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Editor's Corner

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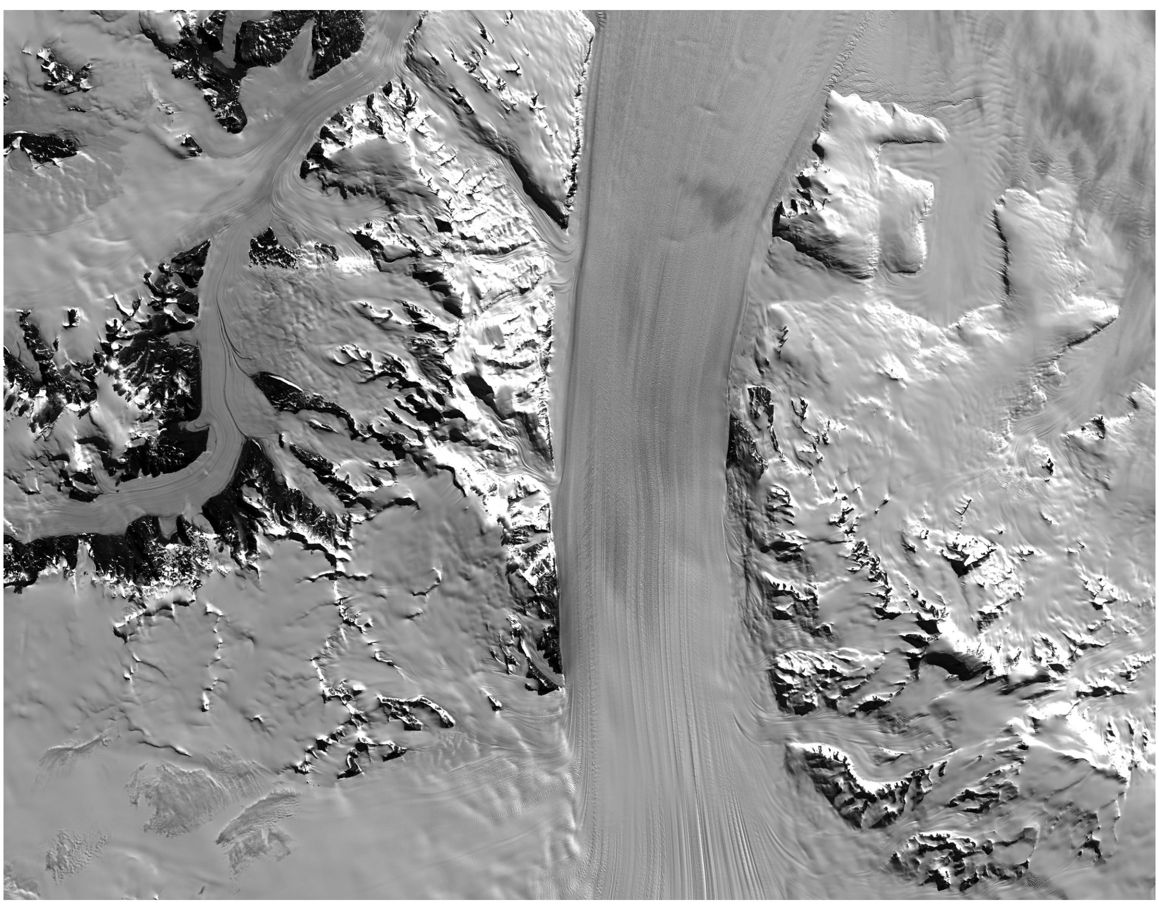
I am happy to report that, on December 26, the President signed into law the omnibus spending bill for 2008, giving NASA $17.117 B, an increase of 5.2% over 2007. Of that amount NASA Earth Science received $1.508 B, an increase of 4.4% over the 2007 budget, and 0.7% over the President's proposed Earth Science budget for 2008. I believe much of this increase can be attributed to the National Research Council's decadal survey for Earth science—*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. The report recommended that, "The U.S. government, working in concert with the private sector, academia, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications." It expressed concern that the 30% decrease in Earth science funding so far this decade could decrease the number of Earth-observing sensors on NASA spacecraft by 40% during this decade if the past funding trend continued. In addition to the decadal survey, the high visibility that global

continued on page 2

This image of the Byrd Glacier captured by the Landsat 7 satellite on December 24, 1999, is just one of the images included in the Landsat Image Mosaic of Antarctica (LIMA). The long stripes in the glacial ice represent the current that carries the glacier towards the Ross Ice Shelf at a rate of one-half mile per year. **Credit:** NASA, the U.S. Geological Survey, the National Science Foundation, and the British Antarctic Survey.



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In This Issue

warming received in the news media during the past year has also raised the awareness of Congress as well as the general public. We are indeed grateful for this much needed increase in funding.

While politicians continue to work out the details of the budget, NASA Earth Science continues to make important contributions that help us get a better picture of the health of the Earth. One such contribution is the newly created Landsat Image Mosaic of Antarctica (LIMA). On November 27, a team of researchers from NASA, the U.S. Geological Survey, the National Science Foundation and the British Antarctic Survey held a press conference at NASA Headquarters to formally unveil a newly completed map of Antarctica that is expected to revolutionize research of the continent's frozen landscape. The new map, created with images captured by the NASA-built Landsat 7 satellite, is a realistic, nearly cloudless satellite view of the continent at a resolution 10 times greater than was previously possible. With the unprecedented ability to see features half the size of a basketball court, the mosaic offers the most geographically accurate, true-color, high-resolution views of Antarctica possible.

LIMA is a result of NASA's state-of-the-art satellite technologies and an example of the prominent role NASA continues to play as a world leader in the development and flight of Earth-observing satellites. LIMA's launch coincides with the ongoing International Polar Year. NASA is participating in IPY, which is organized through the International Council for Science (ICSU) and the World Meteorological Organization (WMO). IPY covers two full annual cycles from March 2007 to March 2009, and includes over 200 projects with thousands of scientists from over 60 nations examining a wide range of physical, biological and social research topics relevant to Polar Regions. It is also an unprecedented opportunity to demonstrate, follow, and get involved with, cutting edge science in real-time.

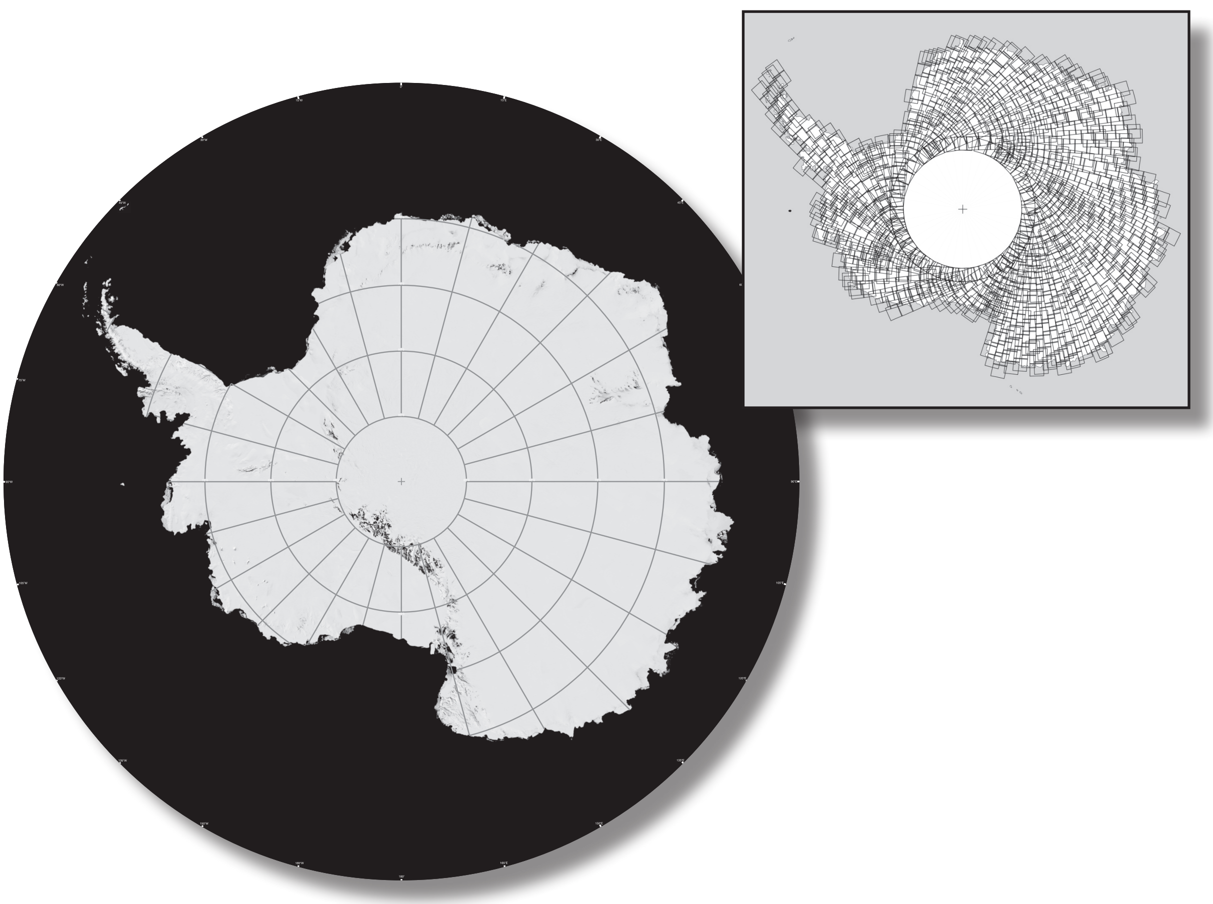
Robert Bindschadler, Chief Scientist of the Hydrospheric and Biospheric Sciences Laboratory at Goddard Space Flight Center, says LIMA opens new windows of opportunity for scientific research and enables the public to become much more familiar with Antarctica and how scientists use imagery in their research. He compares this innovation to watching high-definition TV in living color versus watching the picture on a grainy black-and-white television. For more information on the launch of LIMA, see the news story on page 30 of this issue, and visit: *www.ipy.org/index.php?ipy/detail/lima*.

January 25 marked the fifth anniversary of the launch of the Solar Radiation and Climate Experiment (SORCE). SORCE's four instruments use state-of-the-art technology to provide more accurate spectral and total solar irradiance measurements than any previous measurements, and have helped to improve our understanding of the composition and distribution of solar energy and its impacts on Earth's climate. A SORCE Science Team Meeting will take place February 5-7. Acknowledging SORCE's fifth anniversary, the meeting's theme and title is: *SORCE's Past, Present, and Future Role in Earth Science Research*. A summary of this meeting will appear in a future issue of *The Earth Observer*. I extend my congratulations to the original SORCE Principal Investigator (PI), **Gary Rottman**, and to the current PI **Tom Woods** of the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, and to everyone who has been a part of making the SORCE mission so successful. Keep up the good work!

Lastly, I would like to personally recognize two outstanding achievements that involve some of our staff. **Winnie Humberson**, Task Lead for the EOS Project Science Office Support Task since July 2005, and a member of the EOS Project Science Office Support Team for the past 17 years, received an *RSIS President's Award* from RS Information Systems President Rodney Hunt on December 15, 2007, at the RSIS Holiday Party. The award recognized Humberson's tireless efforts to promote the activities of NASA's Science Mission Directorate and the Earth Observing System Project Science Office. Her efforts have led to new opportunities for the group, and have made the Project Science Office well known not just in Earth Science but throughout the SMD. I tip my hat to Humberson and thank her for all of her hard work and dedication over the years; it has indeed been a pleasure to work with her.

In addition, NASA has presented the **Our Changing Planet Production Team** an *Exceptional Achievement Award* for all of the various and sundry contributions each member of the team made to the recently published book from Cambridge Press: *Our Changing Planet: The View from Space*. I would like to add my personal congratulations and once again thank each and every member of the team for all of the work they did to make this magnificent book a reality. The book represents the culmination of over seven years of work and I am glad that NASA has recognized the team for a job well done.

A team of researchers from NASA, the U.S. Geological Survey, the National Science Foundation and the British Antarctic Survey unveiled a newly completed map [left] of Antarctica that provides a realistic look at the continent in 10 times greater detail than ever before and offers the most geographically accurate, true-color, and high-resolution views of the continent possible. Researchers pieced together [right] more than a thousand images from three years of Landsat satellite observations to construct LIMA. For further details see news story on page 30 of this issue. **Credit:** NASA, the U.S. Geological Survey, the National Science Foundation, and the British Antarctic Survey.



Pollution Trials for the Beijing Olympics

Stephanie Renfrow, National Snow and Ice Data Center, srenfrow@nsidc.org

"I read the article and thought, 'Aha! Wouldn't it be neat if we could take advantage of this natural experiment to improve our ability to detect pollution and see if the restrictions had an impact?"

In the summer of 2008, humanity's fastest, strongest, and most skilled athletes will compete in the Olympic Games in Beijing, China. How will a city that many people associate with traffic-stopping road congestion and health-endangering levels of pollution handle the additional influx of Olympians and their many followers?

In November of 2006, Chinese officials used a smaller-scale gathering, the Summit of the Forum on China-Africa Cooperation, as a sort of dress rehearsal for the Olympics. During six days surrounding the summit, officials increased bus capacity, limited access to certain roads, and banned or restricted the use of government, commercial, and private vehicles. The idea was to make it easier for summit participants to get around Beijing, while also providing a logistical trial run that would benefit athletes and spectators in 2008.

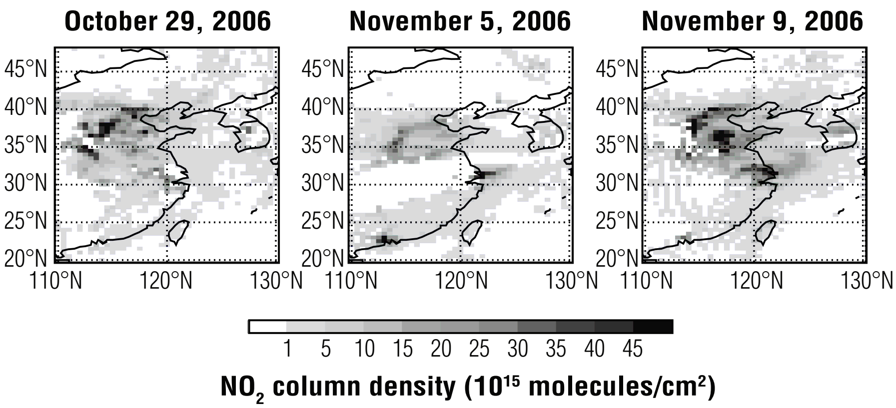
Harvard environmental studies professor **Michael McElroy**, a participant in a lesser-known conference, the China International Counsel for Cooperation on Environment and Development, also happened to be in Beijing in November 2006. McElroy leads Harvard's China Project, an interdisciplinary program that studies the impact of air pollution on the environment, economy, public health, and law. One morning during his visit, he picked up the *China Daily* newspaper and noticed an article about the traffic restrictions. He said, "I read the article and thought, 'Aha! Wouldn't it be neat if we could take advantage of this natural experiment to improve our ability to detect pollution and see if the restrictions had an impact?"

Policy Inspires Research

McElroy called upon postdoctoral student **Yuxuan Wang**, an atmospheric scientist and long-time participant in the China Project, to lead the research study. Wang knew that she would need access to accurate, daily data that offered high-resolution coverage. Based on her experience in using satellite data to understand atmospheric composition, she and her colleagues immediately turned to atmospheric data from the Ozone Monitoring Instrument (OMI). OMI flies on NASA's Aura satellite and the data is archived at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC).

Beijing's traffic volume leads to high levels of pollution, as well as difficulty navigating clogged streets. **Credit:** xpistwv, MorgueFile.

Wang said, "OMI is perfect for this type of work. Unlike previous instruments, it *sees* all parts of the globe daily, which we really needed for a project covering such a short event." Another advantage of OMI is its small footprint, around 15 x 18 miles (24 x 29 km). "The urban center of Beijing, where the traffic restrictions were in place, is about 31 x 31 miles (50 x 50 km)," Wang said, "so OMI's footprint was perfect."



This series of graphics shows the success of traffic restrictions over Beijing; darkest gray areas indicate high levels of nitric oxide before (October 29), during (November 5), and after (November 9) the restrictions were in place. **Credit:** Yuxuan Wang.

Wang began by downloading near-real-time nitric oxide (NO_2) OMI data, which the Royal Netherlands Meteorological Institute in the Netherlands retrieves from the satellite data. Wang chose NO_2 to measure pollution levels both because of the availability and quality of the data and because it is a chemical precursor to smog and ground-level ozone. After downloading the OMI data, she plotted a time series of nitric oxide measurements taken before, during, and after the summit.

However, before Wang could interpret what she saw, she had to take one more step. "When pollution is emitted from the surface, it moves around in the atmosphere," she said. "For example, you might look at the data and think that emissions were reduced—but maybe conditions that day were windy, blowing the pollution away." So, to get an accurate measure of NO_2 levels, Wang first needed to subtract differences caused by natural variation and weather, such as clouds. To do this, she used a chemical transport model called the Goddard Earth Observing System-Chemistry (GEOS-CHEM) model that simulated changes in meteorology, helping her determine their influence on the OMI nitric oxide data.

In addition to using the GEOS-CHEM model, Wang was also glad to see clear weather in Beijing surrounding the summit. "The days we studied were clear, not very cloudy," she said, "so we had an easier time getting a nice series of day-to-day changes. [In other words,] we got lucky!"

Successful Restrictions

With the effects of weather and natural variation removed, Wang could begin to interpret the data. Her findings were clear. "We saw a dramatic change in atmospheric concentrations of NO_2 during the time of the traffic restrictions," she said. "The traffic restrictions were very effective in cutting down NO_2 in Beijing's urban area—the data reveals a 40% reduction in emissions."

"We saw a dramatic change in atmospheric concentrations of NO_2 during the time of the traffic restrictions."

However, Wang acknowledges that verifying the data has been difficult. "We didn't have access to *in situ* observations or to official estimates of how much the flow of traffic was actually reduced," she said. McElroy had originally hoped to access data on gasoline sales before, during, and after the summit. These figures would have provided Wang with a way to corroborate the atmospheric data from OMI. McElroy said, "Unfortunately, we couldn't get that data. There was some nervousness about making adverse comments about the environment in the lead-up to the Olympics."

Although the Chinese were not willing to make gasoline consumption data public, McElroy did get an unofficial confirmation that their measurements were accurate. "A Chinese official did let me know that our estimate was not far from what they had calculated," he said. Wang added, "Plus, Beijing newspapers did report a 30% reduction in traffic, which is also similar to what we found."

The Future: Olympics and the Planet

Despite the lack of *in situ* data to confirm their findings surrounding the summit traffic restrictions, Wang and McElroy hope to push the research forward during next summer's Olympic Games. Wang said, "We are offering to collaborate with Chinese scientists around the Olympics, and we are hopeful that they will share their data with us."

A combination of *in situ* measurements of pollution, a realistic estimate of traffic flow reductions, and the OMI nitric oxide data could provide a more complete picture concerning how traffic restrictions can address pollution concerns. But why is that complete picture important? McElroy said, "With China's economic growth has come an explosion in coal-burning factories and cars on the road—and a steady deterioration of the atmospheric environment. A lot of people are getting sick, and that costs money in medical care and in missed work."

The idea of pollution hurting people's health is becoming more commonly accepted in China. However, the idea that pollution generated by a healthy economy can actually begin to damage the economy itself is an important concept for McElroy. "If the cost of air pollution is 8% of China's Gross Domestic Product, or GDP, and GDP is growing at 10%...you can do the calculation. The economic growth actually isn't very much, in the end."

Beyond being concerned about Olympic athletes breathing in hazardous levels of pollution, **why should people outside of China care about pollution problems on the other side of the world?** "Pollution doesn't stay where it is generated; it can drift halfway around the world," McElroy said. "So the Chinese care what we do, and we should care what they do. The globalization of economies is becoming the globalization of environments."

"Pollution doesn't stay where it is generated; it can drift halfway around the world," McElroy said. "So the Chinese care what we do, and we should care what they do. The globalization of economies is becoming the globalization of environments."

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CHINAdaily. Beijing previews Olympic traffic plans during China-Africa summit.

Wang, Y., M. B. McElroy, K. F. Boersma, H. J. Eskes, and J. P. Veefkind. 2007. Traffic restrictions associated with the Sino-African summit: Reductions of NOx detected from space. *Geophysical Research Letters,* **34**, L08814, doi:10.1029/2007GL029326.

Related Links

NASA Goddard Earth Sciences Data and Information Services Center (GES DISC): *daac.gsfc.nasa.gov/*

Harvard Researcher Listings: Michael McElroy: *harvardscience.harvard.edu/node/2005/*

Yuxuan Wang's Web site: *www.people.fas.harvard.edu/~wang3/index.html*

Using Satellite Remote Sensing to Evaluate the Effectiveness of the Ramsar Convention on Wetlands

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Introduction

Earth observing satellites now routinely collect images of most of Earth's surface and provide far more coverage than previous ground-based and aircraft observations were capable of providing. Satellite images collected over the past three decades have given scientists an invaluable historical record that can be used to assess the quality and extent of terrestrial ecosystems for most regions of the world. Remote sensing data have been used to study a number of different applications that are directly relevant to the enforcement of international environmental agreements (IEAs) including biodiversity and species richness monitoring, mapping of wetlands extent, inventory of forest quality and quantity, monitoring the rate and extent of desertification, and measuring atmospheric pollution. These data could be used to monitor compliance with IEAs such as the Convention on Biological Diversity (CBD), the Ramsar Convention on Wetlands, the Kyoto Protocol, the Convention to Combat Desertification (CCD), and the Convention on Long-Range Transboundary Air Pollution.

As much promise as satellite observations offer for monitoring compliance with IEAs, thus far, they have not achieved their full potential. To date, satellite images have primarily been used to review a snapshot of the environment of a particular moment in time rather than for the kind of continuous monitoring that would be required to use them to enforce environmental agreements. The main reason the satellite images are not used for continuous monitoring more often is that there are few proven means available to process the images so that they can be routinely used to monitor IEA compliance [*Seto and Fragkias*, 2007].

Karen Seto [Stanford University] and **Michail Fragkias** [Arizona State University] are among those who are trying to promote more widespread use of remote sensing to monitor IEA compliance [*Seto and Fragkias*, 2007]. They've proposed an approach that would use remotely sensed images to systematically evaluate the effectiveness of the Ramsar Convention on Wetlands, an international environmental agreement that promotes the wise use of wetlands, and they've tested out there proposed methods on study sites in Vietnam. *The Earth Observer* recently contacted Seto and Fragkias and asked them if they would be willing to provide a summary of their work for our readers, and the author's graciously agreed. This article summarizes Seto and Fragkias' recent paper in *Global Environmental Change* [*Seto and Fragkias*, 2007]. (Elsevier granted us permission to reprint the Figures.) The reader is referred to the full article to learn more details about their research—*www.sciencedirect.com/science/journal/09593780*. There is a fee for downloading the pdf copy.

Background on Wetlands, Mangroves, and the Blue Revolution

Wetlands are broadly defined as areas that are regularly saturated by surface or groundwater; wetland ecosystems include bogs, marshes, swamps, mangroves, and fens; they constitute approximately 4% of the Earth's land surface area. Wetlands benefit ecosystems and society by providing critical habitat for birds, fish and other wildlife, playing key roles in biogeochemical hydrologic cycles, regulating water quality, reducing shoreline erosion, offering flood protection, moderating climate, and supporting numerous economic activities such as hunting, fishing, and recreation. All over the world, wetlands are being threatened or destroyed at alarming rates. Estimates suggest that half of the total wetlands that existed at the turn of the 20th Century have been

Wetland benefits to ecosystems and society include: providing critical habitat for birds, fish and other wildlife, playing key roles in biogeochemical hydrologic cycles, regulating water quality, reducing shoreline erosion, offering flood protection, moderating climate, and supporting numerous economic activities such as hunting, fishing, and recreation. All over the world, wetlands are being threatened or destroyed at alarming rates.

The Convention on Wetlands of International Importance especially as Waterfowl Habitat was signed in 1971 in Ramsar, Iran and is often referred to as the Ramsar Convention.

destroyed [*Dugan*, 1993]. Some common causes of wetland loss and degradation include agricultural conversion; deforestation; redistribution of water resources and the growth of human settlements; and aquaculture including the cultivation, production, or marketing of fish, aquatic invertebrates, or aquatic plants [*Seto and Fragkias*, 2007].

Mangroves are a type of wetlands characterized by coastal salt-tolerant tidal forests in tropical and subtropical zones. Mangroves play an integral role in the ecology of watersheds but the rate and magnitude of mangrove conversion is relatively unknown [*Seto and Fragkias*, 2007]. Over the last 50 years, global aquaculture production has risen to nearly 50 million metric tons, supplying one-third of total seafood consumed worldwide but also threatening and destroying mangrove forests in all tropical regions of the world [*FAO*, 2002; *Alongi*, 2002].

The environmental impacts of this so-called *blue revolution* are enormous—accidental escapes of non-native species, invasion of pathogens to wild stocks, discharge of waste, and destruction of coastal habitats makes current aquaculture practices largely unsustainable [Naylor et al., 2001; Pauly et al., 2002]. The impacts of aquaculture on mangrove forests are estimated to be considerable, especially in Asia, which supplies 90% of world aquaculture production [FAO, 2002], and where an estimated 6,214 mi^2 (10,000 km^2) of coastal lowlands have been converted for shrimp aquaculture. Systematic assessments of the conversion of mangroves to aquaculture are difficult due to politics and limited staff and financial resources. Remote sensing offers an attractive alternative to monitoring mangrove wetlands, aquaculture, and compliance with Ramsar.

Background on the Ramsar Convention

This is the first study to develop an operational remote sensing-based methodology for monitoring and evaluation of Ramsar beyond a simple visual display of satellite imagery.

The Convention on Wetlands of International Importance especially as Waterfowl Habitat was signed in 1971 in Ramsar, Iran and is often referred to as the *Ramsar Convention* [*Ramsar Convention Bureau,* 1997]. The treaty's purpose is to promote the conservation of wetlands by encouraging their *wise use*, defined as, "the sustainable utilization [of wetlands] for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem" [*Ramsar Convention Bureau*, 1997]. As of early 2006, the Convention includes 139 signatories and 1,364 sites totaling more than 74,564 mi^2 (120,000 km^2) designated as wetlands of international importance. The Convention relies mainly on self-reporting for monitoring the efforts and outcomes of States towards the achievement of the existing criteria. The primary commitment of the Contracting Parties to *wise use* is vague and other commitments are also not easily assessed, with no explicitly stated observable and verifiable measures (or quantitative metrics) of failure or success.

Our primary aim is to develop a remote sensing-based analysis to assess the effect of Ramsar, and to apply the methodology to two case studies in Vietnam. While the use of remote sensing or geographic information systems as analytical tools for mangrove mapping is not new, most existing analyses rely on static maps, and do not take advantage of time series of remote sensing data. This is the first study to develop

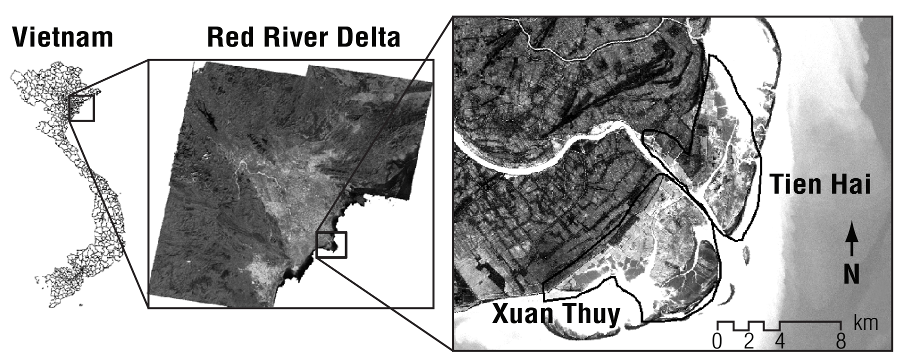

Figure 1. Maps showing (left to right) all of Vietnam, the Red River Delta region, and the Tien Hai and Xuan Thuy study sites.

an operational remote sensing-based methodology for monitoring and evaluation of Ramsar beyond a simple visual display of satellite imagery.

Background on Study Sites in the Red River Delta, Vietnam

Vietnam became a signatory to Ramsar in 1989. Estimates indicate that the total area extent of mangroves in the country decreased by 25% between 1980 and 2000 [*FAO*, 2003]. Our study sites are located 93 mi (150 km) southeast of Hanoi at the mouth of the Red River estuary—see **Figure 1**. Located in the northeast region of Vietnam, the Red River Delta covers 9,942 mi^2 (16,000 km^2) and is one of the country's two major agricultural regions. After the 1986 economic reforms in Vietnam, cash crop agriculture such as farmed shrimp expanded and intensified.

One of the study sites is the Xuan Thuy Natural Wetland Reserve, the only Ramsar site in Vietnam [Ramsar Convention Bureau, 1997]. In 1988, 74 mi^2 (120 km^2) of mangroves were designated for inclusion for a reserve. In 1989, Xuan Thuy was established as a Ramsar site. The second site is the Tien Hai Nature Reserve, located across from Xuan Thuy on the other side of the Red River. Tien Hai was designated a nature preserve in 1995 and officially covers an area of 77 mi^2 (125 km^2), nearly equal in size to Xuan Thuy. The geographic proximity of Xuan Thuy (XT) and Tien Hai (TH) make them ideal test sites for evaluating the efficacy of Ramsar. The combined estuary region is the last remaining area of mangrove and mudflat habitat on the Vietnam coast [Ramsar Convention Bureau, 1997]. During the dry season, the estuary is an important staging and wintering ground for migratory birds and helps stabilize the coast during the typhoon season—see **Figure 2**.

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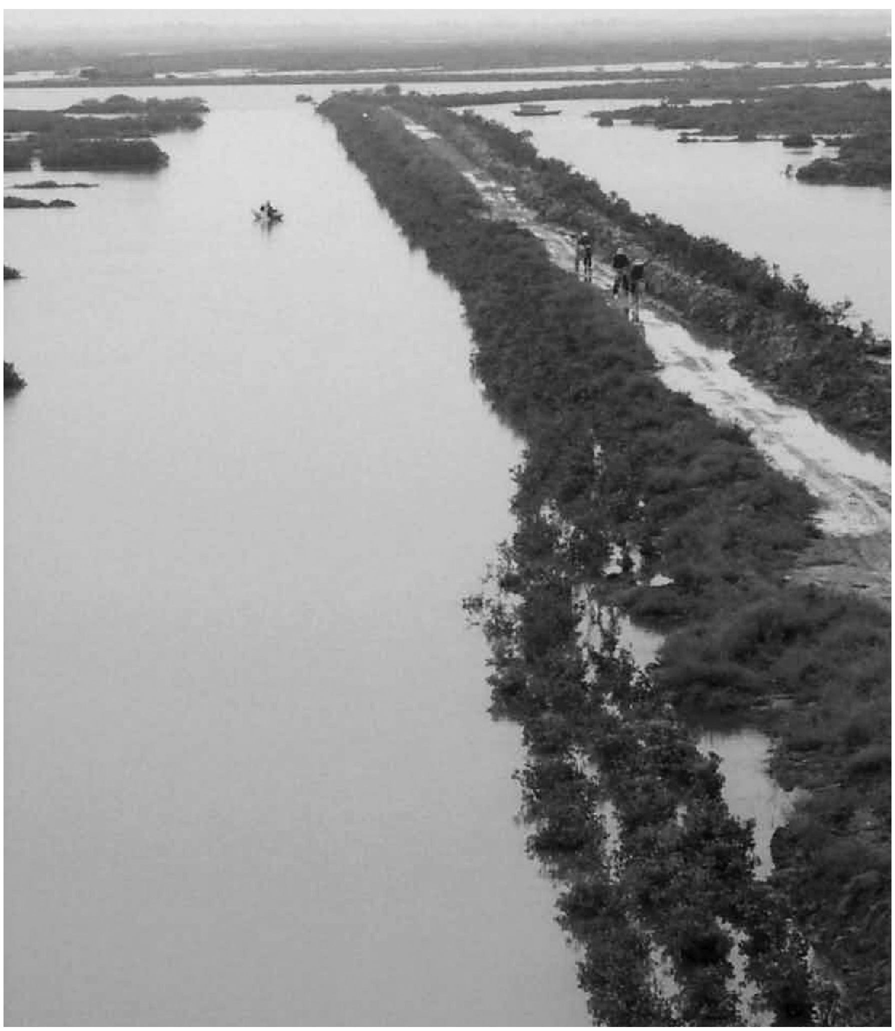

Figure 2. This is a photograph that shows the type of terrain that is typical at both the Tien Hai and Xuan Thuy study sites. The combined estuary region is the last remaining area of mangrove and mudflat habitat on the Vietnam coast and plays an important role in stabilizing the coast during floods that occur during the typhoon season.

Aquaculture was introduced to the area in the early 1980s. Prior to aquaculture, the area was exclusively mangroves and mudflats, with a few farmers engaged in fishing activities. The land use history is corroborated by studying the time series of satellite images.

Data and Methods: Ground Survey, Satellite Data Processing, and Landscape Analysis

In 2001, our research team conducted 26 household surveys to obtain information on aquaculture development patterns and management practices. Additionally, we conducted interviews with regional planners in Hai Phong and Hanoi, Ramsar officials, and village leaders and government officials at multiple administrative levels. During fieldwork, we used global positioning systems (GPS) to identify the location of ponds and mangroves. To identify aquaculture development and historical mangrove extent, we used six Landsat images from 1975 to 2002—acquisition dates: April 20, 1975; January 7, 1986; November 22, 1989; December 1, 1992; May 8, 2001; and August 31, 2002. Two of the Landsat Multispectral Scanner (MSS) images were acquired before the establishment of the Ramsar site, and the remaining images (from the Thematic Mapper on Landsat 5 and Enhanced Thematic Mapper Plus on Landsat 7) were acquired from 1989 to 2002.

Aquaculture was introduced to the area in the early 1980s. Prior to aquaculture, the area was exclusively mangroves and mudflats, with a few farmers engaged in fishing activities. The land-use history is corroborated by studying the time series of satellite images—see **Figure 3**. Note that in the earliest image, acquired in 1975, there are no ponds present. The region is dominated by sand bars which separate the land from the mangroves. By 1986, mangrove extent has increased, as has development along the coast. Further fragmentation is noted by 1989, with significant pond development now evident. By 2002, the entire region is extensively farmed. We used artificial neural networks to classify the images among five classes: mangrove, aquaculture, sand, water, and agriculture [*Seto and Liu*, 2003].

Once we classified the images we looked at how the following four characteristics changed over time at both sites: 1) total mangrove extent; 2) mangrove fragmentation; 3) mangrove density; and 4) aquaculture extent. Our thinking is that if Ramsar is effective in promoting wetlands conservation, there will be slower rates of mangrove conversion, less mangrove fragmentation, higher mangrove density and less aquaculture development in the Ramsar site (XT) than in the non-Ramsar site (TH). Furthermore, we would expect to see a difference in mangrove characteristics for the periods before and after the area was designated a Ramsar site. That is, rates of mangrove conversion, mangrove fragmentation, and aquaculture development are expected to be lower in the period after designation of Ramsar status. Conversely, mangrove density is expected to be greater in the period after Ramsar designation.

To measure mangrove density, we collected values of the *normalized difference vegetation index* (NDVI), a remote sensing derived indicator of vegetation health and density. Values for NDVI range between -1 to +1, with a value close to zero meaning no vegetation and close to +1 indicating a high density of green leaves. We calculate the mean, maximum, minimum, standard deviation, and range of NDVI values for all images for the two sites. Standard deviation of NDVI is used as a proxy of vegetation heterogeneity, while maximum and mean NDVI are proxies of primary productivity [*Seto et al.*, 2004]. Since the reserves are important areas for migratory waterbirds, *wise use* of the XT reserve would be represented in calculated NDVI values. An increase in vegetation heterogeneity is assumed to be positively correlated with bird abundance since waterbirds “rely on specific compositional and structural aspects of vegetation for food, breeding, and shelter.” Hence, for our study, we expect stability in these measures across time with a potential of increases in the mean and maximum value averages across all samples. An increase in NDVI values over time would indicate an increase in vegetation health and heterogeneity, while a decrease in NDVI value would indicate a reduction in vegetation health and heterogeneity.

As another metric for vegetation heterogeneity and health, we calculate a set of *landscape metrics* that measure patch size, patch density, fragmentation, and isolation patterns of the landscape across time. Developed in the field of landscape ecology, landscape metrics are frequently used to quantify landscape structure and spatial configuration. Mangrove ecosystems services also include shoreline stabilization by the reduction of coastal erosion, sediment and nutrient retention, storm protection, flood and flow control and water-quality. We expect to see a less fragmented landscape of mangrove forests associated with *wise use* of the wetland. We use FRAGSTATS [*McGarrigal and Marks*, 1994] for the calculation of a variety of landscape metrics associ-

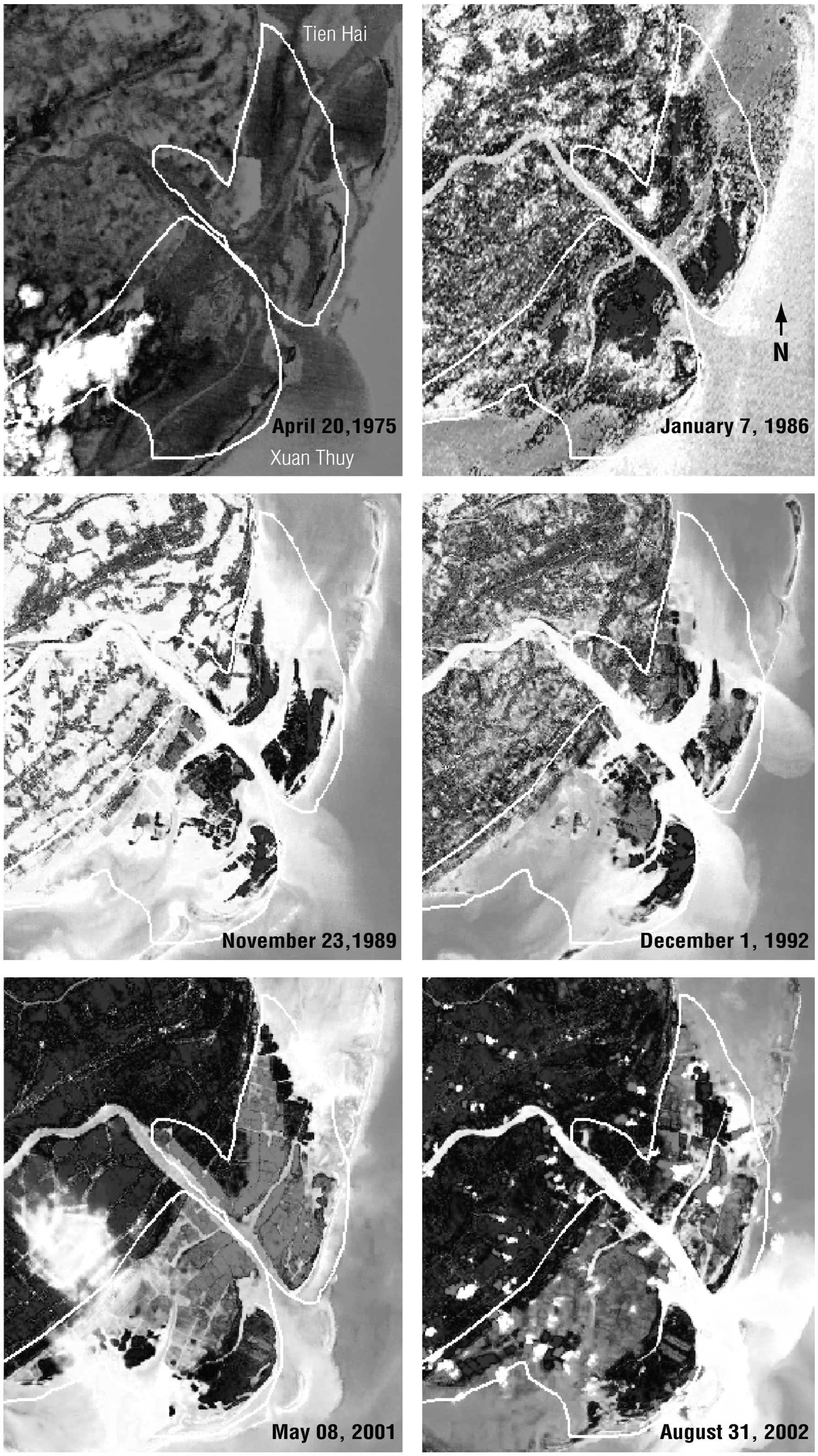

Figure 3. A progression of scenes showing the changes of the study sites from 1975 – 2002 (Landsat TM 432). Areas shown in dark pixels are vegetated. Fragmentation of the mangroves can be detected as early as 1986, with extensive and more evident patterns of aquaculture ponds by 1992.

ated with habitat loss and fragmentation—see **Table 1**. These metrics were calculated for both the mangrove and aquaculture areas.

Table 1. Landscape pattern metrics description. Metrics calculated using FRAGSTATS. Variable and description definition adapted from *McGarigal and Marks* (1994).

Variable	Category	Description
AREA_MN	Size and variability	Mean patch size
AREA_MD	Size and variability	Median patch size
NP	Size and variability	Number of patches
PD	Size and variability	Number of patches per area unit
LPI	Size and variability	Largest patch index—the percent of total area that the largest patch occupies
CONTIG_MN	Fragmentation	Mean patch contiguity (connectedness)
LSI	Shape complexity	Landscape shape index
FRAC_AM	Shape complexity	Area weighted mean patch fractal dimension
ENN_MN	Fragmentation	Average Euclidean nearest neighbor index
ENN_SD	Fragmentation	Standard deviation of distances of patch centers to the center of the nearest neighboring patch

Results and Discussion

The remote sensing analysis shows that there is a discrepancy between the total area extent officially listed as protected versus the area observed from the images—a discrepancy of approximately 43 mi^2 (70 km^2) for the XT Reserve and 49 mi^2 (80 km^2) for the TH Reserve. Unexpectedly, the rate of aquaculture development at the XT Reserve increased after it was declared a Ramsar site (and at a faster rate of growth than in the non-Ramsar TH Reserve).

Fragmentation of the wetlands is noticeable on the 1986 and 1989 images—see **Figure 3**—but aquaculture development during this period was only minimally identified during the image processing. There was no fragmentation of the mangroves evident

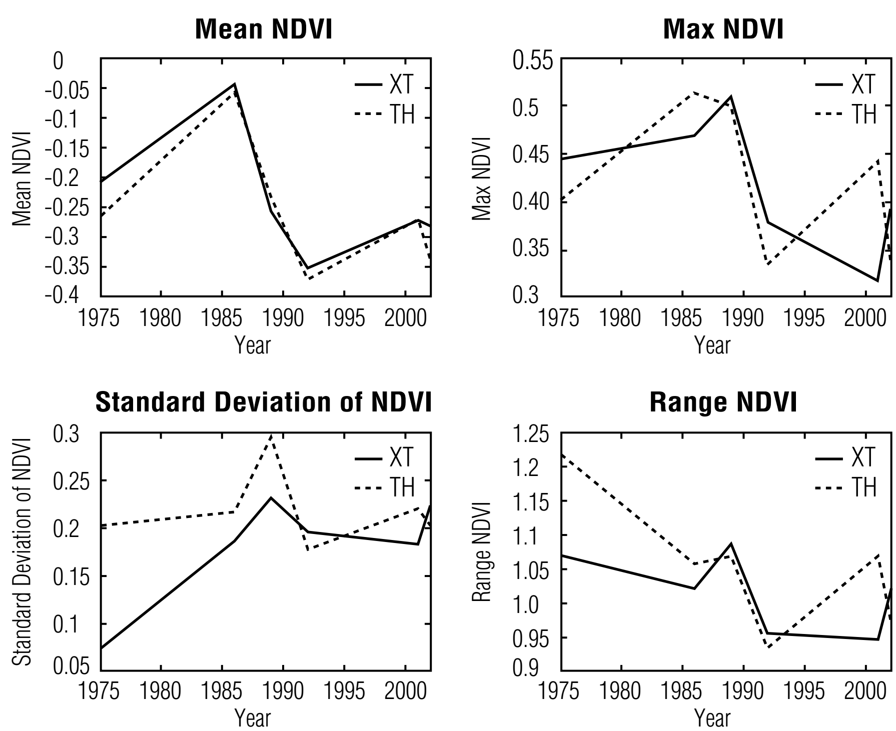

Figure 4. Mean, maximum, standard deviation and range of NDVI values for the TH and XT reserves. Mean and maximum values of NDVI are a proxy for primary productivity. Standard deviation is a proxy for vegetation heterogeneity. [*Seto et. al,* 2004].

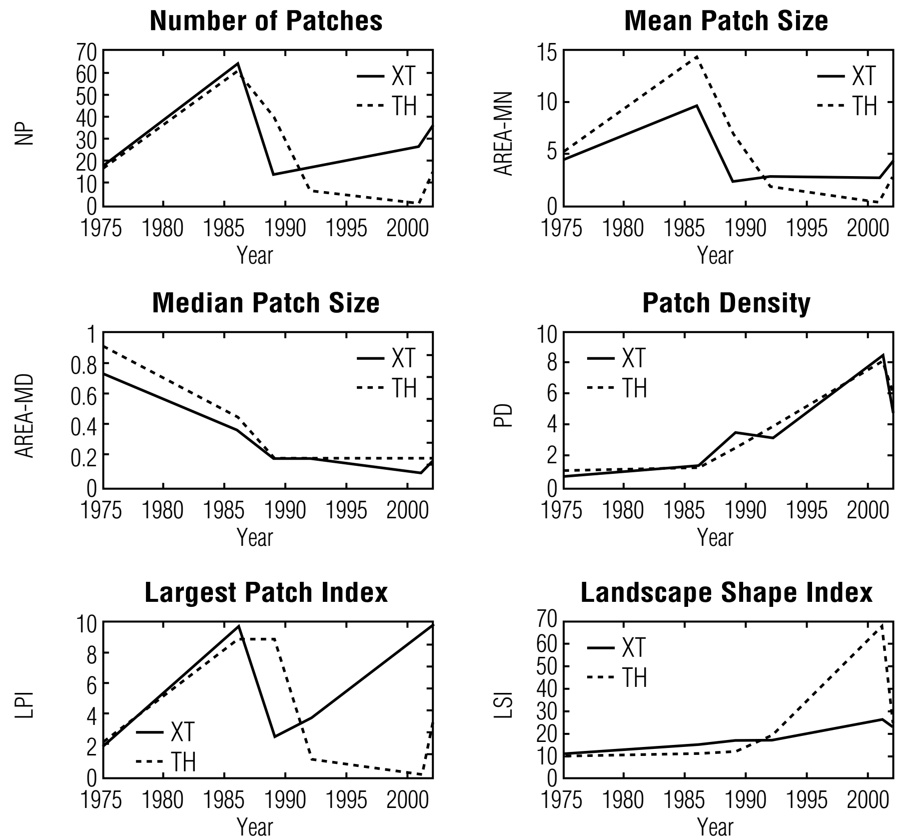

Figure 5. Landscape metrics measuring mangrove patch size, density and shape complexity.

in the 1975 image. Between 1992 and 2002, aquaculture area increased by more than 9-fold in XT and more than 5-fold in TH. Mangrove extent fluctuates significantly during the period 1975 to 2002. Between 1975 and 1986 there was a slight increase in mangrove area to a total of 22 mi^2 (36 km^2). However, by 1992, the first year when aquaculture was clearly evident and three years after Ramsar, total mangrove area drastically declined to 6 mi^2 (10 km^2). Mangrove area, on the other hand, steadily increased in both Reserves between 1992 and 2002. All NDVI measures show significant co-movement and convergence to similar values through time—see **Figure 4**. We interpret this co-movement in values for both sites as an indication of a small effect of Ramsar in promoting mangrove density.

The results of the landscape pattern metrics analysis also reflect increasing fragmentation of the mangroves—see **Figure 5** and **Figure 6**. The mean patch size of the mangrove class (AREA_MN) for both reserves increased between 1975 and 1986 and dropped between 1986 and 1989, just before the XT Reserve was added in the Ramsar list. From then on, it stabilizes until 2001 when we observe a small increasing tendency between 2001 and 2002. The median patch size (AREA_MD) falls throughout the period while it shows a slight increasing tendency during the final years of our sample. Similarly for both reserves, the number of patches (NP) is relatively stable in the 1975–1986 period and steadily increases in the subsequent time periods with a significant drop in the number during the 2001–2002 period. Patch densities (PD) fluctuate during the study period. In XT, the largest mangrove patch (LPI) never surpasses 10% of the total landscape area. A general increase in the number of patches with a falling average and median size is the first sign of an increasingly fragmented environment, although the trend might be reversing. The mangroves are becoming more fragmented over time and there is no significant difference in the distribution and size of mangroves between the Ramsar and non-Ramsar sites.

The measure of mean patch contiguity—or *connectedness*—(CONTIG_MN) shows a continuous drop in its value. The landscape shape index (LSI) steadily increases, an indication of increased shape irregularity/complexity. The area weighted mean patch

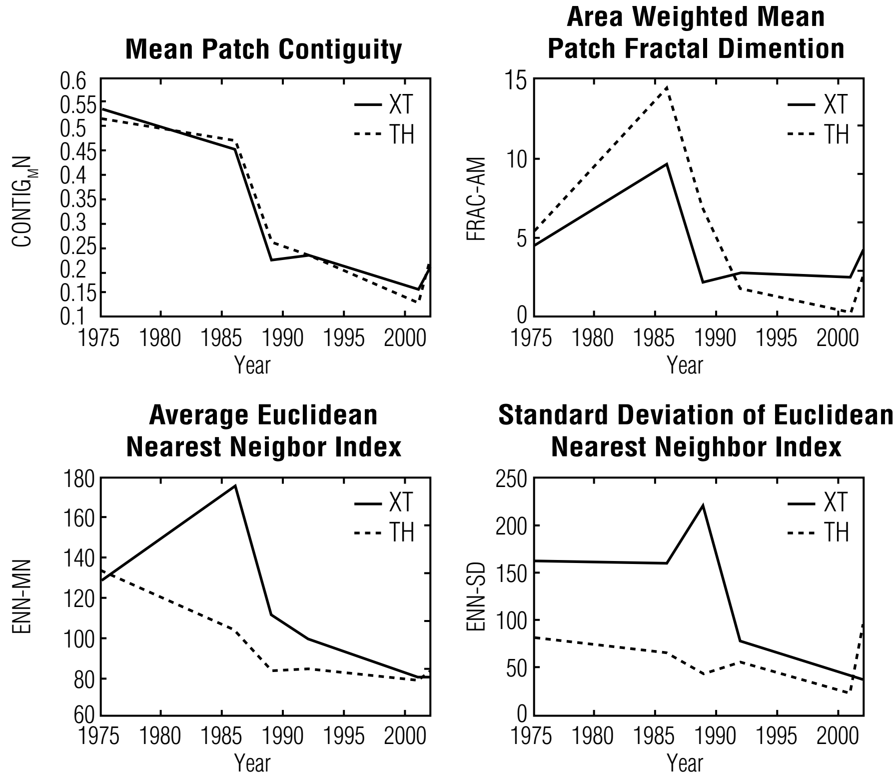

Figure 6. Landscape metrics measuring mangrove contiguity, fractal dimension, and patch distances.

fractal dimension (FRAC_AM) also shows an increasing tendency, although through a cyclical behavior. Overall, the shape complexity of the mangrove land cover increases. Using a proximity/isolation metric, the average Euclidean nearest neighbor index (ENN_MN) steadily decreases for the TH reserve while it increases initially and then also decreases for the XT reserve. The standard deviation of the distances of patch centers to the center of the nearest neighboring patch (ENN_SD) of the class show a declining tendency; patches on average become more concentrated (but not-contiguous) with time.

Conclusions

Using the metric of mangrove extent alone, one may conclude that Ramsar has some effectiveness in encouraging wetland conservation as extent remained relatively constant, primarily due to replanting efforts (but with low survival rates until recently). Using *landscape metric* analysis we observe that despite these restoration efforts (corroborated by field interviews with farmers and local village leaders), patterns of mangrove fragmentation become more dominant during the period 1986–2002 and continued monitoring is required to verify if this trend will continue. Our findings do not show differences in the trajectories of the measures between the XT and TH reserves; the Ramsar Convention did not slow the development of aquaculture in the region. All of the above indicate a minimal effect towards the *wise management* of the wetland ecosystem. Naturally, our results may reflect TH's success as a protected area, rather than Ramsar's failure. However, Ramsar's impact can still be identified through changes in the calculated metrics within site over time. The methodology presented here may not require a control site and it may be more instructive to evaluate changes within a Ramsar site over time.

Although Ramsar has succeeded on several fronts, including placing the rehabilitation of wetlands in public consciousness [*Bowman*, 2003], the effectiveness of Ramsar depends also in quantifiable results such as the health and status of mangroves and the well-being and livelihoods of the people who depend on the resource. **The analysis presented questions the long-term economic sustainability of aquaculture farm-**

ing and the effectiveness of Ramsar to promote *wise use* at Xuan Thuy. As a 'minimal-commitment agreement' [Kline and Raustiala, 2000], the Convention has limited power to affect user behavior that would lead to sustainable use of the mangroves.

The case study presented here demonstrates that with the appropriate satellite record, *in situ* measurements and field observations, remote sensing is a promising technology that can help monitor compliance with international environmental agreements. Successful IEAs require a monitoring process that can evaluate compliance, and parties must agree upon benchmarks and standards for compliance and enforcement. Satellite images can generate a cost effective range of products that can help parties of the agreements set those benchmarks and standards that can be quantitatively and reliably assessed.

Acknowledgements

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continued on page 19

feature articles

Unscrambling the Cause of the Recent Ocean Cooling with Net Radiation Observations from the CERES Instrument on the Terra Satellite

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Scientists soon found CERES readings were breaking new ground in data accuracy. These accurate measurements are essential to climate research, and have been helping scientists answer long-standing questions regarding the radiative effects of clouds and the accuracy of climate models.

When we feel ill, one of the first things the doctor often does when we come in for a visit is to take our temperature. If we are running a temperature, it is a sign that our body is out of balance and the doctor needs to try and diagnose what is wrong with us—i.e., to get us back in balance. Earth scientists look at something similar when they measure the radiation balance at the top of the atmosphere (TOA). The scientists are in effect, "taking the Earth's temperature," as a means of assessing our home planet's health.

In order to maintain a state of climate equilibrium, the total amount of solar energy received by the Earth climate system must be balanced by the emitted thermal energy and the reflected solar energy from the Earth itself. In other words, the net radiation received by the Earth climate system at the TOA must be zero for climate to remain in equilibrium. When the Earth's radiation balance is off, scientists know they need to diagnose the problem—i.e., figure out why the climate is out of equilibrium.

Unlike a physician however, scientists can't take one radiation measurement at one moment in time and get a diagnosis. Readings of net radiation gathered in short time scales are influenced by large local fluctuations in both the energy transport and heat storage capacity of the Earth system and are not reliable for diagnosing climate equilibrium. So, scientists must rely on *global long-term averages* of net radiation.

A physician uses a thermometer to take our temperature. The most reliable tools that a scientist has at his/her disposal to monitor global long-term averages of net radiation at the top of the atmosphere are instruments that continuously look down on the atmosphere from the vantage point of Earth observing satellites. NASA's Earth Radiation Budget Satellite (ERBS) carried the first of three Earth Radiation Budget Experiment (ERBE) instruments into orbit in 1984, and thus began NASA's long record of net radiation balance measurements [*Barkstrom*, 1984]. (The other two ERBE instruments flew on the National Oceanic and Atmospheric Administration (NOAA) weather satellites, NOAA 9 and NOAA 10, launched in 1984 and 1986 respectively.)

In 1997, the first Clouds and the Earth's Radiant Energy System (CERES) instrument launched onboard the Tropical Rainfall Measuring Mission (TRMM) [*Wielicki et. al.*, 1996]. Two CERES instruments also fly on both Terra (1999) and Aqua (2002). CERES measurements continue the record that ERBE measurements began, and are used to monitor the net radiation balance of our planet.

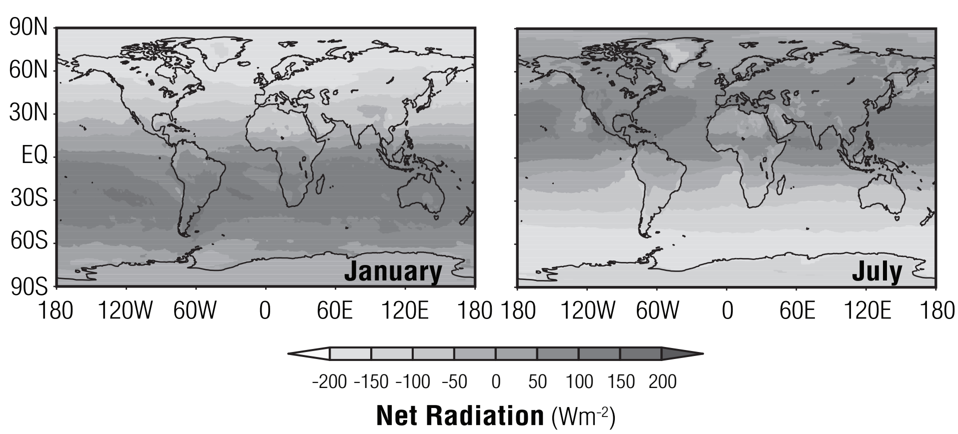

Figure 1. Regional distribution of TOA net radiation from the CERES/Terra instrument for the climatological mean in January and July. Data was collected from March 2000 to February 2003.

Scientists soon found CERES readings were breaking new ground in data accuracy. These accurate measurements are essential to climate research, and have been helping scientists answer long-standing questions regarding the radiative effects of clouds and the accuracy of climate models. With CERES instruments still operational on Terra and Aqua, scientists continue to use the measurements to improve observations of the daily cycle of radiant energy.

Figure 1 is an example of data averaged from CERES instrument readings taken over an extended period of time. The data show the spatial distribution of the TOA net radiation with a large regional imbalance for climatological mean in the months of January and July. Even the global annual mean TOA net radiation can deviate slightly from zero in a given year because there are fluctuations in the global annual mean heat storage (i.e., deep ocean heat storage, melting of ice, and other factors can influence the radiation balance) at an interannual to multi-decadal time scales. Because the ocean heat storage term is a factor of ten or more larger than all other heat storage terms in the energy budget equation [*Levitus et al.*, 2001], the interannual variability of the global annual mean TOA net radiation should, in principle, be reflected in the year-to-year changes of the global annual mean ocean heat storage. This relationship has been confirmed for the first time [*Wong et al.*, 2006] using the satellite observation of TOA net radiation data from both the ERBE and CERES missions and ocean heat storage data from *in-situ* temperature profile sampling [*Willis et al.*, 2004], blended with satellite ocean altimeter observations for the period from 1993 to 2002.

Lyman et al. [2006] recently reported a surprisingly large cooling of the ocean system after 2003. If this much cooling is in fact happening, then it represents a large rapid change in net radiation balance over a short period, and further diagnostic studies are required to understand the exact cause of this change and to find possible "treatments" to this global issue. And if it's happening, it should be reflected in the TOA net radiation observations from the CERES instrument.

Figure 2 shows an extended time series comparison of the 12-month running global mean TOA net flux anomalies from ERBE and CERES for the period from 1993 to 2005 along with the corresponding ocean heat storage estimate for the same period. The interannual TOA net flux anomalies during the first 10 years (1993 to 2002) in **Figure 2** agree well within the ocean heat storage sampling uncertainties, with 1σ differences in the anomalies of 0.4 W/m². This difference is equal to the global mean ocean heat storage annual mean uncertainty [*Willis et al.*, 2004]. The two time series are completely in phase with each other during the first ten years. There are no time lags or leads between the global annual mean TOA net radiation and the ocean heat storage results, as would be expected. This is a remarkable result given the very different nature between ocean heat storage data and Earth's radiation balance datasets. The net flux anomalies within a single decade can be as large as 1.5 to 2.0 W/m² according to both the Earth radiation budget and the ocean storage data.

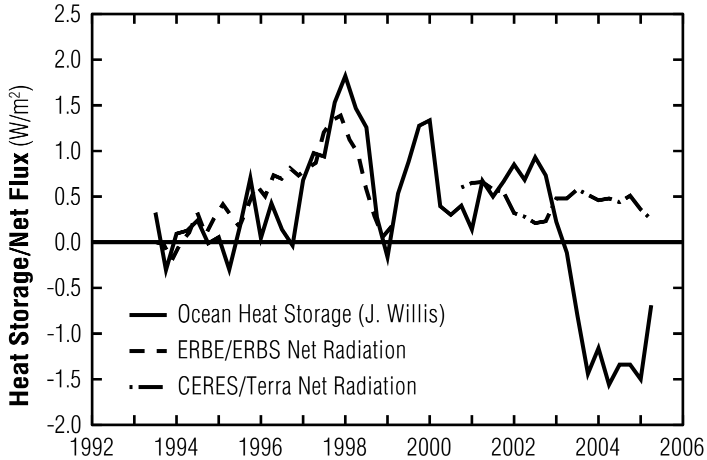

Figure 2. Interannual comparison of global ocean heat storage (solid) against global net flux anomalies from the ERBE/ERBS nonscanner (dashed) and the CERES/Terra instrument (dash-dotted) for the period from 1993 to 2005.

After 2002, however, notice that the data shows surprising differences. The compari-

This study illustrates the important and critical need of multiple independent climate observations to quickly resolve surprising climate change findings.

son in **Figure 2** between the ocean heat storage data and the CERES TOA net radiation data deteriorated with the ocean heat storage data showing a large decrease of up to 1.7 W/m^2 during the period from 2003 to 2005. Because a drop of this magnitude in the ocean heat storage is much larger than the combined uncertainty of both the ocean storage and CERES TOA net radiation data, it should be reflected in the TOA net radiation data. **Yet, the CERES data remained relatively unchanged during the same three-year period.**

So scientists are left with a bit of mystery. **How can two climate datasets that agree so well in the past suddenly have such a large disagreement?** What is causing the large differences in these two datasets? A careful examination of the CERES data shows no data quality issues with the TOA net radiation data so the observed changes in the CERES data appear to be real and further examination is necessary.

To help them figure out what is going on, scientists turned to other satellite observations to see if they could find any other evidence to support this recent cooling trend of the ocean?

Sea level changes respond to cooling and heating of the global ocean system, so such a large cooling ought to be evident in the sea level data. So, the scientists decided to look at sea level data from the Topography Experiment for Ocean Circulation (TOPEX)/Poseidon mission and its follow-on mission, Jason—*sealevel.colorado.edu/current/sl_ib_ns_global.jpg*—to see if there was any decrease in the global annual mean sea level after 2002. **The data suggests that sea level actually continued to rise during this period, which is inconsistent with the recent large ocean cooling.** What could explain this difference?

There are also reports of large glacial melting during this recent period. The scientists wondered if the total volume of fresh water from the melting of these glaciers might be large enough to offset the sea level decrease or thermal contraction of the ocean itself? To answer this question, Wong and his colleagues turned to data on global glacier mass volume from NASA's Gravity Recovery and Climate Experiment (GRACE) mission. **The data from GRACE are generally consistent with the sea-level change observed by satellite altimeter data and do not support a large decrease in ocean heat storage after 2002** [*GRACE team*, personal communication].

So now, the scientists had **three** independent datasets (CERES TOA net radiation, TOPEX and Jason sea level, and GRACE glacier mass volume) that all disagreed with the alleged ocean cooling. This suggests that there may indeed be something wrong with the recent ocean heat storage data.

These findings were enough to convince the scientists who initially reported the ocean cooling [*Willis et al.* (2007)] to go back and closely reexamine the recent ocean heat storage data they had collected. When they did this, they discovered some potential instrument bias problems with the recent dataset, which seem to have resulted from the recent transition of the *in-situ* ocean sounding instruments from the old Expendable Bathythermographs (XBT) system, which has a small warm temperature bias, to the new *Argo* system, which has a small cold temperature bias in a subset of the instruments. The biases from these two *in-situ* instrument systems were large enough to artificially create the spurious cooling trend in the combined time series. **The scientists can now say with confidence that the ocean did <u>not</u> actually experience a large rapid cooling during the 2003 to 2005 period.** The ocean heat storage data are currently being reprocessed to remove this artificial cooling trend in the time series.

This study illustrates the important and critical need of multiple independent climate observations to quickly resolve surprising climate change findings. The CERES, GRACE, TOPEX/Poseidon, and Jason satellite data all played an important role in unscrambling the cause of the recent surprising ocean cooling. Without these three independent sets of observations, it would have been difficult to diagnose what was going on. In the future, independent climate observations such as CERES, GRACE, TOPEX/Poseidon, Jason, and ocean heat storage data should be used in tandem to verify cause and effect and to rule out remaining uncertainties in climate change findings.

Acknowledgments: This work is funded by the NASA Science Mission Directorate through the CERES project at Langley Research Center.

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Using Satellite Remote Sensing to Evaluate the Effectiveness of the Ramsar Convention on Wetlands

continued from page 15

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GRACE Science Team Meeting Summary

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The joint U.S./German [NASA/Deutches Zentrum für Luft und Raumfahrt (DLR)] mission Gravity Recovery And Climate Experiment (GRACE)—*www.csr.utexas.edu/grace*—held its Science Team Meeting October 15-17, 2007. GeoForschungsZentrum (GFZ) Potsdam, Germany is one of the mission partners and hosted the meeting. Due to commonality of goals and themes, this meeting was held jointly with the Deutsche Forschungsgemeinschaft Special Priority Program (DFG-SPP-1257) *Mass Transport and Mass Distribution in System Earth*—*www.massentransporte.de/index.php?id=28&L=1*. The meeting format included oral presentations and accompanying posters on several themes. The meeting program and proceedings are available at—*www.massentransporte.de/index.php?id=gstm07*.

Meeting Opening

Markus Rothacher [GFZ-Potsdam—*GRACE Co-Principal Investigator (PI)*] opened the meeting with a general welcome to the attendees. **Johannes Karte** [DFG] gave the programmatic background for the DFG-SPP. **Karl-Heinz Ilk** [Technical University (TU)-Bonn] coordinator of the SPP-1257 introduced the program, its purpose and goals. He introduced the participating institutions within the Mass Transport Consortium, and described its relationship to other similar programs of geodetic research in Germany.

John LaBrecque [NASA Headquarters] provided a historical perspective on the applications of gravity field, and spoke on the importance of encouraging participation from multi-disciplinary scientists in GRACE-related research. He remarked that GRACE had been awarded the *William T. Pecora Award for 2007* [1]. LaBrecque also announced the selection of the new U.S. Science Team under the NASA/Research Opportunities in Space and Earth Science (ROSES)-2007 call, introduced the investigations, and welcomed the new PIs.

Rune Floberghagen [European Space Agency] provided the ESA/Gravity field and steady-state Ocean Circulation Explorer (GOCE), *www.esa.int/esaLP/LPgoce*, mission status, and announced a launch date of May 15, 2008. He described the GOCE system testing activities underway at ESA/European Space Research and Technology Centre (ESTEC), leading up to Final Acceptance

1 The award was presented to the project at the NASA Town Hall Meeting at the Fall 2007 Assembly of the American Geophysical Union (AGU) in San Francisco).

This is an artist's drawing of the European Space Agency's Gravity Field and Steady State Ocean Circulation Explorer (GOCE) Satellite, which is scheduled to launch in May 2008. GOCE will provide the most accurate measurements of the Earth's gravity field that have been obtained to date. GOCE improves on measurements from the Gravity Recovery and Climate Experiment (GRACE), Challenging Minisatellite Payload (CHAMP), and earlier Gravity Models. **Credit:** ESA/AOES Medialab.

Review in March 2008, followed by transport to Plesetsk Cosmodrome (Russia) for launch. He also noted that the GOCE data calibration/validation campaign assessment would take place some time around January 2009, after which there would be a call for proposals.

Byron Tapley [University of Texas Center for Space Research—*GRACE PI*] presented the GRACE mission status, and announced that—as a result of the 2007 NASA Senior Review—NASA and DLR have both approved funding the GRACE mission until 2009. Tapley also noted that NASA has approved in principle to extend the mission to 2011. He reviewed the importance of a long mission duration for determination of inter-annual and secular changes in the Earth's gravity field, and consequences for sea-level rise measurements. He remarked that the science team should help articulate the consequences of a potential data gap between the GRACE mission and a potential GRACE Follow-On mission (possibly by 2016) as was recommended by the U.S. National Research Council's Decadal Survey for Earth Science. He highlighted the near 100% data recovery status from GRACE, the need for exploring plans for focused GRACE data-user workshops, and expressed a wish for increased cross-mission fertilization to increase multi-disciplinary applications of GRACE.

Joseph Beerer [NASA/Jet Propulsion Laboratory (JPL)—*GRACE Operations Mission Manager*] gave a status report on the ground and flight segments. Beerer noted that the GRACE battery, which shows signs of aging, was a concern. He described the mitigation measures that are being taken to manage the battery lifetime and minimize science data loss. This includes the decision to lower the power consumption on the satellite by lowering the temperatures around the satellite.

Michael Watkins [JPL—*GRACE Project Scientist and Science Data System (SDS) Manager*] gave the SDS status. Watkins reported that the Level-0 to Level-1 processing is now fully automated, and includes data processing and flight data quality monitoring. He also spoke of the status of critical on-board alignments, of the new thermal regime, and surveyed the available Level-2 products from the SDS.

Processing Methods and Validation

These sessions were devoted to the status reports from various groups engaged in extracting mass flux estimates from GRACE data. The GRACE SDS teams from University of Texas-Center for Space Research (UTC-SR), GFZ and JPL presented plans towards assessments of next-generation fields, and on alternative methods of Level-2 processing. In addition to the GRACE SDS, Level-2 analysis efforts were reported by groups at GSFC, Centre National d'Etudes Spatiales (CNES), TU-Bonn, and TU-Delft. All groups are directing efforts towards developing methods to reduce or eliminate the north-south *striping* artifacts, and to improve the spatio-temporal resolution of the products. Methods included the use of multi-scale filters, using Empircal Orthogonal Functions (EOFs) to isolate error modes, and the use of space-localizing basis functions, among others.

An additional topic of discussion was the determination of degree-1 (or geocenter) from other space geodetic methods, since GRACE cannot provide this mode of mass flux, which can have annual signal amplitudes of 10-15 mm of water-layer equivalent. Methods included the use of satellite laser ranging, GPS tracking to low-orbiters, and the inverse methods from a combination of geodetic measurements and geophysical model outputs.

Papers on validation included the use of the terrestrial gravity observations, model outputs, and space-geodetic observations—e.g., Earth rotation.

Oceanography

Several general themes emerged from presentations on GRACE applications to oceanography. These include: comparisons of GRACE measurements to ocean model output; comparisons of GRACE with ocean bottom-pressure measurements; reconciliation of signals between GRACE, radar altimetry (i.e., Jason-1) and drifter *ARGO* measurements; and the prospects for assimilation of GRACE into ocean models.

In comparisons of GRACE with either models or with ocean-bottom pressure measurements, higher correlations were seen at the high latitudes, with GRACE believed to be showing too large a seasonal signal in the tropical oceans.

Oceanography presentations also highlighted that the altimetry, drifter, and GRACE measurements are presently better reconciled with each other on larger spatial scales, with seasonal variations agreeing better than trend estimates. Areas of interest included the global oceans, sub-polar and sub-tropical North Atlantic, the Mediterranean, the Black Sea, etc. Some of the presentations also discussed the role of hydrological contributions to the ocean's mass balance.

Speakers also addressed the trend towards opening up the physics, phenomena, and parameters of the ocean models in response to observations from GRACE. Speakers highlighted contributions from geodesy towards ocean model improvements, and mentioned some of the discrepancies in the contributions from geodetic datasets, in terms of their different impacts on ocean models.

continued on page 23

Eleventh HDF/HDF-EOS Workshop Summary

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The 11th Hierarchical Data Format (HDF) and HDF for the Earth Observing System (HDF-EOS) Workshop took place November 6-8, 2007, at the Raytheon Facility in Landover, MD. Over 75 people attended with varied interests ranging from their perspectives as users, tool developers, and data producers. This year's theme was: ***Connections: Bringing together data users, providers, developers, and stewards***.

The agenda with presentations for all three days can be found at: *www.hdfeos.org/workshops/ws11/agenda.php*. This site also includes posters mentioned below that were presented on the second day of the workshop.

The first day was an HDF/HDF-EOS tutorial session. From The HDF Group (THG), Elena Pourmal, Barbara Jones, Mike Folk, Peter Cao, and Kent Yang provided in-depth information on all aspects of Hierarchical Data Format, Version 5 (HDF5). Tutorials were given on:

- HDF5 data and programming models;
- advanced HDF5 features;
- moving applications to HDF5.1.8;
- caching and buffering in HDF5, HDF5 tools; and
- Network Common Data Form (NetCDF) application development using NetCDF-4 library features based on the underlying HDF5 library and file format.

Abstracts for the tutorials mentioned above can be found at: *www.hdfeos.org/workshops/ws11/abstracts/day1/abstract.php*.

Online help for HDF5 tools can be found at: *www.hdfgroup.org/hdf5tools.html.*

The first day concluded with consulting time where attendees were free to meet with the HDF and HDF-EOS development staff.

The second day was *Status Day*, and was dedicated to talks relating to the status of projects and efforts which make use of HDF or HDF-EOS. Representatives from the Earth Science Data and Information System (ESDIS) Project, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Project Office (IPO), THG and Raytheon gave information on the current state of their development and maintenance efforts.

- **Dan Marinelli** [ESDIS] provided an overview of the Earth Observing System Data Information System (EOSDIS) Status and Developments.
- **Carol Boquist** [ESDIS] provided a summary of the recently concluded 2007 EOSDIS User Survey.
- **Mike Folk** [THG] presented the status of HDF development.
- **Abe Taaheri** [Raytheon/Landover] summarized the state of HDF-EOS development, maintenance, and tools.
- **Richard Ullman** [NPOESS IPO] presented the status of the NPOESS/NPOESS Preparatory Project (NPP) HDF5 file format.
- **Kent Yang** [THG] gave an overview of the software development and maintenance processes at THG that are used to maintain HDF.
- **Jennifer Adams** [Institute of Global Environment and Society Center for Ocean-Land-Atmosphere Studies] discussed supporting HDF5 in their Gridded Analysis and Display System.
- **Peter Cao** [THG] gave a demonstration of a data visualization tool called *HDF-Explorer*.
- **Dave Brown** [National Center for Atmospheric Research] provided an overview of NCAR's geoscience data analysis and visualization tools and their path to HDF5, HDF-EOS5, and NetCDF-4 support.

In addition to these talks, an overview of the HDF-EOS format was provided for users who are new to EOSDIS.

The remainder of the second day was allocated to five-minute poster presentations and then informal *walk-arounds* to view the posters. Poster topics and presenters are listed in the following table.

Poster Topics and Presenters

Topic of Poster	Presenter
HDF5 Support in Database Applications	Mike Folk
"ned"—NPOESS Enhanced Description—A Command Line Tool	Richard Ullman
The HDF-EOS Aura Guidelines—"What's New"	Cheryl Craig
HDF Resources for EOS Users	Carol Boquist

The presentations on the final day focused on Applications and Demonstrations.

- **Ruth Duerr** [National Snow and Ice Data Center] presented the details and status of the HDF Mapping Project, a study that is examining the effort needed to ensure long-term archivability of the HDF data. The intent is to develop tools outside of the HDF library that can use maps of the data to interpret the data.

- **Kent Yang** [THG] gave a project update for the NOAA Science Data Stewardship project and a project update and demonstration of HDF5-Open-source Project for a Network Data Access Protocol (OPeNDAP).
- **Peichuan Li** [George Mason University] provided details on his Implementation of OGC Web Coverage Service Using HDF5/HDF-EOS5 as the Base File Format.

The last two presentations consisted of vendor demonstrations.

- Bill Okubo [ITT Visual Information Solutions] spoke on ENVI/IDL Tools for HDF; and
- Jeff Mather [The Mathworks] presented on Using HDF5 in Matlab.

Before concluding the workshop, the group decided that next year's workshop will take place in the Denver area so that NPOESS/NPP development staff can more easily participate. The dates will be announced in April 2008. Check the EOS Calendar for details.

Program Committee

The following individuals were involved in planning the HDF/HDF-EOS Workshop:

- Dan Marinelli, NASA Goddard Space Flight Center, *daniel.j.marinelli@nasa.gov*
- Carol Boquist, NASA Goddard Space Flight Center, *Carol.L.Boquist@nasa.gov*
- Michael Folk, The HDF Group, *mfolk@hdfgroup.org*
- Richard Ullman, NASA Goddard Space Flight Center, *Richard.E.Ullman@nasa.gov*
- Elena Pourmal, The HDF Group, *epourmal@ncsa.uiuc.edu*
- Kent Yang, The HDF Group, *ymuqun@ncsa.uiuc.edu*
- Ebrahim Taaheri, Raytheon, *Abe_Taaheri@raytheon.com*
- Alan Goldberg, The MITRE Group, *agoldber@mitre.org*

GRACE Science Team Meeting Summary

continued from page 21

Other papers on oceanography addressed the determination of ocean tides using GRACE, and the geodetic contribution of GRACE towards tsunami modeling.

Hydrology

The papers in this session described the results of assimilating GRACE into hydrological models, and as an aid to drought monitoring. The presentations stressed the importance of obtaining accurate trends in river-basin mass balance. The frequency and principal components of the signals within GRACE estimates for hydrological mass flux were characterized. Methods for estimating the mass flux, including filtering effects, were presented.

Other papers described the application of GRACE to water balance and evapo-transpiration studies and identification of transient hydrological events.

Ice Mass Balance and Glacial Isostatic Adjustment

The areas of interest spanned the globe, including Antarctica, Greenland, Fennoscandia, North America, the Alaskan glaciers, and the smaller glaciers in Patagonia, but there were some common findings in each analysis. There is an evident difference between the estimates of secular mass changes in these regions, depending upon the time-series of GRACE gravity fields being used. Two common factors described as adding complexity is the treatment of leakage from nearby hydrological variations (if applicable), and the influence of glacial isostatic adjustment (GIA) corrections that must be applied to gravity in order to extract mass loss estimates. Other related topics of studies included the influence of *a posteriori* error reduction and smoothing of gravity field estimates. Use of forward modeling for localizing gravity signals to independently known geographic bounds was shown to aid the determination of ice-mass trends. Several authors explored the possibility of assimilative interpretation of GRACE for GIA model improvements.

Other Topics

Other topics addressed at the meeting, spanning across all disciplines, included studies of the quality and potential improvements to Level-1 data from GRACE; applications of GRACE data to aeronomy using accelerometry and GPS radio occultations; the potential of GRACE to aid the study of post-seismic trends after the Great Sumatra-Andaman earthquake of 2004; and the prospects for and potential mission design scenario for future solid Earth and gravity field missions.

Summary of the Eighth CERES-II Science Team Meeting

Shashi K. Gupta, Science Systems and Applications, Inc., Shashi.K.Gupta@nasa.gov

The eighth meeting of the Clouds and the Earth's Radiant Energy System (CERES-II) Science Team took place November 12-16, 2007, jointly with workshops on Cloud-Aerosol Feedbacks and Climate, and Aerosol-Cloud Interactions, in Victoria, British Columbia, Canada. **Norman Loeb** [*CERES Co-Principal* Investigator—NASA Langley Research Center (LaRC)] hosted the meeting. The next CERES meeting will be held May 6-8, 2008, in Newport News Virginia.

Major objectives of the meeting included science team review and approval of:

- Terra and Aqua shortwave (SW), longwave (LW), and total channel calibrations for *Edition-3*,
- cloud algorithm development and validation for *Edition-3*,
- production and release of top-of-atmosphere (TOA) and Surface Averages (SRBAVG) monthly products up to December 2005 for both Terra and Aqua, and
- evaluation of the new Modern Era Reanalysis for Research and Applications (MERRA) assimilation product and its influence on cloud properties and fluxes.

In addition to major objectives, the science team also reviewed plans for producing a Level-3 gridded version of the Surface and Atmospheric Radiation Budget (SARB) products; early results from A-Train instruments; comparisons between CERES and Geostationary Earth Radiation Budget (GERB) results; CERES participation in Global Energy and Water-cycle Experiment (GEWEX) Radiative Flux Assessment (RFA) activity; and efforts of the data management group in transitioning CERES processing to commodity cluster-based computing.

Climate Program Overview

Bruce Wielicki [LaRC—*CERES Principal Investigator*] presented an overview of a broad range of topics including the state of the U.S. Climate Change Science Program (CCSP), the Intergovernmental Panel on Climate Change (IPCC), NASA Earth Science, CERES, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), the NPOESS Preparatory Project (NPP), the A-Train, and the National Research Council (NRC) Decadal Study. According to IPCC Assessment Report 4 (AR4), cloud feedback remains the largest uncertainty in climate sensitivity. Aerosol indirect effect remains the largest uncertainty in anthropogenic radiative forcing. Low and high sensitivity models in the AR4 showed similar global mean temperature increases during the next few decades but results diverged greatly beyond 2050. The report of NRC Decadal Survey for Earth Science was out in February 2007 and NASA is committed to follow its overall guidance.

At NASA Headquarters (HQ), Alan Stern is the new Associate Administrator for Space and Earth Science and Mike Freilich is the Director of the Earth Science Division. Don Anderson and Hal Maring are Modeling and Radiation Science leads respectively. Congress is trying to increase the FY2008 budget for Earth Science to address climate issues and start decadal study missions but uncertainties remain. The Senior Review of the CERES program on Terra and Aqua completed during the summer of 2007 went very well. As a result NASA HQ has fixed the 10% funding shortfall in the FY2007 budget and has agreed to fund Terra and Aqua baseline requests for FY2008 and FY2009.

The NASA-NOAA white paper dealing with consequences of dropping climate instruments from NPOESS and the resulting gap-risk in climate data record was submitted to the U.S. Office of Science and Technology Programs (OSTP) and the Office of Management and Budget (OMB) in January 2007. It recommends moving FM-5 to the NPP mission in 2010 and building copies of the CERES instrument for NPOESS flights in 2014 and 2019. Current NASA and NOAA budgets do not include funds for such activities and congressional attempts to increase the FY2008 budget for this purpose face a threat of veto.

Terra/Aqua Instruments and Calibrations

Kory Priestley [LaRC] presented the operational and calibration/validation status of all CERES instruments on Terra and Aqua. With the exception of the SW channel on FM-4, all instruments continue to function nominally. Priestley discussed limitations of *Edition-2* products, improvements being implemented for *Edition-3*, and presented preliminary results from *Edition-3* test runs. Priestly also discussed results of a study of spectral degradation of sensors through contamination, an estimation procedure of gain coefficients for all sensors. FM-1 daytime LW flux showed an anomalous trend relative to nighttime LW flux and also day and night window fluxes. This was most likely caused by residual error in the modeling of SW and total channels.

CERES Cloud Properties

Patrick Minnis [LaRC] presented a summary of Cloud Working Group activities and plans. He presented comparisons of Moderate Resolution Imaging Spectroradiometer (MODIS) *Collection-4* and *Collection-5* data, Goddard Earth Observing System *Version-4* (GEOS-4), and MERRA assimilation products, especially the surface skin temperature. He presented revised calibrations for imaging instruments for use in *Edition-3* processing. Minnis demonstrated the use of Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and CloudSat data for quality assessment of CERES-MODIS cloud products, and showed that differences between them were small. He also listed the changes to be implemented for *Edition-3* processing and showed comparisons of CERES and CALIPSO cloud retrievals.

Simple Surface Fluxes

Shashi Gupta [Science Systems and Applications, Inc. (SSAI)] presented results from the application of a temperature constrainment procedure to all longwave (LW) models used in the Surface-Only Flux Algorithms (SOFA) subsystem for remedying overestimation of downward LW flux (DLF) over dry/arid regions of the globe. Results of sensitivity studies and offline application of this procedure to January and July 2004 data from both Terra and Aqua showed that overestimation was remedied. This procedure will be used for SOFA LW models for CERES Edition-3 processing.

Terra and Aqua SARB Products

Thomas Charlock [LaRC] presented an overview of CERES Surface and Atmospheric Radiation Budget (SARB) products and the effect of applying *Revision-1* correction on SARB results. He also discussed an error afflicting Aqua *Edition-2A* SARB products because of an improper interpolation of MODIS daily average aerosols and its correction in Aqua *Edition-2B* processing. Charlock discussed the effect of applying proposed *Edition-3* calibration changes on SARB products. The bias in SARB SW model results was shown to decrease from 6% to 4%, and bias in outgoing LW radiation (OLR) changed from +2 W/m^2 to -1 W/m^2. He noted a slow trend in the model-observation bias in the five-year (2000-2005) record of Terra data.

David Rutan [SSAI] followed up with a presentation on SARB validation efforts known as the CERES/Atmospheric Radiation Measurement (ARM) Validation Experiment (CAVE). The CAVE website hosts large amounts of ground-based measurements from sites around the globe for validation of satellite retrievals and model products. He presented recently acquired data from two tropical ocean buoy sites and compared SARB footprint level products with them. Rutan also showed comparisons with surface albedo measurements from the Boulder tower.

CERES TISA Activities and Comparisons

David Doelling [SSAI] presented an overview of the activities of the Time Interpolation and Spatial Averaging (TISA) Working Group and demonstrated that using geostationary (GEO) SRBAVG products significantly improves those products as to be appropriate for use in climate change studies. He showed that differences between GEO and non-GEO SRBAVG products can be as large as 20 W/m^2 regionally, even when global averages show little change. Also, GEO SRBAVG products showed no artificial trends. Doelling showed that ephemeris computation in geodetic instead of geocentric coordinates has a significant effect on zonal averages, and outlined a method for closing the net imbalance of global radiation for the use of climate modelers.

Fred Rose [SSAI] presented an overview of improvements implemented in the SARB hourly synoptic products known as SYNI. Improved spectral surface albedos over land, sea ice, and snow surfaces were implemented in the current *Beta-4* version of SYNI processing. *Beta-4* used a new method for creating broadband surface albedo history maps using a weighting for optimal retrieval conditions, and also made changes for simulating *Revision-1* type correction in SW and *Edition-3* type daytime correction in LW for improving SYNI products.

Data Management Status

Erika Geier [LaRC] presented an overview of the status of CERES data processing and outlined plans for *Edition-3* processing. CERES *Edition-2* products are now expected to be extended to December 2007, and may have to be extended further if *Edition-3* processing is delayed. MERRA or its GEOS5-CERES version will be used as meteorological inputs for *Edition-3*. Geier gave a description of all CERES documentation and provided contact information if users had questions or needed help with the use of CERES data.

Jim Closs [Atmospheric Sciences Data Center (ASDC)] presented an overview of the support ASDC provides for CERES. ASDC is responsible for processing, archiving, and distributing CERES data and providing data services to the user community. Closs provided metrics of ASDC activities and a catalog of available CERES products. He also discussed the modernization effort underway at the ASDC including the phasing in of the Archive-Next Generation (ANGe) to replace current archival systems.

Mike Little [LaRC] presented an overview of the transformation underway at the Scientific Computing Facility (SCF). The SCF provides support to scientists and programmers during development of algorithms and codes. Little outlined steps being taken to increase dependability of SCF, provide easier access to sophisticated processing tools, convert scientific codes for little-endian processors, and improve access to data products. Many of these changes are dictated by changing technologies, increased security demands, and the need to use commodity hardware.

GERB Status

Richard Bantges [Imperial College, London] reported on the operational status of the GERB experiment, validation of its scientific products, and comparisons between GERB and CERES products. GERB-1 flying onboard Meteosat-9 is now the prime GERB instrument replacing GERB-2 on Meteosat-8. Bantges described the mechanical problem with the mirror on GERB-1. *Edition-1* Level-1.5 and Level-2 products from GERB-2 are now available though with significant gaps. He outlined plans for producing improved *Edition-2* products. Bantges also presented comparisons of GERB *Edition-1* and CERES *Edition-2* radiances and fluxes for June and December 2004.

CERES Outreach

Norman Loeb [LaRC] reported on the status of the Students' Cloud Observations On-Line (S'COOL) project. The S'COOL database now has more than 65,000 observations from more than 2,400 participants in all 50 states in the U.S. and 73 other countries. More than 28,000 observations are matched with a Terra or Aqua overpass with more than 500 of those matched with both Terra and Aqua at the same time. Loeb urged attendees to participate in S'COOL activities in their own communities.

Invited Presentations

Gerard Roe [University of Washington] made a presentation on serious limitations of the predictability of climate sensitivity which is defined as the surface temperature response to a doubling of carbon dioxide (CO_2). Roe showed climate sensitivities of ensemble runs from *climateprediction.net* and other sources, most of which show probability density functions that peak between 2.0 and 4.5 K with a long tail toward higher values. Refinements of models and the use of larger ensembles over the years have not had much effect on that result. By mapping uncertainties in physical processes on to those of climate sensitivities, he demonstrated that large uncertainty was inherent in a dynamical system with positive feedbacks and it was difficult to control that uncertainty. Roe concluded that narrowing of this uncertainty is not critical to predicting climate change.

George Boer [Canadian Centre for Climate Modeling and Analysis (CCCma)] presented a different approach for estimating climate sensitivity by measuring radiative forcing and the resulting temperature response during volcanic episodes. Radiative forcing by volcanic eruptions of the past was shown to result in a net cooling. Boer performed initial testing of the methodology by examining responses of 2 global models, namely the CCCma Coupled Global Climate Model (CGCM3) and the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM2). The two models showed different radiative forcing but similar temperature response. Boer suggested that future volcanic episodes, readily observable by satellites, provide opportunities for measuring radiative forcing and the temperature response.

Jason Cole [University of British Columbia (UBC)] presented a validation of radiative fluxes and cloud radiative effects (CRE) in CCCma atmospheric GCM (AGCM) simulations using CERES measurements. Cole compared CERES monthly SRBAVG fluxes and clouds data with model results. Five-year monthly global average SW and LW CRE compared well, though zonal averages showed small differences. Model-CERES CRE anomalies in both SW and LW correlated well with corresponding cloud amount anomalies. Comparisons of daily mean model results were also presented. Cole also outlined plans for model improvement by introducing cloud overlap and extending such validation to surface fluxes and diurnal cycle characterization.

Co-Investigator Presentations

Kuan-Man Xu [LaRC] presented the sensitivity of simulations of boundary-layer cloud objects to modifications of input meteorology. The objective was to determine the differences between atmospheric states necessary for simulating stratocumulus and completely overcast cloud objects in the boundary layer. Such cloud objects were identified in CERES single scanner footprint (SSF) data over the southeastern Pacific region. Xu concluded that simultaneous modification of inversion strength and moisture content helps reproduce observed cloud properties of the two object types.

Howard Barker [Environment Canada] presented a study on handling of cloud overlap in radiation computations in GCMs and used Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and CloudSat data for assessing model performance. Barker attempted to estimate the sensitivity of radiative fluxes to cloud overlap and examine the feasibility of developing a simple parameterization. He examined the use of a vertically constant decorrelation length with maximum-random overlap in the models. Barker estimated that LW flux sensitivity to overlap was a factor of 3 smaller than for SW fluxes.

Xiquan Dong [University of North Dakota (UND)] presented comparisons of total cloud fraction, cloud vertical distribution, and surface and TOA radiative fluxes for all months of 2000 made over the ARM Southern Great Plains (SGP) site with radar, lidar, and radiometers, with CERES retrievals, and simulations from three GCMs. Based on comparisons shown, Dong concluded that CERES retrievals of cloud fraction and vertical distribution showed good agreement with ARM data except during January and February, but GCMs showed a varying degree of agreement.

Tom Zhao [NOAA/National Environmental Satellite Data and Information Service (NESDIS)] presented a derivation of aerosol direct radiative forcing (ADRF) distribution over global oceans attributable to individual components based on aerosol optical depths (AOD) from CERES/MODIS SSF data. Partition of total AOD and ADRF was accomplished using information from the Global Ozone Chemistry Aerosol Radiation Transport (GOCART) model. Also, separate estimates of ADRF were reported for natural and anthropogenic sources.

Phil Austin [UBC] presented a case study of satellite retrievals of optical depths and effective droplet radii of nocturnal stratocumulus (Sc) clouds using Bayesian neural network with data taken during the field experiment named Dynamics and Chemistry of Marine Stratocumulus (DYCOMS-II) on July 11, 2001. The cloud field was located off the coast of southern California and contained nocturnal Sc with ship tracks and pockets of open cells. Austin's results demonstrated that a Bayesian neural network was able to retrieve optical depth, top-temperature, and droplet radius for nocturnal Sc clouds.

Shi-Keng Yang [National Centers for Environmental Prediction (NCEP)] substituting for Istvan Laszlo (NOAA/NESDIS) presented comparisons of single-channel (by NESDIS algorithm) and multi-channel (by MODIS algorithm) AODs, both of which are reported on CERES/SSF. Differences between them reported earlier were traced back to small errors in the MODIS algorithm. MODIS retrievals are now based on *Collection-5* data. MODIS Atmosphere Parameters Subset Statistics (MAPSS) datasets over 25 selected ocean locations were used. The two products show good agreement now despite substantial differences between algorithms.

Man-Li Wu [Global Modeling and Assimilation Office (GMAO)] presented an overview of GEOS-5 processing at GMAO and comparisons of GEOS-5 products with other independent datasets. Wu reported that the External Users Group has approved the current version of GEOS-5 for producing MERRA datasets. She showed good agreement for precipitable water (PW) with Special Sensor Microwave/Imager (SSM/I) data, for clear-sky OLR with CERES data, and ozone profiles for January and July 2004. A special stream with restricted inputs, named GEOS5-CERES, will be provided for use in CERES processing.

Shi-Keng Yang [NCEP] outlined plans for introducing several cloud and radiation parameters in the new Climate Forecast System Reanalysis and Reforecast products. The main objective of the new system would be to provide a database for forecast calibration in the future and its main components will provide reanalysis for 1979–2007 and reforecasts for 1981–2007. The new model will combine physics from the current Global Forecast System (GFS) and Climate Forecast System (CFS). It will use the Rapid Radiative Transfer Model (RRTM) for both SW and LW radiation and maximum-random overlap for clouds.

Bing Lin [LaRC] presented a study of the variability of radiative properties and effects of different cloud types as observed in CERES data over a three-year period (January 2003–December 2005). Radiative effects of the same types of clouds were very different for different regions but very similar within the same boreal season despite cloud amount differences. Interannual differences of liquid water path (LWP) for marine stratocumulus and ice water path (IWP) for anvils were quite small. Anvils within North Atlantic storm tracks showed the largest seasonal variability.

Seiji Kato [SSAI] presented an analysis of the standard deviation of monthly anomalies of TOA SW and LW fluxes derived from CERES measurements from March 2000 to February 2004. Largest SW and LW anomalies were shown to occur over the western and central Pacific during El Niño/Southern Oscillation (ENSO) episodes. TOA net flux anomalies over these regions were relatively small because of the cancellation of SW and LW effects. Largest net flux anomalies occurred over the eastern subtropical Pacific and off the coast of the Antarctic peninsula.

Lou Smith [National Institute of Aerospace (NIA)] made a presentation on the use of point spread function (PSF)-weighted MODIS bidirectional reflectances for the validation of GERB/CERES TOA radiances and fluxes over the Valencia Anchor Station (VAS) area. Model computations using site-measured inputs over the VAS area were calibrated using CERES radiances obtained from an instrument operating in Programmable Azimuth Plane Scanning (PAPS) mode. The calibrated model was then applied for validating GERB retrievals over the same area.

Takmeng Wong [LaRC] presented an update on the recovery effort for Earth Radiation Budget Satellite (ERBS) non-scanner SW data for the October 1999 to August 2005 period when the instrument got stuck off the Earth-viewing nadir direction. The efforts comprised of determining the instrument tilt-angle, re-establishing the calibration, and correcting SW fluxes for effects of the instrument tilt. Initial results of this effort are very encouraging and further efforts are underway for validating these data before releasing them to the user community.

Fu-Lung Chang [NIA] presented an improved method for retrieving multi-layer cloud properties that will be used for CERES *Edition-3* processing. The method makes use of cloud heights retrieved for upper and lower layers from 11 and 13.3 µm radiances. This method can be applied to individual MODIS pixels without using information from neighboring pixels. Chang presented examples of multi-layer retrievals from CERES/MODIS and geostationary satellite data and validation of results using CALIPSO and CloudSat data.

Zhonghai Jin [SSAI] presented tests of a two-layer snow-grain size retrieval algorithm over the Antarctic plateau using comparisons with MODIS/CERES radiances for validation. Variation of top-layer grain sizes was large within every season but small from year-to-year. Sizes for the lower layer were larger but showed no variation. Spectral and broadband radiances simulated with these snow-grain sizes showed good agreement with MODIS and CERES measurements. Broadband SW albedo over the Antarctic plateau showed approximately 5% variation during a year.

David Young [LaRC] presented an overview of requirements development and definition type early studies for the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission which was identified as one of the highest priority missions in the NRC Earth Science Decadal Survey. The overarching objective of this mission is to characterize long-term trends in key climate variables with the goal of improving climate prediction accuracy. This mission is seen as the next step in climate monitoring using newest calibration technology to provide in-orbit traceable calibrated radiances in visible, IR, and for the Global Positioning System (GPS).

Seiji Kato [SSAI] gave a status report on the merged CALIPSO-CloudSat-CERES-MODIS (C3M) product being developed under a project funded by the NASA Energy and Water-cycle Study (NEWS) program. Up to 15 cloud and aerosol profiles from CALIPSO and CloudSat, along with similar profiles from all 1-km MODIS pixels along the groundtrack are grouped with a CERES footprint for computing detailed radiation profiles within each. Kato discussed strengths and weaknesses of different components and how they complement one another.

Takmeng Wong [LaRC] presented an update on GEWEX-RFA activities since the last CERES Science Team Meeting. He presented several sets of results contributed by participants at the Third RFA Workshop held at NASA/Goddard Institute for Space Studies (GISS) in June 2007. Efforts in the near future will be focused on data analysis, intercomparison of datasets, and error assessment followed by the assembly of a draft report from participant contributions. A first draft of the report is expected in January 2008.

Laura Hinkelman [University of Washington] presented an assessment of the effect of geostationary artifacts in International Satellite Cloud Climatology project (ISCCP) cloud data on surface fluxes of the NASA/GEWEX Surface Radiation Budget (SRB) project. The assessment found that while ISCCP cloud data show strong geostationary artifacts, GEWEX/SRB SW fluxes derived using those clouds show much smaller artifacts because of mitigation by other factors involved in flux retrievals. Hinkelman recommended several steps for improving ISCCP clouds.

Steven Dewitte [Royal Meteorological Institute of Belgium (RMIB)] presented the first climate results from the GERB project showing strong cooling over Sahara and stratocumulus regions. Dewitte presented 12-month temperature records for Uccle, Belgium for three different periods which showed anomalous warming and a strong correlation of the same with radiation budget anomalies during 2006-2007. He also discussed future plans for radiation budget measurements in Europe and cooperative work with Chinese scientists on the Chinese radiation budget instrument being readied for launch in the near future.

ADM/Inversion Working Group

Norman Loeb [LaRC] led the Angular Distribution Models (ADMs) Working Group discussions. **Steve Hudson** [University of Washington] presented comparisons between CERES permanent snow ADMs with model calculations initialized with surface bidirectional reflectance measurements at Dome C in East Antarctica. Results showed that CERES ADMs represented Dome C data very well. **Lou Smith** [NIA] presented an optimization technique whereby observed CERES fluxes were adjusted for eliminating the TOA net flux imbalance. **Nitchie Manalo-Smith** [SSAI] presented an investigation of the differences between monthly average CERES/FM-1 TOA fluxes from current *Edi-*

tion-2 Revision-1 and *Edition-3* test results for cloud-free conditions. Differences over all surface types were less than 1.5% except for ice surfaces where they were greater than 2%.

SARB/SOFA Working Group

Thomas Charlock [LaRC] led the SARB/SOFA Working Group discussions. **Steve Warren** [University of Washington] discussed a methodology for validation of CERES calibration and ADMs over snow-ice surfaces using surface-based measurements from the Dome C site on East Antarctic plateau. He presented snow albedo as a function of solar zenith angle, spectral albedo of snow, and comparisons of CERES ADMs with model results. Albedo differences were discussed as a potential source contributing to the CERES net flux imbalance. **Fred Rose** [SSAI] discussed surface albedo retrieval in SARB processing and the creation of surface albedo history maps.

Cloud Working Group

Patrick Minnis [LaRC] led the Cloud Working Group discussions. **Xiquan Dong** [University of North Dakota] presented comparisons of CERES cloud property retrievals over the ARM North Slope of Alaska (NSA) site with those measured at the site during the Mixed-Phase Arctic Clouds Experiment (M-PACE) field campaign of October 5-14, 2004. CERES retrieved particle sizes were reported to be 4-5 micrometer smaller and optical depths 5-6 smaller than the measured values.

Patrick Minnis [LaRC] discussed issues arising from the work of several cloud working group members. Terra MODIS was found to be 1% brighter in the visible (0.63 μ) channel than Aqua and provides better optical depths. Aqua radiances will be normalized to Terra values. Issues related to deficiencies in lapse rate data, CERES retrieved total cloud amount, and cloud thickness were also discussed.

KUDOS

The Earth Observer staff would like to recognize the following three accomplishments.

Winnie Humberson, Task Lead for the EOS Project Science Office Support Task, received an *RSIS President's Award* on December 15, 2007, recognizing her tireless efforts to promote the activities of NASA's Science Mission Directorate and the Earth Observing System Project Science Office. Humberson's work has made the EOSPSO well known throughout the SMD.

Ron Trowbridge, Winnie Humberson, and Rodney Hunt

George W. Morrow, Jr. was among 333 Federal executives selected to receive a 2007 Presidential Rank Award. Morrow is currently Director of the Flight Projects Directorate at Goddard but previously served as Project Manager for Aqua from 1998-2001, and was responsible for all aspects of the development, test, and launch of Aqua. Morrow received the *Meritorious Executive* award. To learn more about Presidential Rank Awards, please visit: *www.opm.gov/ses/presrankaward.asp*.

George Morrow

The Gravity Recovery and Climate Experiment (GRACE) Mission was awarded the Pecora Group Award at the American Geophysical Union Fall Meeting on December 10, 2007, in San Francisco, CA. The award recognized GRACE for the design, development, and successful operation of a new satellite-based measurement of the Earth's gravity resulting in significant contributions to the understanding of the changing global environment. To learn more details on the William T. Pecora award please visit: *remotesensing.usgs.gov/pecora.php*.

Congratulations to Humberson, to Morrow, and to everyone involved in the GRACE mission.

NASA-Conceived Map of Antarctica Lays Ground for New Discoveries

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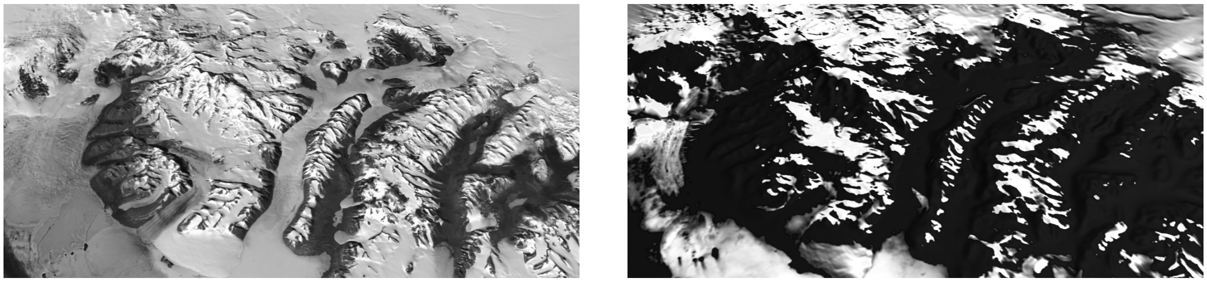


The images above show a comparison of the same Antarctic scene from two different NASA remote sensors, the Enhanced Thematic Mapper Plus (ETM+) sensor aboard the Landsat 7 satellite on the left, and the MODIS instrument on the Terra and Aqua satellites in lower resolution on the right. **Credit:** (right:) NASA; (left:) USGS

On November 27, a team of researchers from NASA, the U.S. Geological Survey, the National Science Foundation and the British Antarctic Survey unveiled a newly completed map of Antarctica that is expected to revolutionize research of the continent's frozen landscape.

The Landsat Image Mosaic of Antarctica (LIMA) is a result of NASA's state-of-the-art satellite technologies and an example of the prominent role NASA continues to play as a world leader in the development and flight of Earth-observing satellites.

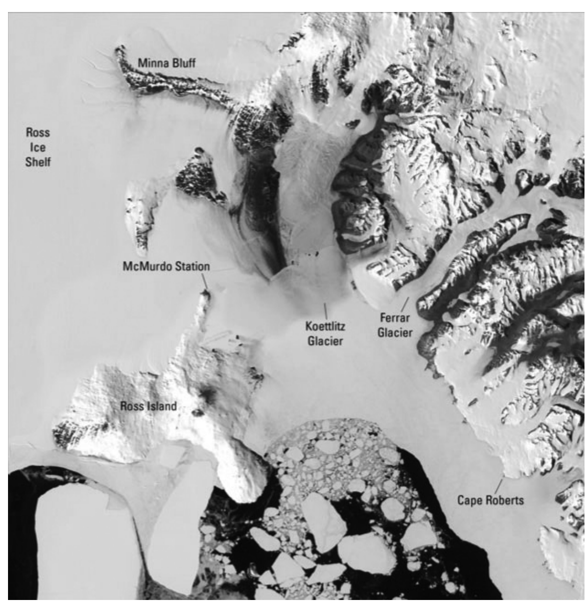
The map, created with images captured by the NASA-built Landsat 7 satellite, is a realistic, nearly cloudless satellite view of the continent at a resolution 10 times greater than was previously possible. With the unprecedented ability to see features half the size of a basketball court, the mosaic offers the most geographically accurate, true-color, high-resolution views of Antarctica possible.

"This mosaic of images opens up a window to the Antarctic that we just haven't had before," said **Robert Bindschadler**, chief scientist of the Hydrospheric and Biospheric Sciences Laboratory at NASA's Goddard Space Flight Center. "It will open new windows of opportunity for scientific research as well as enable the public to become much more familiar with Antarctica and how scientists use imagery in their research. This innovation is like watching high-definition TV in living color versus watching the picture on a grainy black-and-white television. These scenes don't just give us a snapshot, they provide a time-lapse historical record of how Antarctica has changed and will enable us to continue to watch changes."

Researchers can use the detailed map to better plan scientific expeditions. The mosaic's higher resolution gives researchers a clearer view over most of the continent to help interpret changes in land elevation in hard-to-access areas. Scientists also think the true-color mosaic will help geologists better map various rock formations and types.

To construct the new Antarctic map, researchers pieced together more than a thousand images from three years of Landsat satellite observations. The resulting mosaic gives researchers and the public a new way to explore Antarctica through a free, public-access Web portal—*lima.usgs.gov/*. Eight different versions of the full mosaic are available to download.

In 1972, the first satellite images of the Antarctic became available with the launch of NASA's Earth Resources Technology Satellite (later renamed Landsat). The series of Landsat satellites have provided the longest,



As can be seen in this sample Landsat image of the area around McMurdo Station, the new mosaic reveals in unprecedented detail the ice shelves, mountains, and glaciers that make Antarctica a fascinating and important place to study. **Credit:** USGS.

continuous global record of land surface and its historical changes in existence. Prior to these satellite views, researchers had to rely on limited coverage from airplanes and survey ships to map Antarctica's ice-covered terrain. Satellites have revolutionized the way we view the vast frozen land at the bottom of the world.

Images from the Landsat program, now managed by the U.S. Geological Survey, led to more precise and efficient research results as the resolution of digital images improved over the years with upgraded instruments on each new Earth-observing satellite.

We have significantly improved our ability to extract useful information from satellites as embodied in this Antarctic mosaic project," said **Ray Byrnes**, liaison for satellite missions at the U.S. Geological Survey. "As technology progressed, so have the satellites and their image resolution capability. The first three in the Landsat series were limited in comparison to Landsats 4, 5, and 7."

Bindschadler, who conceived the project, initiated NASA's collection of images of Antarctica for the mosaic project in 1999. He and NASA colleagues selected the images that make up the mosaic and developed new techniques to interpret the image data tailored to the project. The mosaic is made up of about 1,100 images from Landsat 7, nearly all of which were captured between 1999 and 2001. The collage contains almost no gaps in the landscape, other than a doughnut hole-shaped area at the South Pole, and shows virtually no seams.

"The mosaic represents an important U.S.-U.K. collaboration and is a major contribution to the International Polar Year," said **Andrew Fleming** of British Antarctic Survey. "Over 60,000 scientists are involved in the global International Polar Year initiative to understand our world. I have no doubt that polar researchers will find this mosaic, one of the first outcomes of that initiative, invaluable for planning science campaigns."

Related Links:

Landsat Image Mosaic of Antarctica: *lima.usgs.gov/*

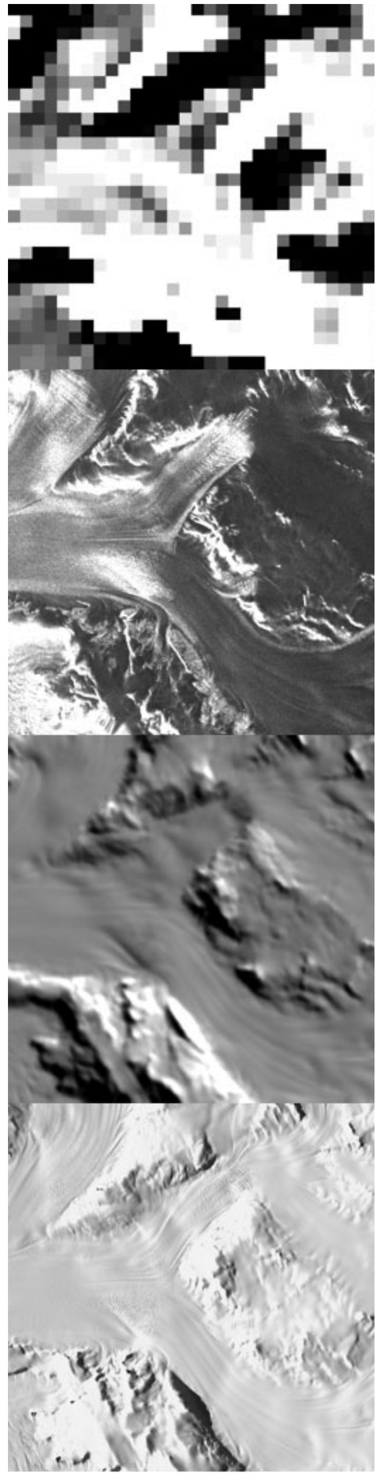
LIMA Press Conference: *www.nasa.gov/vision/earth/lookingatearth/lima_press_conf.html*

LIMA Homepage: *lima.nasa.gov/*

LIMA Animations: *svs.gsfc.nasa.gov/vis/a000000/a003400/a003482/*

NASA & the International Polar Year: *www.nasa.gov/mission_pages/IPY/main/index.html*

U.S. International Polar Year (2007-2008): *www.ipy.gov/Default.aspx*



AVHRR
1000 m pixels

Date: 1996

Radarsat
25 m pixels

Date: 1997

MODIS
175 m pixels

Date: 2006

Landsat
15 m pixels

Date: 2007

The enhanced resolution of the new mosaic map (bottom image) is shown in comparison to three previous Antarctic mosaics. Each pixel from the new mosaic is roughly half the size of a basketball court. In comparison, an earlier satellite mosaic created in 1996 from the Advanced Very High Resolution Radiometer (top image) had pixels a little more than twice the size of Vatican City. **Credit:** NASA

NASA Sees Arctic Ocean Circulation Do an About Face

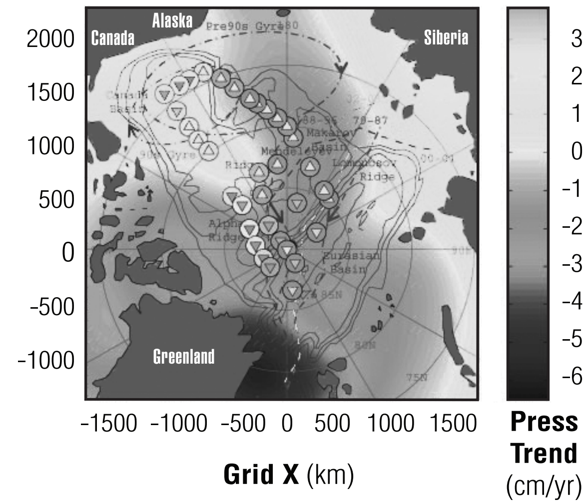
Alan Buis, NASA Jet Propulsion Laboratory, Alan.buis@jpl.nasa.gov

A team of NASA and university scientists has detected an ongoing reversal in Arctic Ocean circulation triggered by atmospheric circulation changes that vary on decade-long time scales. The results suggest not all of the large changes seen in Arctic climate in recent years are a result of long-term trends associated with global warming.

The team, led by **James Morison** of the University of Washington's Polar Science Center Applied Physics Laboratory, used data from an Earth-observing satellite and from deep-sea pressure gauges to monitor Arctic Ocean circulation from 2002 to 2006. They measured changes in the weight of columns of Arctic Ocean water, from the surface to the ocean bottom. That weight is influenced by factors such as the height of the ocean's surface, and its salinity. A saltier ocean is heavier and circulates differently than one with less salt.

The very precise deep-sea gauges were developed with help from the National Oceanic and Atmospheric Administration; the satellite data is from NASA's Gravity Recovery and Climate Experiment (GRACE). The team of scientists found a 10-mb decrease in water pressure at the bottom of the ocean at the North Pole between 2002 and 2006, equal to removing the weight of 4 in (10 cm) of water from the ocean. The distribution and size of the decrease suggest that Arctic Ocean circulation changed from the counterclockwise pattern it exhibited in the 1990s to the clockwise pattern that was dominant prior to 1990.

Reporting in *Geophysical Research Letters*, the authors attribute the reversal to a weakened Arctic Oscillation,



This figure shows contours of the trend in ocean bottom pressure from 2002 to 2006 as measured by GRACE along with hypothetical trends that would apply at the circles if ocean salinity reverted from 1990s values to climatological conditions over the same period. To view this figure in color go to: *www.nasa.gov/images/content/199332main_ipy20071113-2-browse.jpg*

a major atmospheric circulation pattern in the northern hemisphere. The weakening reduced the salinity of the upper ocean near the North Pole, decreasing its weight and changing its circulation.

"Our study confirms many changes seen in upper Arctic Ocean circulation in the 1990s were mostly decadal in nature, rather than trends caused by global warming," said Morison.

"While some 1990s climate trends, such as declines in Arctic sea ice extent, have continued, these results suggest at least for the 'wet' part of the Arctic—the Arctic Ocean—circulation reverted to conditions like those prevalent before the 1990s," he added.

In addition to satellite data from NASA's GRACE mission, the scientists used measurements from Arctic Bottom Pressure Recorders deployed to the Arctic Ocean floor to monitor changes in Arctic Ocean circulation.

The Arctic Oscillation was fairly stable until about 1970, but then varied on more or less decadal time scales, with signs of an underlying upward trend, until the late 1990s, when it again stabilized. During its strong counterclockwise phase in the 1990s, the Arctic environment changed markedly, with the upper Arctic Ocean undergoing major changes that persisted into this century. Many scientists viewed the changes as evidence of an ongoing climate shift, raising concerns about the effects of global warming on the Arctic.

In addition to satellite data from NASA's GRACE mission, the scientists used measurements from Arctic Bottom Pressure Recorders deployed to the Arctic Ocean floor to monitor changes in Arctic Ocean circulation. **Credit:** NASA/JPL.

Since publication of the paper earlier this year, Morison said data gathered by GRACE and the bottom pressure gauges highlight how short-lived the ocean circulation changes can be. The newer data indicate the bottom pressure has increased back toward its 2002 level. "The winter of 2006-2007 was another high Arctic Oscillation year and summer sea ice extent reached a new minimum," he said. "It is too early to say, but it looks as though the Arctic Ocean is ready to start swinging back to the counterclockwise circulation pattern of the 1990s again."

Morison cautioned that while the recent decadal-scale changes in the circulation of the Arctic Ocean may not appear to be directly tied to global warming, most climate models predict the Arctic Oscillation will become even more strongly counterclockwise in the future. "The events of the 1990s may well be a preview of how the Arctic will respond over longer periods of time in a warming world," he said.

GRACE monitors tiny month-to-month changes in Earth's gravity field caused primarily by the movement of water in Earth's land, ocean, ice and atmosphere reservoirs. As such it can infer changes in the weight of columns of ocean water. In contrast, the pressure gauges installed on the sea floor in 2005-2006 directly measured water pressure at the bottom of the ocean. Gauge data were remotely recovered during the first year of the study.

"The close agreement between the North Pole pressure gauges and GRACE data demonstrates GRACE's potential for tracking world ocean circulation," said study co-author **John Wahr** of the University of Colorado, Boulder.

"Satellite altimeters, such as NASA's Jason, are ideal for studying ocean circulation but can't be used at Earth's poles due to ice cover," said study co-author **Ron Kwok** of NASA's Jet Propulsion Laboratory. "Our results show GRACE can be a powerful tool for tracking changes in the distribution of mass in the Arctic Ocean, as well as its circulation."

The study was funded by the National Science Foundation.

Other media contacts for this study include: Peter West, National Science Foundation, Arlington, Va., 703-292-7761, *pwest@nsf.gov*; and Jim Scott, University of Colorado, 303-492-3114, *Jim.Scott@colorado.edu*.

Correction

Volume 19, Issue 6, Page 35. The acronym ACCESS was incorrectly defined as: Advancing Connections for Earth *Space* Science. The correct definition should have read: Advancing Connections for Earth *System* Science. The *Earth Observer* staff regrets any confusion this may have caused.

NASA Langley Celebrates CERES Project Anniversary

Denise M. Stefula, NASA Langley Research Center, Denise.M.Stefula@nasa.gov

A NASA mission that studies the Earth's energy balance, which controls the planet's temperature and climate, observed the tenth anniversary of the launch of its first instrument with a celebration on November 27 at Langley Research Center.

The Clouds and the Earth's Radiant Energy System (CERES) satellite mission team was recognized for its important contribution to monitoring the *Earth's radiation budget*, which determines Earth's temperature and drives the climate system.

CERES data are providing a sound basis for research on the global climate system. Conclusions based on CERES data are giving us a better understanding of global climate change. These findings are informative for the public and policymakers alike.

"The CERES data represent an entirely new generation of climate data accuracy and integration, both of which are critical to accurately predict future climate change," says **Bruce Wielicki**, the mission's Principal Investigator. "The CERES instrument, data and science teams have done an incredible job of bringing all of this together over the last 10 years."

The celebration included keynote speakers to honor the team's work. Langley Center Director **Lesa Roe** led them by heralding CERES program accomplishments. She also cited the Earth Science Decadal Survey's call to action for the scientific community, saying, "This challenge is the largest we face. The work done on CERES is an answer to the decadal survey call."

Langley's lead position in the CERES mission offered its team many occasions to step up to the decadal survey challenge. "Thanks to Langley for opportunities of intellectual growth" that working on the team provided, added **Don Anderson**, a NASA Headquarters Program Manager.

Bruce Wielicki [LaRC] consults with other "PIz R Us" team members to decide the response to one of the *Jeopardy* clues. At stake was "millions of dollars" for future unknown proposals. **Credit:** Sean Smith.

Don Anderson [NASA HQ] was one of the keynote speakers at the CERES 10th Anniversary. He said working with CERES teams offered "opportunities of intellectual growth." **Credit:** Sean Smith.

Lelia Vann, Director of the Science Directorate at Langley, commended the hard work put into the project: "We are here to celebrate the teamwork that brought us to this point and that makes us so successful. CERES work is first rate."

Wielicki's speech noted important changes in public opinion in just the last few years. Most important is that global warming has recently received greater international recognition; for example, a Nobel Peace Prize was presented jointly to climate change scientists and proponents earlier this year. (See the news story on page 36 of this issue for more details.)

After keynotes, a rousing game of team-style *Jeopardy* challenged data specialists, retirees, and principal investigators on CERES facts and had the audience laughing. Maracas rattled, whistles blew and cow bells clanged as teams "rang in" to win "millions of dollars" for future unknown proposals.

The social segment began with a toast from Wielicki, who raised his glass to celebrate the team, project accomplishments, the milestone of 10 years and the future of climate data research.

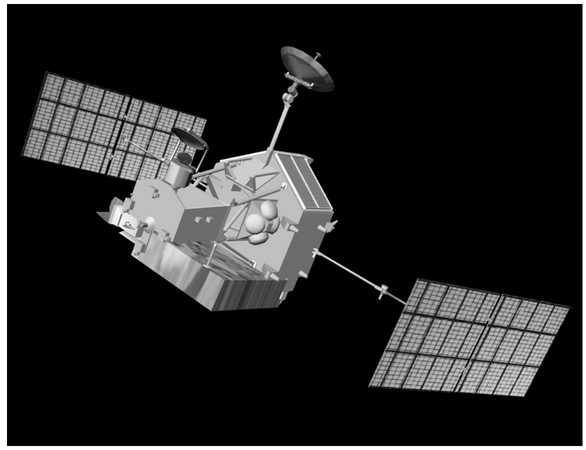
Smaller Storms Drop Larger Overall Rainfall in Hurricane Season

Gretchen Cook-Andersen, NASA Goddard Space Flight Center, Gretchen.R.Cook-Anderson@nasa.gov

Researchers have found that when residents of the U.S. southeastern states look skyward for rain to alleviate a long-term drought, they should be hoping for a tropical storm over a hurricane for more reasons than one. Not only do the tropical storms tend to be less destructive, but according to a new study using NASA satellite data, smaller tropical storms do more to alleviate droughts than hurricanes do over the course of a season by bringing greater cumulative rainfall.

A new study provides insight into what kind of storms are best at tackling drought in the southeastern United States. The study focuses on a decade of first-ever daily rainfall measurements by the Tropical Rainfall Measuring Mission (TRMM)—a NASA satellite carrying a weather radar in space. The study's authors believe the same insights can be applied by meteorologists and public officials to other regions where daily satellite rainfall data and storm tracking data are available.

In the wake of Hurricane Katrina, meteorologist **Marshall Shepherd**, an associate professor of geography and atmospheric sciences at the University of Georgia, Athens, and colleagues delved into the ongoing debate about whether global warming is leading to an increase in rainfall intensity. The researchers wanted to determine how much rainfall each type of cyclone, from tropical depressions to Category 5 hurricanes, contributes to overall rainfall. They focused the study on the



From its low-earth orbit, NASA's Tropical Rainfall Measuring Mission satellite has been providing valuable information on rainfall using a combination of passive microwave and active radar sensors, including the first precipitation radar in space. **Credit:** NASA

Tropical Storm Barry, a weak tropical depression, brought much-needed rain to Florida and parts of the southeast in June 2007, a region suffering from severe drought. NASA's Tropical Rainfall Measuring Mission satellite captured the intensity of the storm's rainfall on June 2. For full color image see: *www.nasa.gov/mission_pages/hurricanes/archives/2007/smallstorm_largerain.html* **Credit:** NASA

Southeast in the hope that results could be harnessed to improve drought relief information for the region. Their findings were published in the American Geophysical Union's *Geophysical Research Letters*.

"As much of the Southeast experiences record drought, our findings indicate that weak tropical systems could significantly contribute to rainfall totals that can bring relief to the region," said Shepherd, lead author of the NASA-funded study. "These types of storms are significant rain producers. The larger hurricanes aren't frequent enough to produce most of the actual rain during the season and therefore are not the primary storm type that relieves drought in the region."

Shepherd created a new measurement method as an efficient way to get a real sense for how much rainfall each type of storm contributes in a given year around the coastal regions of the southeastern U.S. To do so, he had to distinguish an average rainfall day from an extreme rainfall day. Though data from NASA's TRMM satellite could offer daily rainfall amounts, the data could not be used to set apart whether rainfall was average or extreme for any given day.

Shepherd and his team modeled their metric after the *cooling degree day* that energy companies use to relate daily temperature to energy needs for air conditioning. A cooling degree day is found by subtracting 65º from the average daily temperature. Values larger than zero give some indication whether a day was abnormally warm. Shepherd used daily rainfall data from TRMM

continued on page 37

NASA Climate Change Peacemakers Aided Nobel Effort

Stephen Cole, NASA Goddard Space Flight Center, Stephen.E.Cole@nasa.gov

It's not every day that a NASA scientist can wake up and think, "Hey, I did something for world peace." But on December 10, many NASA Earth scientists did exactly that.

In Oslo, Norway, the King of Sweden presented the shared 2007 Nobel Peace Prize to former U.S. Vice President Al Gore and to representatives of a United Nations panel that has spent two decades assessing Earth's changing climate and predicting where it is headed. Hundreds of NASA scientists contributed to the United Nations effort working with thousands of their colleagues from more than 150 countries.

Announcing the Nobel Peace Prize, the Norwegian Nobel Committee said the scientific reports issued since 1990 by the United Nations Intergovernmental Panel on Climate Change (IPCC) have "created an ever-broader informed consensus about the connection between human activities and global warming." The peacemaking value of this scientific finding, according to the committee, is that human-induced changes in climate may cause "large-scale migration and lead to greater competition for the Earth's resources" and an "increased danger of violent conflicts and wars."

The Fourth IPCC Assessment, released this year in four reports, presented the strongest findings thus far that human activities are altering Earth's climate and that the impacts of climate change are occurring already.

As the First IPCC Assessment was reported in 1990, NASA built on a history of Earth remote sensing to develop and deploy the Earth Observing System of satellites to determine the extent, causes and regional consequences of global climate change. In the recent Fourth Assessment, scientists were informed by more than eight years of systematic, global observations of the Earth system. Satellite measurements have revealed fundamental changes in Earth's climate, including temperatures and rainfall, ice extent and properties, and sea levels, as well as physical, chemical, and ecological impacts of climate change. NASA satellite measurements contributed immeasurably to enable the IPCC's strongest conclusions thus far.

"NASA is best known for its cutting-edge satellite instruments and global measurements of Earth from space, but we contribute a lot more than that to climate change science," says **Michael Gunson**, acting Chief Scientist in the Jet Propulsion Laboratory's (JPL) Earth Science and Technology office. "NASA's role extends far beyond space-based measurements into the research to build our understanding of climate change, enabling the critical work of the IPCC."

NASA instruments, data, analysis, and modeling all contributed to the bedrock of the IPCC report: the hundreds of papers published each year in scientific journals, many authored by NASA scientists and many others using NASA observations. The authors of the report draw on this ever-growing body of new knowledge to form their conclusions about climate change.

"The most remarkable thing about the process of assembling an IPCC report is that you can actually get thousands of independent-minded and critical scientists to work together without killing each other," says **Bruce Wielicki**, senior scientist for Earth science at NASA's Langley Research Center.

Wielicki contributed a portion of a chapter in the latest science assessment on how Earth's *energy budget*, the ebb and flow of radiant energy from the Sun and our planet, has changed as measured by satellites. He began the project in October 2004 and, working with a team of 10 scientists, completed a compact summary of the latest research on the topic 20 months later. Like each section of the IPCC reports, Wielicki's section went through repeated rounds of critiques by other scientists.

NASA's **Cynthia Rosenzweig**, a plant and soil scientist at the Goddard Institute for Space Studies, coordinated a key chapter in the new report on the impact of climate change —an effort that took four years. "There were many, many late nights as we worked under strict deadlines to draft the chapter and revise it based on thousands of comments from reviewers, each of which had to be documented and responded to," Rosenzweig recalls.

"But the toughest part of the entire effort was the last step: reviewing our final draft with government officials," Rosenzweig says. Before each IPCC report is published, the lead authors sit down with diplomats, lawyers, and environmental officials from around the world to review their findings, page by page. "These week-long meetings are very challenging as you respond to all sorts of concerns and questions. But this process is the real beauty of the IPCC. The final documents that emerge represent a consensus view of the world's scientific community and government delegates."

"The Nobel-winning IPCC reports have no parallel as the most authoritative source of climate science," says Wielicki. "When I give public lectures on climate, I tell my audience that there are three laws of solid information on climate change: IPCC, IPCC, and IPCC."

The IPCC effort has also boosted public awareness of this critical area of science. "By collecting together the current scientific thinking on climate change, the IPCC showed the world the value of the type of science we are doing at NASA," says JPL's Gunson. "And that has really engaged the public, many of whom were surprised that NASA does climate research. It has really motivated a new interest in the work we do here day in and day out."

Smaller Storms Drop Larger Overall Rainfall in Hurricane Season

continued from page 35

to determine 28.9 mm as the base value of average daily rainfall at one of the world's wettest locations, Maui's Mount Wailea in Hawaii. In the same way as the cooling degree day, the *millimeter day* metric is calculated by subtracting 28.9 millimeters from the average daily rainfall in each of four ocean basins along coastal areas scattered across the south near Houston and New Orleans, east of Miami and south of North Carolina. Values greater than zero indicate a so-called *wet millimeter* day of extreme rainfall.

Using daily rainfall data from the TRMM satellite from 1998-2006, Shepherd's team compared the amount of rain that fell in the basins on extreme rainfall days with the location of tropical storms from the National Hurricane Center's storm tracking database to determine how many extreme rainfall days were associated with a particular type of tropical storm.

The team found that the most extreme rainfall days occurred in September and October, two of the busiest months of the Atlantic hurricane season. They also found that though major hurricanes produced the heaviest rainfall on any given day, the smaller tropical storms and depressions collectively produced the most rainfall over the entire season. Over half of the rainfall during the hurricane season attributed to cyclones of any type came from weaker tropical depressions and storms, compared to 27% from Category 3-5 hurricanes.

TRMM has transformed the way researchers like Shepherd measure rainfall by providing day-to-day information that did not exist before the satellite's 1997 launch. "Though we've had monthly rainfall data available since 1979 from other sources, it's the daily rainfall data that allows us to see that tropical storm days contributed most significantly to cumulative rainfall for the season due to how frequently that kind of storm occurs," said Shepherd.

"It's important in the future to build a longer record of daily rainfall to establish, with better confidence, whether trends are occurring," said Shepherd. "This study sets the stage for us to understand how much rainfall weak and strong tropical cyclones contribute annually and whether this contribution is trending upward in response to global warming-fueled growth in tropical cyclones."

Shepherd believes advances that will improve study of cyclones and rainfall are "just around the corner" with NASA's Global Precipitation Measurement (GPM) satellite, scheduled for launch in 2013. GPM improves upon TRMM's capabilities, and will measure precipitation at higher latitudes, the actual size of snow and rain particles, and distinguish between rain and snow.

For images and more information, visit:

www.nasa.gov/mission_pages/hurricanes/main/index.html

www.nasa.gov/centers/goddard/news/topstory/2007/rainfall_increase.html

trmm.gsfc.nasa.gov/

EOS Scientists in the News

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

NASA's High-Tech Wildfire Weapons, October 2007; *Popular Science*. An automated process that analyzes fire data collected from an unmanned NASA aircraft and satellites helped fire workers in Southern California get the information they needed quickly, says **Dan Mandl** (NASA GSFC).

Greenland's Ice Sheet Melts as Temperatures Rise, October 24; *CNN*. Greenland's ice sheet is melting as temperatures rise and, although warming trends have led the ice sheet to melt in the past, **Jay Zwally** (NASA GSFC) says that the recent trend is more extensive and not likely caused only by natural variability.

The Fire This Time, October 25; *Time*. **William Patzert** (NASA JPL) explains how the Santa Ana winds contributed to the severity of this year's wildfires in Southern California, as well as how water shortages due to population growth could exacerbate the problem in the future.

Scientists Study the Impact of Water on Climate, October 29; *National Public Radio*. Researchers, including **Paul Newman** (NASA GSFC), traveled to Costa Rica this summer and flew instruments aboard a plane to collect key measurements needed to answer questions about climate change, ozone depletion, and atmospheric chemistry.

Food & Climate: A Complicated but Optimistic View, October 30; *National Public Radio*. **Cynthia Rosenzweig** (NASA GISS), co-chair of a working group for the Intergovernmental Panel on Climate Change, describes how she got started looking into how climate change affects food production and what models have revealed so far: that farmers in developing countries are the most vulnerable to climate-induced drops in food production.

Shrinking Ice Means Greenland is Rising Fast, November 2; *New Scientist*. The acceleration of ice loss from Greenland, described in a study by **Eric Rignot** (NASA JPL), reduces the load on the landmass and explains why researchers are now seeing the landmass rise upward by up to 4 cm per year.

Tracking Firestorms, November 9; *Los Angeles Times*. Researchers are looking to see if there are patterns to the destructive wildfires that strike Southern California. **William Patzert** (NASA JPL) says that climate cycles —periods of wet and dry—are also fire cycles.

Polar Ice Hit Where it Hurts, Says Expert, November 14; *Earth & Sky* radio. **Robert Bindschadler** (NASA GSFC) says that ice sheets, such as the West Antarctic Ice Sheet, are most vulnerable at the edges where they meet the water, as this is where stresses from the weight of the ice sheet above are the strongest.

Scientists Fault Climate Exhibit Changes, November 16; *Washington Post*. The change of a 2006 exhibit at the Smithsonian's National Museum of Natural History to downplay global warming disturbed some scientists, including **Waleed Abdalati** (NASA GSFC) who wrote that the changes were made for political reasons, not because of scientific content.

New 'Hi-Def' View of Antarctica, November 27, *BBC News*, *MSNBC*; Dec. 4, *The New York Times*. A new detailed map of Antarctica, created from more than 1,000 satellite images, gives the public a chance to see how the continent "really looks," said **Robert Bindschadler** (NASA GSFC).

NASA Develops Super-Accurate Nav System for Scientific Plane, December 7; *Space.com*. **James Lee** (NASA Dryden) and **Scott Hensley** (NASA JPL) discuss the importance of repeat path interferometry to produce highly detailed microwave images of the Earth's surface.

Northern Lights Energy Source Found, December 12, *Wired News*, *The Independent* (UK); December 13, *Sky & Telescope*. After eight months in operation, satellites that constitute the Time History of Events and Macroscale Interactions mission have turned up evidence that giant magnetic "ropes" connecting Earth to the sun provide the source of energy that drives the Northern Lights, according **David Sibeck** (NASA GSFC).

Ominous Arctic Melt Worries Experts, December 12; *Associated Press*. Amid talk of melting in the arctic, **Jay Zwally** (NASA GSFC) says that the Arctic Ocean could be almost ice-free by 2012, and **Waleed Abdalati** (NASA GSFC) speaks to the significant amount of change in sea ice in 2007 alone. **James Hansen** (NASA

GISS) notes that Earth has already reached some "*tipping points*, although the point of no return has not been reached."

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.*

New Release of Aura-HIRDLS Level-2 Atmospheric Products

Version 003 of Aura-HIRDLS Level-2 Atmospheric Product *HIRDLS2* is now publicly available from the NASA GSFC Earth Sciences (GES) Data and Information Services Center (DISC) *disc.gsfc.nasa.gov/Aura/HIRDLS/hirdls2_v003.shtml.*

The High Resolution Dynamics Limb Sounder instrument (HIRDLS) is a joint project between the U.K. and U.S. It was launched on the NASA Aura spacecraft on July 15, 2004. HIRDLS is a mid-infrared limb emission sounder (21 channels from 6.12 to 17.76 μm), designed to monitor the global distributions of temperature, clouds, aerosols, and concentrations of several trace gases (O_3, H_2O, CH_4, N_2O, NO_2, HNO_3, N_2O_5, $ClONO_2$, $CFCl_2$, $CFCl_3$) at high vertical and horizontal resolution from the upper troposphere to above the stratopause.

The instrument is performing extremely well, providing high vertical resolution information despite the fact that the optical beam is partially obstructed between the scan mirror and the aperture, probably by a piece of inner lining material that became detached during launch. HIRDLS science team members have developed correction algorithms that make use of the partial view of the atmosphere (vertical scans around azimuth angle of 47° line of sight to the orbital plane, on the side away from the sun). In spite of the anomaly, HIRDLS has retained most of its scientific capabilities to support the Aura Mission. Data are retrieved with 1km vertical resolution.

The Principal Investigators for the HIRDLS mission are U.S. scientist **John Gille**, from the University of Colorado and the National Center for Atmospheric Research, and U.K. scientist **John Barnett** from the University of Oxford.

The *Version 003* Level-2 data products (geophysical parameters along the measurement track) derived from the HIRDLS latest improved algorithm (V2.04.09) are of better quality compared to earlier version. This data version contains temperature, ozone, and nitric acid mixing ratios, cloud top heights and other cloud characteristics. The HIRDLS team is in the process of refining the algorithms for other species, which will be made available in later versions.

HIRDLS data are processed at the HIRDLS Science Investigator-led Processing System (SIPS) in Boulder, CO. The standard derived products are made available from the NASA GES DISC and the British Atmospheric Data Center.

For the full set of Aura products available from the NASA GES DISC, please see the following link: *disc.sci.gsfc.nasa.gov/Aura/*

NASA Science Mission Directorate – Science Education Update

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UNDERGRADUATE RESEARCH INTERNSHIP OPPORTUNITY

NASA's University Student Research Program offers research experiences at NASA Centers to undergraduates who are U.S. citizens. Applications are now available for 2008 summer or fall sessions. Applicants must be sophomores, juniors or seniors at the start of the internship, with an academic major or course work concentration in engineering, mathematics, computer science, or physical or life sciences. The application deadlines are January 31, 2008, for summer; and February 29, 2008, for fall. For more information, visit *www.nasa.gov/audience/forstudents/postsecondary/learning/Undergraduate_Student_Research_Project.html.*

RISING TIDES: JOURNAL FOR HIGH SCHOOL TEACHERS AND STUDENTS

"Rising Tides" is an oceanographic education journal developed with high school science teachers and students in mind. The journal focuses on the biological aspects of coastal oceanography with an emphasis on research technology. In the journal, you will find a collection of cutting-edge research articles as well as classroom and laboratory activities, scientist interviews, further reading, and links to a plethora of oceanography topics. It has been developed as part of the CoastalObs Project, and is a collaboration between NOAA and NASA, as well as other partners. The first issue is available online at: *phytoplankton.gsfc.nasa.gov/risingtides/.*

FEATURE ARTICLE: IPY IN THE CLASSROOM

In support of the International Polar Year, NASA scientists are participating in field expeditions to Earth's polar areas and conducting additional research focused on the poles of Earth and other planets and moons. This web page contains a variety of NASA and NASA-sponsored projects offering IPY-related classroom activities and resources. For more information visit *www.nasa.gov/audience/foreducators/k-4/features/F_IPY_in_the_Classroom.html*

EARTH & SKY INTERNATIONAL POLAR YEAR RESOURCES

Earth & Sky editors have compiled radio programs, podcasts, and a photo gallery with content related to polar science to help NASA celebrate the International Polar Year. They will continue to update this site with relevant interviews and sessions with polar scientists. For more information, visit *www.earthsky.org/article/international-polar-year*

MY NASA DATA SUMMER WORKSHOP 2008
June 22-27, 2008, Hampton, VA.

NASA Langley Research Center will host a hands-on workshop designed for educators of grades 6-12, focusing on using Earth system science data sets developed for the pre-college education community as part of the MY NASA DATA program. The data sets are derived from the archive of remotely-sensed data from NASA's Earth Observing System satellites. Participating teachers will explore topics in Earth system science (especially atmospheric science), educational application of data sets and hands-on classroom activities. They will attend lectures and tours led by scientists, and explore how the data sets can be used to enhance their curriculum, and how students can utilize these data for inquiry-based learning and research. A major component of the workshop will be to develop lessons incorporating one or more data sets.

Applications must be postmarked by April 9, 2008. Notification of acceptance will be sent on or before May 2, 2008. For more information, go to: *mynasa-data.larc.nasa.gov/workshop.html*

ESSEA: TEACHING TEACHERS WHO TEACH EARTH SCIENCE

To ensure that future scientists possess the perspective necessary to better understand Earth and tackle complex environmental problems, the Earth System Science Education Alliance (ESSEA) is training geoscience teachers in the systems approach to Earth science. ESSEA offers online Earth system science courses, geared toward K-12 teachers. For more information, go to *www.nasa.gov/audience/foreducators/essea-teaching-teachers.html.*

EOS Science Calendar

2008

February 5-7
SORCE Science Team Meeting, *SORCE's Past, Present, and Future Role in Earth Science Research*, Santa Fe, NM. URL: *lasp.colorado.edu/sorce/news/2008ScienceMeeting/*

March 31-April 3
International EOS/NPP Direct Readout Meeting, Bangkok, Thailand. URL: *dbmeeting.gsfc.nasa.gov*

April 28-30
NASA Carbon Cycle and Ecosystems Focus Area Joint Science Workshop, University of Maryland Conference Center, Adelphi, MD. URL: *cce.nasa.gov/meeting_2008*

May 1-2
LCLUC Science Team Meeting, University of Maryland Conference Center, Adelphi, MD. URL: *lcluc.umd.edu*

May 6-8
9th CERES-II Science Team Meeting, Marriott Hotel City Center at Oyster Point, Newport News, VA. URL: *science.larc.nasa.gov/ceres/meetings.html*

Global Change Calendar

2008

March 2-7
2008 Ocean Sciences Meeting, Orlando, FL. URL: *http://www.ocean.us/node/539*

March 11-13
Oceanology International Global Ocean Forum, London. URL: *www.oceanologyinternational.com*

May 26-30
AGU Joint Assembly, Fort Lauderdale, FL. URL: *www.agu.org/meetings/ja08/program.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*

July 13-20
37th Committee on Space Research (COSPAR) Scientific Assembly, Montreal, Canada. URL: *cosparhq.cnes.fr.*

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.*

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