National Aeronautics and Space Administration

The Earth Observer. May - June 2008. Volume 20, Issue 3.

Editor's Corner

Steve Platnick
EOS Senior Project Scientist – Acting

As was announced in the March–April issue of *The Earth Observer*, on April 3, Michael D. King retired from NASA Goddard Space Flight Center. King served as the EOS Senior Project Scientist since September of 1992, playing a key role in the overall scientific direction of the Earth Observing System. On April 4, a retirement party was held at the Goddard Visitor's Center to honor King's years of service and wish him well in his next endeavor as a Senior Scientist in the Laboratory for Atmospheric Physics (LASP) at the University of Colorado. I am sure you join me in thanking him for his many years of tireless work and leadership that contributed to the success of the Earth Observing System missions.

The task of replacing someone who served so well for so long is daunting to say the least. As announced in the previous issue, I have agreed to serve as EOS Senior Project Scientist on an interim basis while the future role of the Project Science Office is reevaluated in relation to the missions recommended by the National Research Council's Earth Science Decadal Survey and a permanent successor is chosen. In the meantime, the EOS Project Science Office will continue its important roles in areas of project science, calibration/validation, ground-based networks, and mission-specific education and public outreach.

As was also mentioned in the last issue, this is the 20th year of *The Earth Observer* newsletter. We continue to recognize this milestone with a second article on the early days of the EOS Program (see the article, *Putting*

continued on page 2

This sequence of images from the earliest Landsat satellite to the present captures the dramatic growth of Las Vegas, NV. From 1973 to 2006, the population of Las Vegas grew from 358,000 to over 2 million. To view these images in color please visit: *svs.gsfc.nasa.gov/vis/a000000/a003500/a003509/index.html* **Credit:** NASA/Goddard Space Flight Center Scientific Visualization Studio.

1972 1991 2000 2006

the earth observer

www.nasa.gov

editor's corner

eos.nasa.gov

In This Issue

Socks on an Octopus, written by Darrel Williams on page 4). We hope that this continuing series of articles provides some historical context to the development of the EOS missions, and provides a useful perspective as we begin to embark on a new era of NASA Earth observations under the outline of the Decadal Survey missions.

Spring has brought other changes, not the least being the leadership of NASA's Science Mission Directorate (SMD). On March 26, **S. Alan Stern** announced that he was stepping down as Associate Administrator. **Edward J. Weiler**, Director of NASA Goddard Space Flight Center, was named Chief of the Directorate (initially on an interm-basis and then as the permanent appointment on May 7). Weiler, who became the Goddard Director in August 2004, had previously served as the Associate Administrator for the agency's Space Science Enterprise from 1998 to 2004. Prior to his selection as Associate Administrator, Weiler served as Director of the Astronomical Search for Origins Program at NASA Headquarters in Washington. He also served as the Chief Scientist for the Hubble Space Telescope from 1979 until 1998. Weiler joined Headquarters in 1978 as a Staff Scientist and was promoted to the Chief of the Ultraviolet/Visible and Gravitational Astrophysics Division in 1979.

Meanwhile, **Michael R. Luther** has been named SMD Deputy Associate Administrator for Programs. Luther will be responsible for overseeing the safe and successful execution of the Directorate's 36 missions currently in formulation and development, as well as 54 operating science missions. Luther has a strong Earth science background. He began his tenure at NASA Headquarters in 1987 and has served as Program Manager of the Upper Atmosphere Research Satellite and Earth Science Flight Program Director. Prior to the present appointment, Luther was Deputy Director for the Earth Science Division. He has worked at NASA since 1981 when he joined Langley Research Center. Luther's predecessor, **Todd May**, who served in the position since 2007, will return to Marshall Space Flight Center. Congratulations to both Weiler and Luther on their new positions.

There is also news to report on the Landsat Data Continuity Mission (LDCM). NASA has selected General Dynamics Advanced Information Systems, Inc., to build the spacecraft. General Dynamics will be responsible for the design and fabrication of the LDCM spacecraft bus, integration of the government furnished instruments, satellite-level testing, on-orbit satellite check-out, and continuing on-orbit engineering support. They also will provide a spacecraft/observatory simulator.

LDCM is a component of the Landsat Program conducted jointly by NASA and the U.S. Geological Survey (USGS) of the Department of Interior. NASA is providing the LDCM spacecraft, the instruments, the launch vehicle, and the mission operations element of the ground system. USGS is providing the mission operations center and ground processing systems, as well

as the flight operations team. With a five-year design lifetime, the LDCM satellite will continue the series of measurements begun in 1972 with Landsat-1. This continuation of multi-spectral imagery will provide global coverage of the Earth's land surfaces at scales where natural and human-induced changes can be detected and quantified.

In other Landsat news, the USGS announced on April 21 that all Landsat data will be available through the Internet at no charge by February 2009. This represents a major policy change for USGS and is a welcomed development. Newly acquired Landsat 7 ETM+ data of North America and Africa are already being provided free of charge.

Finally, the 39th Earth Day was celebrated on April 22. What started out as a grassroots effort in 1970 is now recognized with activities in countries throughout the world—for a history of how Earth Day came to be see *earthday.envirolink.org/history.html.* In the spirit of Earth Day, we at the *The Earth Observer* took time to consider our own environmental impact, especially as some of our recent issues have exceeded 60 pages in length! The success of the newsletter is evident in the 4809 domestic subscribers and 1080 international subscribers in 70 countries. In an effort to cut back on the amount of paper used to produce the newsletter, as well as associated processing and transportation costs, we would like to invite you to consider receiving your copy of the *The Earth Observer* electronically. While this option has been available for some time (issues dating back to January 1995 can be downloaded as PDFs), we will attempt to make it easier by notifying you when future issues are available for download (for details, see the announcement below). We realize that many readers prefer the convenience of hardcopies and we will certainly continue to provide the printed newsletter for those who desire it. However, those of you who are comfortable with electronic formats may wish to try this *green* approach. And if you change your mind, you can always opt back in for the printed version. ■

Join Our Go Green Campaign

In an effort to cut back on the amount of paper used to produce this newsletter, we would like to announce our Go Green campaign. If you would like to stop receiving a hard copy AND be notified via email when future issues of *The Earth Observer* are available for download as a PDF, please send an email with the subject "Go Green" to *Steve.Graham@nasa.gov*. Your name and email address will then be added to an electronic distribution list and you will receive a bi-monthly email indicating that the next issue is available for download. If you change your mind, the email notification will provide an option for returning to the printed version—so you have nothing to lose.

Issues dating back to January 1995 can be downloaded from this link:

eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php

Reflections on the Early Days of EOS: *Putting Socks on an Octopus*

Darrel L. Williams, NASA Goddard Space Flight Center, Darrel.L.Williams@nasa.gov

But, just as we were giving birth to the Thematic Mapper (TM) era, control of the Landsat Program was being handed off to NOAA, and would ultimately be privatized. So, following the euphoria of the launch of Landsat 4 and getting to process some of the first TM data, it was soberingly clear that NASA's role in overseeing future Landsat missions was going to be minimal—or so it appeared at that time.

Our last issue [*Volume 20, Issue 2, pp. 4-8*] featured an article called: "The Earth Observer: 20 Years Chronicling the History of the EOS Program," in which **Alan Ward** [Executive Editor of *The Earth Observer*] shared his perspectives on Earth Observing System (EOS) after spending time reviewing *The Earth Observer* archives. Starting with this issue, we are pleased to bring you the first in what we hope to be a series of articles offering *Perspectives on EOS* from some of the key players who were actually present during those early years when the EOS Program was taking shape. We hope that these articles help give you a sense of the important role the EOS Project Science Office has played over the years in helping to coordinate and plan the activities of the EOS Program. Our first contributor is **Darrel Williams** [NASA Goddard—*Associate Chief, Hydrospheric and Biospheric Sciences Laboratory, and Landsat 5 / 7 Project Scientist*] who served as EOS Deputy Project Scientist from 1989-1990.

As I read through Alan Ward's opening article in this series, it brought back a flood of memories "from the early days" of the Earth Observing System (EOS) Project Science Office. For example, I had completely forgotten that **JoBea Cimino** (later **Way**) of the Jet Propulsion Laboratory (JPL) and I were the original Executive Editors of *The Earth Observer*. We must have a done a pretty bad job, because I vividly remember **Jerry Soffen**, who was EOS Project Scientist from 1989-1990, saying that we needed to find a newsletter editor with some experience, and he had a person in mind, her name was **Charlotte Griner**. Fortunately she agreed to join our team, so JoBea and I quickly got out from under having to serve as co-editors of *The Earth Observer*.

Before going any further, I would like to step back and explain how it was that I got to be Soffen's deputy. I had arrived at Goddard back in January 1975 as a fresh out master's student with experience in digital analysis of early Landsat Multispectral Scanner (MSS) data. There were no PhD programs in quantitative remote sensing in those days—it was still too new. Then in early 1978, **Vincent Salomonson**, who was Landsat Project Scientist at the time, asked me to serve as his Assistant Project Scientist on Landsats D and D'—later to be known as Landsats 4 and 5. Some five years later Landsat 4 actually launched on my birthday (July 16) in 1982, and oh what a birthday candle that was! But, just as we were giving birth to the Thematic Mapper (TM) era, control of the Landsat Program was being handed off to NOAA, and would ultimately be privatized. So, following the euphoria of the launch of Landsat 4 and getting to process some of the first TM data, it was soberingly clear that NASA's role in overseeing future Landsat missions was going to be minimal—or so it appeared at that time.

Having worked closely with Dr. Salomonson for several years, he strongly encouraged me to enroll in a Ph.D. program, which I did just as Landsat 5 was being readied for launch in March 1984. So, as timing would have it, when the NASA Research Announcement calling for proposals to participate in the EOS Program came out in 1988, I was deeply immersed in writing my dissertation. Talk about frustrating...the next era of Earth remote sensing was taking shape, and there I was on the sidelines watching, too busy working on my dissertation to write a proposal. As 1989 began I was all completed with my advanced education except for the actual graduation ceremony itself, so I was a newly minted Ph.D. looking for exciting work. In the 1988/89 timeframe, Dr. Soffen had been a one-man search committee looking for the "right person" to serve as the EOS Senior Project Scientist at Goddard. He couldn't

Darrel Williams

find the right person, so he took on the role himself, and was seeking to bring on a Deputy to help him with the many duties of that office at that time. To make a long story short, I believe that Dr. Salomonson recommended me to Dr. Soffen and I was interviewed and quickly appointed as the EOS Deputy Project Scientist.

As Ward pointed out in the prior article, the 1989–1991 time period in particular was very hectic as the EOS concept was being restructured, rebaselined, reshaped, and thoroughly reviewed mostly in response to changes in the program's funding levels. We were constantly planning for Investigators Working Group (IWG), Payload Panel and/or Instrument Panel meetings, where there were long hours of deliberation and debate on how to make the "hopeful vision of EOS a reality." The instrument package on the EOS AM-1 platform (to be renamed *Terra* much later on), received a lot of scrutiny, as it was the first in the series of missions. It was also a mission very much focused on land remote sensing, and that lined up very well with my forest science, physical geography, and Landsat experience base.

Not surprisingly, I was particularly drawn to the High Resolution Imaging Spectrometer (HIRIS) instrument concept; however, the projected cost to build HIRIS was quite substantial and it ultimately fell victim to one of the many significant budget cuts that were passed down in this time period. We suddenly had a major Earth-observing platform with a gaping hole on the payload bus to accommodate another instrument, as well as a gaping void in the imaging of the Earth at higher spectral and spatial resolutions. I clearly remember a request being passed down to quickly look at how to best fill the gap on the platform, as well as fill the void in Earth imaging capability. This request came at a time when Dr. Soffen was on extended leave with his wife in Japan and basically out of touch. (As pointed out in Ward's article from last issue, e-mail and the Internet were not readily available back then, and so I was not able to communicate the situation to Dr. Soffen using e-mail and the internet as I could've today.) By 1990, it was pretty clear that the privatization of Landsat was not going too well, so given my background and interests, I proposed that we add a Landsat TM-class instrument to the EOS AM-1 package. I had checked with several scientists selected to serve on the various EOS instrument teams, and there was a unanimous reply that Landsat capability was extremely important and that Landsat itself had not been part of the EOS planning because they all just assumed that it would always be there—that is, in orbit sending back images. Dr. Soffen returned from Japan and I briefed him on what I had proposed, and he was very pleased. However, about two days later he called me in to his office and told me that my idea was "the stupidest thing he had ever heard of" or something very close to that if you get my drift. Apparently, the awkward politics that have always shadowed Landsat reared its ugly head yet again, and my "Landsat on AM-1" idea quickly died.

continued on page 33

The instrument package on the EOS AM-1 platform (to be renamed Terra much later on), received a lot of scrutiny, as it was the first in the series of missions. It was also a mission very much focused on land remote sensing, and that lined up very well with my forest science, physical geography, and Landsat experience base.

feature articles

A High Seas Adventure to Study Gas Exchange: The Southern Ocean Gas Exchange Experiment

Alan Ward, NASA Goddard Space Flight Center, award@sesda2.com
Charlotte Griner, NASA Goddard Space Flight Center, clgriner@earthlink.net
SO GasEX III Team—see each entry for contributing authors' names

Adventure...and Research on the High Seas

Scientists recently embarked on an ocean voyage. But this was no pleasure cruise; it was a 42-day adventure amid the high winds and big waves of the Southern Ocean. Nearly 30 scientists from over a dozen institutions and representing a variety of different scientific disciplines undertook this carefully planned odyssey called the Southern Ocean Gas Exchange Experiment (GasEx III)[1] that ran from February 29—April 10 to make groundbreaking measurements that they hope will help to explain how large amounts of climate-affecting gases move between atmosphere and sea, and vice-versa—the scientific term for such movement is *flux*.

"The cruise should provide important information on factors controlling the flux of the greenhouse gas carbon dioxide between the ocean and atmosphere," said the cruise's chief scientist, **David Ho** of Columbia University's Lamont-Doherty Earth Observatory (LDEO). Comprising 30% of the surface area of global seas, "the Southern Ocean is a source of great uncertainty," he said. "So it's potentially important to our understanding of the global system."

Humans currently put about 8 billion tons of CO_2 into the atmosphere each year, mainly by fossil-fuel burning and deforestation. Scientists believe that approximately one-quarter of that amount is absorbed by the world's oceans, and another quarter by plants or other components of land. The rest stays in the air—where it increases the atmospheric concentration of CO_2 and contributes to warming. That much we know... but there's still much that scientists don't understand. There are huge uncertainties in the calculations—made so far mostly through indirect means—and fluxes seem highly variable from year to year, with some parts of the oceans habitually giving up CO_2—*sources*—while others absorb it—*sinks*. (The Southern Ocean is usually a CO_2 *sink*.)

"Understanding how atmospheric CO_2 reacts with these cold surface waters is important for determining how the ocean uptake of carbon dioxide will respond to future climate change," said **Christopher Sabine**, co-chief scientist on the cruise, and an oceanographer at the U.S. National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environment Laboratory (PMEL). NOAA, NASA, and the National Science Foundation cosponsored the cruise.

The port of departure for this high seas adventure was the southern-most city in the world—Punta Arenas, Chile. It was there that the scientists gathered to board the *Ronald H. Brown*, a 274-foot NOAA research vessel and sail out of the safe harbor of the Straits of Magellan onto the wilds of the Southern Ocean. They would travel about 1000 miles east of Punta Arenas to their chosen study site in the western Atlantic sector of the Southern Ocean. Here high, freezing winds unimpeded by landmasses roar much of the time (the area is sometimes called the roaring 40s because of the

NOAA ship *Ronald H. Brown*. Photo taken during GasEx-2001 in the Eastern Equatorial Pacific.

persistent winds in that latitude region) and waves can routinely top 30 feet. Higher wind speeds correlate with faster exchange of gases. The wind itself can increase gas exchange rates, but the combination of wind and hard-to-observe, wind-driven phenomena, like turbulence and breaking waves, is much more effective in increasing gas exchange rates. Studies have been conducted in the laboratory to simulate gas exchange under strong winds but to date, there have been few studies aimed at directly measuring these exchanges under real-world conditions. The Southern Ocean is an ideal site for such real-world observations. "The conditions are a little grim, but it's ideal for study," said Ho.

To examine these mechanisms, the scientists deployed arrays of sophisticated instruments just above the water surface, and in the water column. Meanwhile, another part of the team measured the amount of phytoplankton present in the water by looking at optical prop-

[1] GasEx III follows two similar experiments: GasEx I, which was conducted in the north Atlantic in 1998; and GasEx II, in the equatorial Pacific in 2001.

Table 1. Research Projects Planned During GasEx III

	Research Projects	Method
1	Direct Measurements of CO_2 and DMS Fluxes	Air-sea CO_2 (NDIR) and DMS (APIMS) flux systems
2	Integrated Gas Transfer Velocities with Deliberate Tracers (SF_6 and $_3$He)	Continuous and discrete SF_6 systems (GCs) and He isotope mass spec
3	Bulk Meteorology and Turbulent Fluxes (winds, momentum, water vapor, temp, IR, Solar radiation, etc.)	Sonic anemometer, thermometer, pyranometer, pyrgeometer
4	Surface and Near-surface Ocean Processes (Large waves, directional wave field; currents; oceanic surface turbulence, oceanic shear, oceanic stratification, bubbles)	Shipboard radar; microwave altimeter. ADV, MAV, thermister chain, video camera, noble gases (mass spec)
5	Core CO_2 and Hydrographic Measurements (DIC; pCO_2; Talk, temp, sal, O_2)	SOMMA/DICE, NDIR, titration, CTD, Winkler
6	Surface and Subsurface pCO_2 and DIC Variability	Shipboard underway pCO_2 system (NDIR), SAMI, CARIOCA, SuperSoar
7	Primary Production; New Production	$_{14}$C and $_{15}$N incubations, O_2/Ar (MIMS)
8	Nutrients ($NO_{2\pm}$, NO_{3-}, NH_{4+}, $PO4_{3-}$ and H_4SiO_4)	Nutrient autoanalyzer

erties such as ocean color, which is an indication of chlorophyll content. Phytoplankton takes up carbon during photosynthesis, and thus can influence surface ocean CO_2 concentrations. "NASA's ongoing effort to understand the global carbon cycle will benefit from the data this cruise will produce," said **Paula Bontempi**, Manager of the ocean biology and biogeochemistry research program at NASA Headquarters. "NASA's global satellite observations of ocean color will be improved, as we validate what our space-based sensors see with direct measurements taken at sea."

The main research objectives for GasEx III are to answer the following questions:

- What are the gas transfer velocities in areas with high winds?
- What effect does the distance waves travel without obstruction—*fetch*—have on gas transfer?
- How do other non-direct wind effects influence gas transfer?
- How does the changing partial pressure of carbon dioxide (pCO_2) and dimethyl sulfide (DMS)[2] levels affect the air-sea CO_2 and DMS flux, respectively in the same locale?
- Are there better predictors of gas exchange in the Southern Ocean other than wind?
- What is the near surface horizontal and vertical variability in turbulence, pCO_2, and other relevant biochemical and physical parameters?
- How do biological processes influence the pCO_2 and gas exchange?
- Do the disparate estimates of fluxes agree, and if not why?
- With the results from GasEx III, can we reconcile the current discrepancy between model-based CO_2 flux estimates and observation-based estimates?

In order to investigate the questions and problems posed in the research objectives, a series of projects were planned, which are summarized in **Table 1**.

Readers interested in learning more about the previous gas exchange experiments, as well as specific details about the science of gas exchange, rationale for choosing the Southern Ocean as the location for GasEx III, and specifics on the projects conducted during GasEx III should refer to—*so-gasex.org/science.html*—where PDFs of the Science Plan and Implementation Plan for GasEx III can be downloaded. Both documents also contain additional references for further reading.

One of the ways that the scientists participating in GasEx III kept the public informed of their progress on this important mission was by feeding a daily blog located at the expedition's website: *so-gasex.org*. *The Earth Observer* has obtained permission to reprint excerpts from that blog. We hope this will give you a feel for the kinds of research that were taking place during GasEx III. The entries come from a variety of different contributors; the author of each entry is listed.

[2] DMS is produced by phytoplankton in the ocean and is the most abundant natural sulfur compound emitted to the atmosphere.

Arrival in Punta Arenas
David Ho [LDEO—*Chief Scientist*]

Sunday, February 24, 2008, 3:02 PM

It's a beautiful day in Punta Arenas: 19°C and sunny.

The NOAA Ship *Ronald H. Brown* arrived yesterday morning, and the *SO GasEx III* scientists are slowly trickling into Punta Arenas as well. Tomorrow, we'll have the use of a shore crane to move most of the gear from the Climate Variability and Predictability (CLIVAR) CO_2 P18 cruise off the ship, and hopefully move most of the gear for GasEx III onto the ship.

Loading and unloading
David Ho

Monday, February 25, 4:07 PM

Another beautiful sunny day in Punta Arenas today, but showers are coming tomorrow.

Two groups from the west coast (one from NOAA/PMEL and one from Oregon State) are still waiting for their container vans to arrive from Valparaiso, Chile. It looks like they will show up on February 28, delaying our scheduled departure by a day.

Meanwhile, the ship continues to take on fuel and food. I saw potatoes and lettuce. What more does one need?

The 4800 L tracer infusion tank being offloaded.

The kitchen sink
Dave Hebert [University of Rhode Island]

Tuesday, February 26, 1:30 PM

The Oregon State and Rhode Island groups have not had much to do so far as our equipment (a 20 ft container and air shipment) is tied up in transit. This afternoon, the air shipment arrived. Finally, we can start setting up our equipment.

We will be towing an undulating vehicle, nicknamed the *SuperSoar* that measures the temperature, salinity and other water properties behind the ship. Water from the towed body will be pumped up to the ship and chemical analysis will be conducted on this water in real-time. The towed body will also carry a microstructure instrument to allow us to estimate the mixing occurring in ocean. With these measurements and the change in carbon content in the upper ocean, we can make an estimate of the amount of CO_2 that is moving from the atmosphere to ocean or vice versa. These values can be compared to values obtained by the other groups using different techniques.

As I mentioned earlier, we pump water into the lab from the *SuperSoar* at 2 gal/min. This water has to go somewhere, preferably over the side of the ship and not in the wastewater tanks. There is a drain in the lab that dumps over the side but we needed to get the water to the drain. Thus, we went to the local hardware store and bought a sink and fittings. So, the motto is now: *Bring everything including the kitchen sink!*

Step right up!
Christopher Sabine [NOAA/PMEL—*Co-chief Scientist]*

Tuesday, February 26, 8:34 PM

As part of an outreach effort for this project we have been working with the American Corners group of the U.S. Embassy in Chile to explain our project to the people of Chile. **Carlos Del Castillo** [Johns Hopkins University] participated in a radio interview on Thursday, February 21 that was conducted at the Embassy in Santiago and broadcast to 106 radio stations around the country. Carlos and I gave a presentation on the GasEx III study to a group of scientists at the Chilean Navy's Hydrographic and Oceanography Service (SHOA) in Valparaiso on Friday, February 22.

This morning **Paula Bontempi** [NASA HQ—*Manager of the Ocean Biology and Biogeochemistry Research Program*], Carlos, and I held a press conference at 9 AM in Punta Arenas and gave a tour of the NOAA research vessel *Ronald H. Brown* (henceforth referred to as the *Ron Brown* in this article) to local grade school and high school students, teachers, scientists, and press people. There were many great questions and we were pleased to have the local people so interested in our work. We also greatly appreciate the Muelle Arturo Prat officials and our local shipping agent, AGUNSA, for accommodating these events. Tomorrow Carlos and I will give another scientific presentation of the GasEx III study at the headquarters of Instituto Nacional Antártico Chileno (INACH)—Chile's Antarctic Institute—in Punta Arenas.

SAMI I am
Mike DeGrandpre [University of Montana]

Wednesday, February 27, 2:32 PM

Mike DeGrandpre holding a SAMI.

The Submersible Autonomous Moored Instruments (SAMIs) will be deployed on NOAA's MAP-CO2 buoy, developed by Chris Sabine's group at NOAA-PMEL. While the scientists onboard will be hanging onto their bunks amidst the high winds and large waves characteristic of the Southern Ocean, the MAP-CO2 buoy will continue merrily collecting data. The Southern Ocean is one of the largest sinks for atmospheric CO_2 and the data that we collect will allow us to determine the natural processes that control CO_2 cycling in this globally important region.

… and we're off!
David Ho

Saturday, March 1, 2008, 8:18 AM

After a one-day delay, we departed Punta Arenas at 7 PM yesterday for the study site near South Georgia Island. Considering how much uncertainty there was about status and arrival times of the various delayed shipments, including the two containers from Oregon State and NOAA/PMEL, it's remarkable that the delay was only a day.

Overnight, we made it out of the Strait of Magellan, and are now on the continental shelf and the territorial waters of Argentina. It'll be another 4 days until we are at the study site. Enroute, various groups will start their instruments and make sure everything is functioning properly. We will continue to look at satellite images (of sea surface temperature, height, and color) to refine our study site, and we will also prepare the tracer infusion tank for injection.

The weather is still fairly nice out here, but I imagine that it will get worse as we get closer to our study site.

The mess
Veronica Lance [LDEO]

Tuesday, March 4, 2008, 1:23 PM

The galley crew of the *Ron Brown* have been hard at work since before we cast off [from Punta Arenas]. **Richard Whitehead** is the Chief Steward, and has full responsibilities for providing meals and linens for the ship's officers, crew and scientists—a total of about 60 people. He likes his work and has been at it since 1979. **Mosies Martinez** and **Herb Watson** make up the rest of the galley crew for this trip. Three

Chief Steward Richard Whitehead in the galley of the *Ron Brown*.

full meals are served each day and ample snacks are available for those who miss regular meals. The menu is diverse, but I've observed it often includes some traditional "southern" fare. For example, *chicken and pastry* and *sweet tea*.

Here is a sampling of some stores that were brought aboard in Punta Arenas: 200 lbs of Argentinean beef, 400-500 lbs fresh Chilean fruits, and 600 lbs of fresh vegetables. Thank you to the guys who keep us well fed!!

Are we there yet?
David Ho

Tuesday, March 4, 2008, 2:18 PM

Four days out of Punta Arenas, and we're almost to the study site. We've been looking at satellite images, and **Joaquin Trinanes** [NOAA/Atlantic Oceanographic and Meteorological Laboratory (AOML)] has been providing us with really cool animations of surface currents derived from altimeters to help us refine the general area.

Once we get to the site, we'll spend two days conducting underway surveys, making sure it satisfies the criteria that we have set out here. The most important measurements we'll make are underway pCO_2, temperature, salinity, and acoustic Doppler current profiler (ADCP). The pattern for the survey we've planned is eerily reminiscent of the Columbia Business School logo, albeit upside down. We will start at 50°S 38°W, and head south to 52°S 38°W. Then we'll head northeast to 51°S 38°W, at which point we have to decide whether to keep going east or head directly west to complete the logo. If we deem the site to be acceptable, we'll conduct a survey with the *SuperSoar* to make sure that the vertical profiles also satisfy our criteria.

After we have selected the site, we'll conduct a background conductivity–temperature–depth device (CTD) survey down to 150 m for Helium-3 (3He) and sulfur hexafluoride (SF_6), then begin the tracer injection. For that, we'll deploy a GPS-enabled drifter, and basically do doughnuts around the drifter for 12 hours while we pump tracer-infused water from the tank on the fantail into the ocean, until all 4800 L of water has been injected. The initial *tracer patch* size should be about 7 x 7 km. After that, the fun will commence.

The weather has been incredibly nice, but according to the forecast at the Navy's Fleet Numerical Meteorology and Oceanography Center, rough seas are coming. Southern Ocean, baby!

Ozone's in da house!
Ludovic Bariteau [University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES)/ NOAA Physical Sciences Division]

Thursday, March 6, 2:14 PM

Yesterday we arrived on the study site approximately located at 50°S 38°W. And all the fun begins here! After some sunny days at sea with a calm ocean, we started to be gently rocked. Although today is calm sea with a heavy fog, we expect more choppy seas for the next few days. My stomach was a bit upset the past morning and my lunch has been light. But everything is back to normal now and the surveillance of the sensors keeps going.

I'm part of the air-sea interaction team from NOAA Physical Sciences Division (PSD), and I am operating the flux system that contains various sensors to measure momentum, sensible heat, latent heat, ozone, and carbon dioxide turbulent fluxes between the atmosphere and ocean. The goal is to improve our gas transfer velocity parameterization. For that purpose, we are working in collaboration with other teams from LDEO, University of Connecticut, and University of Hawaii in order to measure an important panel of processes between the air and ocean.

As a lot has been already said about CO_2, I'm going to talk briefly about ozone. This project is in collaboration with the University of Colorado's Institute of Arctic and Alpine Research (INSTAAR) laboratory. Like CO_2, it is important to have a good understanding of the global ozone atmospheric budget. One significant term in this budget is the deposition to the oceans, and direct observations from ships are quite rare. Thus this is a great opportunity to do such measurements onboard this ship.

The Oracle of Delta pCO_2
Bob Castle [NOAA/AOML]

Saturday, March 8, 9:03 AM

When the ancient Greeks needed answers to important questions, they consulted the *Oracle of Delphi*. For this experiment, we need to find an area of the ocean that meets certain requirements. One of these is that **the CO_2 concentration (pCO_2) in the surface water and the air must differ by at least 40 parts per million (ppm).** This difference is what we refer to as *delta pCO_2*. Today in the open ocean, the atmospheric CO_2 stays relatively constant at around 380 ppm (although it increases from year to year), but the CO_2 content in surface sea water can vary widely. At our present location, surface water pCO_2 is running at 340 ppm or less, for a delta pCO_2 of 380 – 340 = 40 ppm, thus satisfying this important requirement.

Since we cannot consult the *Oracle of Delphi* to find a suitable site, we rely on instruments to tell us about currents, wind speeds, and other parameters, including delta pCO_2. One of these is the underway pCO_2 system that our group installed when the *Ron Brown* was commissioned in July 1997. It records eight surface water and three atmospheric measurements every hour while the ship is steaming. Considering the importance of CO_2 to this experiment, it has become our *Oracle of Delta*.

The Greeks had only one *Oracle of Delphi*, but we are fortunate to have many "oracles." They include instruments aboard ship, satellite imagery, and data provided by shore-based scientists. And unlike the *Oracle of Delphi*, who couched her answers in the form of riddles, our oracles provide answers that are much easier to understand.

What's the patch?
David Ho

Tuesday, March 11, 12:56 PM

GasEx III has four broad categories of projects that together contribute to the overall goals of the experiment: There are those that revolve around (or rather, inside) the Lagrangian *tracer patch*; those that measure atmospheric fluxes of gases; those that involve autonomous buoys; and those that measure optical properties of the water.

Kevin Sullivan with the GPS drifter on the deck of the *Ron Brown*.

Four days ago, we injected ca. 4800 L of 3He and SF_6 infused seawater to create the tracer patch. It was a team effort, headed by **Kevin Sullivan** [NOAA/AOML]. Enroute to the study site from Punta Arenas, we filled the 4800 L tank on the fantail with seawater. We then infused the tank with tracers by bubbling SF_6 through it for a day, and then 3He for a few hours before the injection. While I had previously referred to the tracer infusion during the Stratospheric Aerosol and Gas Experiment (SAGE) Experiment as a *Symphony*

of Bubbles, we used a smaller pump and shorter length of "fizzy hose" during this infusion. It's more accurately characterized as a *Quartet of Bubbles*.

The injection took place over ca. 12-hour period, during which the ship went around a GPS drifter following waypoints that **Matt Reid** [LDEO] and I were generating with a program that Matt had written. The injection started at 8:30 PM; both of us had been up almost the whole day, so staying up for another 12 hours wasn't easy. Various people came in and out of the Hydro Lab throughout the night to talk to us, and while I can't remember many of those conversations, I remember thinking that things made less and less sense with time.

Despite the difficulty of staying up for 12 hours to generate waypoints and guide the ship, I think Matt and I had the easy job. Someone had to be outside on the fantail to watch the inject hose, and make sure that the flow rate out of the tank was constant. We had no shortage of volunteers for this job, and these people are the real heroes. Remember, it was cold, damp, and dark—much like winter in Scandinavia. Kevin started, and was out there for nearly 3 hours. **Steve Archer** [Plymouth Marine Lab—U.K.] took the next watch for 2 hours, and I know he wasn't watching albatrosses because it was pitch black outside. When I went outside to check on him after more than an hour, he was just standing there like one of those Emperor Penguins in Antarctica on a cold winter night. Then, **Pete Strutton** [Oregon State University] (a.k.a., the toe rubber), **Sarah Purkey** [NOAA/PMEL], and **Paul Schmieder** [LDEO] took successive turns, until Kevin came back in the morning to finish the job.

After the injection, we retrieved the GPS drifter and deployed the MAP-CO2 buoy and three drifters in the presumed center of the patch. Then, we started surveying the fruit of our labor. That was another long affair, taking almost 24 hours. In the end, a picture emerged of the initial patch. It was still a bit streaky, and had shifted slightly to the southeast, consistent with the movement of the MAP-CO2 buoy and the currents as measured by the ADCP.

Catching a wave
Christopher Zappa
[LDEO]

Wednesday, March 12, 1:10 PM

I sit writing this entry late at night, listening to the howling wind outside, and feeling the ship being tossed about by the waves on the ocean. Nearly everyone on the ship by now has their *sea legs*—the ability to "roll" with the motion of the ship on the ocean.

I am part of the onboard air-sea interaction group consisting of collaborating scientists from LDEO, University of Connecticut, University of Hawaii, and NOAA PSD. One of the topics our group is studying is how the energy from the wind goes into making waves, how these waves grow, and how they eventually whitecap, or break. The lengths of these breaking waves range in size from a few feet—so-called *microbreakers* that have no visible whitecap—to hundreds of feet—*whitecapping*. **These breaking waves are crucial in enhancing gas transfer over the oceans and important to the overarching goal of Southern Ocean GasEx III–Gas exchange in high winds and big waves.** *Microbreakers* are everywhere on the windswept ocean and break through the resistance to gas transfer at the air-sea interface. *Whitecapping* generates bubbles and mixing that contribute even more to gas transfer.

Measuring waves from ships is a difficult task, especially since the motion of the ocean influences the ship's motion. Until recently, most instruments for measuring waves from ships were one-dimensional. This means we were only able to get an idea of the height of the waves. During this experiment, we are using the Wave Monitoring System (WaMoS II)—an advanced system that uses a ship's radar along with some fancy software to produce images of the waves. This state-of-the-art instrument provides not only information about the height of the waves, but also their frequency, their wavelength, their "age," their steepness, and their direction.

WaMoS II can also tell us if there are various *types* of wave systems at the same time that will cause changes in the motion of the ocean. The other day we had a five-knot

wind but very long ocean swell waves that measured roughly 10-12 ft high. The ship was able to follow along the swell rather easily and the ride was smooth. Later in the day the wind picked up, and overnight the short-wavelength, wind-generated seas had grown and were coming from a different direction than the long ocean swell. The complicated wind sea and swell conditions made it difficult to find that "smooth" ride that the captain looks for by heading with the waves.

Just to the south of us are some of the largest waves on the world's oceans. Think of it…no landmasses to stop the waves from circumnavigating the globe. The wave forecast for that region this week shows a potential of over 30 feet high! We might even experience waves that high during our cruise. For now, it's for sure a smoother ride up here without them.

Meanwhile, at the other end of the food chain…
Bob Vaillancourt
[LDEO]

Friday, March 14,
7:35 PM

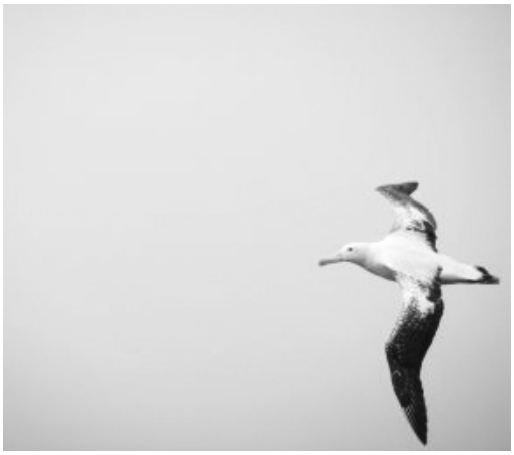
Our group is studying the phytoplankton, which form the base of the food chain in the ocean. But periodically we lift our heads up from our instruments and look overboard where we see a wonderful display of local wildlife that occupy the other end of the food chain.

One of the animals most associated with the Southern Ocean is the *Wandering Albatross*. It is the largest extant bird on Earth, routinely attaining wingspans of 10 ft, and wander the sea their entire lives, lighting on land only to breed. It is the bird shot and killed by the *Ancient Mariner* (S.T. Coleridge), which doomed him and his shipmates to countless days of deprivation and thirst once in the doldrums of the equatorial ocean:

The Sun now rose upon the right:
Out of the sea came he,
Still hid in mist, and on the left
Went down into the sea.

And the good south wind still blew behind
But no sweet bird did follow,
Nor any day for food or play
Came to the mariners' hollo!

And I had done an hellish thing,
And it would work 'em woe:
For all averred, I had killed the bird
That made the breeze to blow.
Ah wretch! said they, the bird to slay
That made the breeze to blow!



An Albatross spotted flying over the Southern Ocean during GasEx III.

Stupid mistake, but it made for one hell of a story he was doomed to repeat for the rest of his life.

Early out of Chile we repeatedly encountered pods of dolphins that would chase our ship, catch on, and ride our bow wave. The weather was calm enough, I was able to bend over the bow rail and take some shots. My best guess is that it is a *Peale's Dolphin*, a smallish dolphin that is indigenous to the southern tip of South America. Why do they ride our bow wave? Are they playing? Can non-humans *have fun*? One guess onboard sounded more reasonable: they ride bow waves to save energy while foraging for food. But maybe they *have fun* while searching for food too. Anyone's guess.

Back on track
Christopher Sabine and David Ho

Monday, March 17, 4:21 PM

Although we seem to be the only ship around for hundreds of miles, we are definitely not alone. The *Ron Brown* regularly receives weather forecasts and severe storm advisories from the U.S. Navy as they keep track of our every move in the Southern Ocean. On Thursday we received a warning from the Navy of high wind and wave conditions approaching our study area, the exact conditions for which we have been planning and waiting. However, the ship experienced a combination of mechanical and software problems that could impact the ship's ability to handle rough seas. The ship's Captain is the final arbiter when it comes to the safety of the ship, and he decided to move the ship to a safer location; in this case, we moved closer to South Georgia Island where the ship could duck behind the island to avoid the wind and waves if necessary.

During the 350-mi trek to South Georgia Island, we passed by some magnificent icebergs. They came from a huge iceberg that broke off of Antarctica in April 2005 and has been slowly breaking up as it drifts north.

While waiting off of South Georgia Island, we took the opportunity to get some much needed rest, perform necessary maintenance on various scientific equipment, and continue to make whatever measurements we could. In the meantime, we informed the organizations that are funding SO GasEx III about our predicament: **We have the perfect weather conditions but the ship might be unable to perform under those conditions.** Even though it was the weekend, this issue quickly reached the highest levels of NOAA Research and Fleet leadership. After much discussion between the different parties, it was decided that since the ship was able to restore the software failure it was indeed fit for service under high wind conditions.

Dyeing for a distraction
Christopher Sabine

Sunday, March 23, 3:28 PM

Scientist and crew come together for some Easter egg dyeing, a welcome respite from the rigors of scientific research during GasEx III.

Our first objective is to return to the MAP-CO2 buoy. We have been able to remotely monitor the storm effects on the seawater CO_2 and other properties. We cannot, however, monitor the tracer patch remotely. We are all anxiously awaiting our arrival at the buoy to see if we can still find the patch after being away for over four days, but it feels good to be back on track for the experiment.

Life at sea can be quite hectic. Operations continue 24 hours a day, 7 days a week with no weekends and no holidays. For some of us, a welcome event last night was the dyeing of hard-boiled eggs in honor of the Easter weekend. A little food coloring, vinegar, hot water, and some imagination is all it took to provide a little evening fun and fellowship. All were welcome regardless of religious beliefs. The only challenge was the fact that we only had brown eggs to dye. It seems that most colors, when mixed with brown, make…brown. Oh well, we had fun and it was a welcome distraction before the next CTD cast.

Down the rabbit hatch
Christopher Buonassissi [University of Connecticut]

Wednesday, March 26, 3:10 PM

I am a graduate student from the University of Connecticut and this is my first long research cruise. While I have been to sea before, this voyage has been particularly interesting.

One of my responsibilities on this cruise is to deploy the Hyperspectral Tethered Spectral Radiometer Buoy (HTSRB) or the buoy for short. This buoy is a collection of instruments that measure the amount of light at many wavelengths. There is one sensor that detects the amount of light hitting the surface of the ocean and three that are underwater to measure the amount of light coming up towards the surface. We can measure how the light field changes in the upper few meters of the water column and also determine the light that a satellite overhead detects. These data will allow us to determine how bubble injection by waves affects light in the ocean and how it impacts the signal that satellites detect. This is particularly important in high wind areas such as our current study area.

The buoy has also proven popular with the local wildlife. We have frequent visits from the penguins and birds in our neck of the ocean. The animals seem to be checking out this strange object bobbing about in their seas and contemplating how best to eat it. While their contemplations make for a great photo op, some of the albatross are a bit too eager in their inspections. My initial fears were allayed as the birds only cause minor damage by picking out a few bits of foam from the buoy's floatation collar. Such are the perils of science on the high seas.

Disaster!
David Ho

Friday, March 28, 6:18 PM

Being out at sea requires that we adapt to different situations and adjust our plans accordingly. Some of these adjustments are expected, while others are genuine surprises.

For instance, when we inject the *tracer patch*, we select an area that is relatively stable so we don't end up chasing the *tracer patch* around the Southern Ocean. However, because there's no guarantee that winds and currents won't change, we really don't know where the patch is going to go. As a result, we don't have fixed survey lines and have to adjust them minute-by-minute. That's expected…

During this cruise, however, we've had some surprises. For instance, what happened to the *SuperSoar* was a surprise, but given the fact that they are pushing the cutting edge of water sampling technology, it's not difficult to accept that it could happen.

What happened to us today topped that.

It was about 9:00 AM, and time for our morning CTD. Paul and I were discussing something in the Hydro Lab and getting ready for sampling when we heard a loud thud. I said to him facetiously, "I hope that wasn't the CTD going into the screws [the propellers]." I went to the Staging Bay to check things out, and ran into Carlos on the way who said to me with a panicked voice, "we just lost the CTD."

I once heard an episode of WNYC's *Radio Lab*, where they talked about what happens to us when we're under stress. One of the common experiences that people under extreme stress has is that time slows down and thoughts become clear and lucid. [I can now relate…]

In the few steps that it took to get to the Staging Bay, all the different scenarios under which we could have "lost the CTD" crossed my mind. I was expecting to see the end of a frayed cable dangling in front of me; what I saw was more surprising.

The CTD was hanging off the side of the ship, and the block that used to hang from the CTD boom was laying on the deck. Apparently, the rosette was accidentally pulled into the block, breaking the block and sending the CTD crashing approximately 20 ft into the side of the ship. Disaster!

The good news out of all this is that nobody was hurt and the rosette/CTD package was eventually recovered. However, the rosette frame was severely damaged and eight sample bottles were crushed.

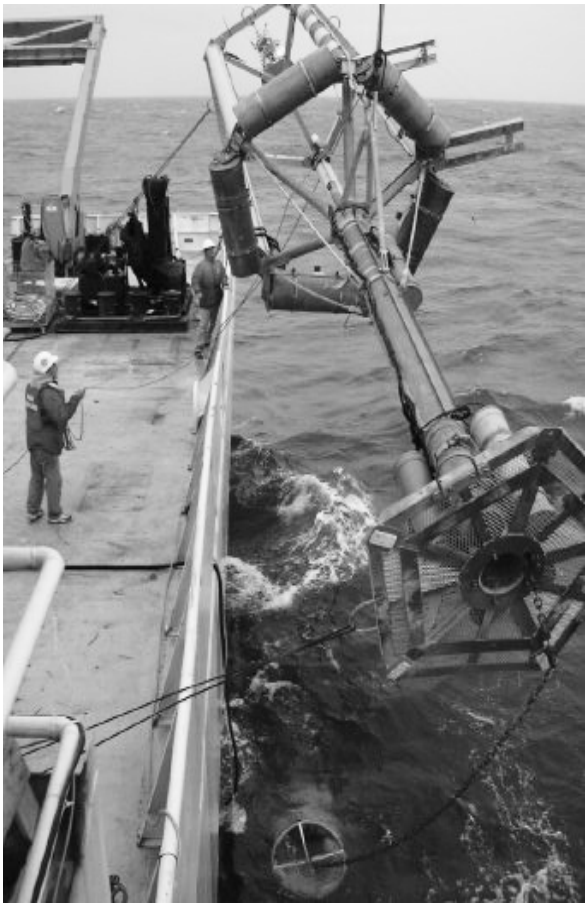
We're working hard to put another rosette/CTD package together, but it will not be ready in time for the upcoming 9:00 PM station. This will be another pumped sampling station. We hope to have the CTD ready for the morning station tomorrow.

ASIS – The Return of Big Bird
Will Drennan [University of Miami]

Monday, March 31, 12:00 AM

The *Ron Brown* recovered the University of Miami's Air-Sea Interaction Spar (ASIS) buoy over a week ago, after a week at sea. The comment most people make when seeing ASIS for the first time is: "Wow, that's big." At 36 x 6 x 6 ft (12 x 2 x 2 m), and weighing close to a ton, it is indeed one of the larger pieces of kit on the deck. As **Mike Rebozo** [University of Miami] can tell you, it can also be difficult to deploy and recover. While he's likely lost count of how many times ASIS has gone over the side of various ships over the past decade, the real question is how many of Mike's grey hairs are a result of ASIS?

The role of ASIS in GasEx III is to make measurements at, and close to, the ocean surface. Above the surface, we measure basic meteorological parameters, as well as the air-sea fluxes of CO_2, water vapor, heat, and momentum. In collaboration with **Ian Brooks** and **Sarah Norris** [University of Leeds] we are also measuring aerosol fluxes and concentrations. At the surface, we measure surface waves and wave slopes at various scales. This is particularly important for gas transfer work, as small scale waves are thought to be significant control on gas transfer rates. Below the water, we measure temperature, salinity, and energy dissipation rates (a measure of surface mixing, which acts as a control on gas transfer). There is also one of Mike DeGrandpre's SAMIs measuring CO_2, dissolved oxygen, and photosynthetically active radiation (PAR). Finally we also measure how ASIS moves in the water. Equipped with three ARGOS beacons giving position, we wanted to make sure to find it again.



The ASIS being deployed off the back of the *Ron Brown*.

Deep breathing
Byron Blomquist [University of Hawaii]

Thursday, April 3, 12:00 AM

Oceans and forests are the *lungs* of our planet. The first microscopic plants in ancient oceans produced the oxygen that makes life possible for animals (like us). We rely on green plants to sustain us. And as they exhale oxygen they inhale CO_2, converting it to wood, leaves, and the carbonate shells of marine plankton. Some of this carbon is returned to the atmosphere as CO_2 through respiration when bacteria, fungi, and animals feed on plants and organic matter. A small amount settles into long-term stor-

age as coal, oil, and chalk deposits. This in brief is the system we call the *carbon cycle*, and the ocean surface is part of the planetary lung, like the lungs in our bodies, that carbon transits during its cycle.

It has been our goal over the past few weeks to examine a patch of our planet's lung and observe the details of gas exchange between the ocean and atmosphere, to better understand how our planet "breathes." Ultimately, we would like to accurately predict when, where, and how much CO_2 (or DMS) passes through the ocean surface, since this information is critical to understanding how the climate system functions and to predicting how it may change in the future. But gas exchange is controlled or influenced by numerous physical processes like wind stress, ocean currents, temperature and, in the case of CO_2 and DMS, by biological activity in the surface ocean, which itself is modulated by nutrients, seasonal cycles, sunlight, ocean currents, population dynamics, etc. Unraveling the mystery is more than any one of us can hope to achieve alone or more than any one group of scientists can achieve in a single study, but it keeps us focused to have the big picture in mind as we labor in the trenches of our sub-disciplines.

So close and yet so far…
Christopher Sabine

Wednesday, April , 9, 12:17 PM

We finished our last CTD cast on Friday and started the 1300-mi trek to Montevideo, Uruguay where we will unload the ship and head our separate ways. For those of us used to traveling at the speed of a car or plane, the transit home can literally feel like the "slow boat to China." When we first left station the ship was making a blazing 12.5 nautical miles per hour (or knots for you sailors). We had high hope of getting into port before our 9 AM Thursday schedule, but that all changed on Sunday night.

We had spent the last two weeks before leaving the study site desperately hoping for high winds and rough seas; something… anything to finish off GasEx III with flair. But it was not to be. We had decent 15-20 knots winds but not the big storm we had all dreamed about as we were writing our proposals. Despite that, we were reasonably satisfied and looking forward to a relatively quick trip home.

Sunday night, however, we drove into that perfect storm and just the kind of conditions we had been hoping for back at the study site. First the wind kicked up to 40 knots then 50 knots. Initially the seas were calm and the wind was just blowing the tops off of the small ocean swells we had been plowing through with ease. Over time, however, the sea started building and the 1000 mi of open ocean between us and Montevideo seemed to grow wider and more angry. With the ship's vent problems we were forced to slow our progress so we did not get too many bubbles into the ship's

The CTD on the deck of the *Ron Brown* against a backdrop of whitecap covered ocean, a sight rarely seen at the study site.

cooling water systems. By late Sunday night the 12 knots had turned into one knot and our hopes of getting in early were whisked away on the wind.

Monday we ranged from essentially no speed over ground to as much as four knots for a couple of hours. Winds were 30-40 knots and the seas were 15-20 ft with the occasional 30 footer just to test that everything was tied down properly. Our hopes of getting in early had changed to hopes of getting in on time but even those looked doubtful as night fell with very little progress towards shore.

Tuesday brought a new promise as we were making 3.5 knots when I woke up. **It didn't really hit me how sad that was until I found myself on the treadmill running twice as fast as the ship.** On Tuesday the winds were a little better, 20-30 knots but it was still impressive to sit in the staging bay looking out over the fantail and watch the waves break over the side and stern of this ship. At least the atmospheric flux guys are getting some measurements out of this. Most of us have completed all the packing we can do for now and are desperately trying to think of ways to entertain ourselves. It is difficult to focus on anything when the whole world is tossing and turning. At least we all have our sea legs so seasickness is not too much of a problem.

Now it is Wednesday. The winds have dropped a little more and the seas are starting to calm as well. We still have a little less than 500 miles to go, but we are hopeful that we are through the worst of it and conditions will only improve from here. I suppose only time will tell.

P.P.S
David Ho

Saturday, April 12,
3:54 PM

Well, it finally happened. We were supposed to get in at 2 AM, then it was changed to 4 AM, then to 8 AM, then to 11 AM, and we finally docked at 12.01 PM. It was a fitting end to the cruise in two ways: The first is just the unpredictability of everything, and the second is that Herb won the pool predicting when we would get in. Herb and Richard from the galley fed us really well the entire cruise, and being a vegetarian, it was certainly the best cruise I've ever been on in terms of the food selection.

The agent in Montevideo was great, and had all the containers waiting for us. With everyone helping unload the ship and load the containers, everything going back to the U.S. via ocean freight was unloaded in less than four hrs. The air freight will go out on Monday.

The entire SO GasEx scientific party on the fantail, taken on the last day before arriving in Montevideo. The weather was completely unrepresentative of what we experienced during our trip, and a welcomed relief to everyone.

Now it's time for everyone from the scientific party to…well… party. We will meet up soon for drinks and food before disbanding and returning to our respective homes. ■

NASA Supports UNESCO Kickoff for International Year of Planet Earth

Winnie Humberson, NASA Goddard Space Flight Center, Winnie.H.Humberson@nasa.gov

Introduction

On February 12-17, 2008, **Winnie Humberson** and **Steve Graham** from NASA's Earth Observing System Project Science/Science Mission Directorate Support Office (EOSPSO) attended a United Nations Educational, Scientific and Cultural Organization (UNESCO) Interdisciplinary Exhibition in Paris, France to recognize the start of the International Year of Planet Earth (IYPE) 2008.

IYPE aims to ensure greater and more effective use by society of the knowledge accumulated by the world's 400,000 Earth scientists. The Year's ultimate goal of helping to build safer, healthier, and wealthier societies around the globe is expressed in the Year's subtitle *Earth Science for Society*. IYPE aims to capture people's imagination with the exciting knowledge we possess about our planet, and to see that knowledge used to make the Earth a safer, healthier, and wealthier place for our children and grandchildren—for more details on IYPE please see sidebar on page 21.

More than 2000 participants from the international community involved in Earth science disciplines, mineral resource management, and energy management participated in the IYPE kickoff event. The event also drew over 850 international delegates and 11 government ministers.

During their visit to France, the EOSPSO representatives:

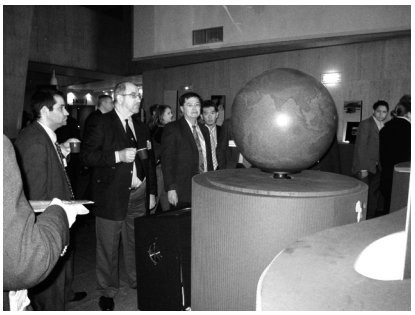
- Staffed an exhibit during the IYPE kickoff event held at UNESCO headquarters in Paris on February 12-13;
- coordinated a NASA E-theater presentation at the IYPE kickoff event;
- explored opportunities to use *Magic Planet* at local museums in Paris; and
- explored future collaboration between NASA and UNESCO.

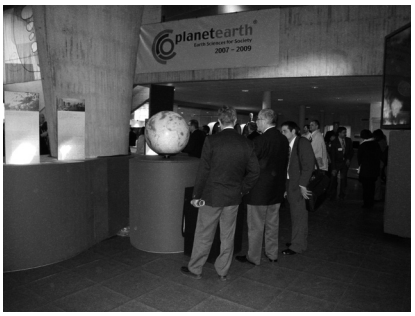
Magic Planet

NASA's *Magic Planet* displays global datasets from NASA's satellites on a spherical surface (see photos) and is guided by input from an interactive touch screen. A *Magic Planet* was the centerpiece of the exhibit during the IYPE kickoff, and UNESCO representatives also configured a *Magic Planet* for use in a three-day public event that took place immediately after the IYPE kickoff.

E-Theater Presentation

Marc Imhoff [NASA Goddard Space Flight Center—*Terra Project Scientist*] presented a one-hour E-theater presentation that was very popular and well-received. Many who saw Imhoff's talk commented that it was the best presentation given during the entire event.





Visitors of all ages enjoyed interacting with NASA's *Magic Planet* display during the UNESCO IYPE kickoff in Paris.

Marc Imhoff (right) from NASA's Goddard Space Flight Center is interviewed by Dan Molina (left) of NASA TV.

The Grand Palais (Grand Palace), Paris, France. **Photo courtesy:** Wikimedia Commons.

The Palais de la découverte (Museum of Science Discovery), Paris, France. **Photo courtesy:** MyParisNet.com

Exploring Partnerships with Museums

On February 14, Humberson, Graham, and Imhoff were invited to visit the Palais de la découverte (Museum of Science Discovery) in Paris. The Palais de la découverte was opened in 1937 in the Grand Palais (Grand Palace) exhibition hall that was built for the Paris Exhibition of 1900. The building is now undergoing renovation and looking for new themes and content.

The team met with museum director **Guy Simonin** and his team to further discuss the possibility of a long-term partnership to develop a multi-language version of *Magic Planet* to display in his museum. The museum already owns two *Magic Planet* systems, and they would like NASA to provide content. The museum would recognize NASA as the primary source for the content that is shown on their display. Subsequent to our visit, the Office of External Relations at NASA HQ approved an agreement with Palais de la découverte to translate the Magic Planet content into French, Spanish and other languages. NASA will then have permission to use the translated versions for educational purposes at no cost to NASA.

On February 15, the group met with the designer for the City of Science Museum in Paris. The museum would like to include *Magic Planet* as part of an eight-month IYPE exhibition. We will work with NASA HQ to see if we can get approval to pursue a loan agreement with the City of Science Museum.

Exploring Possible Future NASA Collaboration with UNESCO

Humberson also met **Walter Erdelen** [UNESCO—*Assistant Director-General for Natural Science*] who expressed interest in further collaboration between NASA and UNESCO during the upcoming International Astronomy Year (IAY) 2009 and for other events in the future. The UNESCO coordinator for IAY will be visiting the U.S. in July and this may provide an opportunity for further discussions about possible NASA involvement in an IAY exhibition.

As a result of the meeting with UNESCO representatives, Imhoff, Humberson, Graham and Mark Malanoski were invited to a reception in honor of the U.S. Commissioners to UNESCO, Sunday, May 18, at Blair House in Washington, DC. The reception was made possible by the President's Committee for the Arts and Humanities.

Conclusion

Overall, the trip to Paris was time well spent. The team made many valuable contacts that could help NASA broaden its international outreach—and Earth science in particular. The next step will be to follow up on these discussions and implement some of the ideas. The U.S. State Department and UNESCO have both been encouraging NASA to pursue these ideas and wish to thank **Jack Kaye** [NASA HQ—*Associate Director for Research, Earth Science Division*] and **Michael King** [NASA Goddard Space Flight Center—*former EOS Senior Project Scientist*] for their support. ■

What is the International Year of Planet Earth?[1]

The International Year of Planet Earth (IYPE) is a 2008 international observance, declared by the 60th United Nations General Assembly. IYPE's activities will actually span three years from 2007-2009.

IYPE aims to raise $20 million from industry and governments and will spend half on co-funding research, and half on "outreach" activities. It will be the biggest international effort ever to promote the Earth sciences.

Apart from researchers, who are expected to benefit under the IYPE's Science Program, the principal target groups for the Year's broader messages are:

- **Decision makers and politicians**, who need to be better informed about the how Earth scientific knowledge can be used for sustainable development.
- **The voting public**, who needs to know how Earth scientific knowledge can contribute to a better society.
- **Geoscientists**, who are very knowledgeable about various aspects of the Earth but who need help in using their knowledge for the benefit of the world's population.

The IYPE research themes, set out in 10 science prospectuses were chosen for their societal relevance, multidisciplinary nature, and outreach potential. IYPE has 12 Founding Partners and 23 Associate Partners and is backed politically by 97 countries representing 87% of the world's population.

IYPE is open to Expressions of Interest from researchers within each of its 10 themes. The IYPE Outreach Program is also now open to expressions of interest, and will work in a similar way by receiving and responding to bids for support from individuals and organizations worldwide.

Eduardo F J de Mulder [former President of the International Union of Geological Sciences (IUGS)] is Project Leader for IYPE. **Edward Derbyshire** [Royal Holloway] chairs the IYPE Science Committee and **Ted Nield** [Geological Survey of London] chairs the IYPE Outreach Committee.

The International Year of Planet Earth project was initiated jointly by the IUGS and the United Nations Educational, Scientific and Cultural Organization (UNESCO). "By a draft on the International Year of Planet Earth, 2008, which the Committee approved without a vote on 11 November, the Assembly would declare 2008 the Year of Planet Earth. It would also designate UNESCO to organize activities to be undertaken during the International Year of Planet Earth, in collaboration with the United Nations Environmental Program (UNEP) and other relevant United Nations bodies, the IUGS, and other Earth sciences societies and groups throughout the world. Also by the above draft, the Assembly encouraged Member States, the United Nations system and other actors to use the Year to increase awareness of the importance of Earth sciences in achieving sustainable development and promoting local, national, regional and international action."

[1] This information is adapted from: *en.wikipedia.org/wiki/International_Year_of_Planet_Earth*. The reader is referred here for more details on the International Year of Planet Earth. Also see the IYPE website—*www.yearofplanetearth.org/*—for more details.

feature articles

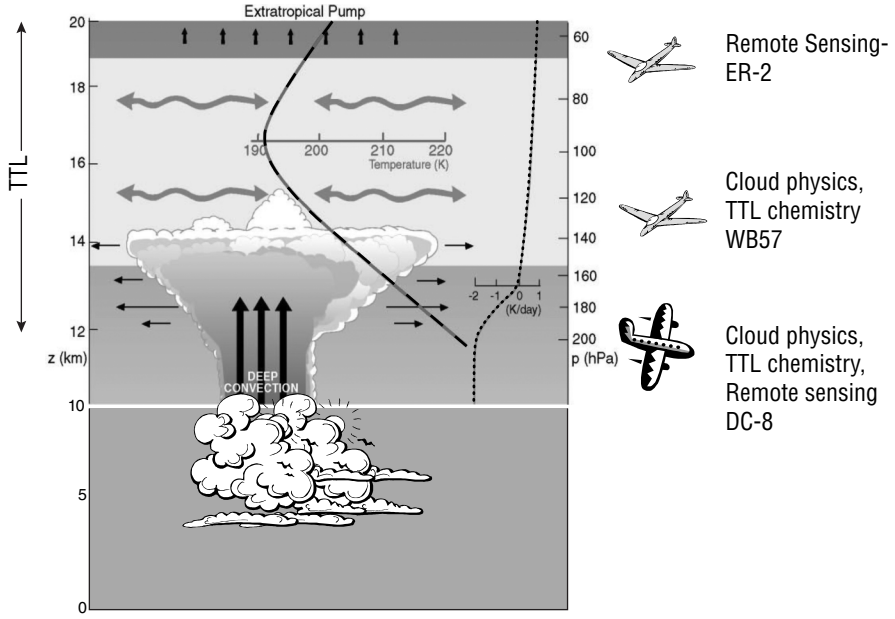
Probing the Mysteries of the Tropopause Transition Layer: The TC4 Experiment

David O'C. Starr, NASA Goddard Space Flight Center, David.Starr@nasa.gov

Introduction to the TTL and TC4

The *tropical tropopause transition layer* (TTL) is the name given to the portion of Earth's atmosphere that extends from about 12 km altitude to the tropical *tropopause*—the coldest point in the lower atmosphere just below the tropical stratosphere—which is located somewhere between 16-17 km altitude. The chemical and physical processes at work in the TTL play important roles in regulating Earth's climate and atmospheric chemistry. For example, scientists know that changes in water vapor in the upper tropsphere and stratosphere can play an important role in modulating the climate since water is the most powerful greenhouse gas in the atmosphere. The TTL is an important reservoir for moisture lofted by tropical convection. Understanding how water behaves in the TTL is one key to better understanding the greenhouse effect, and global climate change.

Sampling Strategy-Costa Rica



A schematic of the tropical atmosphere. The dashed curve denotes a typical temperature profile, whose minimum near 16 km is the tropical tropopause. The dotted curve is a typical radiative heating profile, which switches from cooling to heating near 13 km. The solid black arrows mark the rapid ascent which occurs in cumulus towers. The horizontal shaded areas mark horizontal transport, which carries air away from the central convection. Three aircraft, the ER2, WB57 and DC8 were used during TC4.

The TTL also is the gateway to the stratosphere. Slow gentle upward motions within the TTL are believed to loft materials across the tropical tropopause. As the air slowly moves upward it passes through a layer with extremely cold temperatures and loses most of its moisture—it is *dehydrated*. There are also faster mechanisms to transport air from the TTL to the lower stratosphere. Deep convection from intense thunderstorms in the tropics penetrates the TTL and sometimes reaches the lower stratosphere. Because frozen cloud particles are deposited directly into the lower stratosphere where they evaporate, the injected air is not nearly as dry as in the case of gentle ascent. These *slow* and *fast* transport processes also affect many other chemicals that may be entering the stratosphere where they may ultimately affect ozone chemistry—i.e., air that has resided in the TTL for an extended time, and hence is modified, versus air that has recently arrived from the lower troposphere near the surface. The chemical composition of the air entering the stratosphere depends on the proportion of *fast* and *slow* processes which is largely unknown. Processes that occur in the cirrus clouds that inhabit this region of the atmosphere may also significantly affect the chemistry. Hence, the chemistry of the stratosphere may be affected in a significant way by processes that take place in the TTL—i.e., by anything that alters the transport across the TTL and by the chemicals in the TTL.

In spite of these crucial connections to climate, the TTL remains one of the most mysterious regions of the atmosphere. The region has not been studied in detail and there's still a great deal that scientists need to learn about the processes at work in the TTL. To that end, in the Summer of 2007, over 350 people from the U.S.—representing NASA, NOAA, the National Center for Atmospheric Research (NCAR), and various universities—Costa Rica, and Panama gathered together to take part in the Tropical Composition, Cloud and Climate Coupling (TC4) campaign based out of San Jose, Costa Rica. One of the main objectives of this experiment was to conduct a comprehensive study of the TTL using coordinated satellite, aircraft, and ground-based observations.

One of the main objectives of this experiment was to conduct a comprehensive study of the TTL using coordinated satellite, aircraft, and ground-based observations.

The key TC4 science questions included:

1. How can space-based measurements of geophysical parameters, particularly those known to possess strong variations on small spatial scales (e.g., H_2O, cirrus), be validated in a meaningful fashion?
2. How do convective intensity and aerosol properties affect cirrus anvil properties?
3. How do cirrus anvils, and tropical cirrus in general, evolve over their life cycle? How do they impact the radiation budget and ultimately the circulation?
4. What controls the formation and distribution of thin cirrus in the TTL, and what is the influence of thin cirrus on radiative heating and cooling rates, and on vertical transport?
5. What are the physical mechanisms that control (and cause) long-term changes in the humidity of the upper troposphere in the tropics and subtropics?
6. What are the source regions, identities, concentrations and chemical fates of short-lived compounds transported from the tropical boundary layer into the TTL. (i.e., what is the chemical boundary condition for the stratosphere?)
7. What are the mechanisms that control ozone within and below the TTL?
8. What mechanisms maintain the humidity of the stratosphere? What are the relative roles of large-scale transport and convective transport and how are these processes coupled?

Aircraft Measurements

In order to carry out this field campaign, NASA and the other agencies had to select some aircraft to use, and they did not have a vast array of choices. Only a handful of research aircraft are able to reach the TTL.

In order to carry out this field campaign, NASA and the other agencies had to select some aircraft to use, and they did not have a vast array of choices. Only a handful of research aircraft are able to reach the TTL. The following aircraft were chosen:

NASA's high-altitude (20 km) ER-2 aircraft served as an A-Train satellite simulator platform capable of sampling when and where needed. The ER-2 was outfitted with 11 instruments including: the Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS [MASTER]); the Scanning High-resolution Interferometer Sounder (S-HIS), which simulates the Advanced Infrared Sounder (AIRS) on Aqua and Tropospheric Emission Spectrometer (TES) on Aura; the Cloud Radar System (CRS), which simulates the Cloud Profiling Radar on CloudSat; the Cloud Physics Lidar (CPL), which simulates the Cloud Aerosol Lidar with Orthogonal Projection (CALIOP) on the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO); the Compact Scanning Submillimeter-wave Imaging Radiometer (CoSSIR); the Advanced Microwave Precipitation Radiometer (AMPR); ER-2 Doppler Radar (EDOP); Solar Spectral Flux Radiometer (SSFR); the Video Camera (MVIS); and an IR Radiometer—see the section at the end of this article for a description of some of the instruments.

The ER-2 departs Juan Santamaria International Airport to conduct a science flight.

NASA's WB-57 aircraft[1] was also deployed for TC4 and served as an *in-situ* sampling platform—meaning that it samples the air in its natural or original environment. The instruments deployed on the WB-57 collected cloud and aerosol particle measurements and a wealth of gas measurements from its 27 instruments, both inside clouds as well as in clear air at altitudes from 13-17 km. Most of the measurements were made in TTL but occasionally they extended into the lower stratosphere.

The WB-57 on the ramp.

NASA's DC-8 *Flying Laboratory* was also used, and carried a complement of 26 instruments including upward and downward pointing lidars (for measuring ozone, water vapor and aerosols) and radiometers as well as instruments for *in-situ* measurements of gases, and cloud and aerosol particles. The DC-8 was key for validating measurements from the Aura satellite taken during TC4 as it was able to underfly the afternoon Aura overpass.[2] The DC-8 operated mostly below 13 km, and usually collected some data in the tropical boundary layer at altitudes less than 2 km during most missions.

The DC-8 lands in Costa Rica in early afternoon, just as the daily rains start.

Typical flight missions flown during TC4 focused on cloud observations in the morning using multiple aircraft, with the DC-8 subsequently taking additional measurements more focused on chemistry issues and Aura validation in the early afternoon. For example, the mission on August 8 included: cloud profiles in cirrus *anvils* formed from deep convection rooted in a layer containing Saharan dust at lower levels; chemistry profiles of the TTL to obtain chemical tracers upwind of convection, and chemical samples at low altitudes within the marine boundary layer and over the dense tropical jungles where the former provide inflow, the "fuel", to the observed deep convective clouds. Missions were also flown to sample the chemical and aerosol input to the deep convective clouds and to sample volcanic plumes over South America. A total of 26 science flights were flown over the 23 days of TC4. The majority of these flights included highly coordinated observations with two or more aircraft. For details on flight plans and/or flight reports please visit: *www.espo.nasa.gov/tc4/flightDocs.php*. The schematic on page 22 graphically illustrates where each aircraft was used during TC4.

A total of 26 science flights were flown over the 23 days of TC4. The majority of these flights included highly coordinated observations with two or more aircraft.

Satellite Measurements

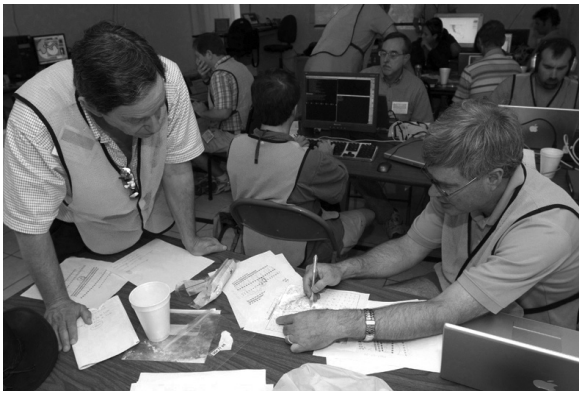
Satellites have opened a new window for observing the TTL. In particular, A-Train satellite observations [i.e., Aura, Aqua, CloudSat, and CALIPSO] and other satellite observations [e.g., Terra and the Tropical Rainfall Measuring Mission (TRMM)] provide crucial information on the characteristics of this region. From their vantage point in orbit they can easily observe the TTL, but their "vision" can often be obscured by high clouds in the layer, and also because it has less mass than the underlying regions of the atmosphere. Many of the clouds in the TTL are so thin that they cannot be seen with the naked eye and so they are called *sub-visible cirrus*. These clouds are thought to form *in situ*, within the local environment of the TTL.

[1] Due to a pre-mission mechanical malfunction of the aircraft, the WB-57 did not join the experiment until the final week during which operations were consequently very intensive.
[2] The higher-flying and more fragile ER-2 and WB-57 aircraft landed around noon on most days to avoid the reliable afternoon thunderstorms around the Juan Santamaria International Airport.

Other cirrus clouds in the TTL form from the *anvils*—the flattened tops—of tropical cumulus clouds. These clouds pump vast quantities of air from near the tropical surface to the TTL in a matter of minutes, and spill the air out into their anvils. In addition to clouds, the transport of various trace gases, such as ozone, into the TTL, and their subsequent evolution there, play an important role in determining what gases are carried into the stratosphere and upper troposphere globally. Carefully planned TC4 aircraft observations were required, both to validate satellite data in this poorly known region and to provide critical observations not available from the satellites, such as

Satellites have opened a new window for observing the TTL. In particular, A-Train and other satellite observations provide crucial information on the characteristics of this region.

The ER-2 crew and AMPR team members reinstall the AMPR instrument in its hatch. (Clockwise from forklift: Kevin Kraft, Mike Kapitzke, Wayne Deats, Mark James, and Pat Lloyd).



Mission Scientists Dave Starr and Brian Toon discuss an upcoming flight in the operations center. TC4 forecasters, modelers, and platform scientists are in the background.

Mike Freilich, NASA HQ Earth Science Director, expresses his appreciation at the Ambassador's residence event (Ambassador Langdale in the background).

During President Sanchez's visit to the DC-8, Ed Browell had the opportunity to tell him, the U.S. Ambassador to Costa Rica, Mark Langdale (back left), and Rick Shetter [University of North Dakota, DC 8 Program Manager] (back right) about Langley's work.
Credit: John Hair

ER-2 Platform Scientist, Paul Newman, watches final preparation for an ER-2 science flight.

A unique aspect of TC4 was the use of a Google Earth application developed at NASA Marshall Space Flight Center to direct the aircraft in real time via satellite phone-internet connections.

details of the ice cloud microphysical composition and measurements of various chemical tracer species, both short- and long-lived in complex cloud environments.

Ground-Based Measurements

In addition to aircraft and satellite observations during TC4, as with any field campaigns, ground-based observations played a vitally important role. Ground-based observations are sometimes used to verify the measurements obtained by aircraft and satellites but they also provide *unique* information that aircraft and satellites may miss. Sometimes an observer on the ground can discover details that a remote observer, no matter how sophisticated, simply cannot see. (Think of them in an analogous role as a field reporter reporting live from the scene to a news anchor in the studio—i.e., the remote reporter can fill in details live on the scene that the studio anchor may or may not be able to see.)

NASA's Polarization (NPOL) radar collected data and provided real-time weather information for the research flights over the Panama Bight. The University of Oklahoma's Shared Mobile Atmospheric Research and Training (SMART) radar provided information on the local weather in San Jose making possible safe landings in a challenging convective environment. Penn State University's Nittany Atmospheric Trailer and Integrated Validation Experiment (NATIVE) also collected data from Las Tablas, Panama. These data can be used to chemically characterize the marine boundary layer that is being lofted in deep convection. For more details on ground-based observations during TC4 including photos, please visit: *www.espo.nasa.gov/tc4/inst_grnd.php.*

Conclusion

Overall, the TC4 mission was a great success despite a number of logistical challenges, including recovery from a lightning strike on the DC-8, fuel issues for the ER-2, and the pre-mission WB-57 malfunction. The pilots, air crews, ground crews and support staff performed admirably under difficult circumstances to ensure mission success. The science findings spanning a diverse set of questions are much anticipated.

A unique aspect of TC4 was the use of a *Google Earth* application developed at NASA Marshall Space Flight Center to direct the aircraft in real time via satellite phone-internet connections. The Real-Time Mission Monitor (RTMM) application was used to display current GOES satellite imagery, often at special very high temporal resolution, NPOL radar scans in real time, and current lightning data from 3 separate networks along with current location of each aircraft including altitude. NASA Langley staff also provided crucial high resolution satellite imagery support, including navigation analysis and interpretation for directing the aircraft *www-angler.larc.nasa.gov/tc4/*. Much more detail on the TC4 campaign can be found at the mission website: *www.espo.nasa.gov/tc4/*.

This section gives a short description of 4 of the 11 instruments that flew on the ER-2 during the TC4 campaign.

S-HIS

The Scanning High-resolution Interferometer Sounder (S-HIS) simulates the Advanced Infrared Sounder (AIRS) on Aqua and Tropospheric Emission Spectrometer (TES) on Aura. It is a scanning interferometer which measures emitted thermal radiation at high spectral resolution between 3.3 and 18 μm. The measured emitted radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere. S-HIS produces sounding data with 2-km resolution (at nadir) across a 40-km ground swath from a nominal altitude of 20 km onboard a NASA ER-2 aircraft, or 20-km ground swath from a nominal altitude of 10 km aboard the NASA DC-8 aircraft.

NASA's high altitude (20 km) ER-2 aircraft served as an A-Train satellite simulator capable of sampling when and where needed.

CPL

The Cloud Physics Lidar simulates the Cloud Aerosol Lidar with Orthogonal Projection (CALIOP) on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). It is an airborne lidar system designed specifically for studying clouds and aerosols using the ER-2 High Altitude Aircraft. Because the ER-2 typically flies at 65,000 ft (20 km), its instruments are above 94% of the Earth's atmosphere, thereby allowing ER-2 instruments to function as spaceborne instrument simulators. The Cloud Physics Lidar provides a unique tool for atmospheric profiling and is sufficiently small and low cost to include in multiple instrument missions.

The Cloud Physics Lidar flies on the ER-2 along with other instruments and is typically located in the forward section of the left wing superpod. A window in the bottom of the superpod allows the instrument to look directly at nadir (this is a non-scanning system).

The Cloud Physics Lidar provides a complete battery of cloud physics information. The CPL provides information to permit a comprehensive analysis of radiative and optical properties of optically thin clouds and aerosol layers.

CRS

The Cloud Radar System (CRS) simulates the Cloud Profiling Radar on CloudSat. It is a 94 GHz (W-band; 3 mm wavelength) Doppler radar developed for autonomous operation in the NASA ER-2 high-altitude aircraft and for ground-based operation. It provides high-resolution profiles of reflectivity, linear depolarization, and Doppler velocity in clouds and has important applications to atmospheric remote sensing studies. The CRS was designed to fly with the Cloud Physics Lidar (CPL) in the tail cone of an ER-2 superpod.

CoSSIR

The Compact Scanning Submillimeter-wave Imaging Radiometer (CoSSIR) can be used to measure ice clouds, water vapor, snowfall, and the snow cover on the ground. CoSSIR is mainly used for the measurements of the vertically-integrated ice water path above the middle troposphere and mass-weighted mean ice particle size ice clouds, key atmospheric parameters that are solely needed for input to the modeling of the Earth's water and energy cycles. The measurements from the channels around the two water vapor lines of 183.3 and 380 GHz enhance the water vapor profiling capability that was not available from previous microwave sensors such as airborne Millimeter-wave Imaging Radiometer (MIR) or Advanced Microwave Sounding Unit B (AMSU-B).

MASTER

MODIS Airborne Simulator (MAS) and MODIS/ASTER Simulator (MASTER) are high spatial resolution imaging spectrometers that flew on the NASA ER-2 during TC4. MAS was used in the early part of the campaign until a scan head problem required it to be replaced with its sister instrument MASTER. Both instruments have the spectral coverage to allow for cloud retrievals using algorithms similar to those that produce the operational MODIS cloud products. For the TC4 campaign, the existing MAS/MASTER retrieval code was updated to use the latest Collection 5 MODIS algorithm, though there are significant differences in some spectral regions. The emphasis in TC4 was on retrieval of cirrus and deep convection ice cloud properties, and well as maritime stratiform clouds. For more information on MAS/MASTER and its use in the TC4 campaign, visit *mas.arc.nasa.gov/data/deploy_html/tc4_home.html* ■

feature articles

Saharan Dust Versus Atlantic Hurricanes

Jane Beitler, National Snow and Ice Data Center, jbeitler@nsidc.org

June 1 marks the beginning of the 2008 Atlantic hurricane season. Once again forecasts are calling for a more active season. The last few years have seen an upswing in hurricane activity, but the past couple of seasons have been quite a bit less active than what was forecasted. ***The Earth Observer*** *has obtained permission to reprint the following article that originally ran in the 2007 DAAC Annual Report—nasadaacs.eos.nasa.gov/articles/2007/2007_hurricanes.html. The article suggests that a layer of desert dust that originates over the Saharan Desert in north Africa may play a role in reducing tropical cyclone activity in the Atlantic and also describes a research field campaign that was organized to study this possible link between dust and hurricanes.*

Researchers think these dry, dusty air layers from Africa may be a key to understanding why Atlantic atmospheric disturbances, called tropical waves, sometimes intensify into hurricanes, and sometimes fizzle.

On a typically hot and humid August day, researcher **Jason Dunion** saw something unusual in the sky over Miami. Dunion said, "It was really humid. It felt like a wet towel outside. But just above us, at 5,000 feet, it was super, super dry. No clouds were forming." Dunion photographed a layer of dry, dusty air over Miami that had journeyed from the Saharan Desert in northern Africa, some 4,000 miles across the Atlantic. Researchers think these dry, dusty air layers from Africa may be a key to understanding why Atlantic atmospheric disturbances, called tropical waves, sometimes intensify into hurricanes, and sometimes fizzle.

Dunion is one of many researchers who want a clearer picture of the genesis and growth of Atlantic tropical storms and hurricanes. Computer storm modeler **Cerese Albers**, at Florida State University, wants to understand why storms intensify. She said, "We are looking for warning signs about which waves have the potential to form serious storms. If we could understand the lifecycle of the disturbance waves, models could better simulate a storm's potential for intensity and growth over the following few days." This knowledge could mean better and faster warnings to coastal residents.

Life Cycle of a Hurricane

Scientists have long understood that convective waves of westward-traveling atmospheric disturbances from the north African coast can be the beginnings of tropical

NASA and the National Oceanic and Atmospheric Administration (NOAA) teamed up to track the dusty Saharan Air Layer across the Atlantic during the 2006 hurricane season. In this photo, small cumulus clouds poke through the tops of the dust layer. A NASA DC-8 aircraft flown out of Cape Verde, Africa, started tracking this dust on September 13, 2006; on September 18, a NOAA P-3 *Orion* aircraft picked up its trail and captured this photo. **Photo courtesy:** Jason Dunion.

Susan Kool monitors data from the Lidar Atmospheric Sensing Experiment (LASE) instrument on board a NASA DC-8 aircraft flying through a Saharan dust storm over the Atlantic. Researchers hope to use these data to track interactions between the dust and tropical storms and to better understand Atlantic hurricane development. **Photo courtesy:** NAMMA team.

storms and hurricanes. Dunion said, "In the Atlantic, more than half of tropical storms and weak hurricanes, and 85% of major hurricanes—categories three, four, and five—come from Africa." Scientists also know that a number of factors, including sea-surface temperatures, unstable atmosphere, and high water-vapor levels, can cause the waves to intensify and form storms.

Albers and Dunion are among more than one hundred researchers who participated in the NASA African Monsoon Multidisciplinary Analyses (NAMMA) campaign, a joint effort between NASA and the National Oceanic and Atmospheric Administration (NOAA), during the Atlantic hurricane season of 2006. **Syed Ismail**, a scientist at NASA Langley Research Center, said, "The objective of NAMMA was to see what role the Saharan dust aerosols play in the development of tropical disturbances, which could eventually become hurricanes in the Atlantic. The disturbances propagate from the coast of north Africa, and they get energized in the warm Atlantic climate. And then they sometimes develop into hurricanes." The researchers suspected that Saharan dust storms sometimes prevent disturbance waves from intensifying into tropical storms and then hurricanes.

"We think a dust storm has three main components that can suppress a hurricane: super-dry air; vertical wind shear; and the dust itself."

Saharan dust keenly interests Dunion, a research meteorologist from the NOAA Hurricane Research Division in Miami. He said, "The Saharan Air Layer is essentially a huge dust storm that can be the size of the continental United States. Every three to five days during the summertime, these storms roll off of the African coast." As the dust storms move off northern Africa, convective waves develop farther to the south, pulling moisture up into the atmosphere.

"We think a dust storm has three main components that can suppress a hurricane," Dunion continued. "One, it's got super-dry air. Hurricanes don't like dry air in the middle parts of the atmosphere, and that's exactly what the Saharan Air Layer has. A Saharan dust storm also has a very strong surge of air embedded within it, called the *midlevel easterly jet*, that can rip a storm apart that's trying to develop. We call that vertical wind shear. And then the third piece is all this dust."

Researchers think **the dust itself suppresses cloud formation**, playing a role in preventing tropical waves from becoming more intense. Ismail said, "We think that dust aerosols can affect tropical disturbances, sometimes even kill those disturbances. Dust inhibits convection, the process of moisture rising to the higher levels of the atmosphere, and then precipitating as rain. So these Saharan dust layers seem to have a blanketing influence on the development of convection."

"When one of these waves moves out over the ocean, you have very little data unless you have a special experiment like NAMMA. You see the wave when it passes Dakar as it leaves west Africa, you get a few measurements as it passes over the Cape Verde islands, and then there's a complete data void until you get to the Lesser Antilles. That's one reason we've never been able to understand what's going on with these waves between Africa and the Caribbean."

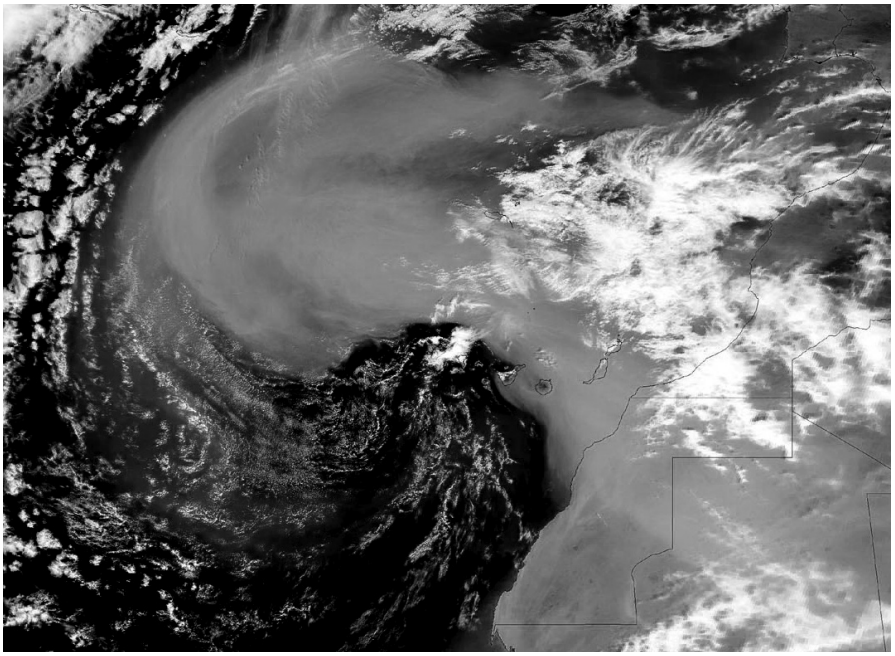
Measuring Saharan Dust

The NAMMA team planned to gather information that they lacked on the desert dust and tropical wave interactions. Tropical researcher **Robert Ross**, also at Florida State University, said, "When one of these waves moves out over the ocean, you have very little data unless you have a special experiment like NAMMA. You see the wave when it passes Dakar as it leaves west Africa, you get a few measurements as it passes over the Cape Verde islands, and then there's a complete data void until you get to the Lesser Antilles. That's one reason we've never been able to understand what's going on with these waves between Africa and the Caribbean."

Researchers have sought several solutions to this lack of data. They hope someday to use satellite data to continuously track the Saharan Air Layer's dry air and suspended dust over the Atlantic, but current satellites that possess that technology pass over any given location only occasionally, so they may miss the interaction between the dust storms and developing tropical cyclones. NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), launched in April 2006, promises to supply the needed data. Researchers are still calibrating CALIPSO by comparing the satellite data to ground and aircraft-based measurements.

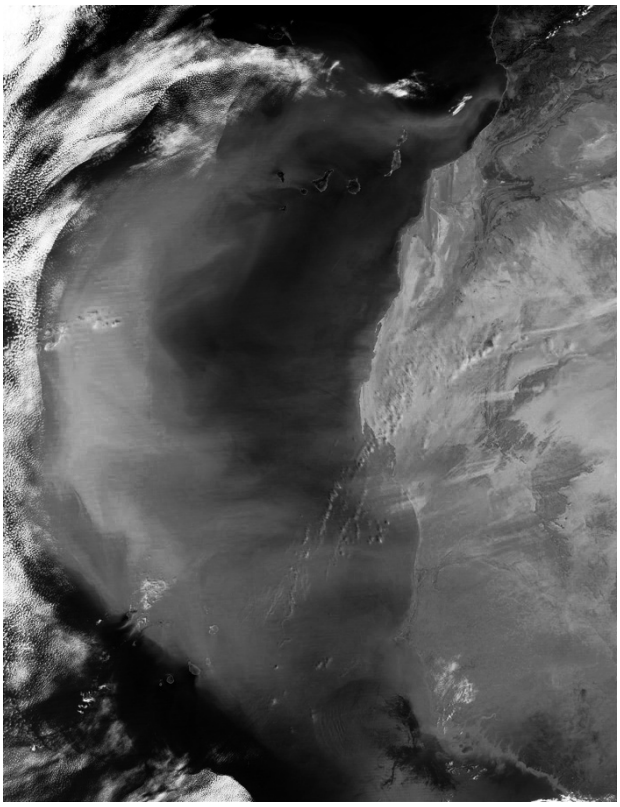
Dunion said, "We were trying to use satellite data to watch how a tropical wave might get embedded in one of these Saharan dust storms. It can really get beat up, it can really get suppressed." Aircraft measurements helped the researchers understand what the new satellite was saying. "We've been flying the NOAA P-3 and G-IV *Hurricane Hunter* aircraft out of Barbados to look at these interactions, and now that we have these new satellite eyes to track the dust storms, we can use that information to better target our aircraft flight tracks," Dunion said. *Hurricane Hunters* fly into storms over the western Atlantic to drop instruments, called Global Positioning System (GPS) *dropsondes*, through the air layers, then relay meteorological measurements and storm positions to forecasters and researchers. To get the complete picture of storm development, they needed similar data from the eastern Atlantic.

To fill the data void over the eastern Atlantic, researchers turned to the Lidar Atmospheric Sensing Experiment (LASE) instrument. LASE, a relatively new instrument developed by NASA, senses aerosols and water vapor using lasers and can be flown on a DC-8 aircraft right into a study area. NASA planned to fly the instrument from



This NASA satellite image shows a dust storm, hundreds of thousands of square miles in size, moving from the Saharan Air Layer over Africa into the eastern Atlantic Ocean. The image was captured by the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) instrument on February 26, 2000. **Image credit:** SeaWiFS/Ocean Color Team.

Africa into developing dust storms and tropical disturbances during the 2006 hurricane season, while the NOAA team would pick up the storm over the central and western Atlantic. Dunion said, "NASA was flying their DC-8 with LASE out of Cape Verde while we flew the NOAA P-3 and G-IV *Hurricane Hunter* planes out of Barbados. They would start tracking a dust storm way out east, then a couple of days later we would pick it up as it came into range of Barbados."



The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, aboard NASA's Terra and Aqua satellites, captured this image of a Saharan Air Layer outbreak moving off of Africa into the North Atlantic on March 2, 2003. **Image credit:** NASA MODIS Rapid Response Team.

LASE also provided an essential piece of data that the Hurricane Hunters could not. Dunion said, "While the GPS dropsonde can measure all sorts of things—pressure, temperature, humidity, wind—it can't measure dust. So that's a piece of the puzzle we can't quite get. The LASE is a great tool to fill that gap. It can measure the super dry air in the Saharan Air Layer, and also look at where dust is situated in the vertical profile. It fills in some of the blanks that we haven't been able to address with our flights over the last couple of years."

"While the GPS dropsonde can measure all sorts of things—pressure, temperature, humidity, wind—it can't measure dust. So that's a piece of the puzzle we can't quite get. The LASE is a great tool to fill that gap. It can measure the super dry air in the Saharan Air Layer, and also look at where dust is situated in the vertical profile. It fills in some of the blanks that we haven't been able to address with our flights over the last couple of years."

The 2006 Atlantic Hurricane Season

In August 2006, as the hurricane season began, researchers assembled in Cape Verde, Africa, to monitor conditions. As a wave began to develop, the team flew the DC-8 and its LASE instrument into it to capture data. Ismail and the data team retrieved the aerosol and water vapor data from LASE and made it available to researchers on the NAMMA team via the NASA Global Hydrology Research Center, which manages and disseminates the data collected for NAMMA.

By scrambling when conditions were right, the NAMMA team successfully captured 2006 storm data with LASE. Ross said, "Seven atmospheric waves moved from Africa out into the Atlantic during the NAMMA experiment. Four ultimately developed into named systems over the Atlantic, three into hurricanes, and one into a tropical storm. The other three did not develop into storms."

Data from all the cases proved valuable. Dunion said, "We're learning that when these systems run into the Saharan Air Layer, they consistently struggle, especially if they're small in size. And positioning and timing is everything." One wave that NAMMA flew into later became Tropical Storm Debby, in August 2006. "That system came off of Africa and curled up into the Saharan Air Layer and got completely embedded inside of it," Dunion said. "It was starved for moisture, and there were strong winds that helped to bring that dry air in closer to the storm. **We learned that systems that are fairly small, like Debby, are vulnerable if they get embedded inside of the Saharan Air Layer."**

"We think that the 2006 hurricane season in the Atlantic might have been less active because the dry Saharan Air Layer seemed to be unusually strong coming across the Atlantic. Because it persisted in such a strong state as it crossed the ocean, the Saharan dry air and dust may have defeated more disturbance waves from developing into stronger storms."

But a larger, differently positioned storm proved less vulnerable. Dunion said, "We followed a system a month later that became category three Hurricane Helene, a much bigger system. It moved along the southern edge of the Saharan Air Layer, so it was tapping into moist tropical air down to the south, but north of it there was dry air lapping into it. That storm seemed to be fighting the effects of the dry air, mid-level easterly jet, and dust."

The NAMMA data also suggested why the 2006 Atlantic hurricane season was below-average for the Atlantic, with only two storms making landfall in the United States, both as weaker tropical storms. Ross said, "**We think that the 2006 hurricane season in the Atlantic might have been less active because the dry Saharan Air Layer seemed to be unusually strong coming across the Atlantic.** Because it persisted in such a strong state as it crossed the ocean, the Saharan dry air and dust may have defeated more disturbance waves from developing into stronger storms."

Intense Studies of Intensity

Much is at stake if researchers can solve the puzzle of Atlantic storm-to-hurricane intensification. Dunion said, "Over the last several decades, we've made steady improvement in hurricane track forecasts, but improvements in intensity forecasts have been much slower, almost flat. We need to take every little step we can to try to get the intensity trend moving more like the track trend." For coastal residents and emergency managers, intensity forecasts can be the difference between deciding to make minor storm preparations or to evacuate. More accurate storm intensity forecasts save money, time, and lives for coastal communities.

The NAMMA team continues to sift through the LASE data and the vast array of other observations taken during the campaign, hoping for more insights on Atlantic hurricane development. The researchers see the campaign as a unique event that was a long time coming. Dunion said, "Ten years ago we didn't have a way to track these dust layers. We've accidentally flown through and over the tops of the Saharan Air Layer in the past without even knowing it. NAMMA used cutting-edge instruments and technology, and those field experiments help us make these little leaps forward. The idea is to keep that ball rolling."

References

Dunion, J.P., and C.S. Velden. 2004. The impact of the Saharan Air Layer on Atlantic tropical cyclone activity. *Bulletin of the American Meteorological Society* 85(3): 353–365.

Kamineni, R., T.N. Krishnamurti, R.A. Ferrare, S. Ismail, and E.V. Browell. 2003. Impact of high resolution water vapor profiles on hurricane forecasts. *Geophysical Research Letters* 30: 1234.

Kamineni, R., T.N. Krishnamurti, S. Pattnaik, E.V. Browell, S. Ismail, and R.A. Ferrare. 2006. Impact of CAMEX-4 data sets for hurricane forecasts using a global model. *Journal of the Atmospheric Sciences* 63: 151–174.

NOAA Aircraft Operations Center. Frequently asked questions: What is an easterly wave? Accessed August 2, 2007.

Ross, Robert S., and T.N. Krishnamurti. 2007. Low-level African easterly wave activity and its relation to Atlantic tropical cyclogenesis in 2001. *Monthly Weather Review* 135, 3950-3964.

Wakimoto, R.M., H.V. Murphey, E.V. Browell, and S. Ismail. 2006. The "Triple Point" on 24 May 2002 during IHOP. Part I: Airborne doppler and LASE analyses

of the frontal boundaries and convection initiation. *Monthly Weather Review* 134(1): 231–250.

Wulfmeyer, V., H.-S. Bauer, M. Grzeschik, A. Behrent, F. Vandenberghe, E.V. Browell, S. Ismail, and R.A. Ferrare. 2006. 4-dimensional variational assimilation of water vapor differential absorption lidar data: The first case study within IHOP 2002. *Monthly Weather Review* 134(1): 209–230.

Related Links

NASA Global Hydrology Resource Center:
ghrc.msfc.nasa.gov/

Lidar Atmospheric Sensing Experiment (LASE):
asd-www.larc.nasa.gov/lase/ASDlase.html

NASA African Monsoon Multidisciplinary Analyses (NAMMA):
namma.nsstc.nasa.gov/

Saharan Air Layer Background:
cimss.ssec.wisc.edu/tropic/real-time/wavetrak/sal-background.html

Reflections on the Early Days of EOS: *Putting Socks on an Octopus*

continued from page 5

Some of the fallout of that episode was factored into my decision to step down as EOS Deputy Project Scientist by late 1990—the exact dates have become a blur. **Jeff Dozier** came in to replace Dr. Soffen soon thereafter, but I don't mean to imply that my departure was Dr. Soffen's downfall. As it turned out for me, my Goddard base of operations, the Biospheric Sciences Branch, was looking for a new Branch Head in about the same time frame. I ultimately took that job and had been in it about one year when Dr. Salomonson called me into his office to say that Landsat was coming back into federal government control, that there would be a Landsat 7 mission built jointly under Department of Defense (DoD) and NASA management, and that he wanted me to serve as Project Scientist. So, I took on that role and I felt that I was back on more comfortable ground. **Piers Sellers**, currently a NASA Astronaut, and a member of my Branch at the time, was appointed as the EOS AM-1 Project Scientist in the early 1990s. Sellers and I were able to work closely together throughout the mid-1990s to propose the idea of flying the AM-1 and Landsat 7 missions in a same day orbit [what became known as the *Morning Constellation*] in order to capture conditions on the ground at multiple spectral and spatial resolutions, through nearly identical atmospheric conditions and under nearly identical plant physiological conditions. So, as it turns out, you could say that I got that Landsat sensor on the AM-1 platform after all—in a roundabout way!

So, as it turns out, you could say that I got that Landsat sensor on the AM-1 platform after all—in a roundabout way!

I could go on here and provide several other remembrances, but it might be best if I were to conclude with this short anecdote that is reflective of the difficult times during the early days of EOS. I recall a presentation that Sellers was making to **Shelby Tilford**, Acting Associate Administrator for *Mission to Planet Earth* at the time. As always there were tense discussions over budget ramifications and technological challenges. As only Sellers could do, he said to Dr. Tilford *"This is extremely difficult—it's like trying to put socks on an octopus!"* At that, Dr. Tilford and the entire gathering burst into laughter... what a visual image that conjures up. I also think that phrase characterizes the difficult early days of EOS—it was like *trying to put socks on an octopus.*

feature articles

Connecting Students with "Great Explorers and Great Events" Through the JASON Project

Tiffany Reedy, JASON Project Media Officer, tiffany@tricomassociates.com

"Taking a student like Brittany into the field on a real science expedition will not only stimulate her own passion for science, but will cast her as a role model for other students when she appears in JASON classroom curriculum."

Brittany Jeanis has always dreamed of becoming a scientist. Last October, the 10th grader's dream moved a step closer to reality when she joined **Robert Ballard**, the renowned explorer and oceanographer, on a science mission to the Gulf of Mexico as part of The JASON Project, a nonprofit subsidiary of *National Geographic Society*.

Ballard led Jeanis, two other students, and a teacher—known as *Student and Teacher Argonauts*—on a three-day science research expedition to the Flower Garden Banks National Marine Sanctuary to examine the health of the coral reefs in that region. Accompanied by a video production crew, Ballard and the Argonauts boarded a vessel in Galveston, TX, and headed 110 mi south to their destination in the Gulf of Mexico. The Argonauts were somewhat surprised to discover that despite the area's frequent exposure to human activity and hurricanes, the coral reef system remained remarkably healthy. Their fieldwork will be featured in JASON's upcoming ecology curriculum unit, *Operation: Resilient Planet*, scheduled for release in the summer of 2008.

Ballard, who is probably best known for his discovery of *RMS Titanic*, is JASON's Founder and Chairman as well as a *National Geographic Society* Explorer-in-Residence. He says that, "Taking a student like Brittany into the field on a real science expedition will not only **stimulate her own passion for science**, but will cast her as a **role model for other students** when she appears in JASON classroom curriculum. Positive role models and mentorship are a critical part of JASON's success."

JASON's theory of science education is based on lighting the spark of inspiration through sustained connections with *great explorers* and *great events*. Embedding these connections into the core science curriculum will, JASON believes, generate deeper student engagement, increased motivation, and higher achievement.

Brittany Jeanis and Robert Ballard with a Remote Operated Vehicle (ROV).

To accomplish this, JASON embeds the cutting-edge research of its partners—NASA, the National Oceanic and Atmospheric Administration (NOAA) and *National Geographic*—into standards-based curriculum units. Compelling scientists from those organizations serve as Host Researchers and *headline* each chapter. Taped on location working side-by-side with Argonauts, the researchers come to life in the classroom and in an online global community, challenging students to apply their knowledge to the same real-world scenarios the scientists face everyday.

Brittany Jeanis tests the water clarity of Lake Michigan at Argonaut Bootcamp held in Milwaukee, Wisconsin last June.

To prepare for the expedition, Jeanis attended an intense weeklong "boot camp" in Milwaukee, WI, where she learned the basics of research procedures: how scientists work in the field, the tools and instruments used to gather information, and proper collection and analysis of data samples.

While on location, she was able to use a variety of research methods—from maneuvering a Remote Operated Vehicle (ROV) to snorkeling in the open sea—to examine the competitive strategies of the species and organisms that inhabit the ecosystem, which is located on rare underwater salt domes.

"If I had it my way, I would always be in the water," said Jeanis, who as a child daydreamed of playing with dolphins and whales. "I loved being able to look down and see the fish in their natural habitat, interacting with one another and seeing how they live."

"If I had it my way, I would always be in the water," said Jeanis, who as a child daydreamed of playing with dolphins and whales. "I loved being able to look down and see the fish in their natural habitat, interacting with one another and seeing how they live."

As part of her two-year JASON internship, Jeanis will also help develop and review components of the standards-based curriculum, which includes videos, podcasts, and Web casts; live interactive sessions; and computer games—all mapped to the scope and sequence of a print curriculum.

JASON has collaborated with NASA for more than 15 years to inspire and motivate middle school students to become proficient in science. The agency's scientists, researchers, technologies, and mission themes have been prominently featured in JASON curricula and professional development, while NASA centers have served as hubs to distribute the curricula to local school districts and hosted workshops to train teachers in its use.

Anthony Guillory, Airborne Science Manager at Wallops Flight Facility, was one of two NASA Host Researchers for JASON's weather science curriculum, *Operation: Monster Storms*. He and a team of four Argonauts built, launched, and recovered an Areosonde to collect weather data.

"They worked from 7:30 in the morning until 10 at night day after day. As one of them said at the time, it drove all of them crazy but it was the best fun they've ever had," said Guillory.

"We arrived at NASA not knowing what to expect," said **Ellen Drake**, an eighth-grade Student Argonaut from Ohio. "We were told we would be performing Aerosonde activities all day. I walked in thinking, 'Oh great, I get to spend the day in a conference, listening to people talk.' Boy was I wrong."

"We were led into our hanger and introduced to our team members [and] shown a room where we would work. A table with lots of plane pieces greeted us. I could not believe they were going to let us build an actual Aerosonde. In the end…it was such a great feeling of accomplishment to see something so technologically advanced built with my own hands. It was an extremely unique experience, and I consider myself fortunate to have worked with such a gifted group of people."

Brittany Jeanis takes a step closer to her dream of becoming a marine biologist after snorkeling in the Gulf of Mexico.

For Jeanis' part, her experience with Ballard and The JASON Project will be one she won't soon forget.

"He is an extremely remarkable man. When I went on the mission, the first thing I noticed was the passion he had for what he did. It made me realize that **passion is key in what you do**. Participating in The JASON Project has made me realize that I want to focus on marine biology in college and in my future," said Jeanis. ■

Public Release of R04 CloudSat Data Product: R04 2B-FLXHR (Fluxes and Heating Rates)

The CloudSat Data Processing Center (DPC) has released, to the General Science Community, the *R04* version of the *2B-TAU* product. This product has been generated for the entire CloudSat Mission and is in the current product generation suite. This is the final CloudSat Standard Data Product that will be released under release *R04*.

All data users are asked to review the updated documentation. In addition, please visit the *Known Issues* page of the DPC website and familiarize yourself with these issues before using the results in publications or presentations. This page is located at *www.cloudsat.cira.colostate.edu/dataIssues.php*. In addition, we ask that you report any anomalies or questions to the DPC at: *cloudsat@cira.colostate.edu*

The on-line product specifications for these updated products are located at:
www.cloudsat.cira.colostate.edu/dataSpecs.php

To access the released data, use the DPC data ordering system interface found at:
cloudsat.cira.colostate.edu/data_dist/OrderData.php

If you have any questions concerning the ordering process, contact the DPC at *cloudsat@cira.colostate.edu*

KUDOS

The year 2008 marks the 50th anniversary of NASA and the agency is showcasing the past, present, and future of NASA Science at a number of events throughout the year. One such event was the 2008 Washington Home & Garden Show held March 13-16, 2008 at the Washington Convention Center. The NASA booth took home a blue ribbon for the *Best Island Booth Design.* NASA Earth scientists volunteered their time to educate the general public on NASA's role in studying our home planet.

The first place blue ribbon awarded for the NASA booth design.

Rob Gutro discussed *How NASA Looks at Hurricanes*.

One of NASA's youngest family members volunteers her time to help staff the booth.

Compton Tucker gave a presentation on *Finding the Ebola Hemorrhagic Fever Hot Zone*.

View of the NASA booth at the *2008 Washington Home and Garden Show*.

Michael King gave an overview of NASA's Earth Observations of the Global Environment, *Our Changing Planet and the View from Space*.

meeting summaries

The High Resolution Dynamics Limb Sounder Science Team Meeting

John Gille, HIRDLS U.S. P.I., University of Colorado and National Center for Atmospheric Research, gille@ucar.edu

The first open High Resolution Dynamics Limb Sounder (HIRDLS) Science Team meeting was held January 30-31, 2008 at the National Center for Atmospheric Research (NCAR) in Boulder, CO.

John Gille [University of Colorado (CU) and the National Center for Atmospheric Research (NCAR)—*HIRDLS U.S. Principal Investigator*] and **John Barnett** [Oxford University—*HIRDLS U.K. Principal Investigator*] welcomed the attendees to the meeting. They outlined the purposes of the meeting as follows:

- introducing new and potential users to the data and their characteristics;
- showing some of the science now being done with these data, identify and encourage other uses; and
- fostering collaborations, where useful, among external users and HIRDLS team members to exploit the data.

John Gille reminded people that HIRDLS had been compromised during the Aura launch, and had not been able to process its data on the same time scale as the other Aura instruments. However, now that processing corrections had been developed, HIRDLS was delivering new and unique data sets. He explained that, at this early stage, their desire was to encourage discussion and to open possibilities, rather than to look for completed studies. In the presentations he suggested that the focus be on the HIRDLS data, although examples of what has been or could be done, based on other data, were certainly appropriate. The PIs hope that this will be the beginning of many explorations of science questions.

The meeting began with an introduction to the characteristics of HIRDLS *version V003* data on the Goddard Data and Information Services Center (DISC). (These data are known internally to the HIRDLS team as *v 2.04.09*).

- **John Gille** began by outlining the effects of a launch-induced blockage in the optical train on global coverage and on the radiometric signals, and the algorithms developed to correct for these effects. He went on to describe the accuracy of the temperature data as warm by 1-2 K from the upper troposphere to the upper stratosphere, with a precision of 0.5 K.
- **John Barnett** followed with an analysis of the vertical resolution of the HIRDLS temperature data, showing that vertical wavelengths of 2 km could be seen. The temperature retrievals are good down to cloud tops.
- **Steven Massie** [NCAR] described how the cloud parameters are determined. These include not only the cloud top pressure or altitudes, but also identification of polar stratospheric clouds (PSC's), cirrus, or deep convective clouds.
- **Bruno Nardi** [NCAR] outlined the validation of the ozone data, showing the accuracy of 5-20% and precision of 5-10% in the stratosphere.
- **Douglas Kinnison** [NCAR] described nitric acid (HNO_3) validation. Although there is a low bias, the morphology is accurate, and the precision is 5-10%.
- **John Gille** concluded the session and reviewed the outlook for other species, indicating that there were good prospects for several of the remaining species, such as water (H_2O), methane (CH_4), nitrogen dioxide (NO_2), and chlorofluorocarbons (CFC) 11 and 12—these are respectively $CFCl_3$ and CF_2Cl_2.

The main body of the meeting was given to seven discussions of scientific topics, which are described below.

Upper Troposphere Lower Stratosphere Investigations

Gloria Manney [NASA/Jet Propulsion Laboratory (JPL) and New Mexico Institute of Mining and Technology] introduced the subject with a talk entitled *Extra-tropical tropopause and Upper Troposphere/Lower Stratosphere Studies using MLS, HIRDLS, and other satellite data*, emphasizing the importance of this region for climate change and ozone recovery studies. She noted that improving the representation of the upper tropospheric/lower stratospheric (UT/LS) in data assimilation systems (DAS) is key to predicting and detecting climate change. While most of the studies to date had involved Microwave Limb Sounder (MLS) data, she was beginning to also use HIRDLS data for detailed studies of quasi-isentropic extra-tropical stratospheric-tropospheric exchange events.

John Gille followed by describing HIRDLS observations of the extra-tropical UT/LS, showing that the 1-km vertical resolution of HIRDLS data allowed thin layers of low ozone from the troposphere to be observed in the LS. He illustrated this capability by showing a case from late January 2006 when there was also a double tropopause bracketing the thin layer. He concluded that the 1-km vertical resolution by 1° latitude resolution allows dynamically consistent observations, and showed poleward motion of UT tropical air and equatorward motion of mid-latitude LS air, consistent with contours of potential vorticity from the Goddard Modeling and Assimilation Office (GMAO) Earth Observing System (GEOS) data.

These layers almost certainly result in irreversible mixing, although more studies would be needed.

Laura Pan [NCAR] described the Stratosphere-Troposphere Analyses of Regional Transport Experiment (START08), an NCAR-led program of integrated studies of coupled dynamics, chemistry, microphysics and radiation in the UT/LS region planned for two deployments in April-June 2008. A key element will be transport studies using tracers and tracer correlations, based on satellite data and modeling activities. She laid out the scientific issues, the strategy, and the scientific questions. The program will pay considerable attention to the dynamical and microphysical role of the secondary tropopause.

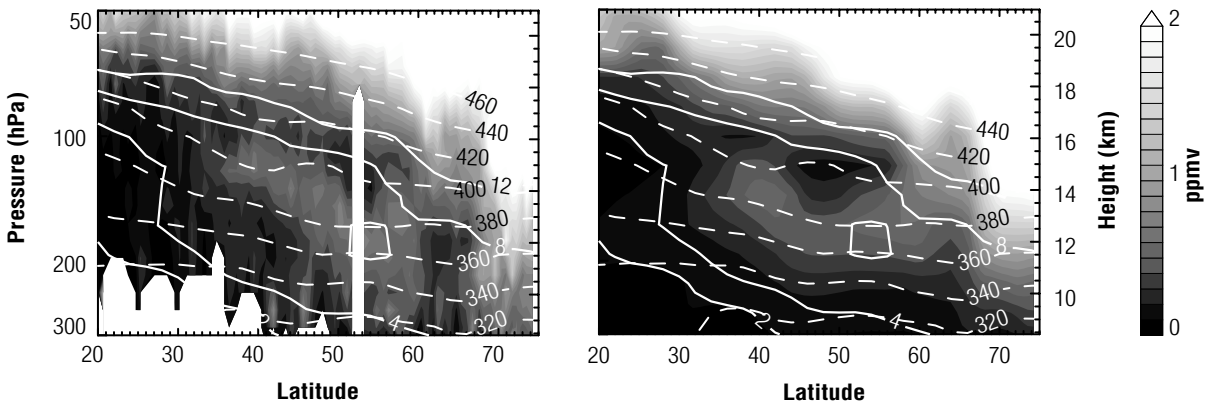
Mijeong Park [NCAR] discussed chemical isolation in the Asian monsoon anticyclone as observed in Atmospheric Chemistry Experiment Fourier Transform Spectrometer *(ACE-FTS)* data. Park described the theory of the Asian monsoon based on a Gill-type solution, and then, using data from the ACE-FTS, showed the differences in trace species mixing ratios between the inside and outside of the anticyclone which was a maximum at an altitude of 15 km. She found that the air inside the anticyclone had relatively larger mixing ratios for shorter-lived species. Park closed by pointing out that the high vertical resolution of HIRDLS data will be useful in transport studies in the UT/LS region.

Eric Ray [NOAA] described the effects of tropical cyclones on upper troposphere composition, in which data from the Atmospheric Infrared Sounder (AIRS) and MLS were used to plot average water vapor mixing ratios near 220 hPa in a coordinate system centered on tropical cyclones (TC), showing similar reductions over the centers in the tropical Atlantic and Pacific. These further showed that the TCs result in much lower mixing ratios of carbon monoxide (CO) and CH_4 over the cyclone centers, with values in the surroundings only slightly low. More intense TCs result in deeper minima.

Atmospheric Modeling

Simone Tilmes [NCAR] presented a statistical method to evaluate UT/LS transport processes in chemistry-climate models (CCMs). This method grouped observational regions with similar transport characteristics. Tilmes separated the UT/LS into tropical, subtropical, and polar regions. This separation was based on meteorological analysis, specifically considering the location of the subtropical zonal jet. In addition, the observations and model results were plotted relative to the thermal tropopause. The example shown in this presentation compared ozone data from a three-dimensional model to sparse high altitude aircraft data from multiple campaigns. The goal was to show the utility of the technique for eventual use in comparing CCM results to HIRDLS ozone and HNO_3 observations.

Anne Douglass [Goddard Space Flight Center (GSFC)—*Aura Deputy Project Scientist*] showed the first comparisons of HIRDLS ozone and HNO_3 observations with model results taken from the NASA Global Modeling Initiative (GMI) model driven with meteorological fields taken from the GMAO data for January 2006, compared for data along orbit tracks. The model successfully simulated the UT/LS ozone and HNO_3 distributions observed by HIRDLS. The figure below shows the comparison between HIRDLS observed (left) and model calculated (right) ozone near 98°W longitude on January 27, 2006 that Douglass presented during her presentation. This level of agreement confirms both the ability of HIRDLS to measure these features, and the ability of the GMI to reproduce the observations based on a physical model. Future work will focus on using the model and observations to estimate the stratosphere–troposphere exchange of ozone and other constituents. NASA GMI results are available to anyone who would like them. Interested users should contact Susan Strahan for more information regarding these GMI simulations—*Susan.E.Strahan@nasa.gov.*



Ozone cross-section on January 27, 2006, measured by HIRDLS (left) and a result of the GMI simulation. Courtesy of Anne Douglass, Mark Olsen, and colleagues [GSFC].

Rolando Garcia [NCAR] presented results using temperature observations from the Sounding of the Atmposphere using Broadband Emission Radiometry (SABER) instrument launched on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Using the Salby Fast-Fourier Synoptic Mapping technique, he was able to derive frequency distributions of equatorial waves (e.g., Kelvin waves). Garcia compared observed equatorial waves with the NCAR Whole Atmosphere Community Climate Model Version 3 (WACCM3). He discussed the importance of understanding the spectrum of waves in the equatorial region, specifically in regards to the formation of a quasi-biennial oscillation (QBO) in a model. Garcia plans to do similar analysis with HIRDLS data to confirm the SABER results for equatorial waves. In addition, the higher vertical resolution of the HIRDLS temperature data may also allow detection of additional tropical waves (e.g., inertia and Rossby gravity waves).

Data Assimilation Studies

Alan O'Neil [National Centre for Earth Observation, and Department of Meteorology, University of Reading, U.K.—*Member, HIRDLS Program Steering Group*] gave an invited overview of the recent success of chemical data assimilation studies and outlined the potential impact of assimilation of HIRDLS data into a global circulation model (GCM), illustrating these points with assimilation studies using MLS ozone and water vapor. O'Neil emphasized that assimilation of research satellite data into operational GCMs is good for science studies of the UT/LS and stratosphere-troposphere exchange. He assigned a high priority to assimilating HIRDLS data in the European Centre for Medium Range Weather Forecasting (ECMWF) operational model and chemical re-analysis. Near real-time MLS and HIRDLS data should be provided for research campaigns.

Alyn Lambert [JPL] spoke on *Near-Real-Time Processing Plans for Aura MLS Data for Use in Data Assimilation*. Time requirements to provide the data for Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) program operational planning require a significant speed-up of the retrieval algorithm. He described activities to develop this capability.

Vince Dean [CU] spoke on *Near-Real-Time HIRDLS Processing for START08*. Here again the time requirements are leading to the development of alternate paths to get the inputs needed, including spacecraft attitude and ephemeris data, and new software.

David Lary [University of Maryland Baltimore County/Joint Center for Earth Systems Technology (UMBC/JCET) and GSFC] discussed another application of data assimilation in his talk on assisting HIRDLS validation. He discussed the role of chemical data assimilation tools in the validation of the multi-instrumental constituent retrievals, emphasizing aspects of bias detection, bias correction, and connecting records with previous and other instruments, as well as recalibration of retrievals using the neural network framework.

Shuntai Zhou [NOAA National Centers for Environmental Prediction (NCEP) Climate Prediction Center] described Assimilation of Aura HIRDLS O_3 profile data in the new NCEP Gridpoint Statistical Interpolation (GSI) system.

Valery Yudin [NCAR] presented an analysis scheme for HIRDLS O_3 and discussed assimilation of recent versions of HIRDLS ozone retrievals in chemistry transport models.

Clouds and Aerosols

Steven Massie gave an overview of HIRDLS observations of clouds (i.e. polar stratospheric clouds and cirrus clouds located near the tropopause), accuracy of the cloud-top pressure determinations, and compared cloud frequency of occurrence latitude-longitude maps to previous Halogen Occultation Experiment (HALOE) measurements.

Brian Kahn [JPL] reviewed recent work with AIRS determinations of relative humidity with respect to ice (RHI) data, and comparisons of AIRS data to CloudSat and Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) correlative data.

Charles Bardeen [CU] presented preliminary results of three-dimensional simulations of thin cirrus clouds in the tropical tropopause layer using a general circulation model with a sectional microphysics model, the Community Aerosol and Radiation Model for Atmospheres (CARMA). Bardeen compared these results to observations from CALIPSO and MLS, identified biases in the model, and indicated the need for observations from HIRDLS of tropical transition layer (TTL) cirrus clouds, temperature and water vapor.

Leonhard Pfister [NASA Ames Research Center (ARC)] reviewed a comparison of model cirrus latitude-longitude maps, produced in collaboration with **Eric Jensen** [Ames] with CALIPSO observations, and indicated that dynamical wave perturbations of temperature can play an important role in enhancing cirrus frequency of occurrence.

Stratospheric Chemistry and Dynamics

Anne Smith [NCAR] began the session with a discussion about measuring the diurnal cycle and how it relates to the QBO and planetary wave activity. Smith went on to talk about the interaction of transport, heat-

ing, and dynamics in the tropics—e.g. pointing out that including interacting ozone in a numerical model slows down the QBO. She presented some results from P. P. Rong [Hampton University] on SABER ozone comparisons with HIRDLS. These comparisons showed agreements of order 10-15% in both bias and standard deviation up to about 50 km altitude, with marked divergence above.

Gloria Manney showed some of her work using MLS, SABER and ACE quasi-tracers such as methane, water vapor, and carbon monoxide to which she expects to add HIRDLS data because of its good vertical resolution.

Lynn Harvey [CU] showed how she had produced an algorithm to automatically locate the areas of low ozone, such as occur in the polar vortex, and how the frequency distributions from HIRDLS match those from MLS.

Joan Alexander [Northwest Research Associates/Colorado Research Associates Division] presented an analysis of Kelvin waves observed in HIRDLS temperature profiles near the equator. Applying Salby's mapping method for asynoptically sampled data to the HIRDLS data, she derived the wavenumbers and frequencies for Kelvin wave modes observed in the data during a three-year period covering 2005–2007. The Kelvin waves appear with wavenumbers 1-5 and periods from 3-20 days. Reconstructions of the amplitude and phase properties of the Kelvin waves show that despite their global scale, they frequently appear in the data as wave packets localized in longitude and height. Kelvin wave amplitudes as a function of time and height show a clear interannual variation with maximum amplitudes descending along the zero wind line of the westerly phase of the QBO.

Bill Schreiner [University Corporation for Atmospheric Research (UCAR)] described and presented results from the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) radio occultation sounding system on the FORMOSAT-3 suite of six satellites launched in 2006. Over 2 million profiles were obtained through December 2007 (and more since) nearly randomly distributed across the Earth, providing high-resolution (i.e., ranging from 0.1 km near the surface to 1 km above the tropopause) temperature data up to about 40 km altitude. Their data are freely available, and they have over 600 registered users. They are having a beneficial impact on numerical weather prediction, and have provided a unique means to validate the high vertical resolution temperature measurements from HIRDLS.

Tropospheric Ozone by the Residual Method

Bruno Nardi made a brief pre-session statement about a perceived discrepancy in the vertical range of validity of HIRDLS *V003* ozone data noted by several of the participants during the meeting. Whereas participants found instances of reasonable HIRDLS ozone data earthward of 100 hPa, the ozone validation paper and the then-current HIRDLS data quality document stated more conservative earthward limits of 50 hPa in the tropics and 100 hPa in the extra-tropics. Nardi explained that the reason for the stated conservative vertical limits was that validation of HIRDLS ozone was statistically verifiable only to the limits indicated, due to sporadic ozone spikes in the lower stratosphere, probably related to the presence of clouds. He clarified that ozone earthward of the stated pressure limits should be used with caution, and that a set of recommended filtering criteria will be included in an updated version of the HIRDLS data quality document.

Mark Schoeberl [GSFC—*Aura Project Scientist*] gave an invited introduction to begin this session. The topic of the presentation was *Tropospheric Ozone Residual* (TOR), the method by which tropospheric ozone is computed, usually using the difference between satellite measurements of total ozone column and stratospheric ozone. Schoeberl first gave a synopsis of the pioneering efforts and the subsequent more advanced efforts that contributed to the evolution of the TOR method. He went on to describe a more recent effort that used the Aura Ozone Monitoring Instrument (OMI) total ozone column and Aura MLS stratospheric ozone, with interpolation used between MLS tracks, and with no time synchronization of measurements. Validation of the results against monthly mean ozonesondes showed poor agreement in the extra-tropics, and a sensitivity to the definition of tropopause height used.

Schoeberl then outlined three avenues for improvement of the TOR method by addressing the problems of: (1) generating a high-resolution stratospheric ozone product; (2) time synchronization of the stratospheric and total ozone products; and (3) instrument bias. Validation of these techniques was shown to give reasonable agreement with ozonesondes and TES in the tropics and seasonally in the northern hemisphere (NH) extra-tropics.

Schoeberl showed a preliminary test of this TOR method using OMI and HIRDLS *V003* ozone data, and compared this with a similarly computed TOR using OMI and MLS *v1.5*. In both cases, there were regions in the high Northern Hemisphere where the stratospheric column was larger than the OMI total column. This was more prevalent with HIRDLS. These demonstrated that the HIRDLS stratospheric column was biased high compared to both sources at high latitudes, and that hot spots (i.e., HIRDLS high) associated with convection were in evidence at low latitudes.

Schoeberl concluded that currently an OMI–MLS potential vorticity-potential temperature (PV- Θ) trajec-

tory mapping TOR product is available for October 2004–May 2007, but that the HIRDLS-OMI TOR product needs tuning, perhaps including use of a combined MLS and HIRDLS stratospheric ozone product.

Xiong Liu [Goddard Earth Sciences and Technology Center (GEST)] presented an intercomparison of MLS ozone profiles using OMI. Liu showed that OMI vertically resolved ozone compared well with MLS ozone and that OMI can be used to derive the tropospheric ozone column directly. The advantage of this is that OMI has excellent global horizontal coverage that does not require any additional analysis steps to produce.

The future work Liu proposed using HIRDLS data included: (1) cross-evaluation of OMI and HIRDLS stratospheric ozone profiles and ozone column; (2) using HIRDLS ozone data to evaluate the performance of OMI retrievals in regions of stratospheric influence and evaluate whether HIRDLS can be used to improve tropospheric ozone retrievals; (3) using OMI to intercompare HIRDLS and MLS and evaluate their random and systematic differences; and (4) combining HIRDLS (high vertical resolution) and OMI (global coverage) to study stratospheric waves, stratospheric intrusions. and other topics of scientific interest.

Valery Yudin concluded the session with an overview of a preliminary computation that uses OMI and HIRDLS *V003* ozone to determine the TOR at low horizontal resolution (i.e., along the HIRDLS measurement track) and compares this to a similar product using OMI and MLS ozone along the MLS track. This is also compared with a HIRDLS experimental product, which has cloud detection and other changes that improve HIRDLS ozone in the lower stratospheric (less high values and spikes).

Yudin also showed estimates of total and tropospheric ozone columns using differential absorption spectroscopy (DAS) and OMI ozone. Yudin continued by showing the relationship between the TOR as calculated using the PV-tropopause height, versus the TOR calculated using the World Meteorological Organization (WMO) temperature-derived tropopause on the one hand, and versus that calculated using the 100 parts per billion by volume (ppbv) level derived tropopause on the other. There were significant differences. The comparisons showed that the TOR derived using the experimental HIRDLS ozone had a markedly better agreement to the OMI–MLS result than did the HIRDLS *V003* TOR, especially in the extra-tropics. Overall the results were encouraging, but require additional development, including the increase of horizontal resolution and inclusion of time synchronization.

Gravity Waves

Joan Alexander gave an overview of gravity waves observed in HIRDLS temperature profiles in May 2006. Alexander explained the advantages of the HIRDLS sampling strategy for gravity wave observations and showed some clear cases of mountain wave propagation into the mesosphere. She also described a gravity wave analysis using a wavelet covariance technique applied to adjacent profile pairs that allows global estimates of gravity wave temperature amplitudes, vertical wavelengths, horizontal wavenumbers, and momentum fluxes as functions of longitude, latitude, and height. Alexander showed maps of these wave properties and compared them to previously published CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) and Global Positioning System (GPS) gravity wave analyses.

Valery Yudin described an analysis of gravity wave signatures in HIRDLS temperature profiles at northern hemisphere polar latitudes in January 2005, 2006, and 2007. During the polar stratospheric warming of 2006, the gravity wave spectrum showed relatively weak intensity compared to spectra from 2005 and 2007 when the Arctic was in its typical cold polar vortex state. The time evolution of gravity wave variance deduced from HIRDLS temperatures in 2006 and 2007 were compared to a model of wave filtering through polar stratospheric winds specified by GMAO/GEOS-5 middle atmosphere assimilation data.

Corwin Wright [Oxford University] reported on a two-dimensional Fourier analysis of temperature perturbations derived from HIRDLS temperature profiles to detect gravity waves in the altitude range of 20-60 km. Wright computed global maps of wave amplitudes and compared the results to previously published MLS results. He also compared the observed vertical wavelengths of waves in HIRDLS profiles to theoretical predictions for mountain waves.

Concluding Remarks

There was a great deal of discussion following the presentations and in the breaks. The participants agreed that this had been a very useful meeting in providing an introduction to a new and unique data set from what was essentially a new instrument. The high vertical resolution, especially in the UT/LS received the most attention. While some participants had begun studies using HIRDLS data, a number had not, and indicated that they had now seen enough to whet their interest in the data. In addition, the HIRDLS team got some very useful feedback on aspects of the HIRDLS data quality that is leading to improvements and refinements that will appear in the next release version, scheduled for release at the end of June 2008. ■

An International Land/Vegetation Direct Readout Working Group Coordination Initiative

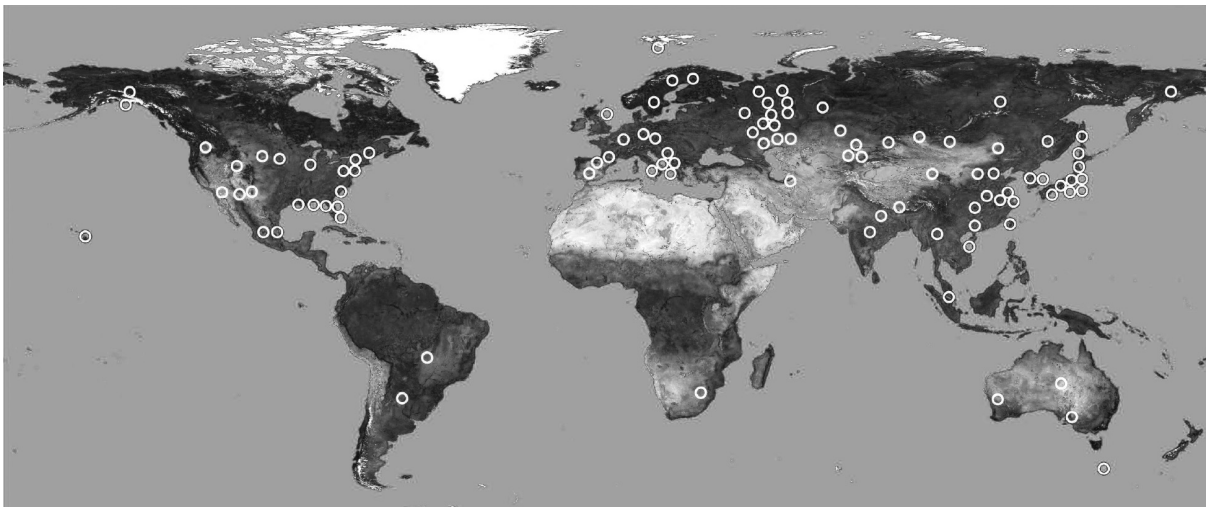
Chris Justice, University of Maryland/GOFC-GOLD, justice@hermes.geog.umd.edu
Brian Schwind, US Forest Service, bschwind@fs.fed.us
Rainer Ressl, The National Commission for the Knowledge and Use of Biodiversity, (CONABIO), Rainer.Ressl@conabio.gob.mx
Craig Smith, Geoscience Australia, craig.smith@ga.gov.au
Garik Gutman, NASA Headquarters, garik.gutman@nasa.gov

Since the launch of NASA's Earth Observing System, there has been an unanticipated growth in the number of Direct Readout (DR) Stations receiving Moderate Resolution Imaging Spectroradiometer (MODIS) data. A very conservative estimate is that there are currently more than 125 stations using the MODIS Direct Broadcast (DB) capability—see map below. DR stations provide near real-time access to imagery and to the land/vegetation data products that are derived from the images, and play an integral role in numerous operational applications worldwide.

Since 2001, the MODIS Land Team in partnership with the NASA Direct Readout Laboratory (DRL) led by **Pat Coronado** [Goddard Space Flight Center] has been making available DR versions of the MODIS Land Product code. Similarly, the Cooperative Institute for Meteorological Satellite Studies (CIMMS) group led by **Liam Gumley** [University of Wisconsin] has been making available code for MODIS Level 1 and the Atmospheric products. This successful transition of NASA *research* to *operations* has happened without much fanfare but with considerable impact. For example, a direct readout version of the MODIS Fire Product developed by **Louis Giglio** [Science Systems and Applications Inc.], implemented initially by the Remote Sensing Application Center (RSAC) of the U.S. Department of Agriculture's (USDA) Forest Service (FS)—*activefiremaps.fs.fed.us/*—is now used by ground stations around the World for operational fire monitoring. One such system is *Sentinel* managed by Geosciences, Australia—*sentinel.ga.gov.au/acres/sentinel/index.shtml*—which has been providing routine fire hot spot information from MODIS Aqua and Terra and the NOAA Advanced Very High Resolution Radiometers (AVHRRs) to fire and emergency services. The *Sentinel* System has had more than 100,000 visits and 100 GB of information downloaded each month during the active fire season in Australia, and is now being expanded into South East Asia through a network of MODIS ground stations.

As a result of the success with MODIS, operational data providers and users are now looking to the future continuity of MODIS Land products with data from the Visible/Infrared Imager/Radiometer Suite (VIIRS) instrument to be flown on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP). The responsibility for managing DB from the VIIRS lies with the Integrated Program Office, which until now has had little interaction with the Land DR community.

Although the ground stations have common needs and objectives and face similar problems of data processing and management, there has been little communication between them or exchange of experience. There is a need for continued prototyping and the transition and implementation of additional land product algorithms into the direct readout environment. In addition, a number of programmatic and technical issues regarding



The map shows the current locations of EOS MODIS X-band ground station sites (provided by NASA Direct Readout Laboratory).

Group photograph of the ILDRC Workshop attendees

the use of high temporal, moderate resolution sensor data in the direct readout environment need addressing.

In this context, a Land/Vegetation Direct Readout Workshop was held October 10-11, 2007, in Mexico City, Mexico. The National Commission for the Knowledge and Use of Biodiversity (CONABIO) hosted the meeting, which was held at the Unidad de Seminarios – Universidad Nacional Autónomia de México (UNAM) University Campus in Mexico City. NASA, CONABIO, USDA FS RSAC, and the International Global Observation of Forest Cover and Land Cover Dynamics (GOFC/GOLD) program were all sponsors of the workshop, The workshop is the first in a series of planned international land direct DR workshops, providing a forum for the Land DR *community of practice* to meet to share experiences and coordinate their activities. The main goal of this first workshop was to initiate sustained self-coordination and information exchange by the moderate resolution, land DR *community of practice*.

The two-day workshop focused specifically on land and vegetation applications derived from current and future moderate resolution environmental sensors that support direct broadcast capabilities (i.e., MODIS, AVHRR and VIIRS). Specific objectives of the workshop included:

- Presentations on and discussion of the status of current and updated land science products and algorithms (MODIS Collection 5) and timelines for their integration into the direct readout environment;
- development, implementation, and sharing of direct readout data processing and visualization technologies;
- establishment of requirements to ensure continuity of current land science product algorithms and associated technologies with future sensor missions;
- technical exchange between direct readout data producers and scientists on land/vegetation science algorithms and applications; and
- facilitation of regional/continental direct readout data integration networks to share data and maximize efficiencies.

Nearly 60 individuals representing eight countries attended the two-day workshop. Workshop participants included land/vegetation scientists from government and universities, representatives of DR facilities, DR data users, and related commercial vendors. **Louis Giglio**, **Chris Justice** [University of Maryland,College Park—GOFC/GOLD], **David Roy** [South Dakota State University], **Crystal Schaaf** [Boston University], and **Alfredo Huete** [University of Arizona] represented the NASA MODIS/NPP Land Science Teams. **Pat Coronado** represented

the NASA DRL and **Liam Gumley** represented the MODIS/NPP Atmospheric Science Team.

The first day of the workshop consisted of two presentation tracks. The morning track covered a programmatic overview of the current state of DR for land applications and future directions by several members of the DR community. The afternoon track included a review of the current status of land products/algorithms for MODIS and AVHRR and their applicability in the DR environment. The second day of the workshop consisted of concurrent breakout sessions focusing on the issues affecting land DR. Breakout group discussions fostered several recommendations and action items that are summarized below. In addition to the workshop meetings, a poster session was also held. Presentations from the workshop can be found at—*www.conabio.gob.mx/conocimiento/premota/doctos/papers.html*.

The workshop participants made several recommendations reported below.

1. An International Land Direct Readout Coordination Committee (ILDRCC) should be formed under the auspices of the GOFC/GOLD Program, to promote international DR dialogue amongst the moderate resolution, DR *community of practice*, to develop regional DR networks, and address and help resolve science and operational issues affecting the international DR community. **Tom Bobbe** [USFS RSAC], **Craig Smith** [Geoscience Australia], and **Rainer Ressl** [CONABIO] will co-chair the group and develop the initial activities of the group. Specifically this international group will:

   - Provide advice to the space agencies on priority land products for transition to the DR domain and feedback on current land algorithms/code and instrument calibration.

   - Coordinate participation in regional community validation and calibration campaigns and initiatives adopting international standards and protocols.

   - Coordinate with other discipline groups concerned with DR algorithms and products.

   - Promote the development of regional Land DR networks following the Sentinel Asia model.

   - Promote the development of DR capability from the international moderate resolution assets.

2. The NASA DRL should serve as a central portal for land algorithms/code and data products from MODIS and VIIRS and a formal linkage should be established between the VIIRS Direct Readout Mission and the IPO Algorithm Division.

3. The DRL should work with the ILDRCC to help coordinate the development of priority DR products which are currently unavailable in the DR domain—e.g. burned area, live fuel moisture, leaf area index, evapotranspiration, net primary production.

4. The ILDRCC should hold a dedicated annual coordination workshop, with opportunistic use of planned international remote sensing workshops. It was agreed that the group would next meet at the International EOS/NPP Workshop in Bangkok, Thailand (March 2008).

Although this first workshop focused on continuing the success of the MODIS Land DR activities into the NPOESS era, future workshops will try and engage the international space agencies in providing Land DR capability for their moderate resolution instruments. The full report from the workshop can be found at—*gofc-fire.umd.edu/implementation/Events/meetings/past.asp*.

Those interested in participating in the ILDRCC activities should contact **Brian Schwind** [USDA FS/RSAC] at *bschwind@fs.fed.us*. ■

NASA Fire Science Workshop Summary

Chris Justice, University of Maryland, College Park, justice@hermes.geog.umd.edu
Kelley O'Neal, University of Maryland, College Park, kelleyo@umd.edu
Ed Sheffner, NASA Ames Research Center, edwin.j.sheffner@nasa.gov

Fire is a global phenomenon and an important process in the Earth System. Fire is an ecosystem disturbance, a land management tool, a source of trace gases and particulates to the atmosphere, and a natural hazard. Recent wildfires related to extreme climatic events in California and around the world are attracting increased attention by the media, land managers and the scientific community. However, despite its importance to the Earth system, there is still much about fire that is poorly understood.

In this context, a NASA Fire Science Workshop was held February 20–22, 2008, at the University of Maryland, College Park (UMCP). The purpose of the workshop was to review NASA's fire science research activities and to develop a 5 to 10 year strategy in this important area.

NASA generates a number of fire satellite data products and numerous other observations that are relevant to assessing fire risk, predicting the intensity and spread of fires, monitoring fires, characterizing fire emissions, understanding fire impacts, and analyzing patterns of recovery. The many facets of fire research occur across a variety of NASA programs including: ecosystem science, land cover and land use change, water and carbon cycles, and atmospheric composition. The workshop reviewed current observations, associated remote sensing science, and research activities that make use of NASA observations. In addition, the meeting outlined a notional 5- to 10-year strategy that extends current efforts and complements the activities of other agencies and institutions. The workshop also provided an opportunity to identify potential linkages between fire science research and NASA's Applied Sciences Program.

This workshop was a follow-on to one that took place in November 2007 that focused specifically on NASA fire applications in the context of the recent California fires.

Over 65 participants representing more than 20 agencies, academic institutions, and private enterprises participated in the workshop, including representatives from several NASA centers, the U.S. Department of Agriculture (USDA) Forest Service (USFS), the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), the Bureau of Land Management (BLM), and the National Oceanic and Atmospheric Administration (NOAA). The workshop included state of the science presentations, targeted break-out discussion groups, and an evening reception and poster session. The meeting agenda, participant list, poster list, presentations, and break-out discussion group reports can be found at *ftp.iluci.org/NASA_Fire_Science_Workshop/*.

Workshop Background and Objectives

The objectives of the workshop were to:

- Review current research relevant to NASA goals and strategies for fire science research.
- Develop a five- to ten-year fire research strategy for NASA Earth Science.
- Consider what can be learned from previous fire events, such as the recent Southern California fires.
- Consider observations, infrastructure, and methods for sharing data and data products needed to undertake effective fire science research within NASA, as well as to support interactions and collaborations with other federal and state agencies and stakeholders.

Paticipants at the 2008 NASA Fire Science Workshop

- Consider relationships and coordination between basic and applied science and with operational activities.
- Consider the synergy with and contribution to national and international fire programs.

Bill Emanuel [NASA Headquarters (HQ)] and **Ed Sheffner** [NASA Ames Research Center (ARC)] opened the meeting, welcoming the attendees and participating agencies. **Jack Kaye** [NASA HQ] summarized the activities and programs contributing to NASA's Earth Systems Science research and applied sciences program and emphasized that the number of participating agencies and the interagency coordination are integral to the program. **Teresa Fryberger** [NASA HQ] noted that NASA is very proud to have worked with the USFS and firefighters during the recent 2007 fires in California. She encouraged the participating agencies to think about a longer-term strategy for cooperation for both applications and science research.

Susan Conard [USFS] described interagency priorities related to disaster reduction and the USFS strategic plan for fire research and development. Conard outlined the critical issues in fire research and provided examples of remote sensing research applied to fire management and monitoring. She explained that the research is focused on both the problems and benefits associated with fire. Conard also noted that NASA has been a very important partner with the USFS in accomplishing fire research.

Chris Justice [UMCP] presented an overview of fire science and examples of fire research, including fire, climate, and land use; ecosystems, disturbance, and recovery; trace gas and particulate emissions; radiative forcing; and atmospheric chemistry and composition. He emphasized the importance of understanding the *human dimension* of fire, which has been largely overlooked. Justice related these topics to satellite fire monitoring and the need to transfer proven NASA research into the operational domain.

State of the Science Presentations

Francis Fujioka [USFS] provided a history of fire weather and risk assessment and an overview of fire weather and fire modeling research. **Philip Dennison** [University of Utah] presented recent findings and future research directions for monitoring fuel type, load, and condition. He noted the capabilities of hyperspectral, RADAR, and LIDAR systems for obtaining information about fuels. **Vince Ambrosia** [ARC/California State University Monterey Bay (CSUMB)] gave a summary of the NASA-sponsored California Wildfire Recovery and Post-fire Assessment Initiative Workshop held November 28–29, 2007, in Pasadena, CA. **Eric Kasischke** [UMCP] presented a review of 33 studies using remote sensing to study fire severity and effects on terrestrial ecosystems with a synthesis of the results. **David Roy** [South Dakota State University] provided an overview of the current status and future directions and priorities for active-fire and burned-area mapping. **Tom Gower** [University of Wisconsin] described ecosystem impacts and recovery in boreal forests, with a focus on carbon dynamics and remote sensing of forest canopy structure. **Tom Bobbe** [USFS] presented an overview of post-fire rehabilitation mapping and monitoring programs and the role of remote sensing, including priorities for future research. **Jim Collatz** [NASA Goddard Space Flight Center (GSFC)] provided an overview of the relationships between fire emissions and climate change, the feedbacks between the various system components, and the resultant effects on the carbon cycle. **Jeff Reid** [Naval Research Laboratory (NRL) & NASA] summarized work on fire emissions and air pollution and the difficulties of operational quantification both spatially and temporally. **Ivan Csiszar** [UMCP] presented an overview of the fire component of the Global Observations for Forest Cover and Land Cover Dynamics (GOFC-GOLD) program. He presented an agenda for international coordination of fire observations, the related research and the role of regional networks. **Chris Justice** reviewed NASA's Earth System Data Records for fire, including the currently available products and the importance of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) for providing data continuity.

Break-Out Discussion Group Recommendations

Priorities for Research on Fire Weather and Fire Danger

Co-Chairs: Francis Fujioka [USFS] and **Timothy Lynham** [Natural Resources Canada, Canadian Forest Service.

This group identified fire applications as its primary discussion topic, including *tactical* and *strategic* planning. *Tactical planning* requires immediate research on obtaining precipitation, temperature, relative humidity, wind speed, wind direction, and soil moisture information from remotely sensed data. *Tactical planning* will become more effective as remote sensing-based mapping capabilities for determining the rate of spread, intensity, perimeter, growth, fire and radiative energy of the fire, as well as fuel mapping, improve. In the long term, tactical planning would also benefit from improvements in weather forecast models with temporal and spatial resolutions within 24–48 hours and less than 1 km. *Strategic planning* has a focus on cyclical events and calls for immediate research on the time lag between climatological events and fire danger, and *teleconnections*—linking fire events to shifts in climate in other areas of the world—as a means to predict fire season activity, and extreme climatic phenomena. *Strategic planning* also

requires continued development of general circulation models and higher resolution regional climate models that can provide improved input to fire danger models used to forecast fire occurrence trends. The group also suggested an increased dialogue with end-users to better define their requirements for improved information and to establish commitments to incorporate the remotely sensed information into operational systems.

Research Priorities Regarding Fuel Loads and Conditions

Co-Chairs: Philip Dennison [University of Utah] and **Laura Bourgeau-Chavez** [Michigan Technological University]

This group identified four major research areas for fuel properties [e.g., fuel type, fuel loading (on the ground, at the surface and in the canopy), and fuel condition]. These areas include: 1) developing spatially-continuous, three-dimensional descriptions of distribution, continuity, and quantity of fuels; 2) mapping fuel moisture along a continuum from live-to-dead fuels, spatially, temporally and vertically; 3) establishing fuel properties necessary for future fuels assessment, fire modeling, and emissions modeling; and 4) assessing the impacts of disturbance, management, and climate on fuels. In this latter regard, particular attention needs to be given to land cover and land use change at the *urban-wildland* interface. Short-term research goals in this area should focus on investigating sensor capabilities for measurement of fuel loading and moisture that would provide the basis for operational remote sensing of fuel properties. The group encouraged the continued development of lidar, hyperspectral, radar, and thermal infrared remote sensing technologies and suggested the need for more research toward developing operational techniques for retrieving canopy-bulk density, canopy-base height, fuel loading, fuel moisture, and disturbance. The group also expressed interest in increased spatial coverage for lidar and hyperspectral data and recommended increased utilization of time series and archival remote sensing data to gain a better understanding of fuel dynamics. Long-term goals are: 1) development of affordable remotely sensed data—primarily spaceborne lidar and hyperspectral data—for fuels assessment; 2) continued development of a network of sites for experimentation and validation; and 3) further development of fire and fuel modeling capabilities.

Integration of Current Observations to Meet Fire Research Objectives

Co-Chairs: Vince Ambrosia [ARC/CSUMB] and **Ivan Csiszar** [UMCP]

This group focused on enabling and enhancing access to geospatial data, models, and information managed by a disparate fire community. They also hoped to facilitate cross-sensor modeling improvements, derive improved estimates of fire radiative and fire physical properties, and derive surrogate indices from the data to enhance our understanding of fire using current observational capabilities. To those ends, the group suggested the several initiatives.

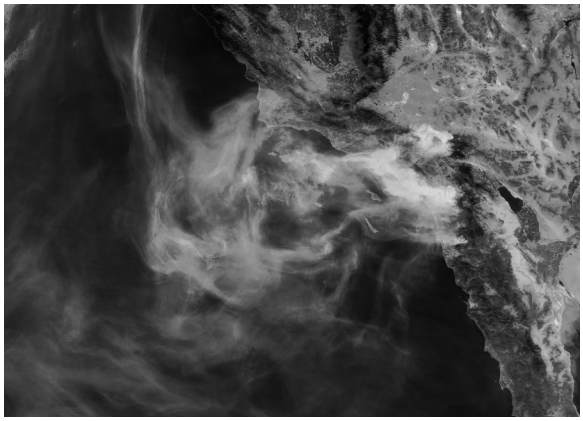
1. Identify a set of global validation sites in representative fire ecosystems to test and improve observation and modeling capabilities.
2. Create common, long-term satellite data records for intercomparison.
3. Integrate multi-scale satellite data to improve monitoring of fire behavior and characterization.
4. Establish standards and protocols for processing, reporting, and sharing data.
5. Increase open access to data.
6. Develop incentives for agencies and investigators to provide data post-experiment to share with the fire science community.
7. Develop new technologies and observational capabilities to enhance fire science.

The group noted the cross-cutting nature of fire research amongst the science disciplines and the need for a unified voice to set long-term goals, mature current systems, and develop future observational requirements necessary to advance the understanding of fire in the Earth system.

Research Campaigns Focused on Major Fire Events

Co-Chairs: Jim Brass [ARC] and **Rob Sohlberg** [UMCP]

This group recounted the lack of accurate, timely information during the fires in Southern California in 2003. They then discussed the improvements to aid in decision making by the time the 2007 fires occurred, including information provided from NASA satellites and high-resolution airborne sensors, the USFS, and the Department of Defense. The next logical step would be a focused program that builds on the accomplishments during the 2007 events and attempts to synthesize and analyze the fire intelligence and environmental data sets from the previous fires and support a coordinated campaign of large fire measurements. Important data sets generated during the 2007 emergency characterized rates of fire spread, fire intensity, and some measures of emissions for fires driven by Santa Ana winds. The group proposed to synthesize these data from several aircraft- and satellite-based instruments along with available pre- and post-fire remote sensing data and ancillary terrain and fire weather data as a means of categorizing fire behavior to aid in the validation of fire simulation models. The group also noted the need for improved systems for prediction of fire spread, intensity, and severity; assessing direct impacts on communities, ecosystems, human health, and the atmosphere; and monitoring post-fire debris flows, water quality, and



The Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra observed the California fires of 2007. NASA's role in monitoring these fires by satellite and unmanned aerial vehicle (UAV) provided the catalyst for this workshop to develop a strategy for NASA's Fire Science.

ecosystem recovery. The group suggested that a series of multidisciplinary, multi-agency intensive field campaigns would help to develop these improved data sets, foster data sharing, and improve methods and models. In the near term the campaigns would take place in the U.S and be *end-to-end*—i.e. they would measure fuels, model fire danger, characterize fires and behavior, and monitor post fire effects. If the initial efforts in the U.S. succeed, then in the longer term, international venues could be chosen for study.

Interagency Fire Research Coordination
Co-Chairs: Diane Wickland [NASA HQ] and **Susan Conard** [USFS]

This group first discussed mechanisms for interagency coordination. Participants agreed that it would be better to work through existing mechanisms, if adequate and applicable, rather than to try and create new mechanisms. They also agreed to consider separate mechanisms for management of fire research and applications efforts among the relevant agencies and communication among the fire research and applications scientists. The group discussed five existing interagency mechanisms and concluded that the Joint Fire Science Program (JFSP) may be the most appropriate mechanism for interagency collaboration in support of domestic fire research and applications because the JFSP is: 1) multi-agency; 2) based on a congressional mandate; 3) directed toward competitive funding of research and development to meet fire and fuels management needs in the U.S.; 4) potentially open to new agencies to participate in program governance and funding; 5) a good mechanism for joint solicitations; and 6) charged with conducting research on applications of remote sensing. In addition, the group believes it advisable to consider reactivating the currently dormant Fire Research Coordination Council as an informal mechanism for coordination of fire research and applications—i.e., it can serve as a forum for communication among the research managers and wildland fire partners in the participating agencies. The group recognized the importance of resolving data management and data access issues related to fire research and applications—especially the continuation of critical data sets such as Landsat and NPOESS—and the need to coordinate collection, product generation and access to critical data sets. It was also noted that NASA should consider the on-going strategic planning activities and recommendations for fire research and the priorities of other agencies, when developing its strategic plans and solicitations for fire research.

Priorities for Research on Fire Emissions and Air Quality
Co-Chairs: Jeff Reid [NRL/NASA], **Charles Ichoku** [NASA GSFC], **Jim Collatz** [NASA GSFC], and **Stefania Korontzi** [UMCP]

This group identified commonalities between climate and global change research and applied science air quality goals, and research activities that can be utilized by research and applications. To begin this dialog, the group proposes to develop a series of small projects that bring together NASA research, data management, and applied science elements, as well as stakeholder scientists. Suggested initial projects include reconciliation between fire *hotspot* and characterization, burned area products, plume injection height data, and remote sensing of plume particulate matter and gas species. As a subsequent step, the group recommended: 1) developing a U.S. based field campaign on biomass burning; 2) involving researchers at cooperating agencies and universities in collecting and archiving regular data streams for distribution within the science community; and 3) promoting the synergistic use of multiple data sets from different sources. Once these ties and programs are well developed, the group recommended a biomass burning field campaign with an air quality component focusing on comparison of *bottom-up* and *top-down* emissions methods. Ultimately, the applied science and global change research communities are well positioned to perform joint research on how domestic and international fire management policies impact emissions (for both *wildlands* and agricultural land). An initiative is also needed with operational agencies to examine the process for transition of proven NASA science techniques and methods into the operational domain.

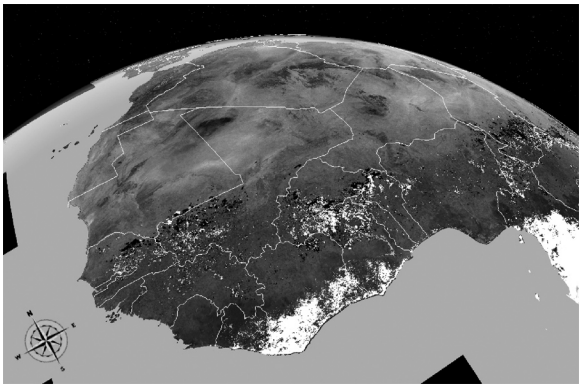
Fire Regimes, Climate Variability and Change, and Land Use
Co-Chairs: Allan Spessa [University of Reading] and **Chris Justice** [UMCP].

The group identified three priority research areas to advance current understanding and predictive capability on the impacts of climate and land-use change on fire regimes. These were: 1) improved assessment of

contemporary and historical patterns of fire regimes; 2) analysis of human-induced versus climate-induced impacts on fire regimes; and 3) predictive modeling at global and regional scales on how fire regimes may change in the future as climate and land-use patterns change.

The group noted that the continued production of a globally consistent and validated remote sensing-based fire regime database over the next decade is a fundamental need for any global scale analyses of causes and trends in fire regimes. Such a database requires accuracy assessment of current systems, establishing standards and protocols for product validation and distribution, intercomparison and validation of current products and quantifying their uncertainty, as well as the design and implementation of an international global fire observing system using best available remotely sensed and *in situ* observations. Continuation and enhancement of the Moderate Resolution Imaging Spectroradiometer (MODIS) fire products through the NPOESS era will be an important component of the system. Improved temporal and regional resolution of climate models will also benefit fire prediction. The group encouraged NASA to start a multi-step process to examine the co-influence of land use and climate change on fire regimes, addressing the influence of climate variability, vegetation characteristics (fuel load), land-use and fire-management practices. The group also identified the several key tasks that need to be accomplished to enable improved prediction and system-based understanding of fire regimes. These include:

- a global assessment of current fire regimes and regional impact assessments of future fire regimes;
- further development of process-based fire-vegetation models;
- analysis of off-line coupled fire-vegetation-land-use models driven by observed climate and landcover;
- development of Earth System Models capturing fire feedbacks between land and atmosphere that quantify current conceptual understanding; and
- moving future predictions beyond straight bio-climatic drivers, entailing improved prediction of socio-economic drivers of land use on fire regimes.



MODIS Terra Burned Area Product, West Africa, November 2000.

Impacts of Fire on Ecosystems and Hydrology
Co-Chairs: Mark Cochrane [South Dakota State University] and **Tom Gower** [University of Wisconsin]

This group identified its overarching priority discussion topic to be the effective utilization of existing assets and products to define the characteristics of fire for all ecosystem types. Spatially quantified characterizations of existing fire regimes are needed as baseline data to evaluate how land cover, land use, and climate changes are altering ecosystems. Activities of high value to the advancement of the ecological understanding of fire include:

- quantification and characterization of the potential for biome change(s) as a function of differing fire regimes and burn severity;
- determination of the effects on major vegetation strata for given ecosystems under differing fire conditions/scenarios;
- evaluation of the potential for new or invasive species introduction under different fire conditions/scenarios;
- quantification of the relative anthropogenic and climate effects on fire and the interactions between these factors;
- determination of the effects of fire events on successional trajectories and rates of succession in different ecosystems; and
- understanding changes in biogeochemical cycles and land-atmosphere interactions with changing fire regimes.

The group noted the following short-term goals:

- increased use of hyperspectral, radar, and lidar data;
- better distinction of the capabilities and limitations of satellite-derived burn severity measures; and
- inclusion of fire in dynamic vegetation models and their validation using remote sensing data sets—with increased focus on fire ecotones.

Long-term goals were also identified, which included:

- global scale decadal assessments of trends in fire regimes and their impact;
- development of a more comprehensive and regionally appropriate measure of burn severity; and
- development of ecosystem models that incorporate changing fire regimes to provide predictive capacity for assessing the likelihood and effect of changing ecosystems.

Future Observations Requirements

Co-Chairs: **Susan Goodman** [Department of Interior, Bureau of Land Management] and **Simon Hook** [NASA JPL].

This group identified key instrument requirements associated with different phases of fire observation. These include: 1) multispectral visible/near infrared data with weekly observations and lidar data for fuel type, structure, and pre-fire conditions; 2) middle and thermal infrared data, with no saturation, and hourly observations for active fire detection and characterization; and 3) multispectral short-wave and thermal infrared data—with observation frequency less than one week—for assessing immediate post-fire conditions.

Near-term gaps in spaceborne observations included high-spatial resolution data (<100m, with daily to weekly coverage), lidar and hyperspectal data. Near-term priorities for airborne systems should be focused on resource allocation and institutional collaboration. Long-term emphasis (5-10 years) for spaceborne instrumentation should include high spatial resolution (ca. 30m) thermal and a tropical fire mission. Long-term emphasis for airborne systems should involve new sensor development and longer mission duration for unmanned aerial vehicles (UAVs). The group stressed the importance of international collaboration and planning to help fill these identified gaps, to avoid duplication of effort and share resources for both operational and experimental systems.The group also noted the importance of ensuring data continuity beyond MODIS with the Visible/Infrared Imager/Radiometer Suite (VIIRS) on NPP and NPOESS. Additonally, the group emphasized the need for increased visibility of the fire community and its representation on critical national and international sensor planning and design reviews and instrument science teams. Fire sensor calibration also needs additional attention. The group proposed the creation of a calibration and validation network for fire as a solution to some fire sensor calibration needs that have been discussed. The network could have geographical sites that would provide standardized measurements of different fuel and fire properties over time and a range of ecosystems.

Panel on Priorities, Necessary Infrastructure, and Synergies

The following summarizes the panel discussions. **Ralph Kahn** [GSFC] suggested the need for new directions, including new methods and datasets, and integration of data from multiple sources, models, and communities. Kahn stressed the importance of better communication between the different disciplines and groups working on fire. He identified the need for funding incentives to encourage disciplines to work together and explore dataset inter-use and alternative analysis methods. Collaborative approaches resulting from such a funding mechanism could reduce the shortcomings of the current methods, allow groups to gain a broader perspective on the topic, and encourage further integration of satellite, modeling, and ground data. Kahn encouraged the funding agencies to *"think outside of the box"* to fund projects that are higher risk but could potentially have exciting results.

Tom Bobbe noted the need for more opportunities to further the research and expand collaborations. Bobbe suggested a better look at existing programs across the agencies to leverage and foster community interaction. He stressed the importance of data continuity and quality issues and recommended the increased use of NASA's unmanned aerial vehicles for fire research.

Susan Conard emphasized the need to continue discussions and work together across agencies to meet the common fire research objectives. A critical research area for the USFS is to understand and quantify relationships between fire and climate. We need to estimate all components of fire systems over large areas and understand, monitor, and model feedback loops between the components, including soils and emissions. Conard stressed the importance of understanding fire regime relationships with climate in the past, present and future, as well as shifts in vegetation and species and interactions with other disturbances patterns. She noted the need for better data and methods for landscape-scale three-dimensional characterization of fuels, e.g., using LIDAR. Conard warned the research community to be careful to not over-promise operational capabilities to the fire management community.

David Roy emphasized the need for long-term data records, both backwards and forwards, and validation of current datasets. Roy suggested a focus on requirements for products based on user input and a move toward research focusing on the relationships between fire, climate, and humans and the fully-coupled models needed to do so. He noted the absence of researchers working on the human dimension of fire at the workshop.

Bill Emanuel and **Teresa Fryberger** wrapped up the meeting noting common themes between the breakout groups and opportunities for expanded interagency cooperation to build on current capabilities and explore new research avenues in fire science research.

Conclusion

From the overview presentations, the break-out group reports, and the discussions, the authors identified nine examples of short-term (1-5 years) initiatives for NASA fire science research.

1. Participate in a series of multidisciplinary, multi-agency intensive field campaigns to improve understanding of remote sensing measurements and the quality of fire data products derived from satellite observations, and to improve methods and models. These campaigns would be interdisciplinary and *end-to-end*, i.e., measuring fuels, modeling fire danger, characterizing fires and behavior, fire emissions, and air quality, and monitoring post-fire effects. The campaigns would utilize airborne and satellite assets, to investigate fire management applications.

2. Develop an initiative to improve the availability, standardization, and utility of multi-resolution spaceborne, airborne, and surface data sets. The fire science community would benefit substantially from the availability of such comprehensive fire data, including measurements to characterize fuel loads and properties, impacts, and recovery. This initiative would include: 1) establishing a set of global test sites, across a range of fire and vegetation types, to contribute to the development of new multi-resolution products and long-term data sets, facilitating product inter-comparison and product validation; and 2) providing access to the disparate data sets collected during major fire events, such as the southern California fires of 2007.

3. Improve the spatial resolution of climate models and the generation of parameters needed for fire danger and fire behavior modeling, e.g., temperature, relative humidity, wind speed and direction, soil moisture—and extreme events, e.g., drought and winds.

4. Start to include fire dynamics in Earth system and dynamic vegetation models, addressing component interactions and feedbacks and the examination of the interactions between fire, climate, and land use.

5. Conduct a global remote sensing assessment of current fire regimes (over the existing satellite record), providing a baseline for monitoring future changes in fire regimes and their impacts. Develop long-term, consistent fire data records from existing and past sensors and their continuity through the NPOESS era. Support from an explicit program of product validation is critical for this initiative to succeed.

6. Develop new airborne and space-based remote sensing capabilities that can provide improved products and information on fuel structure and condition, fire and emissions characterization, burn severity, and post-fire impacts and air quality.

Workshop discussions went long into the evening.

7. Form a more cohesive, unified fire science community with better interaction between discipline sub-groups (e.g., fire danger, air quality, ecosystem effects, land use, and fire management) to provide a more holistic view of fire science. This initiative would include periodic interagency symposia on fire science, providing a means to continue and expand the interdisciplinary interactions amongst the science and applications researchers and practitioners initiated at this workshop.

8. Strengthen interagency coordination of fire research by the interagency Joint Fire Science Program and the Fire Research Coordination Council. Investigate pathways for transferring proven and appropriate NASA research into the operational domain, and identifying mechanisms for securing the long-term operational provision of satellite data products to the fire management community.

9. Increase international coordination and cooperation with respect to the development of a Global Fire Observing System of Systems—including satellite and *in situ* data—as well as international research partnerships to study fire, climate, and land-use change in different ecosystem complexes.

The next step will be to build on this workshop to develop a strategic fire-research plan for the next 5-10 years, to further develop and utilize NASA assets for fire research and strengthen interagency cooperation. ■

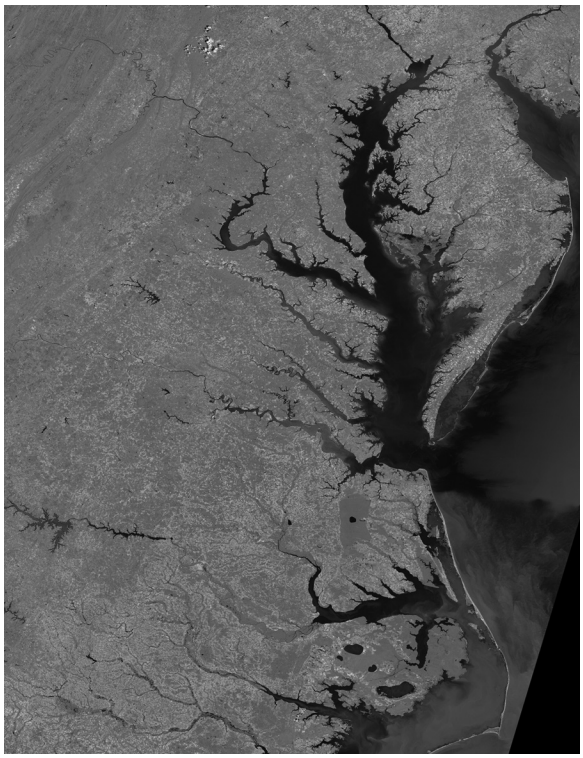
An Earth Day Perspective: NASA Satellites Aid in Chesapeake Bay Recovery

Andrew Freeberg, NASA Goddard Space Flight Center, andrew.h.freeberg@nasa.gov

From the distant reaches of the universe, to black holes and Saturn's rings, NASA explores some of the most far-out parts of space. But NASA also does research much closer to home. In fact, NASA Earth Science satellites are taking part in the management and recovery of an ecosystem right in our own backyard, the Chesapeake Bay.

By studying the landscape around the Chesapeake, NASA spacecraft such as Landsat, Terra and Aqua are helping land managers figure out how to battle the harmful pollutants that have added to the destruction of the Bay's once legendary productivity. While still a commercially important ecosystem—home to some 3,600 species—four centuries of local population growth have crippled the Bay's health, earning it a place on the U.S. Environmental Protection Agency's "dirty waters" list and a 2007 overall grade of C-minus by the University of Maryland Center for Environmental Science.

Many of these harmful pollutants come from the Chesapeake Bay's watershed, an area of about 64,000 mi^2 that covers parts of six states. Water from this massive region constantly drains into the Bay, carrying with it sediments from erosion, excessive nutrients and other contaminants that hurt the Bay's water quality. This runoff also feeds large algae blooms that consume oxygen in the water; oxygen that crabs, fish and other Bay species rely on.



This Chesapeake Bay Landsat-7 Mosaic is a composite of eight Landsat-7 scenes acquired during the period of 1999-2002. Each pixel represents about 15 square meters on the ground. To view this image in color and see more Chesapeake Bay visualizations please go to: *svs.gsfc.nasa.gov/search/Series/ChesapeakeBay.html* **Credit:** NASA/Goddard Space Flight Center Scientific Visualization Studio.

Runoff carries more pollutants when it travels over paved surfaces and cropland, versus marshland or forest. Land cover information from satellite imagers like Landsat and the Moderate Resolution Imaging Spectroradiometer (MODIS) help Bay managers identify the best places to curb non-point source pollution.

"The impervious, tree cover and land cover type map products derived from Landsat data are used on a daily basis by the Chesapeake Bay Program," says **Scott Goetz**, a NASA-funded scientist at Woods Hole Research Center, whose team used Landsat data to create a series of Chesapeake watershed maps.

The Chesapeake Bay Program is a unique regional partnership that leads and directs the restoration of the Bay. They often use Landsat data to help build models that predict the location of nutrient loads and identify areas where managers should take action towards conservation, restoration and growth.

In addition, NASA sensors Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and MODIS detect water color, and are used to calculate sediment and chlorophyll concentrations. The National Oceanic and Atmospheric Administration's *CoastWatch* program provides this type of oceanographic data in near real-time to federal, state and local marine scientists, coastal resource managers and the general public.

Other organizations, such as the Virginia Department of Conservation and Recreation and the Maryland Department of Natural Resources, also use NASA-derived information to prioritize land conservation efforts. The states have now set nutrient and sediment reduction targets for each of the Chesapeake watershed sub-regions thanks to a Landsat-enabled assessment of relative pollution contributions.

In all these ways, NASA satellites are helping Chesapeake Bay managers reduce harmful pollutants. If the bay is ever to recover enough to be taken off of the *dirty waters* list, NASA data will be essential for deciding how to best care for our troubled neighbor. ■

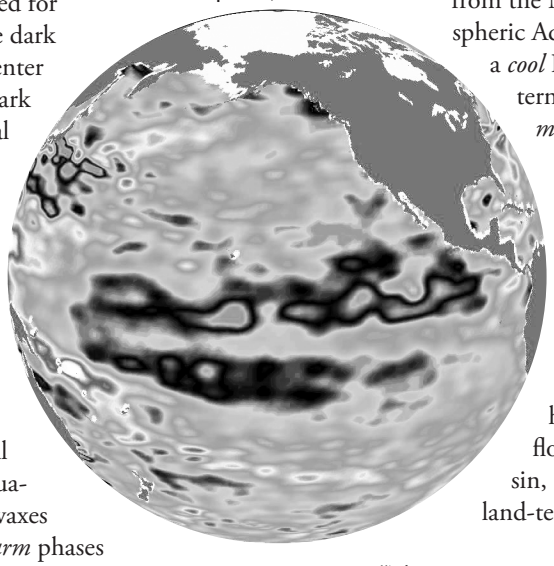
in the news

Larger Pacific Climate Event Helps Current La Niña Linger

Alan Buis, NASA Jet Propulsion Laboratory, Alan.buis@jpl.nasa.gov

Boosted by the influence of a larger climate event in the Pacific, one of the strongest La Niñas in many years is slowly weakening but continues to blanket the Pacific Ocean near the Equator, as shown by new sea-level height data collected by the U.S.-French Jason oceanographic satellite.

Jason image from April 1, 2008



This La Niña, which has persisted for the past year, is indicated by the dark area along the Equator in the center of the image to the right. The dark areas indicate lower than normal sea level (cold water). The data were gathered in early April.

The image also shows that this La Niña is occurring within the context of a larger climate event, the early stages of a *cool* phase of the basin-wide Pacific Decadal Oscillation. The Pacific Decadal Oscillation is a long-term fluctuation of the Pacific Ocean that waxes and wanes between *cool* and *warm* phases approximately every 5 to 20 years. In the cool phase, higher than normal sea-surface heights caused by warm water form a horseshoe pattern that connects the north, west and southern Pacific, with cool water in the middle. During most of the 1980s and 1990s, the Pacific was locked in the oscillation's *warm* phase, during which these warm and cool regions are reversed. For an explanation of the Pacific Decadal Oscillation and its present state, see: *jisao.washington.edu/pdo/* and *www.esr.org/pdo_index.html.*

A La Niña is essentially the opposite of an El Niño. During El Niño, trade winds weaken and warm water occupies the entire tropical Pacific Ocean. Heavy rains tied to the warm water move into the central Pacific Ocean and cause drought in Indonesia and Australia while altering the path of the atmospheric jet stream over North and South America. During La Niña, trade winds are stronger than normal. Cold water that usually sits along the coast of South America is pushed to the middle of the equatorial Pacific. A La Niña changes global weather patterns and is associated with less moisture in the air, and less rain along the coasts of North and South America.

"This multi-year Pacific Decadal Oscillation *cool* trend can intensify La Niña or diminish El Niño impacts around the Pacific basin," said **Bill Patzert**, an oceanographer and climatologist at NASA's Jet Propulsion Laboratory, Pasadena, CA. "The persistence of this large-scale pattern tells us there is much more than an isolated La Niña occurring in the Pacific Ocean."

Sea surface temperature satellite data from the National Oceanic and Atmospheric Administration also clearly show a *cool* Pacific Decadal Oscillation pattern, as seen at: *www.cdc.noaa.gov/map/images/sst/sst.anom.gif*.

The shift in the Pacific Decadal Oscillation, with its widespread Pacific Ocean-temperature changes, will have significant implications for global climate. It can affect Pacific and Atlantic hurricane activity, droughts and flooding around the Pacific basin, marine ecosystems, and global land-temperature patterns.

"The comings and goings of El Niño, La Niña, and the Pacific Decadal Oscillation are part of a longer, ongoing change in global climate," said **Josh Willis**, a JPL oceanographer and climate scientist. Sea-level rise and global warming due to increases in greenhouse gases can be strongly affected by large natural climate phenomenon such as the Pacific Decadal Oscillation and the El Niño-Southern Oscillation. "In fact," said Willis, "these natural climate phenomena can sometimes hide global warming caused by human activities. Or they can have the opposite effect of accentuating it."

Jason's follow-on mission, the Ocean Surface Topography Mission/Jason-2, is scheduled for launch this June and will extend to two decades the continuous data record of sea-surface heights begun by Topex/Poseidon in 1992. JPL manages the U.S. portion of the Jason mission for NASA's Science Mission Directorate, Washington, D.C.

For more information on NASA's ocean surface topography missions, see: *sealevel.jpl.nasa.gov/*; or to view the latest Jason data, visit: *sealevel.jpl.nasa.gov/science/jason1-quick-look/*.

JPL is managed for NASA by the California Institute of Technology in Pasadena. ■

EOS Scientists in the News

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

Into Antarctica's Action Zone, March 14, 2008; *New Scientist*; **Robert Bindschadler** (GSFC) recalls his January expedition to Pine Island Glacier—a dangerous, crevassed glacier in Antarctica, where the team worked to evaluate the glacier's response to climate change.

NASA Measures East Asian Pollution, March 18, 2008; *United Press International*; Research led by **Hongbin Yu** (GSFC) an associate research scientist at the University of Maryland, Baltimore County, used improvements in satellite sensor capabilities to offer the first measurement-based estimate of the amount of pollution from East Asian forest fires, urban exhaust, and industrial production that makes its way to western North America.

Arctic Sea Ice Builds, but Remains Vulnerable, March 18, 2008; *Associated Press*; **Waleed Abdalati** (GSFC) puts the Arctic's declining sea ice into human context, noting that although the Arctic is distant in location, the thinning ice has global implications.

The Mystery of Global Warming's Missing Heat, March 19, 2008; *National Public Radio*; Data from robots studying the ocean show that the oceans have not warmed up over the last few years. Still, sea level has continued to rise suggesting warmer ocean temperatures, according to **Josh Willis** (JPL), and poses a mystery to researchers.

Perennial Arctic Ice Cover Diminishing, Officials Say, March 19, 2008; *Washington Post*; Despite a cold winter, NASA satellites data show that perennial sea ice is in steep decline. **Josefino Comiso** (GSFC) says that Arctic Ocean temperatures appear to be rising quickly because less of the water is covered by ice, which reflects sunlight and keeps water temperatures lower.

New Tsunami Warning System May Save Lives, March 24, 2008; *Earth & Sky*; **Tony Song** (JPL) and colleagues found that horizontal movement, not vertical movement, from an earthquake is what drives the size of a tsunami. The movement is detectable by GPS, which is helping researchers determine the type of wave generated during an earthquake.

Water Worries Not Over, Experts Say, March 27, 2008; *Los Angeles Times*; In an analysis of the state of California's water supply in March, **Bill Patzert** (JPL) says that the region's warm weather took a toll on the snowpack. That's not a good sign, considering the snowpack is preferred to melt slowly to provide water though spring.

Sounds Good, But …, April 14, 2008; *Newsweek*; Efforts to reduce carbon footprints aren't always straightforward, as evidenced by a recent paper by **James Hansen** (NASA GISS) noting that carbon dioxide is beyond the levels that sustained Earth during the development and adaptation of human civilization.

U.S. Scientists to Study Arctic Smog, April 16, 2008; *The Christian Science Monitor*; In April, scientists from NASA and other agencies undertook the most ambitious effort yet to study pollution in the Arctic and its influence on climate. **James Crawford** (HQ) says the mission's importance lies in predicting the consequences of delivering pollution to the Arctic.

Horrible Fire Year Forecasted, April 16, 2008; *Los Angeles Daily News*; Southern California is preparing for a harsh fire season thanks to above average temperatures and Santa Ana winds. **Bill Patzert** (NASA JPL) thinks the issue will be compounded by large amounts of fuel, high population density, and ecosystem changes due to previous firefighting.

Earthquake Sensors Track Rise in Ocean Storms, April 18, 2008; *New Scientist*; A new study suggests that previously disregarded vibrations measured by a network of seismometers could aid in storm prediction and inform researchers about climate change. **Sharon Kedar** (JPL) thinks the measurements could fill in the data gaps and help fill out the long-running theory.

Jet Lab Cruises Alaska Skies as Scientists Study Bits of Pollution, April 20, 2008; *The Associated Press*; **Daniel Jacob** (Harvard/NASA), co-project scientist for Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS), joined hundreds of researchers and support staff in the field campaign to fly research planes in the Arctic to better understand the origins and chemistry of arctic haze.

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

NASA Science Mission Directorate – Science Education Update

Ming-Ying Wei, NASA Headquarters, mwei@hq.nasa.gov
Liz Burck, NASA Headquarters, Liz.B.Burck@nasa.gov
Theresa Schwerin, Institute of Global Environment and Society (IGES), theresa_schwerin@strategies.org

REGISTRATION OPEN FOR ANTARCTIC RESEARCH CHALLENGE

Calling all students who would like to become scientists and propose Antarctic research! The Landsat Image Mosaic of Antarctica (LIMA) is the first true-color, high-resolution satellite view of the Antarctic continent. Using this view of Antarctica, students are asked to develop a research question surrounding a chosen feature of Antarctica and to debate the value of studying that area. Registration is now open to educators and club or program leaders wishing to have their students participate in the LIMA Quest Challenge. Register at: *www.surveymonkey.com/s.aspx?sm=R052zai3Fr_2bl3W1ZcuIh8Q_3d_3d.*

NASA OCEAN MISSION EDUCATOR CONFERENCE
June 14-15, Lompoc and Vandenberg Air Force Base, CA.

NASA's Ocean Surface Topography Mission on the Jason-2 satellite (OSTM/Jason-2) is scheduled to launch on June 15, 2008. An Educator Launch Conference will be held June 14-15, 2008. The conference will have education workshops in the afternoon at Alan Hancock College in Lompoc, and a dinner banquet followed by presentations by NASA and industry scientists and engineers at the Pacific Coast Officer's Club, Vandenberg Air Force Base. Participants will be bussed to see the Jason-2 satellite launch scheduled for 1:47 AM on a Delta II launch vehicle from Vandenberg. For more information on the Educator Launch Conference, go to *endeavours.org/sec* For more information on NASA's OSTM/Jason-2, visit: *sealevel.jpl.nasa.gov/mission/ostm.html*

TEACHER WORKSHOP ON GEOSCIENCE TIME SCALES & GLOBAL CLIMATE CHANGE
July 9-10, University of Wisconsin-Madison

Look backward and forward in time by studying weather for one day, one week, one month; climate for a year, 30 years, 400,000 years; and geology for millions of years. Sessions will include hands-on activities utilizing real-time NASA and NOAA satellite imagery in *Google Earth* to study the Earth System and detailed discussions of the Intergovernmental Panel on Climate Change (IPCC) 2007 Summary for Policy Makers. Teachers can earn one graduate level credit through the UW-Madison's Atmospheric and Oceanic Sciences Department (course # 508). A nominal registration fee of $20.00 is required; otherwise the workshop (including lunches) is free to all educators with lodging provided for educators residing outside of Dane county. For more information please visit: *cimss.ssec.wisc.edu/teacherworkshop* or contact Margaret Mooney (mooney@ssec.wisc.edu), phone: (608) 265-2123.

CALL FOR ENTRIES FOR THE 2008 DISCOVERY EDUCATION/3M YOUNG SCIENTIST CHALLENGE
Deadline: June 15

Discovery Education and *3M* are partnering with NASA for the 2008 *Young Scientist Challenge*. Currently in its 10th year, the YSC encourages the exploration of science among America's youth and promotes the importance of science communication at a critical age when interest in science begins to decline.

The challenge sponsors are looking for a few great students and teachers who can inspire others with their enthusiasm for science and their ability to communicate. What does it take to be America's Top Young Scientist or America's Top Science Teacher? Students in grades 5-8 and teachers of grades K-12 are being asked to create a short (1-2 minute) video about one of this year's scientific topics, which all relate to this year's theme, *The Science of Space*. Participants should enter their videos online and will become eligible to win a trip to Washington, D.C., in the fall to compete in the YSC finals at NASA's Goddard Space Flight Center. For more information, log on to *www.discoveryeducation.com/youngscientist.* Videos will be accepted through June 15, 2008. Finalists will be announced this summer, and the competition finals will take place October 4-7, 2008.

GET YOUR GUMMY GREENHOUSE GASES!

Making science edible—and sweet—is a reliable way to attract kids' interest. The new "Gummy Greenhouse Gases" activity on *The Space Place* Website makes it fun and easy to learn a bit of chemistry and to find out why too many of these kinds of molecules in the air are likely to cause Earth to get warmer. At *spaceplace.nasa.gov/en/kids/tes/gumdrops*, kids use gumdrops and toothpicks to make simple molecules of ozone, nitrous oxide, carbon dioxide, water vapor, and methane. The

curious can go on to *spaceplace.nasa.gov/en/kids/tes/gases* to learn more about the greenhouse effect and about the "good and bad" roles of ozone.

ARCTIC IMPRESSIONS – MIDDLE SCHOOL TEACHER'S PODCAST JOURNAL

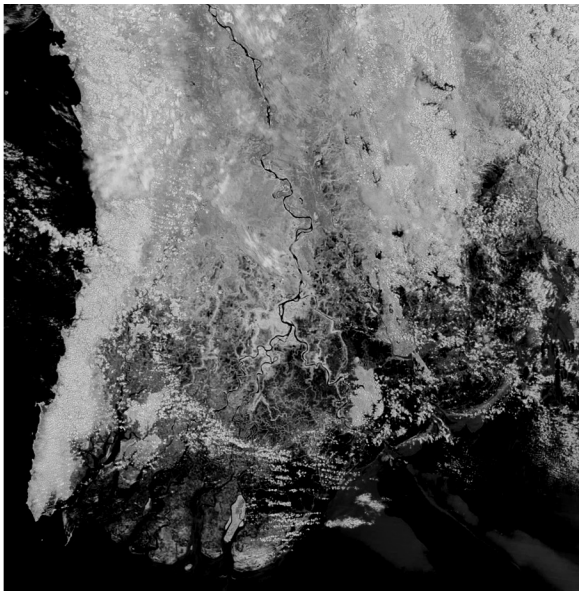
Arctic Impressions is the audio journal of Dorian Janney, a middle school teacher from Rockville, MD. Dorian joined NASA's Sun-Earth Day team in Barrow, Alaska, for the "Polar Gateways Arctic Circle Sunrise 2008." One of the main goals of this conference was to share information about changes in the Earth's polar regions due to global climate change. Other topics included our Sun's influence on the solar system as well as our future exploration of other planets. In these podcasts you will hear from Dorian as she reads directly from her journal. Visit *sunearthday.gsfc.nasa.gov/2008/multimedia/arctic.php*

CLIMATE DISCOVERY ONLINE COURSES FOR EDUCATORS—SUMMER SESSION NOW ACCEPTING REGISTRATIONS

This summer the National Center for Atmospheric Research (NCAR) offers a series of seven-week online courses for middle and high school teachers that combine geoscience content, information about current climate research, easy to implement hands-on activities, and group discussion. The courses run concurrently June 20-August 15 and include: Introduction to Earth's Climate; Earth System Science: A Climate Change Perspective; and Understanding Climate Change Today. There is a $200 fee per course. For complete course schedule and registration information, visit *ecourses.ncar.ucar.edu* or contact: Sandra Henderson, *sandrah@ucar.edu.* ■

April 15, 2008

May 5, 2008



The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra satellite captured these two images of the Burma coast before and after devastating flooding that was caused by Cyclone Nargis. In the April 15, 2008 image the dark rivers and lakes are sharply defined against the lighter land areas. In the May 5, 2008 image the entire coastal plain is flooded. Flood waters are visible as dark areas in the lower portion of the image. For more information and to view these images in color please visit: *www.nasa.gov/topics/earth/features/nargis_floods.html*
Credit: NASA/MODIS Rapid Response Team.

Release of New CERES Surface (SFC) and Clouds & Radiative Swath (CRS) Products for Terra and Aqua

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center in collaboration with the CERES Science Team announces the release of the following data sets:

Terra:
CER_SFC_Terra-FM1-MODIS_Edition2F
CER_SFC_Terra-FM2-MODIS_Edition2F

Aqua:
CER_CRS_Aqua-FM3-MODIS_Edition2B
CER_CRS_Aqua-FM4-MODIS_Edition2B
CER_SFC_Aqua-FM3-MODIS_Edition2C

The Monthly Gridded TOA/Surface Fluxes and Clouds (SFC) data product contains hourly single satellite surface/top-of-atmosphere flux and cloud parameters averaged over 1.0-degree regions. For each instrument, there are 36 SFC files per month and each file contains five 1.0-degree latitude zones. The Terra *Edition2F* SFC data set is a continuation of the Terra *Edition2C* data set and the Aqua *Edition2C* SFC data set is a continuation of the Aqua *Edition2B* data set. The edition change is to differentiate the MODIS collection 4 and 5 input.

The CRS product is designed for studies which require fields of clouds, humidity and aerosols that are consistent with radiative fluxes from the surface to the top of the atmosphere (TOA); for example, studies of cloud and aerosol forcing at both TOA and surface, or investigations of possible errors in retrievals of TOA fluxes, cloud properties, surface skin temperature, etc. Each CRS is an hourly file containing instantaneous data (computed fluxes and observed fluxes) at the CERES field-of-view scale (20-km diameter at nadir) from a single CERES instrument mounted on one satellite.

The temporal coverage for the SFC Terra Edition2F data set and the SFC Aqua Edition 2C data set is from May 2006 through December 2006. Temporal coverage for the CRS Aqua *Edition 2B* data set is from July 2002 through April 2006.

Information about the CERES products, including products available, documentation, relevant links, sample software, tools for working with the data, etc. can be found at the CERES data table:
eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.html

HOW TO CONTACT US:
For information regarding our data products or for assistance in placing an order, please contact:

NASA Langley Atmospheric Science Data Center
User and Data Services
Mail Stop 157D, 2 S. Wright Street
Hampton, VA 23681-2199
Phone: 757-864-8656
E-mail: *larc@eos.nasa.gov*
URL: *eosweb.larc.nasa.gov*

announcement

EOS Science Calendar

June 9
ASTER Science Team Meeting, Tokyo, Japan, Public Workshop, June 13. Contact Mike Abrams, *Michael. J. Abrams@jpl.nasa.gov*

July 15-17
Landsat Science Team Meeting, Reston, VA. Contact: Thomas Loveland, Loveland@usgs.gov

Global Change Calendar

June 1-6
International Workshop on Solar Variability, Earth's Climate and Space Environment, Bozeman, MT. URL: *solar.physics.montana.edu/SVECSE2008/index.html*

June 2-6
Northern Eurasian Earth Science Partnership Initiative (NEESPI) Plenary Science Team Meeting, Helsinki, Finland. URL: *neespi.org*

June 22-24
10th Biennial HITRAN Conference, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. URL: *www.cfa.Harvard.edu/HITRAN*

June 22-28
2008 GLOBE International Conference, Cape Town, South Africa. URL: *www.globe.gov*

June 24-27
101st Annual Air & Water Management Conference, Portland, OR. URL: *www.awma.org/ACE2008/*

July 6-11
IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Hynes Convention Center Boston, MA. URL: *www.igarss08.org/*

August 3-8
The Ecological Society of America (ESA), 93rd Annual Meeting, Milwaukee, WI. URL: *www.esa.org/milwaukee/*

August 3-8
IRS 2008; Session on Radiative Transfer and Modeling, Foz do Iguacu, Brazil. URL: *irs2008.org.br/site/index.php*

August 10-14
Earth Observing Systems XIII, SPIE International Symposium on Optical Engineering & Applications, San Diego, CA. URL: *spie.org/optics-photonics.xml*

September 7-12
10th IGAC International Symposium, Bridging the Scales in Atmospheric Chemistry: Local to Global, Annecy, France. URL: *www.igacfrance2008.fr/*

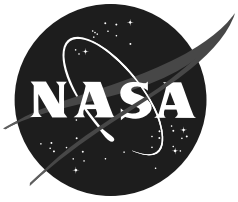
September 29-October 3
59th International Astronautical Congress (IAC), Earth Observation Symposium, Glasgow, Scotland. Call for Abstracts. URL: *www.iac2008.co.uk*

October 15-18
Social Challenges of Global Change - IHDP Open Meeting 2008, New Delhi, India. URL: *www.openmeeting2008.org/*

October 18-21
Association of Science - Technology Conference (ASTC) 2008. Philadelphia, PA. URL: *www.astc.org/conference/index.htm*

November 17-21
SPIE Asia-Pacific Remote Sensing 2008, Noumea, New Caledonia. URL: *spie.org/asia-pacific-remote-sensing.xml*

December 15-19
2008 Fall AGU, San Francisco, CA. URL: *www.agu.org/meetings/fm08/*



Code 610
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

PRSRT STD
Postage and Fees Paid
National Aeronautics and Space Administration
Permit 396

Official Business
Penalty for Private Use: $300

(affix mailing label here)

eos.nasa.gov

The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 610, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available on the World Wide Web at *http://eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php* or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call Steve Graham at (301) 614-5561, or send a message to *Steve.Graham@nasa.gov*, or write to the address above.

Printed on Recycled Paper