and presentation. Following an enthusiastic display of interest for access to calibration and validation datasets during the SMAP/GPM/GRACE FO/SWOT[1] joint mission tutorial, the SMAP project decided to grant early access to all users willing to sign an early-data-use agreement.

An Early Adopter data page is currently being developed by the Mission, where scientists and other interested parties will have the opportunity to request access to the SMAP simulation data and to all approved calibration and validation data. A detailed description of the SMAP Early Adopters efforts can be found at *smap.jpl.nasa.gov/science/wgroups/applicWG/EarlyAdopters.*

Tutorial Success Stories

Presented here are the highlights from two novel tutorials conducted by the SMAP Applications Program, designed to engage communities across missions and to achieve the goals of the SMAP Mission: The Alaska Satellite Facility (ASF) in Fairbanks, AK, hosted a SMAP/ICESat-2 tutorial[2], and the USGS in Reston, VA, hosted a SMAP/GPM/GRACE FO/SWOT Hydrology and Water Management tutorial. The objective of these multimission tutorials was to identify overlap in potential uses of cross-mission data. Bringing together the user communities and the mission scientists important not only to address applications, but also to address new ways of combining data products in ways that will enhance the use of combined data over the mission products alone.

[*Left to right*] **Molly Brown** and **Vanessa Escobar** at the SMAP/ICESat-2 tutorial in Fairbanks, AK. **Image credit:** NASA

SMAP/ICESat-2 Tutorial

The purpose of the SMAP/ICESat-2 tutorial was to connect the science from the two satellite missions with Alaskan remote sensing and environmental communities in order to identify the benefits of incorporating SMAP soil moisture, surface freeze/thaw state, and ICESat-2 altimetry products into existing research, operational applications, and local agency decision-making activities. Specific applications that could benefit from this collaboration include the areas of permafrost, sea ice, and vegetation cover. Another purpose for the tutorial was to explore the possibilities for innovative cryospheric and hydrospheric applications by combining products from existing instruments—like the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua platforms—with data products from SMAP and ICESat-2.

Beata Csatho [University of Buffalo—*ICESat-2 Science Definition Team (SDT) Chair*] and **Dara Entekhabi** [Massachusetts Institute of Technology—*SMAP SDT Chair*], as well as key members of the science teams, attended the meeting. The presentations during the tutorial gave detailed and specific information about the mission design, instrument capabilities, and planned algorithms. Because these key science team members and representatives of the potential user community were in the same room, these science and technical presentations led to concrete and constructive discussions about the possible uses of data from two sensors together to meet specific needs of the end users.

[1] Products and applications from SMAP, the Global Precipitation Measurement (GPM), Gravity Recovery and Climate Experiment-Follow On (GRACE FO), and Surface Water Ocean Topography (SWOT) missions were discussed during the SMAP/GPM/GRACE FO/SWOT Hydrology and Water Management tutorial.

[2] Products and applications from SMAP and the second Ice, Cloud, and land Elevation Satellite (ICESat-2) were discussed during the SMAP/ICESat-2 tutorial.

These discussions resulted in several new collaboration products and data formatting approaches that are described below, along with the possible strengths and challenges to implementation of each idea.

- *Geomorphology Permafrost Product* for the Department of Transportation and the Bureau of Land Management that combines ICESat-2 altimetry data with SMAP freeze/thaw product to describe permafrost melt in thermokarst areas and the resulting slumping of the land surface.
- *Sea Ice Product* for the Department of Defense, U.S. Navy, and the University of Alaska, Fairbanks, using both ICESat-2 and SMAP data, that seeks to provide information on multi-year ice as well as ice density. To do this, changes in the SMAP data acquisition map need to be made to allow acquisition of data over the Arctic Ocean. This could be done by acquiring data only over oceans that are of specific interest. A 1-to-3 km- (~0.6-to-2- mi) resolution L-Band sea-ice product would also be useful for an ice-motion product in both Polar Regions.
- *SMAP Data Product over Antarctica* for the University of Alaska, Fairbanks and the ASF Data Center, for use with ICESat-2 altimetry data. These data would be useful for differentiating smooth from rough ice areas, and to find unfrozen water during summer months. To accomplish this, SMAP data would need to be downloaded at McMurdo Station[3]—since the satellite has very limited onboard data storage.
- *Permafrost Airborne Datasets* acquired from MABEL[4] (the ICESat-2 simulator) and PALS[5] (SMAP simulator), taken during a Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) campaign in Alaska, could be used to develop new products that better describe the permafrost ecosystem to support the Bureau of Land Management, Alaska Park Services, and the Army Corps of Engineers.
- *GIS-compatible formats for mission data,* developed and distributed by data centers such as the ASF and the National Snow and Ice Data Center (NSIDC). These datasets would reflect the prelaunch synthetic mission data and calibration/validation data for SMAP so that user communities could take a quick look how the data will be represented after launch. ICESat-2 data would also be needed. Data collected during MABEL are available, but there are several to-be-determined steps needed to turn MABEL data into ICESat-2 data.

The SMAP/GPM/GRACE FO/SWOT Hydrology and Water Management joint mission tutorial, hosted by the USGS, was another opportunity for several missions to work together to collect and distribute information about different user requirements, while discussing how planned NASA-generated data could be used to improve hydrological applications.

SMAP/GPM/GRACE FO/ SWOT Hydrology and Water Management Tutorial

The SMAP/GPM/GRACE FO/SWOT Hydrology and Water Management joint mission tutorial, hosted by the USGS, was another opportunity for several missions to work together to collect and distribute information about different user requirements, while discussing how planned NASA-generated data could be used to improve hydrological applications. The workshop focused on collaborative opportunities for future use of SMAP, GPM, GRACE FO, and SWOT data in conjunction with existing satellite observation capabilities. This effort created a platform for joint-mission research, prepared users for future mission data, identified

SMAP/GPM/GRACE FO/ SWOT tutorial panel participants. [*Left to right*] **Michael Jasinski**, **Dara Entekhabi**, **Barry Weiss**, **Felix Landerer**, **Phillip Callahan**, **Erick Stocker**. **Image credit**: **Vanessa Escobar**, NASA

[3] McMurdo Station is a U.S. Antarctic research center located on the southern tip of Ross Island.
[4] MABEL stands for Multiple Altimeter Beam Experimental Lidar.
[5] PALS stands for Passive and Active L-Band Simulator.

collaborators for prelaunch efforts, and identified areas where remote sensing data could help improve operational products used for policy, management, and decision-making in water-resource management.

The meeting was held at the USGS National Center in Reston, VA. The focus was on needs for satellite data for a wide range of USGS-provided hydrological products and tools. Mission representatives and scientists from SMAP, GPM, GRACE and GRACE FO, and SWOT were present at the meeting, who provided key information about the USGS-relevant use of and potential products from each mission.

The location for joint mission tutorials is almost as important as the topic itself. To this end, the SMAP Applications team focuses on getting the end user involved early, and as much as possible.

Given the wide variety of topics covered in this meeting, it was clear that there are tremendous opportunities for use of multisensor products. A brief summary of possible new products include:

- *Streamflow* estimates from multiple sensors;
- A *groundwater recharge product*, particularly for low flow periods;
- *Evapotranspiration (ET) products*, as thermal data alone do not generate water budgets, whereas having data from each mission will allow new approximations of this critical parameter; and
- *SMAP, GRACE FO, GPM, SWOT, and ET datasets* (Landsat and MODIS), which, working together, can be used to develop remote water-balance estimates and to map antecedent conditions that set the stage for severe floods. Overlap with missions can provide a level of data validation.

The SMAP Applications Program will work with the personnel of all participating missions to develop these and other ideas that are not reported here. The hydrological community will continue to work on using NASA data to improve water resources decision making.

A Lesson Learned: Location…Location…Location!

The location for joint mission tutorials is almost as important as the topic itself. To this end, the SMAP Applications team focuses on getting the end user involved early, and as much as possible. Benefits to end users hosting events at their home institutions include exposure to different communities as a result of holding the meeting, by providing local access to the event without onerous and potentially expensive travel requirements—such expenses are not covered by the SMAP Applications Program. There is no registration fee, and the host institution donates the facilities and amenities. The willingness of SMAP users to sponsor SMAP events and to support attendance using their own resources further demonstrates the value of the mission. The SMAP Applications team plans and organizes the entire event, and works with the host facility with respect to their specific usage policies.

When selecting a potential host for a SMAP tutorial, the Applications team begins with a host whose activities best fit a relevant thematic discipline. For example, the USGS has done extensive work in hydrology, and therefore was able to provide concrete examples of the ways in which satellite data are used in science and operations within the U.S. and internationally. By focusing on large user groups, the Applications team not only highlights the host's data requirements, but also expands the ways that new partners associated with the host can understand the benefits of access to and usage of the data.

When selecting what data and models to present, the SMAP Applications team allows the host to showcase their groups' research and to inform the parallels between the users' needs and the mission capabilities. These events provide an opportunity for information exchange between the user and the mission, focusing on how data can be applied in different applications. The meetings then allow time during breakout sessions for discussion about challenges and requirements. Ample time is also dedicated to panel discussions on synergistic opportunities. At the end of each tutorial, the Applications team provides a report about the event, and lists opportunities and lessons learned. These documents serve as a record of progress in mission applications, and support the NASA Headquarters mission to enhance applications support.

Addressing Broader Needs

Joint mission tutorials, such as the two described here, are important to NASA as well as to end users. NASA provides huge amounts of remotely sensed data for Earth science; getting those data into the hands of those who can make the most of them to address practical applications that impact society requires engagement and interaction with end users. To ensure that NASA maximizes the impact of its data, it is necessary for users with diverse perspectives to use those data. Leveraging the pool of information that NASA has available is important; working to achieve this goal before missions are launched increases the potential for significant use in a timely fashion after data are made available.

The SMAP Applications Program seeks to engage the decision makers at the local scale, and to demonstrate the impact science can have on our day-to-day lives by expanding use of satellite data beyond typical organizational boundaries. To this end, the two joint mission tutorials described here have increased the variety of users for SMAP mission data to address government, commercial, and private industry—from federal agencies—such as the National Oceanic and Atmospheric Administration (NOAA), USDA, USGS, U.S. Department of Defense (DOD), and Cold Regions Research and Engineering Laboratory (CRREL)—to more localized organizations, such as the New York City Department of Environmental Protection Management, Willis Insurance Company from London, U.K., and Storm Center Communications from Baltimore, MD.

Moving Forward

The SMAP Applications program would like to expand the diversity of data uses to have a broad community of users after the satellite is launched.

To do this, the SMAP Applications Program promotes applications research and collaborative opportunities through the community of SMAP users. SMAP uses tutorials, workshops, and focus sessions to aggressively enhance team dynamics that will elicit innovative and balanced ideas from people that can both develop and apply information in organizations who have operational responsibilities. By learning more about the groups the SMAP Applications team has engaged, the plan is to help users develop their applications with guidance and assistance from SMAP mission scientists, and to provide feedback to the mission about user needs.

Over the next two years the SMAP Applications team will expand its reach to smaller conferences and meetings in order to engage more thematic users in operational and decision-making environments. Details pertaining to additional SMAP events will be posted to the SMAP Applications website at *smap.jpl.nasa.gov/applications.*

The Applications Program will work to increase the visibility and participation of policy and decision-making communities who use satellite data in the prelaunch applications activities to ensure the maximum use of SMAP products after launch. ■

By learning more about the groups the SMAP Applications team has engaged, the plan is to help users develop their applications with guidance and assistance from SMAP mission scientists, and to provide feedback to the mission about user needs.

DEVELOP Students Use NASA Satellite Data to Study Louisiana Coastal Swamp Forests

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Ross Reahard, DEVELOP National Program, NASA's Stennis Space Center, ross.r.reahard@nasa.gov

The DEVELOP National Program, a component of NASA's Earth Science Applied Sciences Program, provides student interns, guided by multidisciplinary science advisors, with the opportunity to work on applied science research projects using NASA's Earth observations.

The DEVELOP team at NASA's Stennis Space Center (SSC), on the U.S. Gulf Coast, has been successful at using Earth science data products to assist nonprofit organizations and local, state, and federal agencies in the region in their efforts to rebuild, monitor, and maintain ecosystems.

DEVELOP interns from Stennis Space Center visited an area where baldcypress seedlings were recently planted in St. Bernard Parish, Louisiana. Project partner **Blaise Pezold** [*far left*], from the Wetland Tree Foundation, provided invaluable knowledge and guidance during field visits. **Image credit:** Michael Ewing

Specifically, during the Summer 2012 term, DEVELOP interns at SSC focused their attention on losses in *baldcypress* and *cypress-tupelo* coastal swamp forests in St. Bernard Parish, LA, southeast of New Orleans. Many such areas are losing coastal forests at an alarming rate. The dredging of the Mississippi River Gulf Outlet (MRGO) canal in the early 1960s to connect New Orleans to the Gulf of Mexico via Breton Sound resulted in a dramatic increase in salinity in the river, which led to the destruction of thousands of acres of wetlands east of New Orleans. The MRGO canal was intended to help the area prosper economically; instead, it has only added—directly and indirectly—to numerous issues that plague this region, including major damaging effects to its surrounding ecosystems by way of land loss, erosion, increases in salinity, and habitat shifts and degradation. Project partner, **Rebecca Livaudais** [St. Bernard Wetlands Foundation] said, "Everyone needs to spread the word that Louisiana's wetlands are really America's wetlands."

Hurricane Katrina (2005) compounded the damage to this delicate ecosystem. The storm severely damaged many coastal forests and wetland ecosystems that formed natural barriers and provided protection to the citizens of St. Bernard Parish. These vital coastal ecosystems must be rebuilt to protect the communities within St. Bernard Parish, and to restore coastal biodiversity. Loss of coastal forests has not only increased the vulnerability of human populations to storm impacts, but has also decreased the amount of biodiversity in the Parish, through the conversion of swamp and marshland to open water. Cypress-tupelo swamps and marshlands provide vital habitat to several threatened or endangered species, such as the Brown Pelican (*Pelecanus occidentalis),* the Bald Eagle (*Haliaeetus leucocephalus)*, the Whooping Crane (*Grus americana),* and the Louisiana Black Bear (*Ursus americanus luteolus).*

Volunteer groups, nongovernmental organizations (NGOs), and government entities often work independently and use different sets of information to choose the best planting sites for restoring coastal forests. The SSC DEVELOP team aided all these groups by using NASA's Earth Observing System (EOS) satellite data to create maps showing ideal planting sites for baldcypress and other coastal tree species in St. Bernard Parish. As a result of DEVELOP's research, the St. Bernard Wetlands Foundation, Wetlands Tree Foundation, Louisiana State University

Agricultural Center, St. Bernard Parish Planning Commission, and Meraux Foundation now have one set of unbiased, science-based maps to guide reforestation planning and implementation.

Together with NASA's EOS data, a robust assortment of complimentary information laid the foundation for the project methodology. The project used an array of datasets such as Natural Resources Conservation Service (NRCS) soil surveys, ancillary road and canal data, digital elevation models (DEM) obtained from the U.S. Geological Survey (USGS) National Elevation Dataset (NED), and ground-truth data—see **Figure 1**. These data, in conjunction with NASA's EOS satellite data, were used to create a comprehensive geographic information system (GIS) to help identify suitable planting sites. The ancillary datasets provided the team with knowledge of suitable soil types and elevation for planting, transportation infrastructure data, and freshwater inputs.

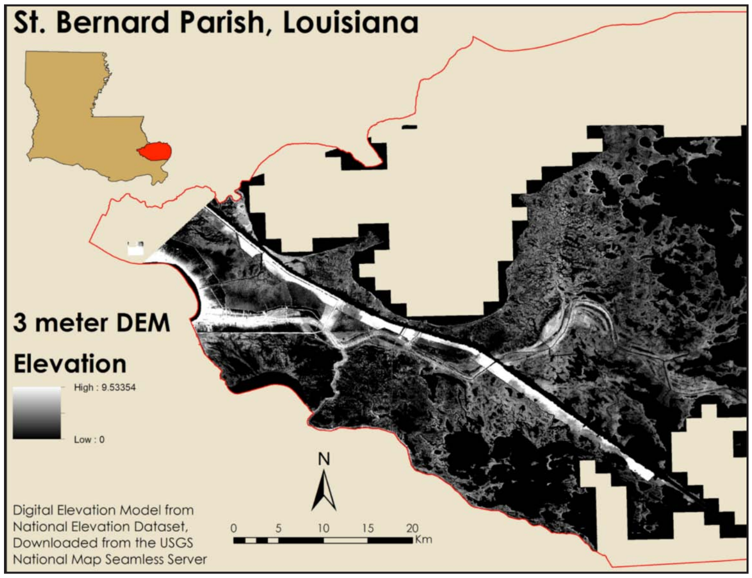


Figure 1. The USGS National Elevation Dataset was obtained at 1/9-arc-sec (~3-m) spatial resolution from the National Map Seamless Server (NMSS). This information was important to the project because it helped to determine suitable planting sites for baldcypress, as the tree grows best at elevations of 1.5 to 5 ft (~0.5 to 2 m). The DEM was reclassified into ranges of elevation using half-meter (~1.6-ft) increments for ease of analysis and interpretation of results. **Image credit:** Ross Reahard, Emma Strong, Michael Ewing, Maria Arguelles, and Chelsey Kelly

The team obtained historical aerial photography from USGS's Earth Explorer (*earthexplorer.usgs.gov*), and used it to estimate the spatial extent of forested land before the construction of the MRGO canal, which took place before the era of spaceborne data acquisition. Imagery collection dates include April and May of 1952 and February of 1956—see **Figure 2**.

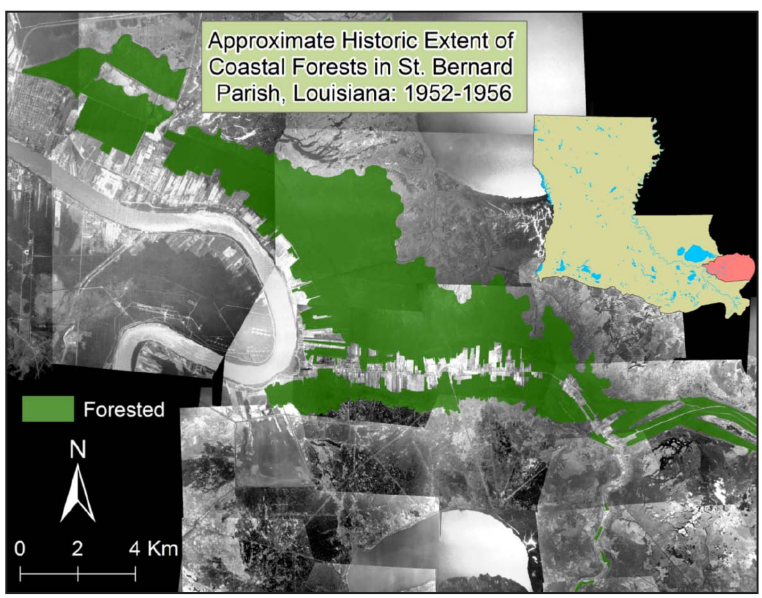


Figure 2. This map, created with historical aerial imagery, shows coastal forests between 1952 and 1956. **Image credit:** Ross Reahard, Emma Strong, Michael Ewing, Maria Arguelles, and Chelsey Kelly

The students used multispectral imagery of St. Bernard Parish from 1976 to 2011 to create land classifications and to demonstrate changes in land use and land cover. These images were obtained from the Thematic Mapper on Landsats 4 and 5, as well as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), on the EOS Terra satellite.

Adding to the diverse imagery collected for this project, the team obtained hyperspectral Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) imagery for the years 2010 and 2011 from the NASA/Jet Propulsion Laboratory (JPL) AVIRIS 2006–2010 Flight Data Locator to create a high-resolution land-cover classification map. The data were characterized and recoded to give the team a map containing four distinct land-cover classes: water, marsh, forest/shrub, and urban. Furthermore, AVIRIS data from a single low-altitude swath from May 5, 2010, were processed to calculate a red-edge Normalized Difference Vegetation Index (red-edge NDVI). This analysis was conducted to highlight the robust capabilities of AVIRIS, as well as demonstrate to end-users one potential method of monitoring restored vegetation health. If used responsibly, this index can yield valuable information on tree stand composition and health at fine spatial scales. If hyperspectral data are not available after the planting process is complete, multispectral vegetation indices, such as the standard Normalized Difference Vegetation Index (NDVI), can easily be calculated by end-users to monitor spatiotemporal trends in the health of restored forests.

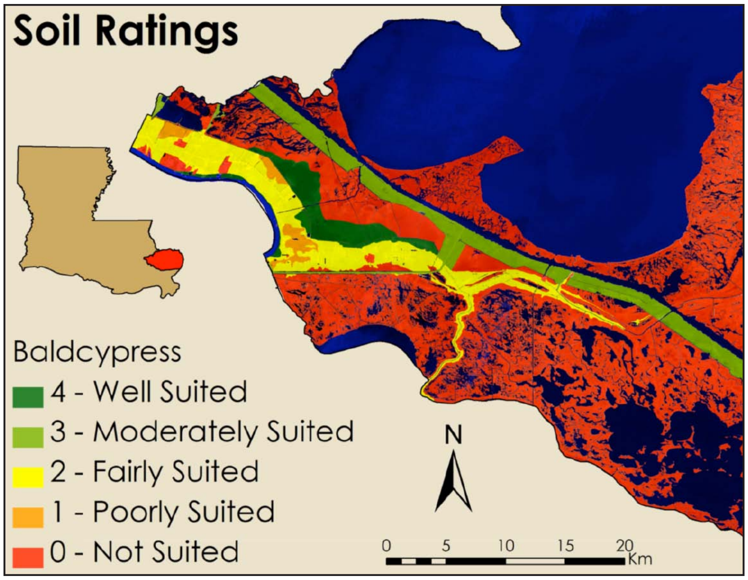


Figure 3. This map shows soil suitability for baldcypress (*Taxodium distichum*). **Image credit:** Ross Reahard, Emma Strong, Michael Ewing, Maria Arguelles, and Chelsey Kelly

The availability of wide-ranging, free NASA data contributed greatly to the success of this project. The team was able to present their partners with maps indicating which areas had the most suitable soil ratings—see **Figure 3**—and elevations for a particular tree species of interest, along with a land-cover classification map created from high-resolution imagery. Most importantly, maps created through use of the team's comprehensive GIS analysis, depicting ideal planting locations, were handed over to the St. Bernard Wetlands Foundation, Wetlands Tree Foundation, Louisiana State University Agricultural Center, St. Bernard Parish Planning Commission, and Meraux Foundation and put into immediate use, and will continue to guide coastal reforestation efforts for the foreseeable future. **Brandie Mitchell** [DEVELOP SSC—*Student Director*] explained, "The goal of the SSC DEVELOP team was to provide a tangible resource for all of the organizations to use in order to rebuild the coastal forests in this parish."

In addition, the basic methodology that the team developed can be easily tailored to fit a variety of other coastal restoration applications, further extending the usefulness and role of NASA's EOS satellite data for rebuilding coastal ecosystems.

The project was awarded first place in a virtual poster session sponsored by Esri and hosted on the Institute of Electrical and Electronics Engineers' *Earthzine* website at *www.earthzine.org/nasa-develop-fall-virtual-poster-session*. ■

A baldcypress stand in St. Bernard Parish, LA, near the outflow from a local pumping station. Pumping stations drive freshwater from urban runoff into areas outside of the levee protection, creating a suitable habitat for the trees. **Image credit:** Emma Strong

Ocean Surface Topography Science Team Meeting and Twenty Years of Progress in Radar Altimetry Symposium

Josh Willis, Jason-1 Deputy Project Scientist, NASA/Jet Propulsion Laboratory, joshua.k.willis@jpl.nasa.gov
Pascal Bonnefond, Project Scientist, Geoazur, France, pascal.bonnefond@obs-azur.fr

Introduction and Meeting Overview

The 2012 Ocean Surface Topography Science Team (OSTST) Meeting was held, September 27-28. The meeting was part of a weeklong program of altimetry-related workshops held in Venice, Italy (*www.altimetry2012.org*). The week included the *20 Years of Progress in Radar Altimetry* Symposium (September 24-26), the International DORIS[1] Service (IDS) Workshop (September 25-26), the *Fourth Argo Science Workshop* (September 27-29), and the OSTST Meeting itself. In addition, the *Sixth Coastal Altimetry Workshop* took place in Riva del Garda, Italy (September 20-21) —immediately prior to the meetings in Venice.

The focus in this report is on the OSTST Meeting, the primary objectives of which were to:

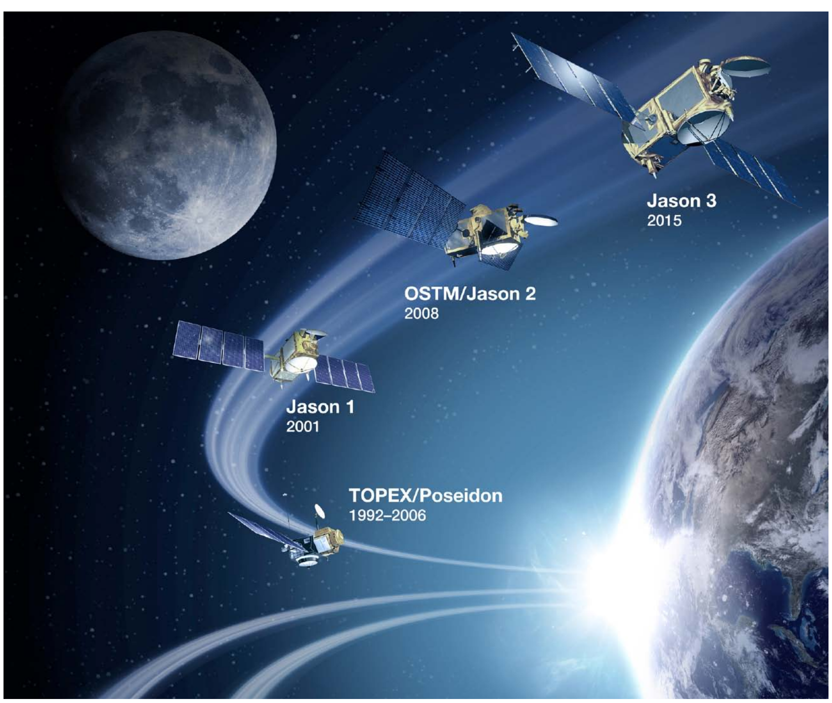
- conduct splinter meetings on the various corrections, altimetry data products, and activities[2];
- provide updates on the status of Jason-1 and OSTM–Jason-2 (hereinafter, Jason-2); and
- discuss the science and technical requirements for future altimetry missions.

[1] DORIS stands for Doppler Orbitography and Radiopositioning Integrated by Satellite.
[2] While listed as an objective of the OSTST Meeting, the bulk of the science content came during the *20 Years of Progress in Radar Altimetry* symposium that took place earlier in the week. Although separate meetings, their content was complementary, and many attended both.

20 Years of Progress in Radar Altimetry Symposium

This three-day symposium was held in honor of the twentieth anniversary of the launch of the Earth Research Satellite (ERS)-1 and the Ocean Topography Experiment (TOPEX)/Poseidon [T/P]. Reviews of science results and operational achievements of the past 20 years were presented, including many aspects of satellite altimetry. It included opening and closing plenary sessions—speakers and presentations for which are listed in **Tables 1** and **2** respectively—and these splinter sessions:

- Oceanography – Tides, Internal Tides, and High Frequency Processes
- Building the 20-Year Altimetric Record
- Cryosphere
- Oceanography – Large Scale
- Oceanography – Wind and Waves



Satellite altimeter missions supported by the Ocean Surface Topography Science Team. Since 1992 (when TOPEX/Poseidon launched), satellite altimeters have continuously monitored the changing "topography" (i.e., the height) of the ocean's surface. TOPEX/Poseidon overlapped with Jason-1 (launched in 2001), and Jason-1 overlapped with Jason-2 (launched in 2008), enabling the creation of a climate-quality record of sea surface height that spans 20 years. Jason-3 (planned for launch in 2015) will extend this record into its third decade—and a Jason Continuity-of-Service (CS) mission is planned after that. The OSTST has helped to ensure the accuracy, integrity, and continuity of this important climate record.

- Hydrology and Land Processes
- Oceanography – Mean Sea Level Trends
- Outreach
- Hydrology and Land Processes
- The Integrated Approach
- Coastal Altimetry
- Oceanography – Mesoscale
- Marine Geodesy, Gravity Bathymetry, and Mean Sea Surface
- The Future of Altimetry

Table 1: 20 Years of Progress in Radar Altimetry Symposium Opening Plenary Presentations.

Topic	Speaker	Institution
The Challenges in Long-term Altimetry Calibration for Addressing the Problem of Global Sea Level Change	**Lee-Lueng Fu**	NASA/Jet Propulsion Laboratory (JPL)
From Satellite Altimetry to Operational Oceanography: A Historical Perspective	**Pierre Yves Le Traon**	Centre National d'Études Spatiale (CNES)
A 20-Year Climate Data Record of Sea Level Change: What Have We Learned?	**Steven Nerem**	University of Colorado
Warming in the Southern Ocean: Assessing the Mechanisms with Altimetry and Argo	**Sarah Gille**	Scripps Institution of Oceanography
The Ocean Mean Dynamic Topography: 20 Years of Improvements	**Marie-Helene Rio**	Collecte Localisation Satellites (CLS)
Self-Induced Ekman Pumping Over Oceanic Mesoscale Eddies	**Dudley Chelton**	Oregon State University (OSU)
Twenty Years of Progress on Global Ocean Tides: The Impact of Satellite Altimetry	**Gary Egbert**	OSU
Conquering the Coastal Zone: A New Frontier for Satellite Altimetry	**Paolo Cipollini**	National Oceanography Centre, Southampton (NOCS)
Advances in Our Understanding of the Polar Ice Sheets due to Satellite Altimetry	**Andrew Shepherd**	University of Leeds
20 Years of River and Lake Monitoring from Multi-mission Satellite Radar Altimetry	**Philippa Berry**	Earth and Planetary Sensing (EAPRS) Lab, De Montfort University, U.K.

Table 2: 20 Years of Progress in Radar Altimetry Symposium Closing Plenary Presentations.

Topic	Speaker	Institution
Argonautica: An Educational Project Using JASON Data	**Danielle de Staerke**	CNES
The Sea Level Climate Record	**Anny Cazenave**	Laboratoire d'Études en Géophysique et Océanographie Spatiale (LEGOS)
The Small Scale Processes: Sub-Mesoscale, Coastal, and Marine Geoid	**Lee-Lueng Fu**	JPL
Inland Surface Water	**Peter Bauer-Gottwein**	Technical University of Denmark
The Cryosphere	**Federique Remy**	LEGOS
Operational Oceanograghy and Forecasting (Assimilation, Wind-Wave)	**Eric Dombrowsky**	MERCATOR Ocean (France)
The Role of the Altimetry Constellation	**Hans Bonekamp**	European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

Ocean Surface Topography Science Team Meeting

The science splinter groups and plenaries having been completed earlier in the week, the deliberations at this year's OSTST Meeting delved into various technical aspects of the current and future OST missions. These discussions led to a number of important recommendations, which are included below.

Status of Current OST Missions (Jason-1 and Jason-2)

A topic of significant discussion at the 2012 meeting was the status of current Ocean Surface Topography missions. The Jason-2 mission launched in June 2008 on the former ground tracks of Jason-1 and T/P. All systems are in excellent condition and the satellite is operating nominally. The calibration and validation of Jason-2 data have shown that all mission and Level 1 science requirements continue to be met. Reprocessing of the Geophysical Data Record, Release D (GDR-D) is now complete. Thanks to the errors discovered and corrected by the Jason-2 Project (see OSTST 2011 report), *the Jason-2 altimeter bias is no longer distinguishable from zero. This reconciles the Jason-2 time series with the one begun by T/P in 1992.*

The year 2012 has been a milestone year in the life of Jason-1, as the satellite was successfully placed into a new geodetic orbit. This new orbit removes Jason-1 from the 1336-km reference orbit that it shared with Jason-2 and the now defunct T/P, thereby minimizing the risk of any collision or increased debris, should Jason-1 become uncontrollable. In its new orbit Jason-1 continues to make essential contributions to oceanographic research and operational activities, as well as improving knowledge of the marine gravity field. As part of its new geodetic mission, Jason-1 is helping to produce high-resolution maps of the sea surface, shaped by the pull of gravity from the rough topography of the ocean floor. It does so by overflying new regions along a much more densely spaced ground track with relatively low inclination.

Plans and Requirements for Future OST Missions (Jason-3 and Jason-CS)

Another major topic of discussion at the meeting was planning for future OST missions. The next planned mission is Jason-3, which is nearly identical in design to Jason-2—but incorporates some new features. These include an onboard calibration process for the Advanced Microwave Radiometer (AMR), which involves pitching the satellite while on orbit to view the cold sky. This process was adopted following OSTST recommendations from the 2010 meeting in Lisbon, Portugal, to improve AMR stability, and the discussion of the cold-sky maneuver at the 2011 meeting in San Diego, CA. In mid-July 2012 Jason-3 achieved an important milestone with the selection of the Falcon 9 from *SpaceX* as a launch vehicle. The OSTST recognized this important milestone, but stressed the importance of maintaining the December 2014 launch date for Jason-3 in order to preserve the continuity of the sea level record. **Despite this recommendation, SpaceX recently announced a delay in readiness of the launch vehicle that will further slip the launch date to March 2015**.

Following Jason-3, the Jason Continuity-of-Service (CS) mission will continue the Jason series of research and operational oceanography missions. The CS mission will comprise as part of its payload a K_u/C-band radar altimeter; a K/K_a band passive microwave radiometer; and global navigation satellite system (GNSS) equipment, including DORIS. At this stage of development two important issues were raised and intensively discussed in the various splinter groups: the configuration of the microwave radiometer and the possibility of flying multiple radiometer instruments, and the mode of operation for the altimeter.

These discussions led to two important recommendations from the OSTST, summarized as follows:

1. The primary enhancement needed on any Jason-CS radiometer should enable long-term stability from the radiometer, eliminate dependence on ancillary data sources, and reduce the latency of the final calibrated product. The Jason-CS system will also benefit significantly from a three-frequency radiometer. Finally, the most significant benefit from the deployment of two radiometers would be for the second to operate at high frequencies to improve coastally altimetry and inland hydrology applications

2. The OSTST strongly recommends that the Jason-CS altimeter deliver both backward-compatible low-resolution mode (LRM) and high-resolution synthetic aperture radar (SAR) range measurements over the entire ocean, seamlessly and simultaneously.

During this and the previous meeting in San Diego there were numerous studies and discussions about the SAR mode of measurement. These included potential use of SAR mode on Jason-CS as well as existing instruments with SAR capabilities [e.g., the European Space Agency's (ESA's) CryoSat-2] and those on upcoming missions (e.g., ESA's Sentinel-3, planned for launch in 2014). The potential for improved accuracy and resolution using SAR-mode systems was clearly noted. In particular, discussions focused on an apparent improvement in the accuracy of altimeter observations on wavelengths between 7 and 50 km. However, it was also noted that further studies are needed to identify and

continued on page 30

CERES Science Team Meeting

Sarah Crecelius, NASA's Langley Research Center/Science Systems and Applications, Inc. (SSAI), sarah.a.crecelius@nasa.gov
Cristian Mitrescu, NASA's Langley Research Center/SSAI, cristian.mitrescu@nasa.gov

The Fall 2012 Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting was held October 22-26, 2012, at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, NJ. **Leo Donner** [Geophysical Fluid Dynamics Laboratory (GFDL)] and **Norman Loeb** [NASA's Langley Research Center (LaRC)—*CERES Principal Investigator*] conducted the meeting.

The major objectives of the meeting were to review and provide status updates on CERES instruments and data products, including the:

- State of CERES address;
- CERES Flight Model (FM) 1–6 instruments;
- Moderate Resolution Imaging Spectroradiometer (MODIS) *Edition 4* algorithm;
- Next generation CERES Angular Distribution Models (ADMs);
- Surface-Only Flux Algorithm *Edition 4*;
- Surface Atmospheric Radiation Budget (SARB);
- Time-Space Averaging;
- CERES Data Management Team;
- Atmospheric Sciences Data Center (ASDC); and
- CERES Education and Public Outreach (E/PO) efforts.

Norman Loeb gave the *State of CERES* address. He began with a description of the role CERES plays in understanding Earth's radiation budget. Loeb emphasized how CERES provides continuous, long-term, Earth radiation budget observations at the top of the atmosphere, within the atmosphere, and at the surface, together with coincident cloud, aerosol, and meteorological data. This capability makes CERES products attractive for climate model evaluation and improvement. He then presented details on the CERES Data Processing Flow (made possible by an array of CERES working groups), recent accomplishments, and plans for the future of CERES—i.e., data processing, conferences, missions, collaborations, and field experiments, such as the CERES Ocean Validation Experiment.

Kory Priestley [LaRC] provided a status report on CERES FM 1–6 instruments, focusing on the efforts and challenges that the CERES Instrument Working Group must tackle to ensure the continuity of the climate data record in the broader picture of multi-agency collaboration and interaction. Priestley next emphasized the current status of the CERES FM6 sensor with reference to the Mirror Attenuator Mosaic (MAM) scatter nonuniformity, In-flight Calibration Module (ICM) lamp brightening, and the decrease in ICM lamp monitor (photodiode) response.

Susan Thomas [LaRC/Science Systems and Applications Inc. (SSAI)] provided a status report on the Suomi National Polar-orbiting Partnership (NPP)/CERES FM5, stating that the instrument's characteristics are within the expected range. For the CERES FM1-4, an investigation on the Aqua/Terra *Edition 3* data measurement (longwave during daytime) trends is ongoing.

A complete list of CERES meeting reports can be found in **Table 1**[1] (next page).

The Scanner for Radiation Budget[2] (ScaRaB) and Geostationary Earth Radiation Budget[3] (GERB) meetings were held during day two of the CERES Science Team Meeting at GFDL. **Remy Roca** [Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS), France] and **Jacqui Russell** [Imperial College London, U.K. (Imperial)] conducted the joint sessions.

Remy Roca provided an overview of the ScaRaB FM3 on the Megha-Tropiques[4] (MT) mission, including a comparison between GERB and ScaRaB. He also described progress since the last joint meeting, including updates on

[1] A comprehensive list of CERES-related acronyms including many used in **Tables 1-4** can be found at *ceres.larc.nasa.gov/acronyms_main.php*.
[2] The Scanner for Radiation Budget (ScaRaB) project was a cooperative effort by France, Russia, and Germany, intended to continue measurements made by the Earth Radiation Budget Experiment (ERBE). ScaRaB FM1 flew on the Russian Meteor-3/7 weather satellite between 1994 and 1995; FM2 flew on the Russian Resurs-01/4 satellite between 1998 and 1999.
[3] The Geostationary Earth Radiation Budget (GERB) flies aboard the European Organisation for the Exploitation of Meteorological Satellites' (EUMETSAT) Meteosat Second Generation geostationary satellites. The three GERB instruments are designed to make accurate measurements of the Earth's radiation budget and were built by a European consortium consisting of the U.K., Belgium, and Italy. The first, known as GERB 2, launched on August 28, 2002; the second, GERB 1, launched on December 21, 2005; and the third, GERB 3, launched on July 5, 2012.
[4] Megha-Tropiques (MT) is the result of collaborative effort between Indian Space Research Organisation (ISRO) and French Centre National d'Études Spatiales (CNES). Designed to study water and energy cycles in the tropics and their connection to climate change, Megha-Tropiques was successfully placed into orbit by an Indian Polar Satellite Launch Vehicle (PSLV) in October 2011.

the coincidence campaign using CERES Programmable Azimuth Plane Scan (PAPS) mode, the validation of cloud mask/type against CALIPSO, the current science investigations using CERES, and new products.

Jacqui Russell provided an overview of the GERB Project Status. She began with the Meteosat Long-Term Planning Perspective, and then focused on the technical and science aspects of GERB. Russell mentioned GERB calibration efforts, data availability, and solutions to the sunglint problem. She also presented comparisons between GERB 2 and GERB 1, and GERB 2 and CERES. After cross-calibration of the recently launched GERB 3 and GERB 1 is complete, the team plans to conduct the studies required to tie the three records together and to correct for in-orbit calibration changes, enabling a consistent, combined record for *Edition 2* data.

Additional ScaRaB and GERB presentations are listed in **Table 2** below.

Table 1: CERES meeting reports from Monday, October 22, 2012.

CERES Technical Sessions		
Topic	Speaker	Institution
State of CERES	**Norman Loeb**	NASA's Langley Research Center (LaRC)
CERES FM1-6 Instrument Update (Part 1)	**Kory Priestley**	LaRC
CERES FM1-6 Instrument Update (Part 2)	**Susan Thomas**	LaRC/Science Systems and Applications, Inc. (SSAI)
CERES *Edition 4* Clouds Update	**Patrick Minnis**	LaRC
Update on the Next Generation CERES Angular Distribution Models	**Wenying Su**	LaRC
Status of the *Edition 4* Surface-Only Flux Algorithm	**David Kratz**	LaRC
Surface Atmospheric Radiation Budget	**Seiji Kato**	LaRC
Time-Space Averaging Update	**Dave Doelling**	LaRC
CERES Data Management Team Status	**Jonathan Gleason**	LaRC
Atmospheric Sciences Data Center Update	**Lindsay Parker**	LaRC/SSAI
Education and Public Outreach Update	**Sarah Crecelius**	LaRC/SSAI

Table 2: Complete list of the joint meeting reports (i.e., ScaRaB and GERB) presented on Tuesday, October 23, 2012.

ScaRaB Technical Sessions		
Topic	**Speaker**	**Institution**
Overview of the Megha-Tropiques (MT) Mission	**Remy Roca**	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)
The ScaRaB FM3 Instrument and Performance	**Nadia Karouche**	Centre National d'Etudes Spatiales (CNES)
Scarab: First Calibration Results	**Alain Rozach**	CNES
The Orbit of MT and Consequences for Sampling	**Michel Capderou**	Laboratoire de Météorologie Dynamique (LMD)
Coincidence Campaign Between CERES and ScaRaB: First Results	**Olivier Chomette**	LMD

Table 2 (cont): Complete list of the joint meeting reports (i.e., ScaRaB and GERB) presented on Tuesday, October 23, 2012.

GERB Technical Sessions		
GERB Project Status: An Overview	**Jacqui Russell**	Imperial College London (Imperial)
Calibration Report, Data Status,and Future Planning	**Jacqui Russell**	Imperial
Commissioning and Operations Status Report	**James Rufus**	Imperial
GERB X-Cal Plans	**Richard Bantges**	Imperial
GGSPS Report: Evolution of the GERB Ground Segment Processing System	**Peter Allan**	Rutherford Appleton Laboratory (RAL)
ROLLS Report: Status of GERB Level 2 Instantaneous Fluxes and CM SAF Level 3 Monthly Mean	**Nicolas Clerbaux**	Royal Meteorological Institute of Belgium (RMIB)
Sunglint Filling: Status	**Edward Baudrez**	RMIB
Composite TOA Clear-Sky Solar Fluxes for the GERB Processing	**Alessandro Ipe**	RMIB
Cloud Detection Using SEVIRI IR Channels for GERB Processing	**Alessandro Ipe**	RMIB
Wrap-Up and Actions	**Jacqui Russell**	Imperial

In addition to CERES-specific science reports presented by science team members, **Leo Donner** [GFDL], **Stephen Fueglistaler** [Princeton University], and **Isaac Held** [GFDL] gave invited presentations that are summarized below. For a complete list of invited presentations see **Table 3**.

Leo Donner [GFDL] presented *Recent Advances in Modeling Physical Processes in Climate Models: Implications for Global Space-Based Measurements*. He showed comparisons between several models against A-Train[5]-derived quantities, pointing out that these types of global observations of radiative fluxes, cloud microphysical properties, and their relationship to aerosols are essential for constraining global models, but are also an invaluable resource for both testing and improving much-needed physical parameterizations in numerical models at any resolution.

[5] The November–December 2012 issue of *The Earth Observer* includes a description of the A-Train in the context of the Aqua mission [**Volume 24**, **Issue 5**, p. 16.] The constellation also has a website: *atrain.nasa.gov*.

Stephan Fueglistaler [Princeton University] presented *Global Energy Constraints and Local Variability - Insights from Natural Variability.* He described his motivation to find answers to the mechanisms responsible for local balances within an energetically constrained Earth system. To do this, he turned to observations and model output, trying to find out how the balance of terms shifts in each dataset is associated with variability. Fueglistaler concluded that there is a remarkably high degree of "compensation" in the climate system, both for aspects of the mean annual cycle and El Niño/Southern Oscillation (ENSO)-related variability (noting also that ENSO has little impact on shortwave radi-

Table 3: CERES invited presentations from Wednesday, October 24, and Thursday, October 25, 2012.

Invited Science Presentations		
Topic	**Speaker**	**Institution**
Recent Advances in Modeling Physical Processes in Climate Models: Implications for Global Space-Based Measurements	**Leo Donner**	GFDL
Model versus Radiation Budget Associated with Interannual Variability	**Stephan Fueglistaler**	Princeton University
Some Issues Related to Feedback Analyses of Climate Sensitivity	**Isaac Held**	GFDL

ation). Models' responses to forcings are locally biased and partially linearly related to bias in global mean state. The lesson learned is that the variations in global mean can be easily understood from the perspective of the global mean energy balance, but emergence of the "mean" signal is still a challenge to understand.

Isaac Held [GFDL] discussed *Some Issues Related to Feedback Analyses of Climate Sensitivity*. He examined possible climatic scenarios, using simple physical concepts to describe the equation for global mean temperature. However, model simulations show that equilibrium response brings into play feedbacks/dynamics in subpolar oceans that are suppressed in the transient response. A possible solution to alleviate this problem is to focus on constraining transient climate sensitivity in terms of the tropospheric relative humidity feedback, rather than the water vapor feedback.

Following the invited presentations, there were a series of co-investigator reports, with updates on new data products and science results—see **Table 4**, below, which includes some of the presentations that have already been described.

Table 4: Complete list of CERES co-investigator reports given on Thursday, October 25, 2012.

Contributed Science Presentations		
Topic	**Speaker**	**Institution**
An Update on Spectral Flux Estimation from Collocated AIRS and CERES Measurements	**Xianglei Huang**	University of Michigan
Variability of the TOA Flux Diurnal Cycle at Monthly Timescales	**Patrick Taylor**	LaRC
Tropical Clear-sky OLR Variability Studies from a Simple Model	**Rodrigo Guzman**	LMD
CERES Suomi NPP ERBE-like Monthly Mean Fluxes	**Takmeng Wong**	LaRC
Climate Monitoring with Earth Radiation Budget Measurements	**Steven Dewitte**	RMIB
Cloud Radiation Anomalies Observed by CERES	**Bing Lin**	LaRC
Cloud Radiative Forcing in the Indian Monsoon Region	**Bijoy Thampi**	LEGOS
Cloud-Radiation Response to Large-Scale Circulation Variability	**Norman Loeb**	LaRC
Direct Aerosol Radiative Effect from C3M	**Dave Winker**	LaRC
Radiative Closure of CERES TOA SSF Fluxes Over Volcanic Ash Plumes Using MODIS, CCCM, and MATCH	**David Fillmore**	Tech-X Corp.
Retrieved Vertical Distribution of Saharan Dust and Comparison to Models Over the Northern Tropical Atlantic	**Weijie Wang**	University of Virginia/SSAI
Aerosol Optical Depth and Direct Aerosol Forcing Using SEVIRI/GERB	**Stijn Nevens**	RMIB
Observations of the Net Direct Radiative Effect of Saharan Mineral Dust From SEVIRI and GERB	**Catherine Ansell**	Imperial
Progress in CERES Clear-sky Aerosol Optical Thickness-Dependent Shortwave ADMs over Ocean	**Lusheng Liang**	LaRC/SSAI
Status of the BBR LW Radiance-to-Flux Baseline Conversion Algorithms	**A. Velazquez**	RMIB
CERES Ordering Tool: Highlights of Its Capabilities	**Cristian Mitrescu**	LaRC/SSAI

Table 4 (cont)**:** Complete list of CERES co-investigator reports given on Thursday, October 25, 2012.

Contributed Science Presentations		
Topic	**Speaker**	**Institution**
Aging Model for Meteosat First-Generation VIS Band	**Ilse Decoster**	RMIB
Comparisons of CERES FLASHFlux and EBAF TOA Fluxes	**Shashi Gupta**	LaRC/SSAI
TISA LW Narrowband-to-Broadband Radiance Algorithm and CERES Simulator	**Moguo Sun**	LaRC/SSAI
EBAF Surface Product Updates	**Fred Rose**	LaRC/SSAI
Overview of CERES *Edition 4* Multilayer Cloud Properties	**Fu-Long Chang**	LaRC/SSAI
CERES Clouds Edition4 Validation with C3M	**Sunny Sun-Mack**	LaRC/SSAI
Macro- and Microphysical Properties of Low-Level Marine Stratus Retrieved by Ground-Based and Satellite Measurements at Azores	**Baike Xi**	University of North Dakota
SIMBA the Nanosatellite	**Steve Dewitte**	RMIB

Full presentations are available on the CERES website at *ceres.larc.nasa.gov* (found under the *CERES Meeting* button on the left navigation bar.) The next CERES science team meeting will be held from May 7-9, 2013, at the Pearl Young Theater at NASA's Langley Research Center in Hampton, VA. ■

Ocean Surface Topography Science Team Meeting and Twenty Years of Progress in Radar Altimetry Symposium

continued from page 25

eliminate any possible biases between LRM and SAR modes of operation, and that models that correct for sea-state bias have yet to be developed and tested for SAR-mode data. It was also noted that data from existing and upcoming missions could provide important opportunities for calibration and validation of SAR data from Jason-CS.

The ensuing discussion led to the following additional recommendations from the OSTST directed to CryoSat-2 and Sentinel-3 Programs respectively:

To CryoSat-2: Allow distribution of currently generated value-added science products on a free and open basis. Provide a global seamless product over the ocean (LRM and SAR regions) as soon as possible.

To Sentinel-3: The area of Sentinel-3 SAR altimeter acquisitions should be maximized over the ocean to include all open ocean, coastal regions, and marginal seas.

Conclusion

Overall, the two meetings were very successful and productive. The full meeting report, which includes the proceedings of the OSTST Meeting along with all of the individual presentations from the plenary, splinter, and poster sessions during the "20 Years" symposium, are available on the Aviso[3] website: *www.aviso.oceanobs.com/ostst*. The next OSTST Meeting has been scheduled for the week of October 7, 2013, in Boulder, CO. ■

[3] Aviso stands for Archiving, Validation, and Interpretation of Satellite Oceanographic data.

Sounder Science Team Meeting

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NASA Sounder Science Team meeting participants. **Image credit:** Hartmut Aumann.

The NASA Sounder Science Team meeting was held November 13-16, 2012, at the Greenbelt Marriott in Greenbelt, MD. The sounding science community is currently examining data from hyperspectral instruments and associated microwave sounders on three operating spacecraft, spanning more than ten years of coverage. Oldest are the Atmospheric Infrared Sounder (AIRS) and Advanced Microwave Sounder (AMSU) suite, launched on NASA's Aqua spacecraft on May 4, 2002. Second to be launched were the Infrared Atmospheric Sounding Interferometer (IASI) and AMSU on the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) MetOp satellites[1], on orbit since October 19, 2006. The third instruments set includes the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) on the Suomi National Polar-orbiting Partnership (NPP) satellite launched October 28, 2011. The data from these instruments are a significant international resource and have received attention from a large community of engineers and scientists in many fields, especially weather forecasting, climate, and atmospheric composition.

The presentations given during the workshop included results from all three of these instrument suites, although the majority addressed the AIRS/AMSU data record, reflecting its longevity, the meeting's NASA sponsorship, and meeting organization by the AIRS project. Over 100 registered participants gave more than 70 presentations, including describing significant milestones for each instrument. The AIRS data record is now more than a decade long, dating to when the instrument became fully operational on August 31, 2002. In addition, the AIRS Version 6 (V6) Level 2 data products are currently being processed and made publicly available, and show significant improvements over those from V5, which have been available since 2007. The IASI instrument record is over six years long; its broad and fine spectral coverage has made it especially useful for characterizing atmospheric trace gases and for weather forecasting. The CrIS instrument has been working for over a year now. With its calibration complete and within prelaunch specifications, the CrIS/ATMS retrieved products also are approaching their prelaunch specifications.

[1] MetOp is a series of three polar-orbiting meteorological satellites.

The workshop results were presented in ten separate sessions described hereinafter. The session titles reflect the major topics in sounder science research. The contents of the talks are posted online at the AIRS project website: *airs.jpl.nasa.gov*.

Session 1: Introduction and Project Status

Tom Pagano [NASA/Jet Propulsion Laboratory (JPL)—*AIRS Project Manager*], welcomed the participants, and described the status of the AIRS and AMSU instruments, as well as the Aqua spacecraft itself. All are anticipated to operate well beyond the 2020 timeframe. Pagano also recognized **Scott Hannon** [University of Maryland, Baltimore County] and **Gyula Molnar** [NASA's Goddard Space Flight Center (GSFC)], both of whom passed away this fall, for their significant contributions to the sounding community.

Joao Teixeira [JPL—*AIRS Science Team Leader*] showed the value of AIRS for weather forecast improvement and climate model validation, and discussed project plans to develop V7 retrievals and to improve the value of AIRS products for operational applications.

Jack Kaye [NASA Headquarters—*Earth Science Division Associate Director for Research*] summarized new Earth science missions at NASA, and commended the operational teams for sustained instrument performance.

Mitch Goldberg [National Oceanic and Atmospheric Administration (NOAA)] showed results from the Suomi NPP Sensor Data Records review team, who concluded that CrIS, ATMS, and Visible Infrared Imaging Radiometer Suite (VIIRS) products are ready to be declared *provisional*, the first step toward full product characterization.

Eric Fetzer [JPL—*AIRS Project Scientist*] showed science highlights from various scientists using AIRS/AMSU data, and noted there were more peer-reviewed publications in 2012 (70, as of November 1, 2012) using these datasets than in any prior year.

Thomas August [EUMETSAT] presented the IASI V5 data products, showing significant improvements in atmospheric and land surface temperature, clouds, carbon monoxide (CO), and ozone (O_3).

Session 2: Climate Processes and Model Validation

Norman Loeb [NASA's Langley Research Center (LaRC)] showed that Earth currently absorbs 0.5 W/m^2 more energy than is reradiated to space, based on deep ocean buoy temperature measurements. The challenge remains to confirm this finding with the Clouds and Earth's Radiant Energy System (CERES)-derived Outgoing Longwave Radiation (OLR) and Reflected Shortwave Radiation (RSW) products.

Hartmut "George" Aumann [JPL] showed decadal trends in OLR and RSW derived from AIRS infrared and visible observations. In the past ten years there has been no discernible change in the global energy balance—this, despite significant Arctic surface warming.

Larrabee Strow [UMBC] discussed how AIRS radiance probability density functions could be used for climate trending. He suggested that combining data from AIRS, IASI, and CrIS could provide an early multidecadal record to supplement the long wavelength infrared (IR) observations from the Climate Absolute Radiance and Refractivity Observatory (CLARREO[2]), currently in pre-phase-A status.

Sun Wong [JPL] showed that colder and higher clouds are more sensitive to changes in sea surface temperature than other cloud types.

Xianglei Huang [University of Michigan] showed that AIRS OLR and CERES OLR data products agree extremely well. He also showed that spectral band-by-band comparisons of observed cloud radiative effects with those from climate models provide a more-rigorous validation of climate than OLR alone.

Stephen Eckermann [Naval Research Laboratory (NRL)] showed that stratospheric gravity waves derived from nine years of AIRS radiances reveal novel signatures of orographically forced wave activity throughout the wintertime subtropical stratosphere over Australia and southern Africa.

Gerald Potter [GSFC] introduced a new tool, that allows public access to data from climate models, observations, and reanalysis. Potter also described related analytical tools.

Alexander Ruzmaikin [JPL] showed that supersaturation and dry extremes of relative humidity follow the *Gumbel distribution function*[3].

David Chapman [UMBC] described a nearest-neighbor estimator of the AIRS retrieval moisture bias using V6 Level 2 data. He concluded that, globally, AIRS data are about 2% too dry.

Baijun Tian [JPL] described evaluating Modern-Era Retrospective Analysis for Research and Applications (MERRA) and Coupled Model Intercomparison Project 5 (CMIP5) models, using tropospheric temperature and specific humidity data from AIRS. Tian concluded that AIRS data values are colder than MERRA in the free troposphere, but are warmer in the boundary layer. AIRS data values are slightly wetter than MERRA in the tropical boundary layer, but 30% drier in the tropical-free troposphere and in the extratropical troposphere. The CMIP5 models have a significant tropospheric cold bias.

Session 3: Data Services

Steven Friedman [JPL] reviewed the AIRS V6 release. Public release of Level 2 products is expected in early in January 2013. Level 3 products should be delivered to the Goddard Earth Sciences Data and Information Services Center (GES DISC) early in 2013. Friedman also described results from a study of AIRS data customers, based on statistics maintained by the GES DISC data services. Orders for AIRS products have increased substantially since 2007. Level 1B data (radiances) dominate download volume, but the demand for Level 3 products is increasing.

Thomas Hearty [GSFC] summarized AIRS products available at the GES DISC, which include those from AIRS/AMSU for the life of the mission, and AIRS-only data since May 31, 2007. The V6 reprocessing includes both AIRS/AMSU and AIRS-only retrievals for the entire mission life. The V5 processing will stop once V6 goes public, but the products will remain available for

[2] The 2007 Earth Science Decadal Survey (conducted by the National Research Council) identified CLARREO as a *Tier 1* mission—i.e., highest priority for development. However, the President's FY 2012 budget cut funding for CLARREO, and since then, the mission has been in an extended pre-Phase A. Mission and science team members continue to advance the science of CLARREO and explore alternative options to achieve some or all of the objectives of the mission.

[3] The *Gumbel Distribution Function* models maxima or minima for samples of various distributions.

ten years after that. AIRS near-real-time processing will be processed using the V6 AIRS/AMSU products, but without cloud microphysical retrievals[4], so as to meet latency requirements.

Gene Major [GSFC] described the effects of NASA's Earth Observing System (EOS) instrument data on Journals. The Moderate Resolution Imaging Spectroradiometer (MODIS) is the most-frequently referenced instrument, while other instruments are referenced much less frequently. Major found that 70% of all articles were published in 20 journals—and most of those were concentrated in five geophysical journals. These results suggest heavy science specialist data usage, but little penetration of the applications community—though a small trend toward general usage has begun.

Eric Fetzer [JPL] described how AIRS samples various CloudSat cloud types based on AIRS retrieval quality—done as part of NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) project. Fetzer found that AIRS retrieves best for clear conditions or when small numbers of trade cumulus clouds prevail. In contrast, AIRS does not do well with retrievals for higher, thicker clouds.

Session 4: Clouds and Aerosols

Brian Kahn [JPL] summarized ongoing efforts to include cloud thermodynamic phase and ice cloud effective diameter and optical thickness in the V6 retrieval process. Initial studies for January 2007 showed highly realistic and physically consistent global distributions. Kahn also showed a strong, realistic diurnal signal in the optical thickness over the Maritime Continent and consistent pixel-scale matches to MODIS.

Mark Zelinka [Lawrence Livermore National Laboratory] summarized work being done to test the *proportionately higher anvil temperature* (PHAT) hypothesis. AIRS data have shown that cloud tops have moved upward with time, implying a positive cloud-climate feedback. This establishes a robust test for the evaluation of climate models.

Dan Lubin [Scripps Institute of Oceanography] described recent advances in observing ice cloud properties over and around Antarctica, and noted the lack of a rigorous climatology. Initial AIRS cloud property results over Western and Eastern Antarctica showed systematic differences in cloud variability, as well as in the frequency of ice *versus* liquid clouds. Lubin expects that significant advances in understanding clouds over Antarctica will come from studies using AIRS data.

Nicholas Nalli [NOAA] showed scan-angle dependence of AIRS cloud-clearing residuals due to dust and cloud contamination. *In situ* observations from ship campaigns in the tropical Atlantic were used to quantify these residuals and their causes, with many lessons learned for advancing improvements in AIRS retrievals.

Eric Maddy [NOAA] presented a retrieval of volcanic and dust plumes using AIRS, and quantified the effects of dust on the AIRS temperature and water-vapor retrievals.

Lazaros Oreopoulos [GSFC] summarized recent work on *cloud clustering* using data from the International Satellite Cloud Climatology Project (ISCCP) and MODIS. These clusters were mapped globally, and Oreopoulos discussed their implications for understanding atmospheric processes.

Session 5: Atmospheric Composition

Edward Olsen [JPL] described the development of the AIRS V6 carbon dioxide (CO_2) retrieval code and supporting channel-selection analysis. Initial tests showed good agreement with released V5 CO_2 products and *in situ* aircraft measurements poleward of 40° N latitude.

Thomas Pagano showed global variations of CO_2 using AIRS data. Pagano derived Gross Primary Productivity (GPP). He showed that the GPP and CO_2 seasonal amplitudes are correlated by region, and that the annual CO_2 drawdown is highly correlated with GPP growth in Northern Eurasia.

Junjie Liu [JPL] showed how AIRS mid-tropospheric CO_2 and Greenhouse Gases Observing Satellite[5] (GOSAT) total column CO_2 could help constrain the tropical surface flux forcing using a four-dimensional variational assimilation Observing System Simulation Experiment (OSSE). The connection between tropical surface flux forcing and tropospheric CO_2 concentration is vertically direct due to stronger tropical convective transport and CO_2 land flux.

Xun Jiang [University of Houston] presented her analysis of the seasonal and latitude variations of CO_2, comparing data from AIRS, GOSAT, and the Tropospheric Emission Spectrometer (TES) with surface flask measurements and Total Carbon Column Observing Network (TCCON)-generated column measurements. The variations in all datasets are consistent, and show that the CO_2 seasonal cycle amplitude decreases with altitude. She showed a decrease in AIRS midtropospheric CO_2 during a sudden stratospheric warming event, consistent with downward subsidence of older air. Finally, Jiang demonstrated that the depletion of midtropospheric CO_2 observed over the Atlantic by AIRS is related to the sinking branch in the Atlantic Walker Circulation.

[4] Refer to Brian Kahn's presentation in *Session 4*.

[5] The Greenhouse Gas Observing satellite is a Japanese mission dedicated to greenhouse gas monitoring. It is also called *Ibuki,* which is the Japanese word for "breath."

Paul Dimotakis [California Institute of Technology] described the development of a maximum-likelihood estimator method for simultaneously retrieving CO_2, temperature, water vapor, and O_3—along with their associated uncertainty estimates from AIRS data. Initial results with an OSSE demonstrated retrieval of a CO_2 profile, assuming realistic instrument noise.

Meiyun Lin [Princeton University/NOAA's Geophysical Fluid Dynamic Laboratory (GFDL)] compared AIRS CO and O_3 observations with *in situ* measurements over Boulder, CO, and predictions from the GFDL Atmospheric Model 3 (AM3) model for stratospheric contributions to U.S. surface O_3 in spring.

Can Li [GSFC] presented research using Ozone Monitoring Instrument (OMI) and AIRS sensors to observe transpacific transport events in the autumn, finding an average of about four events per year. He looked at Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) vertical features over Northeast China to determine aerosol plume heights, and traced back sulfur dioxide (SO_2) and CO to their source regions. Li found that the warm conveyor belt is the main mechanism for exporting Asian pollution in fall and spring, and that meteorology over the Eastern Pacific is important for controlling rapid transport.

Juying Warner [University of Maryland, College Park] presented early results for AIRS retrieval of ammonia (NH_3). Warner found that AIRS does indeed capture global NH_3 emission from both natural and anthropogenic sources with good accuracy (i.e., a volume mixing ratio (VMR) of approximately 2 - 3 ppmv).

Xiaozhen Xiong [NOAA] showed that AIRS-retrieved methane (CH_4) data are significantly improved in V6, including larger *degrees of freedom of signal* (DOFS), better sensitivity in the lower troposphere, and smaller bias and *root mean square* error as compared to *in situ* measurements. The latitude variation of AIRS CH_4 DOFS matches that of IASI, although IASI has a DOFS that is between 0.1 and 0.3 higher, equatorward of 70°.

Leonid Yurgonov [UMBC] examined CH_4 from AIRS V5 and IASI for possible Arctic emission regions. He found that IASI is more sensitive to the lower troposphere than AIRS V5, and that IASI retrievals can be used as a qualitative indicator for Arctic Ocean emissions. The current growth of CH_4 in the Arctic is gradual, an indication that no sudden venting of CH_4 has occurred.

William Irion [JPL] compared AIRS O_3 retrievals to collocated World Ozone and *in situ* Ultraviolet radiation Data Center (WOUDC) ozonesonde measurements, with sonde profiles supplemented with Solar Backscatter Ultraviolet Instrument (SBUV/2) data at altitudes above the 30-hPa level.

Session 6: Product Applications and Validation

Xavier Calbet [EUMETSAT] showed the value of high-quality radiosondes as a standard for assessing outgoing radiances and quantities retrieved from hyperspectral sounders, including AIRS and IASI.

Robert Knuteson [University of Wisconsin, Madison (UW)] described the validation of AIRS/AMSU and IASI temperatures in the upper troposphere and lower stratosphere, using global positioning system radio occultation measurements.

Mingui Diao [Princeton University] compared AIRS retrievals with aircraft temperature and humidity observations obtained from flights between 67° S and 87° N latitude. The aircraft observations were obtained over a large altitude range, representing the full dynamic range of AIRS humidity observations and a wide range of temperatures.

Bill Smith [Hampton University/UW] processed retrievals from AIRS and the Suomi NPP CrIS instrument using a consistent algorithm, which showed good agreement from collocated fields of regard.

Session 7: Weather Forecast Improvement and Data Assimilation

Will McCarty [GSFC] described work to assimilate IR radiances affected by clouds. This is a significant change from the standard practice of using stringently cloud-free radiances.

Peter Norris [GSFC] showed a method to parameterize model cloud physical processes by constraining the total water content of water vapor and cloud liquid and ice amounts. He explained that because total water content is quasiconserved, this approach allows assimilation of water vapor and cloud microphysical observations, including those from satellites.

Kristen Brown [North Carolina State University] described simulations of the assimilation of irregularly spaced, sparse observations into a mechanistic dynamical model. She then assessed the impacts of several statistical filtering and interpolation techniques.

Zhiquan Liu [NCAR] discussed assimilation of hyperspectral IR radiances using a principal-component-based radiative transfer model. This approach significantly simplifies the assimilation problem, because the principal component series can be truncated to those modes representing geophysical variability.

Oreste Reale [GSFC] showed the impact of AIRS retrieved quantities on tropical cyclone forecasting, using NASA's Goddard Earth Observing System Model, V5 (GEOS-5). This promising approach exploits information in partially cloudy scenes that is not usually assimilated into forecast models.

Ding Feng [GES DISC/ADNET Systems, Inc.] showed the potential of using AIRS retrieved surface temperature for improving river-flow forecasts.

Oreste Reale showed that assimilating AIRS retrievals significantly improved the analysis and forecast of an extreme rainfall event over the Indus River Valley in Pakistan during 2010 that led to widespread flooding, with consequent loss of life and property damage.

Session 8: Suomi NPP Instruments, Algorithms, and Data Products

Larrabee Strow described the calibration and validation of the CrIS sensor, concentrating on the radiometric precision among the nine CrIS detectors on each of the three focal planes, and a comparison of CrIS noise to AIRS and IASI noise. Generally, the CrIS radiances are found to agree with those from AIRS and IASI to the nominal 0.2-K level. He then proceeded to give a more in-depth overview of CrIS performance in *high-spectral-resolution mode*, which records full interferograms; this was tested on orbit, February 23, 2012[6]. CrIS can robustly detect CO in this mode, and has significantly improved absolute spectral calibration. The NOAA/Joint Polar Satellite System (JPSS) Program Office announced that CrIS will be placed in this high-spectral-resolution mode starting in late spring 2013.

Anthony Reale [NOAA] gave an overview of the NOAA/Center for Satellite Applications and Research (STAR) product validation system, highlighting preliminary analysis of Cross-Track Infrared and Microwave Sounder Suite (CrIMSS—made up of CrIS and ATMS) Environmental Data Record (EDR) product accuracies *versus* those from operational radiosondes. Results for temperature and water vapor operational EDRs available from the Comprehensive Large Array-data Stewardship System (CLASS) were encouraging.

Mike Wilson [NOAA] provided detailed comparisons of the CrIMSS EDR products with AIRS Level 2 retrievals. Additional quality control work is needed, as well as retrieval bias tuning.

Nick Nalli [NOAA/STAR] reviewed the dedicated Suomi NPP CrIMSS EDR Intensive calibration/validation radiosonde and ozonesondes campaign, which is currently underway. A total of 393 out of a possible 610 model RS-92 sonde launches coincident with CrIS (and some AIRS) overpasses have now taken place for this assessment of EDR accuracy.

Xu Liu [LaRC] also presented CrIMSS EDR assessments, but using an offline algorithm with more realistic NOAA product accuracies. Improvements include new lookup tables for bias correction, better background covariances, and methods to increase the algorithm convergence rate.

Antonia Gambacorta [NOAA/STAR] gave an overview of the NOAA Unique CrIS ATMS Processing System (NUCAPS), an operational algorithm that uses the heritage of the NASA AIRS Science Team's Level 2 retrieval and the NOAA IASI inversion algorithm. Although ATMS has been operating for far less than one year, NUCAPS is already producing temperature, water vapor, and O_3 retrievals comparable in accuracy to the AIRS V6 algorithm. These retrieval products will become operational in January 2013.

Joel Susskind [GSFC] presented an early assessment of whether the CrIMSS on Suomi NPP can allow for seamless continuation of the AIRS/AMSU climate record. His CrIMSS retrieval system is a modified version of the AIRS/AMSU V5.59 Level 2 system. Susskind found that while the CrIMSS temperature and water vapor retrievals perform well, they are not yet as good as the AIRS/AMSU retrievals in the troposphere—especially over land.

Steve Friedman gave an overview of the Sounder Product Evaluation and Analysis Tools Elements (PEATE), highlighting such activities as the creation of CrIS *calibration subsets*—consisting of CrIS and collocated IASI, AIRS and NOAA-18/19 AMSU simultaneous nadir observations, and radiosondes. The PEATE also produces CrIS Level 3 EDR products, and is working to produce other PEATE products from the Suomi NPP Science Team on demand, such as an ATMS rain rate product.

Sung-Yung Lee [JPL] continued the presentation of Sounder PEATE activities, giving more detail on the various calibration data subsets and the status of the NOAA/Interface Data Processing Segment (IDPS) EDR software changes and improvements. He noted that the CrIMSS EDR products contain a number of major liens that presently prevent their use in climate applications.

Session 9: AIRS V6 Product Testing

Eric Fetzer showed results of V6 Level 2 product testing. These results are being made publicly available as a test report with the AIRS V6 data release, and include comprehensive studies of most variables in the V6 Level 2 products.

[6] Presently only the CrIS long-wave band records the full 0.8-cm interferograms.

William Irion [JPL] showed comparisons between operational radiosonde temperature measurements and those from AIRS V5 and V6 retrievals. The V6 data show smaller biases and significantly smaller spurious cooling trends.

Adam Milstein [MIT] showed the latest developments with the neural network algorithm. A similar algorithm is used in the AIRS V6 retrieval system.

Joel Susskind showed differences between AIRS V5 and V6 datasets. Many of these results are described in the V6 test report described by Eric Fetzer at the beginning of this session.

Glynn Hulley [JPL] described changes in surface properties retrieved with the V6 algorithm. Compared with V5, ocean emissivities have far fewer unrealistic low values, land emissivities that better capture several surface spectral features, and both ocean and land surface temperatures that are more consistent with other observations.

Baijun Tian [JPL] described changes to the Level 3 V6 products. These include water vapor on pressure levels, and new products based on consistent quality control for both temperature and water vapor.

Session 10: Instrument Calibration

Denis Elliott [JPL] summarized the health status of AIRS as excellent, AMSU-A as good, and the Aqua spacecraft as excellent. He noted that the automated weather station at Dome C on the Antarctic Plateau shows no temperature trend during the 10 years that AIRS has been operational, and AIRS brightness temperatures at 1231 cm^{-1} show no significant trend *versus* the weather station.

Fangfang Yu [NOAA NES DISC/Earth Resources Technology (ERT), Inc.] described the use of the Global Space-based Inter-Calibration System (GSICS) database to compare the radiances of AIRS, IASI, and CrIS. The purpose is to improve calibration of Geostationary Operational Environmental Satellites (GOES) IR sensors, which show some calibration anomalies. The three instruments compare well, although there are some small differences that are not yet understood. Yu noted that a good AIRS gap-filling method is needed to correct the GOES radiances. They are testing the AIRS Level 1C gap filling and comparing it to an existing method, developed by the Japanese Meteorological Agency.

Evan Manning [JPL] described the AIRS Level 1C algorithms and proposed software. Spectral cleanup, gap filling, and frequency resampling have all been implemented and tested. The form of the final software is still under discussion.

George Aumann compared AIRS and CrIS radiances, and discussed the goal of using CrIS to extend the AIRS climate data record. He noted that there are small biases between CrIS and AIRS that vary from night to day and geographically. Some aspects of the CrIS radiances are not understood at this time, and more analysis is needed before AIRS and CrIS data records are directly comparable for climate studies.

Milt Halem [UMBC] described a database that enables easy trending of AIRS data, both globally and regionally, for any channel. He noted significant differences between Northern and Southern Hemisphere temperature trends, and discussed their implications for climate studies.

Joe Predina [ITT Exelis] talked about potential improvements for future versions of the CrIS instrument, including increased spectral resolution, a better blackbody, additional simultaneous fields-of-view, and even the possibility of three-dimensional wind-velocity determination.

Conclusion

Hyperspectral infrared observations from the AIRS, IASI and CrIS instruments, and associated microwave observations, complete one of the most detailed records of Earth observations ever obtained. Now over a decade long, this dataset can be expected to be a valuable source of information about the atmosphere and surface for many years. This meeting highlighted the wide range of research that is being carried out with the sounder record. We expect continuing interesting discoveries in the future. ■

GRACE Science Team Meeting

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The now-venerable joint NASA-German Aerospace Center (DLR) Gravity Recovery and Climate Experiment (GRACE) mission celebrated ten years in orbit on March 18, 2012. The twin GRACE satellites continue to improve our understanding of the Earth's dynamical system, making precise measurements of changes in the gravity signals associated with exchange of mass between the components of Earth's systems. Nearly 1000 science articles based on GRACE data have been published since 2004 on geodesy, oceanography, hydrology, cryospheric sciences, and other GRACE science applications.

The 2012 GRACE Science Team Meeting (STM) took place September 17-19, 2012, at the GeoForschungsZentrum (GFZ), German Research Centre for Geosciences in Potsdam, Germany. This was a joint meeting with the Final Colloquium of the German Research Foundation (DFG) Special Priority Program (SPP) 1257—*Mass Transport and Mass Distribution in the Earth System*. A joint German National Academy of Sciences (Leopoldina) and DFG SPP 1257 Sea Level Workshop took place immediately following the GRACE STM.

More than 160 scientists and engineers attended the meeting, which consisted of 56 oral presentations and 30 posters in moderated discussions in seven scientific sessions, addressing:

- Geodesy and analysis techniques;
- GRACE and the European Space Agency's (ESA) Gravity and Steady-State Ocean Circulation Experiment (GOCE);
- GRACE Follow-On mission;
- Solid Earth Sciences;
- Cryosphere;
- Oceanography and Sea Level; and
- Hydrology.

Opening Remarks, Keynote Addresses, and Programmatic Updates

Following a welcome and meeting overview from host **Frank Flechtner** [GFZ—*GRACE Co-Principal Investigator (co-PI)*], the meeting began with two keynote addresses and several programmatic presentations, emphasizing the tenth anniversary of GRACE. The first presentation focused on the GRACE mission as it begins its second decade, while the second described a German program, with goals that dovetail nicely with the results flowing from GRACE.

Byron Tapley [University of Texas Center for Space Research (UTCSR)—*GRACE Principal Investigator*] presented a retrospective examination of the accomplishments of the mission team and the science community—in the context of what was originally proposed for the mission in 1996[1]. He noted the objectives proposed originally for the mission in the hydrological, oceanographic, cryospheric, and solid Earth sciences, and then presented examples of each from the recent GRACE literature, showing how GRACE data have been used to[2]:

- Create more than 120 monthly measurements of Earth's gravity field that are at least 100 times more accurate than previous solutions;
- determine near-surface and deep-ocean currents to improve our understanding of global ocean circulation—in combination with satellite altimetry;
- separate thermal- and mass-induced changes in global sea level and to observe seasonal mass exchange between the land and ocean;
- determine geographic distribution of decadal and seasonal changes in continental ice sheets—revealing an accelerating decline in polar ice mass over the past decade;
- track water movement on and beneath Earth's surface (i.e., change in river basins and underground aquifers);
- observe changes in the solid Earth, such as those caused by *glacial isostatic adjustment* (GIA) and large earthquakes (e.g., the 2004 Sumatra Andaman and the 2011 Japan earthquakes);
- incorporate GRACE water storage measurements into models used for drought prediction; and
- improve precision orbit determination of spacecraft, and the terrestrial and gravimetric reference frames.

[1] To learn more about some of the original plans for GRACE and read a reflection from the PI on the tenth anniversary of the launch, refer to *Assessing the State of GRACE@10* article in the March–April 2012 issue of *The Earth Observer* [**Volume 24**, **Issue 2**, pp. 4-13].

[2] The *Assessing the State of GRACE@10* article referenced in *Footnote 1* (above) includes "The Top 10 Achievements for GRACE" [**Volume 24, Issue 2**, p. 7] that lists these and several other achievements.

Tapley then briefly reported on the status of the new *Release 05* (RL-05) gravity field data products from GRACE. He concluded with a discussion of several programmatic events, including the upcoming NASA Senior Review in 2013, and the mission operating philosophy, which emphasizes maximizing the lifetime in orbit.

Jürgen Kusche [Universität Bonn (Uni-Bonn), Institute for Geodesy and Geoinformation] presented an overview of the DFG SPP1257, *Mass Transport and Mass Distribution in the System Earth*, starting with a brief historical overview of its program life from 2006 through 2012. In the field of mass transport and mass distribution of the Earth system, the goals of the program were to:

- Advance knowledge in an emerging field of research, through collaborative networked support over several locations;
- enhance the quality of research through the use of new methods and forms of collaboration in emerging fields; and
- add value through interdisciplinary cooperation and networking.

The research in this program was organized around three themes: understanding satellite signals (e.g., uncertainty, separation, resolution, and consistency); steady-state and long-term processes (e.g., crustal structure, mantle viscosity, ice-mass trends, and sea-level rise); and short-term processes (e.g., water storage changes and oceanographic processes.)

Kusche then went on to give examples of accomplishments under each theme, including determining:

- The effects of errors in knowledge of nontidal atmospheric and oceanic processes;
- *admittance*[3] between hydrological loading and crustal deformation from global positioning satellite (GPS) data;
- geostrophic velocities from assimilation of geodetic mean dynamic topography and ocean heat transport estimates;
- geodynamic models of the Andean margin;
- Greenland mass balance from GRACE and the Ice, Clouds, and Elevation Satellite (ICESat); and
- water-storage variability and sea level in the Mediterranean and Black Seas.

[3] In this context, *admittance* refers to the ratio between water loading and crustal deformation.

The outcomes of the program are to be published in a special issue of the *Journal of Geodynamics* after mid-2013. Kusche ended with a description of the education aspect of the SPP, including the summer schools and the training of researchers and students.

Other speakers in the opening session also gave programmatic reports. **John LaBrecque** [NASA Headquarters—*GRACE Program Manager*] reported on the support within NASA for GRACE and the GRACE Follow-On mission. **Johannes Karte** [DFG] discussed the framework of SPPs, such as the one described above, and possible follow-up; and **Harald Schuh** [GFZ—*Director of Division 1*], reported on further geodetic activities at GFZ.

Project Status

The Project Status session provided information on GRACE flight operations, the satellites' health, Level-1 data processing and calibrations, and detailed information on the new Level-2 RL05 data products. The GRACE mission is being operated in a manner designed to maximize its operational lifetime. The GRACE satellites are experiencing altitude decay due to atmospheric drag and thruster fuel limitations, but this should not limit the remaining mission lifetime. Four of the subsystems on GRACE-1, and two on GRACE-2, operate with no redundancy. Since the previous STM in 2011, the only noteworthy event with impacts on fault tolerance is the loss of redundancy in the GRACE-2 transmitter—which is used to communicate with ground stations. The two spacecrafts' battery operations require regular monitoring and management to maintain routine operations. Charge management is carried out daily, with yaw turns during the full-sun orbits. The accelerometer and the K-band ranging system are turned off for approximately 30 out of every 160 days. The German Space Operations Centre (GSOC) continues to do excellent work, coordinating with the GFZ Ny-Alesund station in Spitzbergen, Norway, to closely monitor the satellites' and battery performance.

The major accomplishment of the Science Data System (SDS) has been the preparation and release of the reprocessed Level-1 data (labeled *Version 02* or V02), and Level-2 data (labeled Release 05 or RL05). This session included detailed descriptions of the improvements leading up to the L1B_V02 data, including the new orbit determination strategy, improvement in the knowledge of the alignments between the science instruments, flight calibrations of the satellite center-of-mass, and the recovery and reprocessing schedule.

Each SDS center then provided a detailed description of the resulting Level-2 RL05 data products, which include the monthly gravity fields in the form of spherical harmonic coefficients and *mascons*. It was emphasized that the information content in the RL05 data products is the same as that in RL04, with one notable exception: The background gravity field in RL05 did not include any rates for the spherical harmonics. Each SDS center presented an error assessment of their RL05 time series, showing that RL05 products were approximately a factor of two-to-three better in terms of noise variance reduction than the previous-generation RL04 products.

Presenters in this session included: **Mona Witkowski** [NASA/Jet Propulsion Laboratory (JPL)]; **Gerhard Kruizinga** [JPL]; **Srinivas Bettadpur** [UTCSR]; **Christoph Dahle** [GFZ]; and **Dah-Ning Yuan** [JPL].

Science Sessions

The meeting then moved into the seven science sessions**,** each of which consisted of invited and contributed presentations, and included a period for questions and answers. In addition, posters relevant to each topic were displayed for discussion throughout the meeting. The GRACE STM program, abstracts, along with a document containing the presentations and posters are available at *www.gfz-potsdam.de/portal/gfz/Neuestes/Veranstaltungen/Tagungen+und+Konferenzen/2012/GRACE+Meeting/GRACE+meeting_Startseite/proceedings* or through *www.csr.utexas.edu/grace/GSTM/past.html*.

GRACE Follow-On

The GRACE Follow-On (GRACE-FO) session focused on the planned mission, which is scheduled for launch in August 2017. This mission—also a joint NASA–DLR partnership—entered *Phase B* in September 2012. Its architecture and operations concept is very similar to that of GRACE. This session reviewed the programmatic and mission status and the status of two key technology elements of the GRACE-FO mission: its laser interferometer and accelerometer. The GRACE-FO Applications Strategy will be developed within the NASA framework for the Applied Science Program, the intention for which is to connect data and science to decision making. Additional topics discussed included the methods of filling a possible data gap between GRACE and GRACE-FO as well as improvements in science outcomes using various future GRACE-like mission configurations.

Presenters in this session included: **Frank Flechtner** [GFZ]; **John Bolten** [NASA's Goddard Space Flight Center (GSFC)]; **Benjamin Sheard** [Albert Einstein Institute (AEI)—Hannover, Germany]; **Bruno Christophe** [Office National d'Études et de Recherches Aérospatiales (ONERA); French Aeronautics and Space Research Center]; **Matthias Weigelt** [Université du Luxembourg (Uni-Lu)]; and **Basem Elsaka** [Uni-Bonn].

GRACE Analysis Techniques

Presentations in the GRACE Analysis Techniques session focused on improvements to GRACE-related data analysis methods and algorithms, techniques for extraction of geophysical signals from GRACE data, and the assessments of available science data products. The JPL SDS team delivers mascon Level-2 solutions in addition to the harmonic Level-2 data products; this session included a global quality evaluation of these products. The Groupe de Recherche de Géodésie Spatiale (GRGS) data processing strategy and web user interface were also presented. One important determinant of the quality of the current GRACE Level-2 data products is the error in our knowledge of the nontidal, short-period atmospheric and oceanic variability—the current state of this knowledge, and prospects for reducing this source of error were discussed. Two presentations addressed the nature and physical processes that might explain the remaining discrepancies in the knowledge of GRACE flight alignments, and certain artifacts in GRACE accelerometer data, known as *twangs*. Another presentation addressed the long-standing question of comparing the "regionally averaged" GRACE measurement with point observations from a network of superconducting gravimeters. While a large fraction of the signal variance in point observations are from processes within few-hundred-meter zone around the instrument, it was possible to use empirical orthogonal functions (EOFs) to compare the point observations from this network with the regional measurement from GRACE.

Presenters in this session included: **David Wiese** [JPL]; **Richard Biancale** [GRGS]; **Lieselotte Zenner** [Institut für Astronomische und Physikalische Geodaesie, Technical University Munich (TUM)]; **Nadja Peterseim** [TUM]; and **Gerhard Jentzsch** [Friedrich Schiller University Jena, Institute of Geosciences].

Oceanography and Sea Level

The Oceanography and Sea Level session opened with a discussion of the current progress in global tide modeling by assimilating GRACE data into state-of-the-art tide models and using GRACE Level-1 data directly to infer major tidal constituents. In particular, GRACE contributes significantly to our understanding of tides in polar regions, where data coverage from satellite missions and *in situ* data is sparse. The ensuing presentations described methods to derive optimized *mean dynamic topography* (MDT) products using GRACE data. The MDT solutions are used to improve the representation of circulation in *ocean general circulation models* (OGCMs). On a regional scale, GRACE was shown to track transport variability in the Antarctic Circumpolar Current (ACC) to smaller spatial scales and shorter time scales than previously studied—see **Figure 1**.

Meanwhile, in the Arctic Ocean, the impact of freshwater input through Greenland ice sheet melting was studied by feeding GRACE mass-loss rates into an OGCM. Further presentations discussed the contribution of the fingerprint due to mass redistribution on regional sea level. Sea-level changes in the Mediterranean and Black Seas were discussed in particular, with respect to the recent change from Release 04 to Release 05. A new concept of using *in situ* bottom pressure data to validate GRACE global mean ocean mass was presented. A model study showed that a single mooring in the Pacific could potentially monitor global mean ocean mass changes if trends could be observed. However, the presenters pointed out that the required technology for drift-free bottom-pressure recorders currently does not exist; a push for technology development is needed.

Presenters in this session included: **Roman Savcenko** [German Geodetic Research Institute]; **Eifu Taguchi** [University of Hamburg]; **Bryan Killett** [JPL]; **Silvia Becker** [Uni-Bonn]; **Roelof Rietbroek** [Uni-Bonn]; **Chia-Wei Hsu** [University of California Irvine (UCI)]; **Luciana Fenoglio-Marc** [Darmstadt Technical University]; **Mark Tamisiea** [National Oceanography Centre]; **Sandra–Esther Brunnabend** [Alfred Wegener Institute (AWI)]; **Kazuo Shibuya** [National Institute of Polar Research]; **Don Chambers** [University of South Florida (USF)]; **Henryk Dobslaw** [GFZ]; **Jens Schröter** [AWI]; **Grit Freiwald** [AWI]; and **Y. Tony Song** [JPL].

GRACE and GOCE

The GRACE and Gravity and Steady-State Ocean Circulation Experiment (GOCE) session started with an update of the current mission status of GOCE and future developments. Presenters discussed the improvements in processing GOCE data and advantages of combining GOCE and GRACE gravity models.

Presenters in this session included: **Thomas Gruber** [TUM]; **Roland Pail** [TUM]; and **Majid Naeimi** [University of Hannover].

Solid Earth

The Solid Earth presentations focused on using time-variable gravity data to study the GIA process and the co- and post-seismic processes associated with large earthquakes. The GIA signal in Antarctica is of great concern for two reasons: (1) its value has not yet been

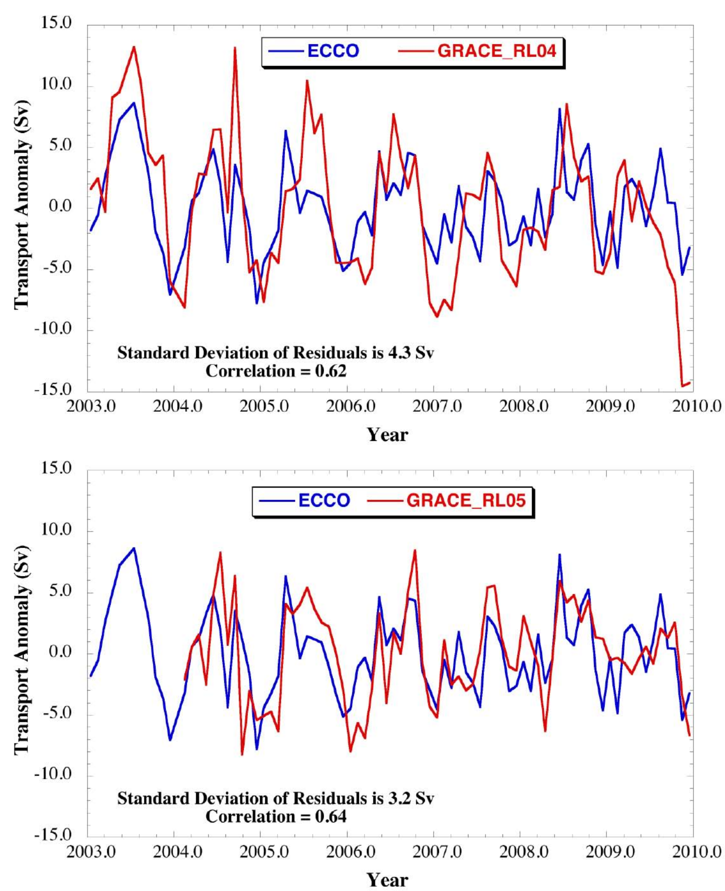

Figure 1. The Antarctic Circumpolar Current (ACC) flows from east to west around the continent of Antarctica, and is the dominant feature of the Southern Ocean. Variations in the transport of the ACC can be estimated from gradients of *ocean bottom pressure* (OBP), but historically, these measurements have been difficult to obtain. Before GRACE, no continuous transects of OBP are available for longer than two years—and those datasets are impossible to use for detecting long-term changes in the strength of the ACC transport. Likewise, current models of OBP also have inherent difficulties (resulting from poor initial conditions at depth and the lag-time for the deep ocean to adjust to surface winds and heat) and cannot be used to detect long-term changes in the transport strength

These figures demonstrate that GRACE is capable of computing low-frequency variations in the ACC transport along a single transect at 150° E longitude, with an accuracy approaching 3 *Sverdrups*[1] (Sv) for monthly estimates. The improvement from Release-04 [*top graph*] to Release-05 [*bottom graph*] is significant. With this level of uncertainty, trends in transport as small as 0.3 Sv/year should be detectable with 90% confidence. With longer records, even smaller trends are detectable.
Figure Credit: From **Don Chamber's** presentation.

[1] Named in honour of the pioneering oceanographer Harald Sverdrup, a *Sverdrup* [Sv] is a unit of measure of volume transport, and used almost exclusively to measure the transport of ocean currents. 1 Sv = 10^6 m^3/s

determined from independent data; and (2) that uncertainty makes it difficult to determine how much of the observed mass change observed from GRACE can be attributed to GIA and to Antarctic ice-melt. A presentation in this session discussed the separability of GIA from present-day ice melt effects from a joint use of GRACE gravity and GPS uplift observations. In Greenland, the contribution from the GIA to the uncertainty of mass-loss estimates is smaller; intercomparisons between different datasets were discussed. The session also included two presentations on the use of GRACE and terrestrial gravity data for lithospheric structure and stress modeling; and two presentations on the influence of the GRACE geoid and data on the study of models for a convecting mantle. It was stated that the use of RL05 Level-2 GRACE data products show better localization of the co- and post-seismic signals associated with the recent large earthquakes in Sumatra (2005), Chile (2010), and Japan (2011).

Presenters in this session included: **Ingo Sasgen** [GFZ]; **Tyler Sutterly** [UCI]; **Benjamin Gutknecht** [Christian Albrechts Universitaet Kiel]; **Michael Hosse** [TUM]; **Alexei Petrunin** [GFZ]; **Meysam Shahraki** [Goethe University Frankfurt, Institute of Geosciences]; and **Shin-Chan Han** [GSFC].

Cryosphere

The next session addressed the cryosphere, with presentations covering three broad themes: the status of efforts to reconcile the ice-sheet mass-loss estimates from diverse techniques; improvements in techniques for deriving mass rates and their error estimates; and studies of cryospheric processes at spatial scales smaller than the entire ice sheet. The session included a description of the joint NASA–ESA Ice Mass Balance Intercomparison Exercise (IMBIE), addressing the influence of GIA in attempts to reconcile ice-sheet mass-loss estimates from different geodetic techniques, and addressing the influence of technique differences. One presentation detailed mass-balance estimates for mountain glaciers and ice caps (i.e., other than Antarctica and Greenland ice sheets)—see **Figure 2**.

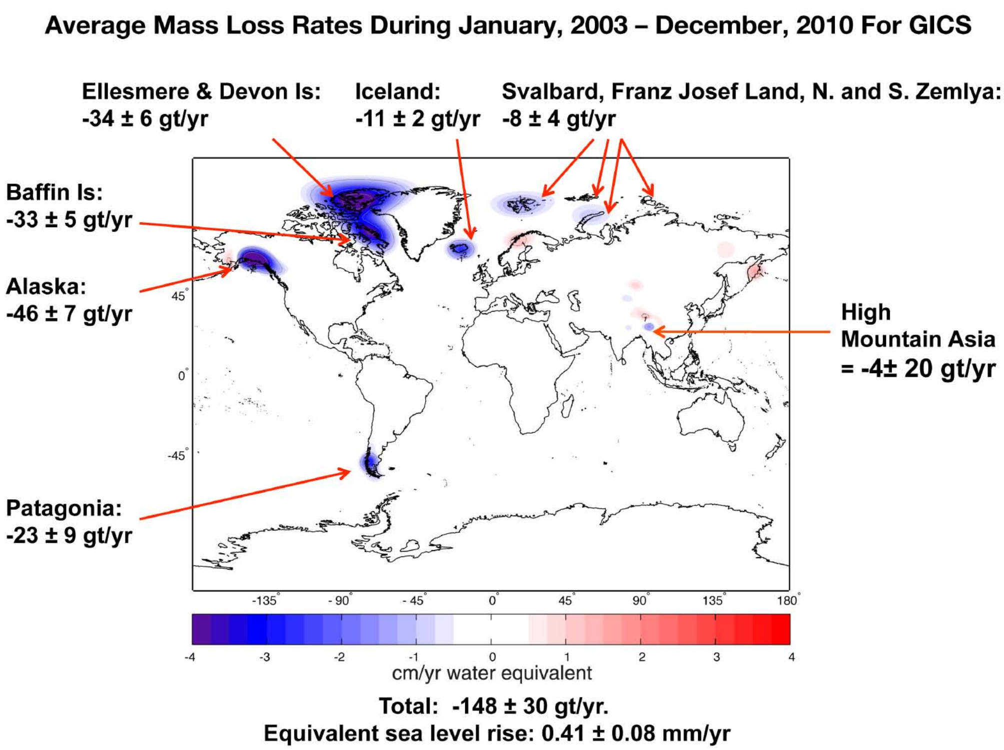

Figure 2: This figure shows the rate of change of ice mass, in *gigatonnes*[1] (Gt)/year, of all the world's ice-covered regions **outside of Greenland and Antarctica**—as inferred from GRACE data between January 2003 and December 2010. Blue (negative) regions are losing mass; Red (positive) regions are gaining mass. The rate, with its uncertainty (denoted as a positive or negative value), is shown for every region where the mass rate differs from zero by more than the uncertainty. **Every such region is losing mass.**

A rate, with its uncertainty, is also shown for *High Mountain Asia*, which includes the mountains of the Himalaya, the Karakoram, the Pamirs, the Tien Shan, the Kunlun Shan, the Qilian Shan, and Tibet. For this region and this time period, the mass loss rate inferred from GRACE is not significantly different from zero—although the uncertainty of the estimate is very large. Shown at the bottom is the total rate of mass change from all ice-covered regions outside of Greenland and Antarctica, and its equivalent contribution to global sea level rise**. Figure Credit**: From **Thomas Jacob's** presentation.

[1] One *gigatonne* equals one trillion kilograms, and is equivalent to the weight of slightly more than one cubic kilometer of ice.

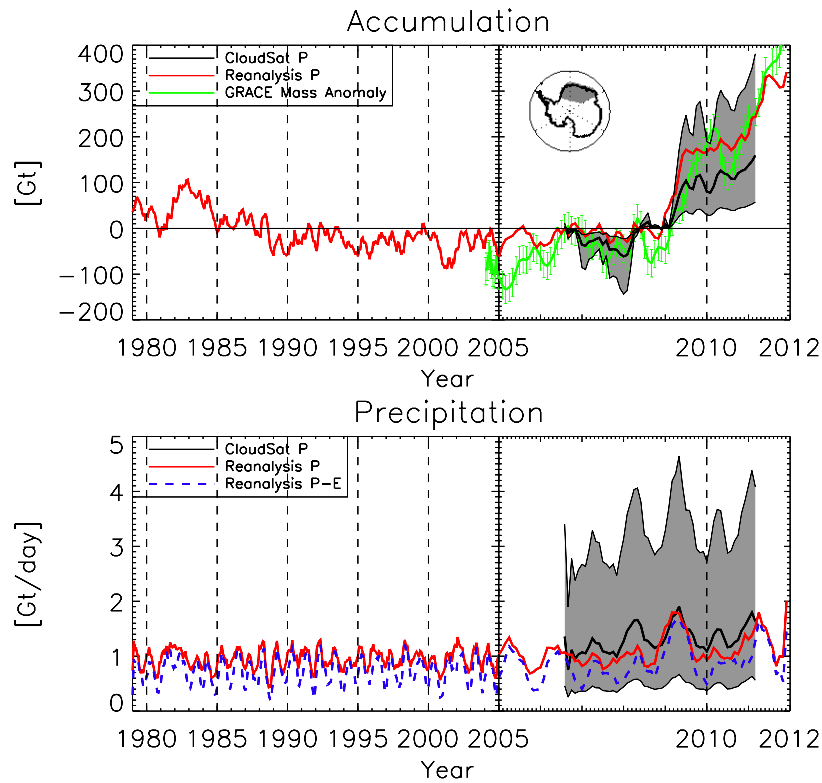

Figure 3. GRACE provides unique observations of the ice mass balance of the major ice sheets. While ice loss from West Antarctica dominates the Antarctic mass balance, East Antarctica has remained stable from 2002 to 2008. Recently, GRACE observed a significant mass gain (light gray) of ~350 Gt along the coast of Queen Maud Land (gray shaded region) where only little variability has been observed before. Snow accumulation derived from Cloudsat (green - error bar) and ERA-Interim (medium gray) precipitation data indicate that the mass increase was related to high-precipitation events in 2009 and 2011. Further analysis shows that only a few days of heavy snowfall during May 2009 and June 2011 have led to the significant change in the surface mass balance in East Antarctica. Observing these changes using data from GRACE and understanding their causes improves our knowledge of not only the present but also future developments in the ice sheet mass balance, which has important implications for reducing uncertainties in sea-level projections. GRACE provides unique observations of the ice-mass balance of the major ice sheets. While ice loss from West Antarctica dominates the Antarctic mass balance, East Antarctica has remained stable from 2002 to 2008. **Figure Credit**: From **Carmen Boening's** presentation.

Another presentation discussed the details of contributions to overall errors that arise from using GRACE mass estimates and post-processing steps to generate the ice-sheet mass-loss estimates. Next came descriptions of related technique-specific improvements that have been developed for mascon solutions, the role of self-consistent deformation modeling in improving the consistency with GPS-derived uplift rates, and improvements in forward-modeling methods to derive mass-loss estimates for the ice sheets. Insights derived from GRACE data into cryospheric processes were also presented for the Gulf of Alaska, where summer mass balance correlates with summer temperature anomalies; and suggests a potential role of volcanic ash. In Queen Maud Land, the large accumulation events observed from GRACE are corroborated with mass-flux estimates from the ERA-Interim reanalysis models and from Cloudsat data—see **Figure 3**. Because of the close connection between present-day melt signals and GIA, presentations in the Solid Earth session (see above) also shed light on the cryosphere.

Presenters in this session included: **Erik Ivins** [JPL]; **Thomas Jacob** [CU]; **Scott Luthcke** [GSFC]; **Rainer Groh** [Dresden University of Technology (TUD)]; **Valentina Barletta** [Technical University of Denmark National Space Institute]; **Reinhard Dietrich** [TUD]; **Carmen Boening** [JPL]; **Isabella Velicogna** [UCI]; and **Jennifer Bonin** [USF].

Hydrology

The hydrology session presentations addressed the topics of water availability information to be derived from GRACE and model-based data products; the disaggregation of components that add up to the total-water-storage estimates from GRACE; and applications that involve assimilating GRACE data into hydrological models. One presentation examined the conditions under which GRACE data could improve global estimates of human influence on water storage and consumption; others examined the use of GRACE to study this variability over Africa and over India under diverse hydrological regimes—see **Figure 4**. The ses-

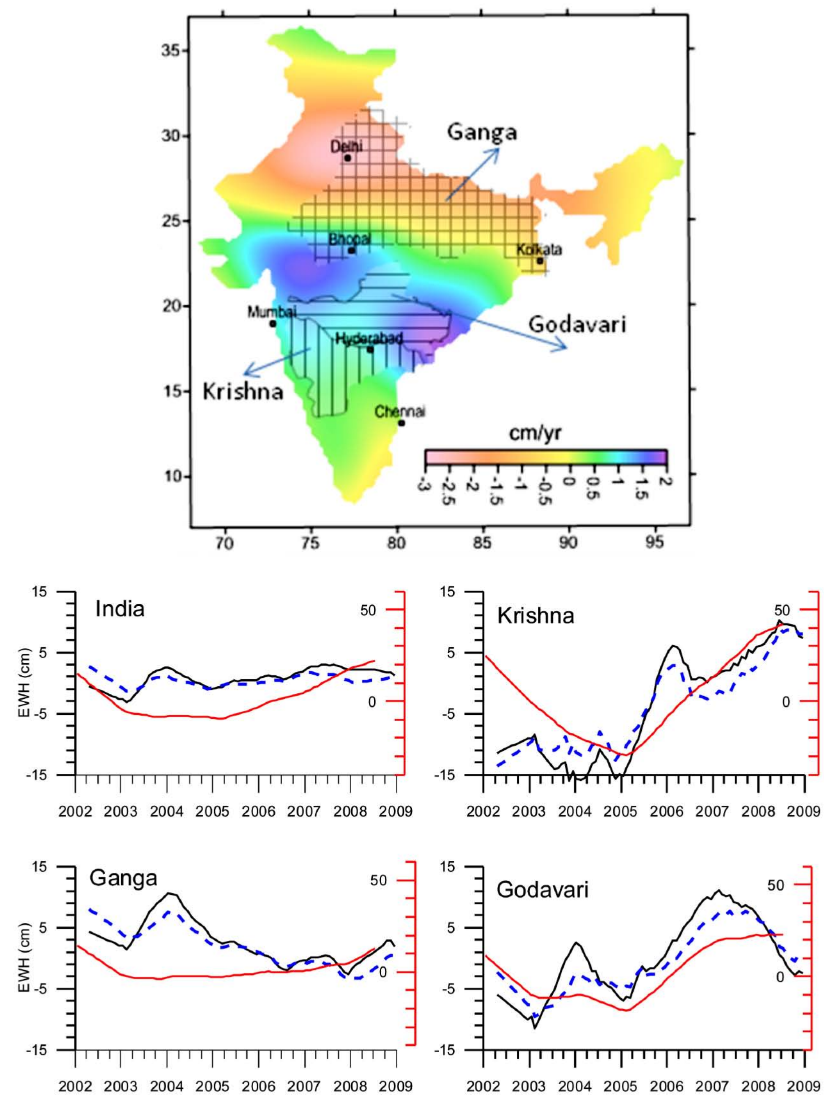

Figure 4. Using GRACE satellite data from 2002 to 2008 and soil moisture estimates obtained from a global hydrological model (i.e., the Global Land Data Assimilation System (GLDAS) model), scientists can estimate hydrological mass variability over India [*top*].

The graphs show variations in total terrestrial water storage (TWS) [solid black], *groundwater storage*[1] (GWS) [dashed blue], and accumulated rainfall [solid red] over all of India [*top left*] and its three major river basins: the Ganga [*bottom left*]; the Krishna [*top right*]; and the Godavari [*bottom right*]—with boundaries of each indicated [*top image*]. Each of the curves has had the seasonal variability removed and the values are expressed in terms of equivalent water height in cm (*left axis*) and similarly filtered accumulated rainfall in cm (*right axis*).

Results indicate that the Indian territorial region retains ~40% of its monsoonal rainfall (June–September) as TWS and ~10% as GWS. GRACE data also suggest that the Godavari and Krishna basins have large interannual variations whereas the Ganga basin shows a decreasing trend—a new contribution to understanding regional-scale water dynamics on the Indian subcontinent. **Figure Credit**: From **Virendra Tiwari's** presentation.

[1] *Groundwater storage* is estimated by model (GLDAS) soil moisture values from the GRACE estimates of total water storage.

sion also included descriptions of a variety of applications over several regions of the world where GRACE data are being used jointly with data from the Moderate Resolution Imaging Spectroradiometer (MODIS), radar altimetry, multispectral satellite images, sea surface temperature measurements, and other hydrometeorological model outputs, such as precipitation amounts. Several presentations examined improvements in the methods of assimilating GRACE data into hydrological models, and the potential benefits of these improvements.

Presenters in this session included: **Petra Doell** [Goethe University]; **Annette Eicker** [Uni-Bonn]; **Wenjing Liang** [Goethe University]; **Martin Wattenbach** [Goethe University]; **Matthew Roddell** [GSFC]; **Sibylle Vey** [University of Hannover]; **Mohamed Sultan** [Western Michigan University]; **Virendra Tiwari** [Indian National Geophysical Research Institute]; **Nico Sneeuw** [University of Stuttgart]; and **Caroline de Linage** [UCI].

Conclusion

Ten years after launch, the GRACE mission has exceeded expectations, as judged by the diversity of the user community, the range of the science outcomes, and the number and variety of papers on science from GRACE data products. The user community at the STM was appreciative of the continued improvements in the GRACE data products, and of the efforts of the mission team to ensure extended mass flux data records for as long as possible. Looking forward, there is an eager anticipation of continued science with minimal interruptions between the GRACE and GRACE-FO missions going into the next decade.

The next GRACE STM will be held in Austin, TX, October 23-25, 2013. For more information, visit: *www.csr.utexas.edu/grace/GSTM*. ■

Plant Stress Paints Early Picture of Drought

Kathryn Hansen, NASA's Goddard Space Flight Center, kathryn.h.hansen@nasa.gov

In July 2012, the U.S. Midwest and Plains experienced what experts called a *flash drought*—meaning that unpredicted drought conditions developed very rapidly. Soil moisture levels in the area were already low, and the problem was further exacerbated by a heat wave that started in May. A period of prolonged drought abruptly followed. Farmers could only sit and watch helplessly as the crops they had planted wilted and eventually succumbed to the relentless heat.

Well before the effects of the drought became obvious to the casual observer, however, scientists with the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) were tuned into the looming threat of a drought.

The scientists started with data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites. The images were processed to distinguish between land surfaces covered by soil and surfaces covered with vegetation.

Having determined the vegetated areas with MODIS data, the scientists next needed to measure moisture availability. They know that healthy vegetation requires a certain amount of water from the soil every day to stay alive: When soil moisture falls below adequate levels, plants become stressed. Plants cool themselves by "sweating" water extracted from the soil through their roots—a process called *evapotranspiration*. When access to water is limited, plants respond by reducing water

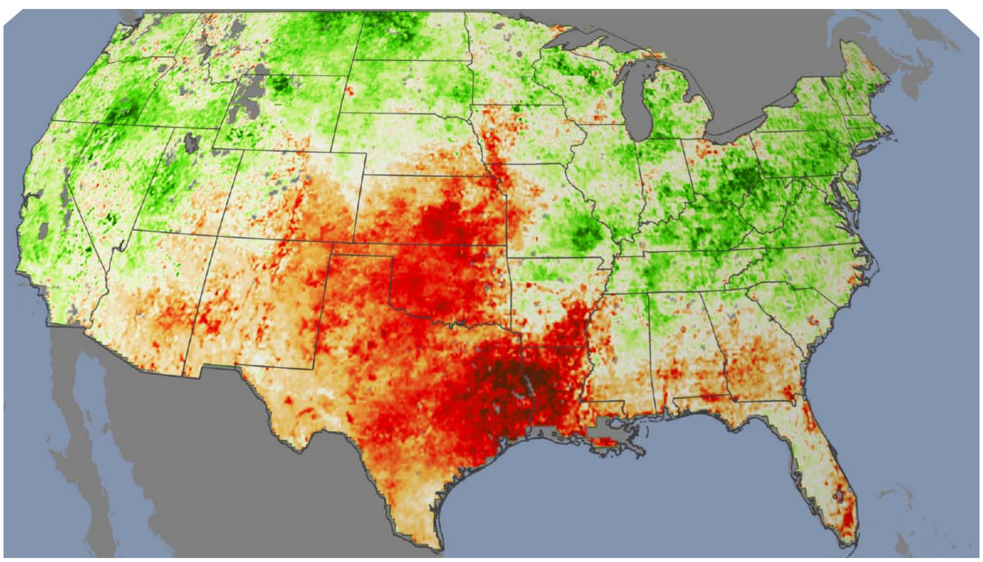

Figure 1. Plant stress on June 24, 2011 indicated significant drought in the southern U.S. **Image credit:** NASA/ Goddard Scientific Visualization Studio/ USDA-ARS

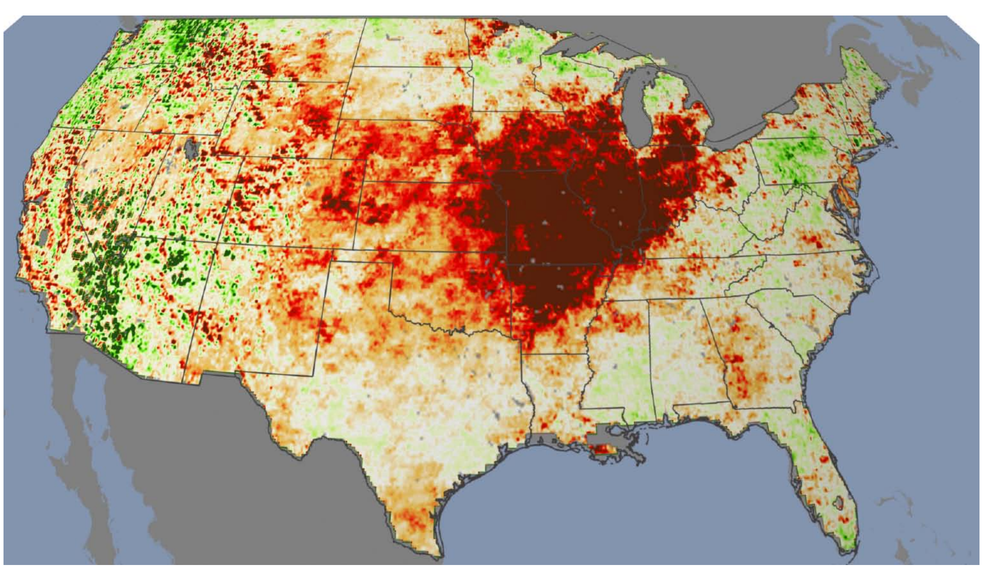

Figure 2. Plant stress on August 28, 2012 indicated significant drought in the U.S. Midwest. **Image credit:** NASA/ Goddard Scientific Visualization Studio/ USDA-ARS

consumption and evapotranspiration from leaf surfaces. As a result, leaves heat up and produce elevated leaf or canopy temperature, which can be detected by thermal sensors on the National Oceanic and Atmospheric Administration's geostationary weather satellites. In short, hotter plants imply limited water in the soil.

Martha Anderson of USDA-ARS used this information to develop maps of plant stress, and presented the research December 5, at the 2012 Fall American Geophysical Union conference in San Francisco, CA. At the same time, NASA unveiled a new animation based on Anderson's maps that shows how plant stress evolved across the U.S. from January 2010 through September 2012. In spring 2010 satellites measured cool leaf temperatures, indicating healthy plants and wetter-than-average conditions, over many areas across the country. By summer 2011, however, satellites saw the warming of stressed vegetation, indicating significantly lower-than-usual water availability in many areas—most notably in Texas—see **Figure 1**. Crops in these areas were either dead or would soon be dead. As the plant stress animation continues, drought wanes in the south and shifts to the Midwest in 2012—see **Figure 2**.

"This is not a drought forecast. It's a map of what's going on right now," Anderson says. "Is there more or less water than usual?" However, exactly what constitutes as *usual* or *normal*? The answer can depend on the season or even the year.

Scientists currently define normal by calculating and mapping plant stress averaged over periods of one-to-three months—from the start of MODIS data collection in 2000 to the present. The mean of these historic maps is considered normal. When scientists compare a current map with the longer-term *normal* map, they get an *anomaly map* that shows a picture of the amount by which current conditions deviate from normal. "What was normal back in 1920 is not what's normal now, so the more years we have under the belt the better we can define normal," noted Anderson, who was quick to point out that, "…This year [2012] is so far out of line with respect to previous years, it is unusual regardless of the period of record used as the baseline."

Drought in 2012 was in fact the most severe and extensive in at least 25 years, according to the USDA's Economic Research Service. By August 60% of farms were in areas experiencing drought, and by mid-September the USDA had designated more than 2000 counties as disaster areas. "[The 2012 event] was record-breaking; this was just a huge event," says Anderson.

Discussing the potential applicability of the new product, Anderson said, "We think there's some early-warning potential with these plant stress maps, alerting us as the crops start to run out of water."

As described above, signals of plant stress may appear first in satellite-derived maps of vegetation temperature well before the crops have actually started to wilt and die. "The earlier we can learn things are 'turning south'," continued Anderson, "presumably the more time we have to prepare for whatever actions might be taken." For example, farmers may decide they need to buy supplemental feed from outside the drought-affected area to support their livestock, or they may need to adjust contract or insurance decisions.

The U.S. Drought Monitor already uses a combination of indices to describe drought conditions each week. The monitor currently does not include plant stress, but the potential of adding it is being explored.

"Plant stress is one representation of drought impacts, and the drought monitoring community agrees that you can't do this with just one tool—you need a lot of different tools," Anderson says.

Plant stress information has the potential to improve the skill of existing forecasts that predict drought out to weeks or months. Also, because the plant stress information is derived from satellites, it can describe drought conditions in areas where rain gauge and radar networks are sparse—and it can do so at the scale of individual fields. ■

Climate Models Project Increase in U.S. Wildfire Risk

Kathryn Hansen, NASA's Goddard Space Flight Center, kathryn.h.hansen@nasa.gov

Scientists using NASA satellite data and climate models have projected drier conditions likely will cause increased fire activity across the U.S. in coming decades. Other findings about U.S. wildfires, including the amount of carbon emissions and how the length and strength of fire seasons are expected to change under future climate conditions, were also presented at the annual meeting of the American Geophysical Union in San Francisco, CA.

Doug Morton [NASA's Goddard Space Flight Center (GSFC)] presented the new analysis of future U.S. fire activity. The analysis was based on current fire trends and predicted greenhouse gas emissions.

"Climate models project an increase in fire risk across the U.S. by 2050, based on a trend toward drier conditions that favor fire activity and an increase in the frequency of extreme events," Morton said.

The analysis by Morton and colleagues used climate projections, prepared for the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC AR5), to examine how dryness, and therefore fire activity, is expected to change.

The researchers calculated results for low and high greenhouse gas emissions scenarios. In both cases, results suggest more fire seasons that are longer and stronger across all regions of the U.S. in the next 30-50 years. Specifically, high-fire years like 2012—see **Figure 1**—would likely occur two to four times per decade by mid-century, instead of once per decade under current climate conditions.

Through August of 2012, the U.S. burned area topped 2.5 million hectares (6.17 million acres), according to a fire emissions database that incorporates burned area estimates produced from observations by the Moderate Resolution Imaging Spectroradiometers on NASA's Aqua and Terra satellites. That is short of the record 3.2 million hectares (7.90 million acres) burned in 2011, but exceeds the area burned during 12 of the 15 years since record keeping began in 1997. This and other satellite records, along with more-refined climate and emissions models, are allowing scientists to tease out new information about fire trends.

"Fire is an inherently global phenomenon, and the only practical way to track large-scale patterns and changes in fire activity is with satellites," says **Louis Giglio** [University of Maryland, College Park/GSFC].

As the U.S. land area burned by fire each year has increased significantly in the past 25 years, so too have the emissions. Carbon dioxide emissions from wildfires in the Western U.S. have more than doubled since the 1980s, according to **Chris Williams** [Clark University].

The satellite-based view allowed Williams and his colleagues to quantify how much carbon has been released from fires in the Western U.S. The team used data on fire extent and severity derived from Landsat satellites to calculate how much biomass is burned and killed, and how quickly the associated carbon was released to the atmosphere —e.g., before and after images of the High Park Fire shown in **Figure 2**. The team found carbon emissions from fires have grown from an average of 8 teragrams (8.8 million tons) per year from 1984 to 1995 to an average of 20 teragrams (22 million tons) per year from 1996 to 2008, increasing 2.4 times in the latter period.

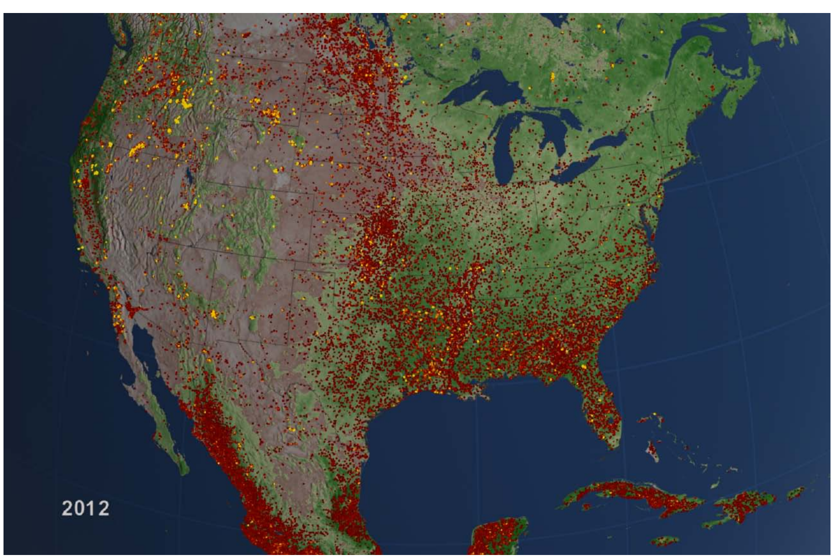

Figure 1. A visualization of cumulative fires from January 1 through October 31, 2012, detected by the MODIS instruments onboard the Terra and Aqua satellites. Bright yellow dots show areas that are more intense and have a larger area that are actively burning, flaming, and/or smoldering. **Image credit:** NASA

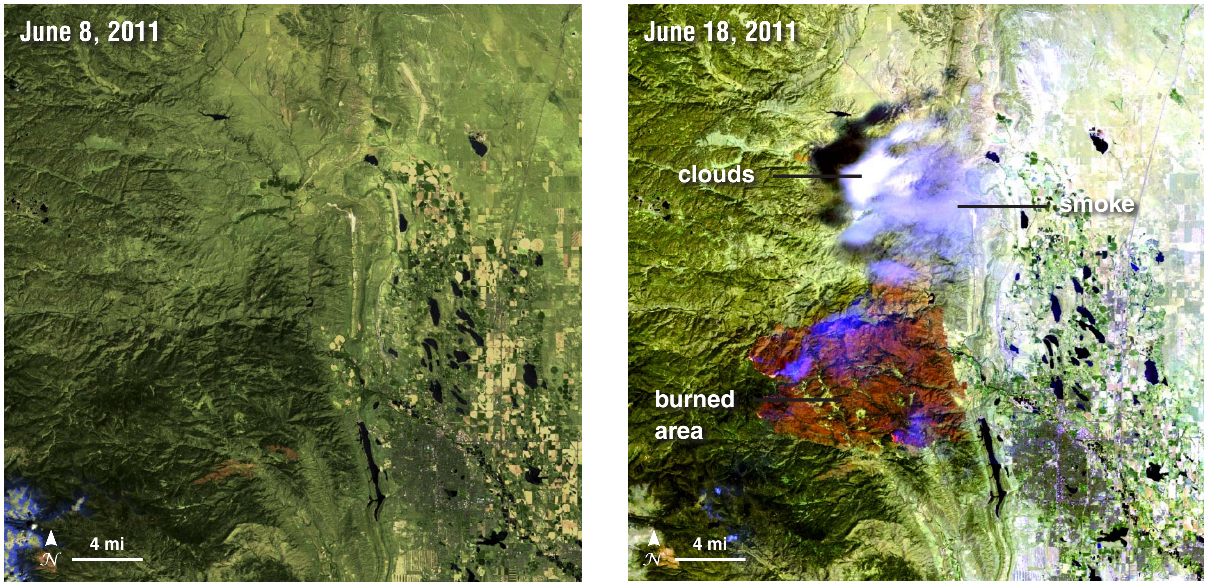

Figure 2. The image on the right from Landsat 7 shows the 60,000 acres burned by the *High Park wildfire* just west of Fort Collins, CO as of June 18, 2012. The left image, taken by Landsat 5, shows the same region taken on June 8, 2011—a year before the fire. The fire, which was started on June 9 as a result of lightning strike, destroyed 189 homes as of June 19. In the June 18 image, clouds hover just north of the burned area, with smoke from the fire visible as blue. **Image credit:** USGS/NASA

The Whitewater-Baldy Complex wildfire in Gila National Forest, NM, as it burned on June 6, 2012. Scientists calculate that high-fire years like 2012 are likely occur two to four times per decade by midcentury, instead of once per decade under current climate conditions. **Image credit: Kari Greer/** USFS Gila National Forest

"With the climate change forecast for the region, this trend likely will continue as the western U.S. gets warmer and drier on average," Williams said. "If this comes to pass, we can anticipate increased fire severity and an even greater area burned annually, causing a further rise in the release of carbon dioxide."

Researchers expect a drier and more wildfire-prone U.S. in future decades. Previous research confirmed the connection between the measure of an environment's potential evaporation, or dryness, and fire activity.

From a fire and emissions management perspective, wildfires are not the entire U.S. fire story, according to research by **Hsiao-Wen Lin** [University of California, Irvine]. Satellite data show agricultural and prescribed fires are a significant factor and account for 70% of the total number of active fires in the continental U.S. Agricultural fires have increased 30% in the last decade.

In contrast with wildfires, agricultural and prescribed fires are less affected by climate, especially drought, during the fire season.

"That means there is greater potential to manage fire emissions, even in a future, drier climate with more wildfires. We need to use cost-benefit analysis to assess whether reductions in agricultural fire emissions—which would benefit public health—would significantly impact crop yields or other ecosystem services," Lin said. ■

NASA Earth Science in the News

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

Climate Change Study: It's the Heat and Humidity, November 14, *talkingpointsmemo.com.* A new, NASA-funded study of climate change software found that models that are most accurate in accounting for humidity also project temperature increases, upwards of 7 °F (-14 °C), by the end of the twenty-first century. The results of the study, published in the journal *Science*, analyzed the output from 16 leading climate models, using data from the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua spacecraft and the Clouds and Earth's Radiant Energy System (CERES) instruments, along with data from NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA). **John Fasullo** [National Center for Atmospheric Research (NCAR)] and **Kevin Trenberth** [NCAR] analyzed the models, focusing on how accurate they were in representing the current, real-world distribution of relative humidity in the subtropics (from 10 to 30° north and south of the Equator)—regions that are mostly dry and desert-filled.

Drop in Sea Levels Found Only Temporary, November 19, *upi.com.* Based on satellite data, the trend of rising sea levels hit a "speed bump" in 2010, as global sea level fell sharply. Researchers at the NASA/Jet Propulsion Laboratory (JPL) in Pasadena, CA, and the University of Colorado in Boulder said that global sea level fell by about a quarter of an inch between early 2010 and summer 2011. Data from the NASA/German Aerospace Center's Gravity Recovery and Climate Experiment (GRACE) satellites showed that the drop was caused by the very strong La Niña event that began in late 2010. "The water the ocean lost was compensated for rather quickly," stated lead study author **Carmen Boening** [JPL]. "The newest data clearly indicate that the drop in 2010-2011 was only temporary."

New Study Affirms Ice-sheet-loss Estimates in Greenland, Antarctica, November 29, *Washington Post.* According to a study hailed by scientists as the most accurate assessment of polar ice melt to date, the giant polar ice sheets in Greenland and Antarctica are losing three times as much ice as they were 20 years ago. The study, published in the journal *Science* shows that this melting is adding to the sea-level rise that already threatens low-lying coastal areas. In one startling finding, Greenland's melt was five times higher than it was in the mid-1990s, representing more than two-thirds of the total ice loss; Antarctica's slower thaw accounted for the rest. The study, by an international group of 47 experts who study satellite-mapping data, is the first to pull together 50 different ice-sheet-loss estimates that cover two decades and to reconcile the research methods and findings into a single report. The group was led by scientist **Erik Ivins** [JPL] and professor **Andrew Shepherd** [University of Leeds, U.K.].

"Black Marble" Glitters with Earth's Night Lights, December 5, *nbcnews.com.* NASA is known for its "Blue Marble" images, which show Earth's sunlit disk as seen from space. Now it's making a splash with a nighttime view, nicknamed the "Black Marble." The image—next page—made with data from Suomi National Polar-orbiting Partnership's (NPP's) Visible Infrared Imaging Radiometer Suite (VIIRS), was unveiled at the American Geophysical Union annual meeting in San Francisco, CA, December 5, 2012.

***How NASA Satellites Forecast Droughts Earlier**, December 7, *msnbc.com.* A month before rainfall measurements or other drought indicators picked it up, satellite data showed what was coming for the American South and Midwest: hot, water-stressed crops that would eventually die under a prolonged drought. Scientists at the U.S. Department of Agriculture (USDA) have developed a way to harvest numbers from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instruments and National Oceanographic and Atmospheric Administration (NOAA) satellites and turn them into maps showing plant stress. Now scientists from USDA say their maps could help the U.S. predict and prepare for drought sooner. "We think there's some early-warning potential with these plant stress maps, alerting us as the crops start to run out of water," says **Martha Anderson** [USDA's Agricultural Research Service]. "The earlier we can learn things are turning south, presumably the more time we have to prepare for whatever actions might be taken."

***Area Burned by U.S. Wildfires Expected to Double by 2050**, December 14, c*limatecentral.org.* Warmer and drier conditions in coming decades will likely cause areas in the U.S. burned by wildfires to double in size by 2050, according to new research based on satellite observations and computer modeling experiments. The research was first presented at the American Geophysical Union annual meeting in San Francisco, CA, December 4, 2012. The study provides insight into both recent wildfire trends and the sharp increase in dryness—and therefore wildfire susceptibility—in some regions of the country, said **Doug Morton** [NASA's Goddard Space Flight Center]. Morton said other regions of the country, including the Western U.S. will likely see a continued increase in burned area, as well.

*See news story in this issue for more details.

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

This image of night lights over North and South America is just one frame in the Black Marble series, which is based on VIIRS data from the Suomi NPP satellite. **Image credit**: NASA's Earth Observatory, **Robert Simmon**, **Chris Elvidge**

NASA Science Mission Directorate – Science Education and Public Outreach Update

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NASA Postdoctoral Fellowships

Deadline—March 1

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

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

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

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

Polar Science Weekend at Pacific Science Center

February 28-March 3; Pacific Science Center, Seattle, WA

The eighth annual Polar Science Weekend (PSW) is just around the corner! Students, teachers, and families will have the opportunity in a fun and informal setting to interact directly with scientists who are working in some of the most remote and challenging places on Earth to learn first-hand about Arctic and Antarctic research. The researchers will present dozens of hands-on activities, live demonstrations, and exhibits about current polar research; NASA-funded work in the polar regions will be highlighted. For more information, visit: *psc.apl.washington.edu/wordpress/education/polar-science-weekend*.

AMS Climate Studies Diversity Project Course Implementation Workshop for Qualifying Faculty

Deadline—March 15

The American Meteorological Society (AMS) has partnered with Second Nature, administrator of the American College and University Presidents' Climate Commitment, to implement the AMS Climate Studies course at 100 eligible, minority-serving institutions (MSIs) over a five-year period. As part of this National Science Foundation-supported Diversity Project, AMS is recruiting 25 MSI faculty for the Course Implementation Workshop to be held May 19-24, 2013, in Washington, DC.

Faculty will be trained to offer the climate course and will hear presentations from top-level scientists from NASA, the National Oceanic and Atmospheric Administration (NOAA), and universities. The AMS Climate Studies course was developed and pilot-tested with support from NASA. All expenses are paid for those selected to attend the workshop, and the AMS Climate Studies license fee is waived for the first two years the course is offered. For more information and to apply, visit: *www.ametsoc.org/amsedu/online/climateinfo/diversity.html*.

2013 Thacher Environmental Research Contest for High School Students

Deadline—April 15

New discoveries about our planet are being made every day—using geospatial tools. The 2013 Thacher Environmental Research Contest, sponsored by the Institute for Global Environmental Strategies, challenges high school students to conduct innovative research on our changing planet using the latest geospatial tools and data.

The best projects will receive a first-place cash prize of $2000, $1000 for second place, and $500 for third place. Individuals or teams of up to four students may submit entries. For winning teams, the prize will be split equally among the team members. In addition to the student prizes, teachers or adult "coaches" of the first-, second-, and third-place students will receive a $200 *Amazon.com* gift card. For more information, visit: *strategies.org/education/student-contests/thacher-contest*.

Earthzine Call for Papers on Environmental Awareness

Deadline—March 21

Earthzine.org is soliciting articles for its 2012 fourth-quarter theme, on environmental awareness. Because observation is inextricably linked to awareness, the development of a collective global perspective, made possible through highly integrated Earth observations, will fundamentally change humanity's awareness of its environment. *Earthzine* seeks contributions addressing theory and practices related to creating and expanding awareness of Earth's environment. Earthzine seeks to publish articles from all regions of the globe; however, all submissions must be in English. For full details on desired themes and how to submit, visit: *www.earthzine.org/2012/08/01/call-for-papers-environmental-awareness*. ■

EOS Science Calendar

April 2–4, 2013
2013 Spring Land-Cover/Land-Use Change Science Team Meeting, Rockville, MD. URL: *lcluc.umd.edu/meetings.php?mid=40*

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

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

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

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

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

Global Change Calendar

March 24–28, 2013

ASPRS 2013 Annual Conference, Confluence by the Bay—A Gathering of Geospatial Insights, Baltimore, MD. URL: *www.asprs.org/Conferences/Baltimore-2013/blog*

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

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

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

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

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

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

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