National Aeronautics and Space Administration

the earth observer

The Earth Observer. November - December 2007. Volume 19, Issue 6.

Editor's Corner

Michael King
EOS Senior Project Scientist

I am pleased to announce that Cambridge University Press has released our new book: *Our Changing Planet: The View from Space*. This book explains the critical role that satellites have played and continue to play in observing the Earth, and chronicles *change* on many different spatial and temporal scales, from movements in the land and volcanic eruptions, to human-caused changes such as the growth of cities, deforestation, and the spread of pollutants in the atmosphere and oceans.

The book showcases some spectacular and beautiful satellite imagery along with informed essays on the science behind these images written by many of the world's top remote sensing scientists. The material is intended to be accessible to a wide variety of readers and should provide inspiration for students, teachers, environmentalists and the general public alike.

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NASA Astronaut (and former Terra Project Scientist) **Piers Sellers** wrote the book's Foreword and Epilogue, and in his words: *"The book provides a compilation of stunning images that will appeal to the human and the aesthetic in each of us, as the world is a staggeringly beautiful place at almost every scale we choose to observe … the planet is truly beautiful—small, precious, intricate, detailed and complex.… the book is equivalent to a medical report on the health of the Earth."*

A team of four editors led the production effort and had support from the Earth Observing System Project Science Office staff. On behalf of all the editors, I wish to thank everyone who was involved in this massive undertaking. I hope that you will enjoy this impressive tome and that you will find it a valuable reference. To view more details, see reviews of the book, and order your copy from Cambridge Press please visit: *www.cambridge.org/king*.

I'm also pleased to report that the *2007 Nobel Peace Prize* has been awarded to the Intergovernmental Panel on Climate Change and to former U.S. Vice President Al Gore in recognition of their efforts to build and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.

From the official press release announcing the award: *"Through the scientific reports it has issued over the past two decades, the IPCC has created an ever-broader informed consensus about the connection between human activities and global warming. Thousands of scientists and officials from over one hundred countries have collaborated to achieve greater certainty as to the scale of the warming. Whereas in the 1980s global warming seemed to be merely an interesting hypothesis, the 1990s produced firmer evidence in its support. In the last few years, the connections have become even clearer and the consequences still more apparent."*

Over 600 scientists contributed to Working Group 1 of this report, plus many others in the other two reports. I would like to personally thank everyone that worked so hard to compile this important report, which included many EOS investigators both within NASA and at other federal agencies, universities, and industry, and extend my congratulations on being selected to receive such a prestigious award.

To view the full press release please visit: *nobelprize.org/nobel_prizes/peace/laureates/2007/press.html*.

I would also like to acknowledge the Landsat/Landsat Data Continuity Mission Education and Public Outreach (EPO) Team (**Anita Davis**, **Jeannie Allen** and **Laura Rocchio** from Goddard) who recently received the U.S. Geological Survey's (USGS) *2007 Shoemaker Award for Communications Product Excellence*, together with staff from USGS and the Smithsonian Institution, for their work on the *Earth from Space* traveling exhibition. *Earth from Space* opened at the Smithsonian Institution in November of 2006, and is fully booked at museums across the nation through January 2010.

The exhibition explains how satellite imagery is gathered and used to expand our understanding of life on Earth, and features Landsat, Terra, and Aqua among other Earth Observing satellites. An educational companion contains an online version of the exhibition, as

well as additional images and information—*www.earth-fromspace.si.edu.* It also provides numerous educational resources, including lesson plans, classroom activities, web site links, and available publications.

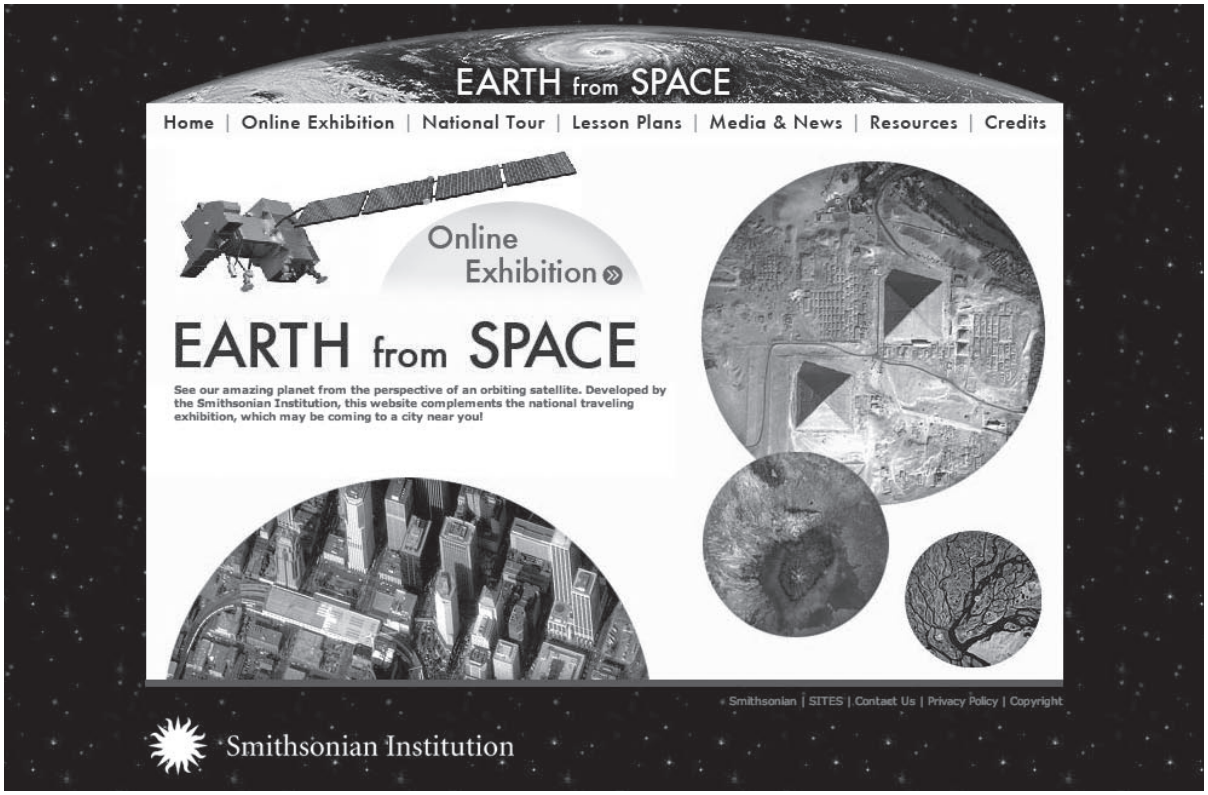
The Shoemaker Award, USGS' most prestigious award for communications, was presented to the team by the Director of USGS, and by the Secretary of the Department of the Interior, at a ceremony at USGS' Reston, VA Headquarters. *Earth from Space* was funded in part by USGS; the Landsat EPO team contributed time, talent, and educational products to the effort.

In other news, November 27 marks the 10th anniversary of the launch of the Tropical Rainfall Measuring Mission (TRMM). TRMM is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA), designed to study tropical rainfall and the associated release of energy that helps to power the global atmospheric circulation, shaping both weather and climate around the globe. TRMM was originally designed to carry out a three-year mission, but is approaching 10 years on orbit, and is expected to continue operating until at least 2010. The Global Precipitation Measurement (GPM) mission will eventually succeed TRMM and allow for even more detailed precipitation measurements.

As TRMM celebrates 10 years, **Bob Adler** [TRMM Project Scientist] is being recognized for his outstanding long-term contributions to precipitation science, in particular his dedicated efforts toward ensuring the phenomenal success of the TRMM mission. Adler has been selected as the recipient of the *2007 William Nordberg Award*, and received his award at the William Nordberg Memorial Lecture of the Goddard Science Colloquium on November 16. I tip my hat to Bob for his years of service, and to everyone who has worked so hard to make the TRMM mission successful over the past decade.

November 27 is also a significant milestone for the Clouds and Earth's Radiant Energy System (CERES) instrument. TRMM carried the first CERES instrument into orbit 10 years ago and began a climate data record that continues to the present. (CERES instruments now fly on Terra and Aqua.) To celebrate this special anniversary, *The Earth Observer* began running a series of articles focusing on CERES research in the September/October issue [Volume 19, Issue 5]. For more details please see the sidebar on page 15 of this issue. NASA Langley Research Center is the proud home of CERES.

Finally, once again we come to the end of another successful year for Earth science at NASA and, on behalf of the entire staff of *The Earth Observer*, I would like to take this opportunity to wish everyone a *Happy and Safe Holiday Season*. ■



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Buzzing About Climate Change

Rebecca Lindsey, NASA Goddard Space Flight Center, Rebecca.E.Lindsey@nasa.gov

This story is printed with permission from the Earth Observatory. For color photos and graphs go to *earthobservatory.nasa.gov/Study/Bees/* and follow all of the links listed.

If we had the time and knew how to listen, Nature could tell us thousands of stories about how climate change is affecting life on Earth. Every tree, every insect, every bird has something important to say on the subject. From every forest, every wetland, every ocean come more stories than there are scientists to listen. Several years ago, NASA oceanographer and amateur beekeeper **Wayne Esaias** realized he was overhearing one of those stories. The talk of climate change was coming from his bees.

Much of the science we hear about—brought to us by schoolbooks or 10-second blurbs on the radio or TV news—are stories whose end is already known. Knowledge itself may be provisional, but the stories we hear about science often focus on what's finished—i.e., an experiment is complete, the data are in, a result is known.

But when you're a scientist, you know that between the moment when you think *"I wonder why...?"* and the moment when you finally understand can lie a long stretch of time where the significance of your idea, your ability to collect the data you need to test it, and the ultimate outcome of your effort is uncertain. Biological oceanographer Wayne Esaias has been passing through one of those uncertain stretches.

The most important event in the life of flowering plants and their pollinators—flowering itself—is happening much earlier in the year than it used to.

The 25-year NASA veteran has made a career studying patterns of plant growth in the world's oceans and how they relate to climate and ecosystem change, first from ships, then from aircraft, and finally from satellites. But for the past year, he's been preoccupied with his beehives, which started as a family project around 1990 when his son was in the Boy Scouts. According to his honeybees, big changes are underway in Maryland forests. The most important event in the life of flowering plants and their pollinators—flowering itself—is happening much earlier in the year than it used to.

The discovery has driven Esaias to completely remodel his ocean-centric career. He is now trying to rally financial support and scientific enthusiasm for the development of a national network of beekeepers whose hive observations can give scientists direct evidence of how climate change is affecting flowering plants and their pollinators. The information could refine predictions of the productivity of agricultural and natural ecosystems, help predict the spread of invasive species, and provide a tangible, missing link between satellite-based indicators of seasonal patterns of vegetation and the real world.

Wayne Esaias, a NASA scientist, records the weight of his beehives. Once a hobby, his beekeeping has developed into a scientific pursuit. Esaias believes that a beehive's seasonal cycle of weight gain and loss is a sensitive indicator of the impact of climate change on flowering plants. **Credit:** Elaine Esaias.

Whether he can pull it off is far from guaranteed. That he is willing to accept the challenges and risks of venturing outside his specialty—failing to get funding, having colleagues challenge his expertise, or discovering that the honeybee hive network doesn't turn into the goldmine of ecological information he predicts—shows just how important he thinks the bees' story is.

The Story of Honeybees

Europeans imported the honeybee along with most of our food crops when they came to America more than 400 years ago. As generalist pollinators that can feed from almost any flowering plant, honeybees are adaptable. Many escaped from their caretakers and set up residence in woods across the country. Whether the imports have been good or bad for native plants and pollinators in natural ecosystems isn't settled, but when it comes to America's agricultural productivity, it's almost impossible to overestimate how dependent we have become on honeybees.

Agriculture depends on managed honeybees not only because some crops, such as the 700,000 acres of almonds in California, can only be pollinated by honeybees, but also because our industrial-scale system of crop production hinges on huge numbers of pollinators being available in a very limited window of time, sometimes as short as a few days.

In the modern, industrial-scale system of agriculture, growers manage hundreds of acres of a single crop so that all the plants flower, ripen, and are ready to harvest at the same time. When farms are surrounded by abundant natural vegetation, native pollinators may be able to handle the workload, but more often, growers must hire a beekeeper to bring in hives by the truckload at flowering time. **Credit:** ©2006 Dave Gilmore.

"When you grow a large crop for agriculture, you might have hundreds acres of, say, cucumbers all being managed to bloom at the same time, to be harvested at the same time, for efficiency," Esaias explains. That kind of uniformity isn't natural for native pollinators, which need a diverse and season-long food supply.

Scientists have shown that at farms surrounded by adequate natural vegetation, native pollinators alone seem to be able to provide pollination services even for *heavy demand* species such as watermelon. At most conventional farms, however, natural vegetation is too scarce and broad-spectrum insecticide use is too common to support populations of native pollinators that are large enough to service crops. "The only way for growers to ensure pollination is to have somebody bring in a colony of bees, one to two colonies per acre, and put them out in the field," says Esaias.

A few stints pollinating watermelons over the course of a summer, however, isn't enough to support a hive. From spring until fall, worker bees forage from dawn until twilight over a radius of up to about 5 km from the hive, bringing back pollen and nectar from plants that are blooming. They turn the nectar into honey, which feeds the colony in the winter or when nectar and pollen are scarce. As the bees stockpile honey,

"During the peak of the nectar flow, a good, strong colony can gain 10 to 20 pounds in one day,"

the hive weight goes up. In Maryland, the primary nectar source for honeybees is flowering trees, namely tulip poplar, black locust, basswood, and holly.

"During the peak of the nectar flow, a good, strong colony can gain 10–20 lbs in one day," he says. "In Maryland, that goes on for a few weeks in late spring, and then, suddenly, it's over." For the remainder of the year, the weight of the hive dwindles as bees sustain themselves on the honey and pollen they have stockpiled during their three-to-four-week feeding frenzy. It was through this annual yo-yoing of weight gain and loss that Esaias' bees began to tell him their story of climate change.

"In about 1990, my son was in Scouts," he explained, "and the assistant scout master came to a meeting one night and said he's leaving for a job out of state. He said, 'I've got a problem. I've got three hives of bees, and I need somebody to take them. Who wants them?' And my son said, 'We'll take 'em. Right, Dad?'"

Hive weight is an important indicator of hive health. It tells a beekeeper when nectar is available in the area, when the bees need supplemental food, and when the keeper can harvest the honey. The seasonal pattern of weight gain and loss in a hive is different from ecosystem to ecosystem, but changes in the pattern in a particular location over time can be a sign that long-term climate change is influencing the plants in the region. **Credit:** Wayne Esaias.

When they went to pick up the hives, the scout master pointed out a large rectangular scale, like the one a veterinarian would use for weighing your pet. "'You better take that, too, he said,'" Esaias recalls. "Of course, at the time, I knew nothing about bees, so I didn't really know what you want it for, but I took it." It wasn't until he was up to his ears in books on beekeeping that he realized what an important tool the scale was for keeping tabs on the health of the colony.

"Based on the weight of the hive you can tell if you need to give them supplemental food, when the nectar is coming in the area, when to add supers [stackable chambers added to the top of the hive where the bees store extra honey], and when to harvest the honey," he explains. Tending the bees and selling the honey became a family activity. Everyone took turns weighing the hive.

As a field biologist who over the course of his career had found himself spending less and less time in the field, and more and more time in front of a computer analyzing satellite data, the hive monitoring was a real outlet for him.

"Nearly every night in the spring and summer someone would go out and weigh the hives," he said. "And I guess just because I am a scientist, I started writing these things down. Even after my kids graduated and went off to school, I still kept the records. One day, I just decided to plot it all up [on a graph], just out of curiosity. And what I saw was that although you do see a lot of variability from year to year due to climate events, there was a very noticeable long-term trend, with flowering and nectar flows getting earlier and earlier in the year."

"Once I saw this trend, I wondered, well, how does what I see in my backyard compare with what other people have seen in this area? I found basically two datasets for comparison: one from 1922-23 in what is now downtown Chevy Chase, when it used to be a U.S. Department of Agriculture agricultural research center; another study with hive weights was done by a researcher at the University of Maryland."

To compare his data to older records, he had to adjust for the difference in elevation; his home near Clarksville is in Maryland's Piedmont, while the other locations were down on the coastal plain. "But once I adjusted for these regional differences based on elevation," he said, "you see this dramatic advance in peak flowering time of almost a month."

Esaias scoured scientific books and papers for observations that could corroborate the story his bees were telling about how flowering times were changing in Maryland. He discovered that for several decades, Smithsonian botanist **Stan Shetler** had been keeping track of flowering dates for trees in and around Washington, D.C., based on calls from city residents that their backyard trees—including tulip poplar and black locust, two of the most important nectar producers in the state—were in bloom. Those records showed an advance in flowering (i.e., earlier blooming) beginning as far back as 1970.

"My hive records don't go back that far. They start in 1992," says Esaias. "But what's interesting is that when I project the trend I see in my data back in time, it seems like the changes in my area could have started in the mid-1980s, which is about 15 years later than the changes began in D.C. I wondered, why is that?"

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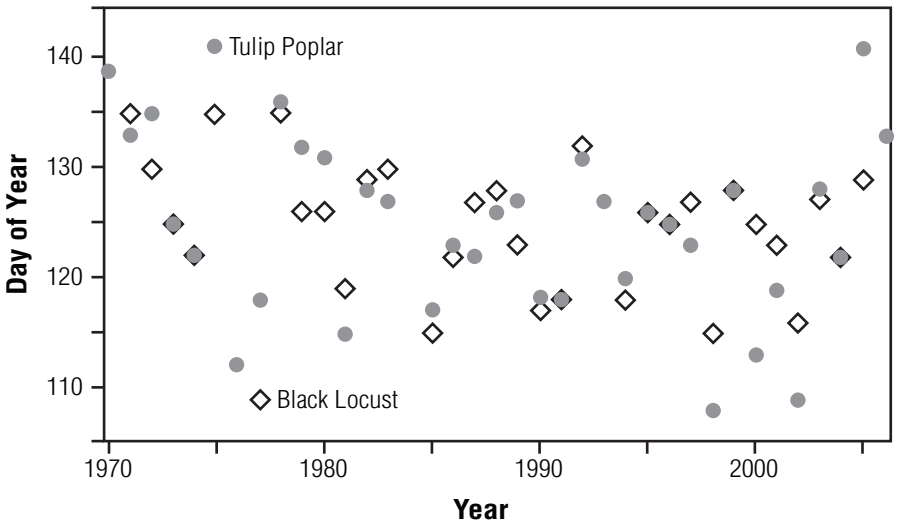

Since the 1970s, Smithsonian botanists have kept track of Washington, D.C., residents' reports of when their backyard trees first bloomed each spring. The dates vary from year to year depending on the weather, but on average, blooming is starting earlier. Solid diamonds represent overlapping flowering dates. **Credit:** Robert Simmon, based on data from Abu-Asab et al.

Esaias thinks that urbanization is mostly responsible for the changes in flowering. Urbanization would also explain why flowering seems to have been affected earlier in D.C. than in his "backyard." Urbanization creates a *heat island*, an area where surface temperatures are much higher than surrounding rural areas. Pavement, less soil moisture, air pollution, and heat generated by energy use conspire to raise the city temperatures as much as 10°F (6°C) over surrounding areas. As cities get bigger, the urban heat

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island expands, too. As temperatures rise, spring comes earlier. Earlier leaf emergence and flowering have been observed in numerous cities across the world.

"I am farther out from the city, and it took 15 years for the urban heat island effect to get here," he concludes. Between urbanization and global warming from greenhouse gases, temperatures will continue to rise in coming years; the acceleration in flowering times that Esaias' honeybees have documented so far may not be the end of the changes.

Will Plants and Pollinators Get Out of Sync?

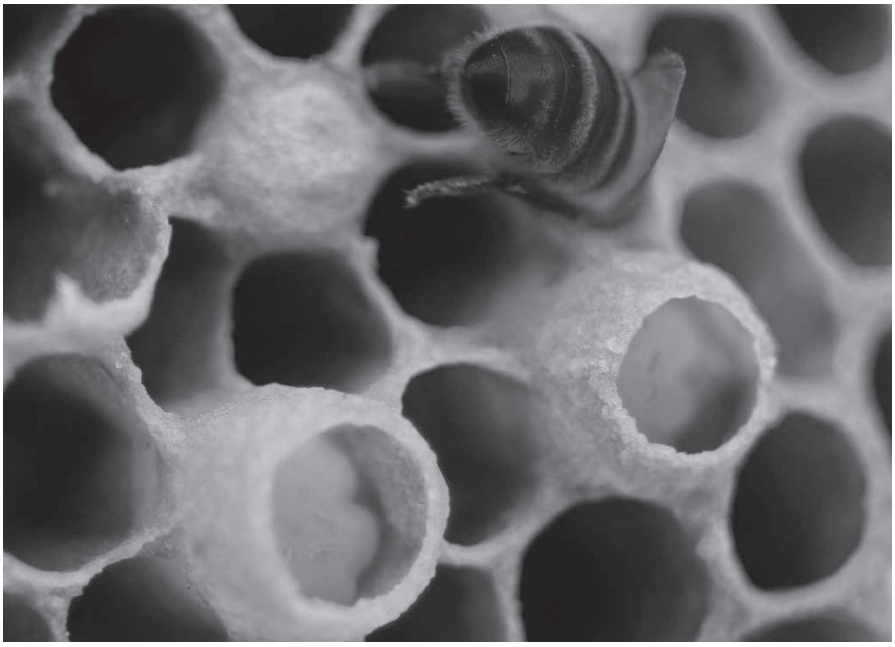
According to Esaias, the changes aren't just dramatic, they're also kind of scary. The fertility of most flowering plants, including nearly all fruits and vegetables, depends on insect/animal-mediated pollination. As the pollinators move from flower to flower for nectar—a high-energy, sugary enticement—the plants dust them with pollen, which the insects/animals transfer from flower to flower.

"Flowering plants and pollinators co-evolved. Pollination is the key event for a plant and for the pollinators in the year. That's where pollinators get their food, and that's what determines whether the plant will set fruit. Some species of pollinators have co-evolved with one species of plant, and the two species time their cycles to coincide, for example, insects maturing from larva to adult precisely when nectar flows begin," says Esaias.

The concern is that in thousands upon thousands of cases, we don't really know what environmental and genetic cues plants and pollinators use to manage this synchrony. According to ecologist **David Inouye** of the University of Maryland, some plant-pollinator pairs in a particular area likely do respond to the same environmental cues, and it's reasonable to expect they will react similarly to climate change. But other pairs use different cues, the pollinator emerging in response to air temperature, for example, while the plant flowers in response to snow melt. Migratory pollinators, like hummingbirds, seem to be particularly at risk, since climate change will almost certainly affect different latitudes differently. There is no guarantee that the thousands of plant-pollinator interactions that sustain the productivity of our crops and natural ecosystems won't be disrupted by climate change.

As an example of how environmental cues for the timing of significant life cycle events might become uncoupled, Esaias points out that you don't have to look any further than his bees. "What limits the growth of my honeybees in the spring are those coldest of the cold nights, because what is happening in their colony is that they are in a

Individual grains of pumpkin pollen hitch a ride on a honeybee. As bees move from flower to flower, they carry pollen with them, fertilizing nearby plants. This relationship between plants and pollinators may be affected by climate change. **Credit:** ©2007 John Kimbler.



Broods of honeybee larvae depend on warm temperatures to survive. An early-spring cold snap can kill the developing workers at the outer edges of the cluster at the heart of the hive. This setback slows the hive's preparations for the honey-production season. If plants are not affected in the same way, the bees may become out of sync with their primary food source. **Credit:** ©2005 Max Westby.

cluster, and they have to keep the queen and the larvae at 93°F. They do that by eating lots of honey, and tensing their muscles, and generating heat."

When it gets warm enough outside for them to maintain a temperature of 93°F, they start laying eggs around the edges of the cluster, and the cluster begins to expand. As long as the workers can keep the brood temperatures at 93°F, the eggs will grow into adult bees in about 3 weeks. But if a single cold, cold night in March intervenes, says Esaias, then eggs at the edges that the workers can't keep warm will die. The cluster shrinks, and the colony must begin again.

"Trees, on the other hand, may not feel those cold temperatures in the same way because their roots are well insulated," Esaias suggests. The sun-warmed ground is slower to chill than the air, so trees may not be feeling the cold snaps in the same way that the bee colony does. Thus, flowering may occur before the bee colony has built up enough workers to take advantage of it, which means the hive will struggle to stockpile enough honey to sustain them through the next winter.

"I am not saying they are definitely different," Esaias stresses, "I am just saying there are good reasons to think that their response to climate change would not be identical. The truth is we don't know what the relationships are between weather and climate, pollinators, and plants for thousands of species."

Since crops alone can't sustain the pollen and nectar requirements of honeybee colonies, the potential for honeybees and other pollinators to become out of sync with their most important natural food sources is something that concerns Esaias. A national network of scale-equipped honeybee hives, Esaias believes, would reveal when flowering occurs now and help us better predict how plants and pollinators in both natural and agricultural ecosystems will—or won't—adapt to climate change in the future.

Perhaps the best part of the whole idea, according to Esaias, is that the 1-to-5-km-radius area in which a hive's worker bees forage is the same spatial scale that many ecological and climate models use to predict ecosystems' responses to climate change. It matches the spatial scale of the satellite images that NASA's Terra and Aqua satellites collects. **This similarity of scale means that all these ways of studying ecosystems could be integrated into a more sophisticated picture of how plant and animal communities will respond to climate change than any one method alone could provide.**

"If we want to relate models and satellite data to something as tangible as food for people and wildlife, if we want to be able to predict where the thousands of species that occupy ecosystems today will survive in the future, we need to monitor when that plant-pollinator interaction is occurring."

Esaias is particularly interested in comparing the hive data to satellite-based maps of vegetation *greenness*, a scale that remote-sensing scientists commonly use to map the health and density of Earth's vegetation. Scientists have been making these types of maps for decades, and they have used them to document how warming temperatures in the Northern Hemisphere are causing vegetation to green up earlier in the spring than it did in the 1980s. Such maps are an excellent general indicator of seasonal changes in vegetation, says Esaias, but by themselves, they won't tell you something as tangible as when plants are flowering.

"But if we compare flowering times based on the bee hives to the satellite data, it's possible we will see some correlated signal or pattern that we didn't notice before," he says. "If we can establish a relationship between the hive data in a particular ecosystem and satellite data, then we could use our global satellite data from Terra and Aqua to map flowering times for similar ecosystems. We could make predictions about what is happening to nectar flows and the species that depend on them in places where we don't have scale hives."

That sort of *ground-truth* data from scale hives could also be used to evaluate ecosystem models. According to **Hank Shugart**, a scientist at the University of Virginia who specializes in forest ecosystem modeling, the timing of seasonal events like leaf emergence and flowering are usually related to the accumulated time an area spends above a plant's minimum growth temperature, a biological benchmark known as *growing degree days*.

"It turns out that these heat-sum type approaches are pretty good at predicting the timing of these seasonal events," says Shugart. In general, a plant will put out leaves or flower after the number of growing degrees days that species requires has passed. "What that means," he says, "is that **the greening-up that the satellites can see is probably also related, for most plants, to their flowering time," which satellites cannot see**. Honeybee hive data would be "a marvelous idea" for verifying the connections, says Shugart.

HoneybeeNet

"In my mind, the data from a network of hive scales would be an essential addition to ecosystem models," Esaias concludes. "If we want to relate models and satellite data to something as tangible as food for people and wildlife, if we want to be able to predict where the thousands of species that occupy ecosystems today will survive in the future, we need to monitor when that plant-pollinator interaction is occurring."

"The best part," Esaias says excitedly, "is that the observers we need are already out there! The bees are already collecting these data for us." About half of the approximately 6 million honeybee colonies in the U.S. are kept by individual or family-scale beekeepers. Esaias' vision is to develop a how-to guide, an automatic data recorder, and the computer and networking resources at Goddard Space Flight Center that would be needed to collect and preserve the data. Ideally, a hive data recorder would be hooked up to the Internet so that volunteers' hive weights could appear on a Website hosted at Goddard. His goal is to get the cost per kit below $200 and then to get NASA funding to outfit a network of volunteers—*HoneybeeNet*—and analyze their data.

"Ultimately, what we'd like to have is thousands of these across the country. Even if we can get the cost down to $200 a piece, that is still a lot of money to ask for until you have a test data set that proves it is valuable," admits Esaias. He's been working with local bee clubs in Maryland, rounding up some 20 volunteers who already have or are willing to purchase their own scales. He hopes that the data collected during the 2007 spring-summer season will be a prototype that will convince NASA to fund a pilot project.

In the meantime, he and several colleagues at NASA, the Department of Agriculture, and several U.S. universities submitted a proposal to NASA to integrate satellite, hive data, and the results from ecological models into an early-detection system operated by the U.S. Geological Survey that monitors the spread of invasive species. By using satellite data on landscape and vegetation type along with honeybee hive data, they hope to improve predictions of the spread of the African honeybee, an aggressive and unpredictable species of bee that is colonizing the southern United States.

In addition, satellite and ecological model information on vegetation could help scientists pin down the cause or causes of *colony collapse disorder*. Beginning in the winter of 2006-07, hive keepers across the country began to report wintertime losses of 30–90% of their colonies. The adult worker bees seem to simply abandon the hive, including a seemingly healthy queen, immature bees, and remaining honey. As of Summer 2007, scientists were still investigating numerous possible causes, including pesticides and diseases. Added stress on colonies from climate-related environmental change may be contributing, too.

"I have no idea how it's all going to turn out, but we'll see," he says. "I don't know if I'll ever go back to ocean studies. Honestly, I'm having a lot more fun. And, really it's not that different from what I was doing before. Of course, terrestrial ecosystems are very different from marine ecosystems, but conceptually, my focus hasn't changed—I'm still interested in the factors that influence the abundance and distribution of organisms, only now it's bees and plants instead of phytoplankton."

He feels a sense of urgency about getting the *HoneybeeNet* going now. "All I can say right now is that much of what is in the [scientific] literature about the dates of the Maryland nectar flow is wrong; it's obsolete data. We are headed into an era of global change across the country, and we don't even know where we are starting from! How are we possibly going to predict change? If we don't get on board quick, we're gonna miss the boat."

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feature articles

Can Earth's Plants Keep Up With Us?

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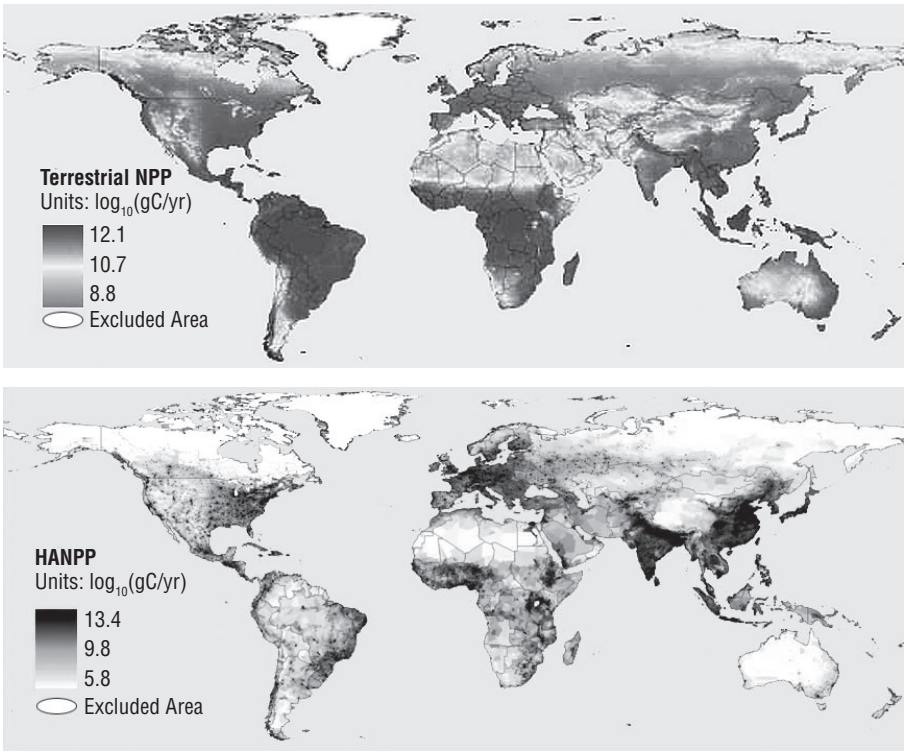
All over the planet, people use more food and fuel than the local environment can provide, with implications for regional and national food security.

Our lives depend on plants. Plants turn the energy of the sun into our most basic needs: lumber for houses, fuel for cooking, fiber for clothing, feed for livestock, and food for our own growing bodies. **But as global population and incomes rise, will plants be able to keep up with the human appetite?** And if they cannot, which regions will be short on food and other plant-based resources, and what will that mean for nations as they try to assure food security for their citizens?



The top map shows the Earth's estimated annual terrestrial *net primary production* (NPP), with darkest areas indicating where productivity is highest. The bottom map shows the *human appropriation of net primary production* (HANPP) in each grid cell on an annual basis. Darkest areas indicate where human demand is highest. **Credit:** M. Imhoff, L. Bounoua/GSFC, with collaborators T. Ricketts, C. Loucks, R. Harriss, W. Lawrence.

Marc Imhoff, a biophysical scientist with NASA, has been exploring these questions with colleagues from the University of Maryland's Earth System Science Interdisciplinary Center, the World Wildlife Fund, and the International Food Policy Research Institute for six years. He said, "Our primary motivation has been to find out where we stand relative to our survival on the planet, and what our needs are compared to the capability of the biosphere to sustain them. In fact, it goes beyond just need; it includes our different lifestyles—our appetites." To build some answers, Imhoff set about measuring global plant productivity, calculating human consumption levels on a cultural level, and then comparing what he learned. His findings remind us that we all rely on the same finite Earth.

The Green Supply

Net primary production is a measure of plant productivity—think of it as the amount of plant material left over after respiration. Imhoff put it this way: "Net primary production is the plant material that we see above ground, as well as what is below ground, like root systems. All of our food, much of our fiber, and for many people in developing countries fuel for cooking, is derived from plant material."

To measure net primary production, Imhoff used Normalized Difference Vegetation Index (NDVI) data, based on satellite data from the Advanced Very High Resolution Radiometer (AVHRR) instrument. NDVI, which quantifies the presence of healthy vegetation, was taken every sixteen days from 1982 to 1998, allowing Imhoff to compute an average maximum NDVI for each month of the year. The monthly NDVI data were input to a biophysical model together with temperature, humidity, rainfall, and land-cover type. The model output provided Imhoff and his colleagues with an estimate of the planet's net primary production. Imhoff said, "This information gave us the planetary supply of plant production on land that is available to humans in an average year."

The Human Appetite

Imhoff's next step was to measure the amount of net primary production that humans use worldwide in an average year, and then tie it to cultural consumption habits. To do that, he turned to statistics from the United Nations Food and

Agricultural Organization (FAO) on food and fiber consumption by country, taking the data from 1995 as a typical year that matched the satellite timeline. He said, "We divided the consumption statistics into food—both plant- and animal-derived—and fiber—including wood, wood-based fuel, and paper. Then, we backed out what you would need to see in the field to get those products," he said. "This way, we could double-check what the AVHRR data would have shown in the field with what the consumption statistics indicated was actually used."

Next, Imhoff requested the Gridded Population of the World (GPW) data set, which provides population numbers and density on a regular latitude-longitude grid, from the Socioeconomic Data and Applications Center (SEDAC). "We overlaid the consumption data on the population map and ended up with a gridded surface map showing the amount of net primary production required to support the consumption habits of different human populations all over the world." This map gave Imhoff the information he needed to compare production supply with human demand.

Keeping Up with Demand

When he compared the global supply of net primary production to the human appetite, Imhoff confirmed some ideas that did not surprise him. "Some things were a no-brainer," he said. "For example, urban populations with a high density consume way more primary production than local ecosystems can produce." One sharp example of this was New York City, which consumed 30,000% more primary production than it created. "That says a lot about the dependence of urban areas on our transportation networks and agricultural infrastructure," he said. The ratio of consumption to regional net primary productivity might prove to be a useful indicator of potential trouble spots should natural disasters, economic insecurity, or other problems undermine networks or infrastructure.

Having enough food may seem like a concern only for developing countries, but industrialized countries also have concerns about *food security*, which is defined simply as always having enough food for an active, healthy life. Developed countries may have dense urban populations, import more food, and be accustomed to high levels of consumption—all of which make these countries susceptible to transitory food supply disruptions. In addition, developed countries may have poor populations that are vulnerable to rising food prices in spite of typical governmental support services. Imhoff said, "Worldwide, we have some very vulnerable populations that could never survive just on the productivity of the land on which they live—with some important implications for national and regional food security."

Closely tied to the question of having enough food for survival is the idea of having enough fuel, clothing, and building materials for survival. The availability of everything from firewood to winter coats begins with plants. Consumption of material goods is an important factor in economic stability and security, as well as in maintaining or improving lifestyle levels. The more a population consumes, the more effort it takes to maintain that standard of consumption. Imhoff found that there were two big factors that lead to high consumption levels. The first is high per-capita consumption rates, as seen in much of the developed world; the second is large populations. Even a low per-capita consumption rate can result in a huge overall level of total consumption if multiplied over a large number of people.

To Imhoff, a more surprising finding was the importance of technology in helping balance the equation between supply and consumption. "We found that using improved technology—especially in harvesting and storage techniques—can actually halve the amount of waste in agricultural production," he said. "Take logging. Without the benefits of improved harvesting technology, you might literally lose a tree for every one that you use."

The interplay between population, consumption rates, affluence, and technology leads to some thought-provoking realizations. "For example, Asia's per-capita consumption is on the rise," he said. "If consumption begins to match Western levels, there will be a significant increase in demand for

New York City consumed 30,000% more primary production than it created.

The more a population consumes, the more effort it takes to maintain that standard of consumption.

Although citizens in industrialized countries may not find the rising population in developing nations of immediate concern, poverty has been connected to terrorism, war, underemployment, border pressures, disease, and political unrest.

food and fiber products. If technology improvements do not come with that growth, then you'll see populations that are outstripping their regional food production capacity. They'll be more dependent on resources elsewhere, and will have to compete for them." Although citizens in industrialized countries may not find the rising population in developing nations of immediate concern, poverty has been connected to terrorism, war, underemployment, border pressures, disease, and political unrest.

"It's a question of how much we are willing to pay to keep getting the level of production that we want, and to transport it from one place to another," Imhoff said.

Can We Afford It?

Stanley Wood, of the International Food Policy Research Institute (IFPRI), agreed with Imhoff's emphasis on the question of costs. "The bottom line is food availability and food affordability. How stretched will our incomes be to meet our food requirements?" Wood works with a team from the IFPRI that collaborated with Imhoff on the net primary production work and which has joined with him on a new proposal that builds on the initial work.

The data isn't just showing us the bad news; it is also giving us the power to study the changes ahead and understand them

Imhoff and the IFPRI team hope to improve their understanding of the flow of net primary production between countries. Wood said, "For example, let's say that energy security becomes an increasing concern and the U.S. turns to biofuels. The global price of maize could rise steeply because of competition between maize for food and feed, and maize for biofuels. This would create a double-edged sword for poor countries: the increased prices would generate more income for developing country farmers, but would be bad news for poor consumers."

Widening the global picture is also something that Imhoff looks to do. "We have begun projecting what would happen to plant production with climate change, and you don't have to look very far to see that the geopolitics of food production could change significantly, with some countries winning and others losing. **Even without climate change, we are already rubbing up against some limits in our planet's ability to supply us,"** he said.

Both Wood and Imhoff hope their data set on human use of net primary productivity, which is now available through SEDAC, will be useful to policy and decision makers, both in governmental and nongovernmental agencies. "We hope to have more one-on-one conversations with users in the future," Imhoff said. "With the unprecedented population levels that we have now, surprises can develop very quickly. We need to be ready."

However, even with a growing global population, increasing consumption levels, and other global changes bearing down on us, Imhoff emphasized the positive. "We have the technology to get out ahead of this. The data isn't just showing us the bad news; it is also giving us the power to study the changes ahead and understand them," he said. "We are far from being helpless. Our ability to assess our environment and our situation should give us a sense of empowerment."

Please see *nasadaacs.eos.nasa.gov/articles/2007/2007_plants.html* for full story including additional information and color images.

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Top-of-Atmosphere Albedo Variability from CERES and Earthshine

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Introduction: Planetary Radiation Balance and the Earth's Albedo

The amount of solar radiation absorbed by the Earth is the principle source of energy that drives the climate system. It is determined from the difference between how much solar radiation is intercepted by the planet and how much is reflected back to space. Over a year, a planetary radiation balance is approached whereby the absorbed solar radiation is nearly balanced by outgoing terrestrial infrared radiation.

Even a change in albedo could significantly modify this balance and alter climate. For example, an increase in albedo would mean less solar heating and offset the influence of increased absorption of infrared radiation in the atmosphere due to the buildup of carbon dioxide (CO_2), methane (CH_4), and other greenhouse gases. Sensitivity studies show that an absolute increase (decrease) in planetary albedo of 0.01 could potentially lead to a decrease (increase) in equilibrium surface temperature by as much as 1.75°C [Cess, 1976].

Norman Loeb is a researcher at NASA Langley Research Center and he and some of his colleagues at Langley have been using CERES data to measure variations in the Earth's albedo. *The Earth Observer* recently contacted Loeb and asked him to give a report on some of his recent work and he was gracious enough to provide us with this summary of a recent paper published in *Geophysical Research Letters (GRL)*. For more details on this research, please refer to the original article in GRL [*Loeb et al.*, 2007.]

November 27 marks an exciting milestone in the history of the Clouds and Earth's Radiant Energy System (CERES) mission. On that date 10 years ago, the Tropical Rainfall Measuring Mission (TRMM) satellite was launched, thus beginning what is now a 10-year climate data record. When combined with the earlier Nimbus 7 and Earth Radiation Budget Experiment (ERBE) radiation budget experiments, the total climate record extends to almost 30 years. To celebrate this special anniversary, we invite you to enjoy reading about how CERES data are being used to research the Earth's planetary radiation balance. In this issue, Norman G. Loeb reports on recent variations in the Earth's albedo as observed by various approaches. In the next two issues, enjoy further reports from CERES team researchers on ocean heat storage (Tak Wong) and cloud behavior studies (Kuan-Man Xu). NASA Langley Research Center is the proud home of CERES. In case you missed it, the September - October 2007 issue included an article by **Seiji Kato** entitled: *Changing Arctic Observed by CERES Instruments and MODIS*.

Recent Measurements of Albedo Variability

Recently a number of publications have emerged showing contradictory changes in planetary albedo during the first part of the 21st century. For example, a group including Professor Enric Palle of the New Jersey Institute of Technology used a ground-based telescope at the Big Bear Solar Observatory (BBSO) in California to measure Earthshine, the visible solar radiation that is first reflected by the Earth towards the Moon and then back from the Moon to an observer on the night-side of the Earth [*Pallé et al.*,2004]. When they did this, the researchers concluded that the Earth's reflectance has increased by as much as 0.018 between 1999 and 2003, corresponding to a change of approximately 6 W/m^2 in top-of-atmosphere (TOA) radiative flux.[1]

If correct, such a change would be climatologically significant, as it exceeds the radiative forcing caused by the eruption of Mount Pinatubo in the early 1990s by a factor of 2.5, and is twice as large as the longwave radiative forcing by greenhouse gases since 1850 [*Houghton et al.*, 2001]. However, it should be noted that these ground-based Earthshine measurements have some serious limitations since they sample only approximately 1/3 of the Earth on any given day, and cover at most approximately 1/3 of each lunar month provided the night-sky is cloud-free. On the other hand, Pallé and his team do find

[1] $\Delta F = \Delta\alpha \times C/4$, where F=TOA flux, α=albedo, C=1365 W/m^{-2}.

support for their results from another source. Recently, scientists have observed variations in the satellite on-board temperatures of the Global Ozone Monitoring Experiment (GOME) instrument, and they speculate that the variations are caused by changes in Earth's outgoing radiance [*Casadio et al.*, 2005].

In contrast to these findings, the global CERES observations show a small decrease of ~2 W/m^2 in shortwave reflected flux between 2000 and 2004 [*Wielicki et al.*, 2005]. More recently, Norman Loeb and other colleagues used a revised version of the CERES data to show that no statistically significant changes in the Earth's albedo have occurred between 2000 and 2005 [*Loeb et al.*, 2007b]. These results are consistent with measurements of the change in Photosynthetically Active Radiation (PAR)[2] during the same period from Sea-Viewing Wide-Field-of-View Sensor (SeaWiFS) TOA radiance measurements [*Patt et al.*, 2003] for all-sky conditions over ocean. The same group also found consistent results between CERES monthly shortwave (SW) TOA flux anomalies and those from the International Satellite Cloud Climatology Project (ISCCP) radiative flux profile data set (ISCCP-FD product) [*Zhang et al.*, 2004].

Seasonal Cycle of Albedo

Global albedo has a distinct and repeatable seasonal cycle. Because of the tilt of the Earth's axis and the large surface albedo of snow at high latitudes, it reaches maximum values during the solstice months (i.e., summer and winter) and minimum values during the equinox months (i.e., spring and fall). Changes in cloud and surface properties from year-to-year introduce slight variations in the seasonal cycle of albedo, but these perturbations are much smaller than the basic seasonal cycle of albedo. Therefore, any approach that attempts to measure subtle changes in the Earth's albedo must at least be able to characterize the broad features of global albedo changes with season.

Loeb and his colleagues simulated the seasonal cycle of the Earth's reflectance as it would appear from an observer on the moon viewing Earthshine. The simulation uses CERES Angular Distribution Models (ADMs) [*Loeb et al.*, 2003] and measurements from the CERES Terra Single Satellite Footprint (SSF) product for 2002 through 2004 and makes the assumption that there are no changes in scene properties between the CERES and Earthshine measurement times. This simplifying assumption allows the scientists to use the CERES ADMs to transform the observed reflectance at the CERES viewing geometry to that corresponding to the sun-Earth-moon viewing geometry at the Earthshine observation time. Once they make this transformation, they can simulate the reflectance contributions from all points on the Earth that contribute to Earthshine. These reflectances are then integrated over the lunar viewing geometry to determine the total Earthshine reflectance intercepted by the moon. Conceptually, we can think of the moon as a "satellite" measuring the Earth's reflectance over a large portion of the Earth from a viewing geometry defined by the relative position of the sun, Earth, and moon. **Because the lunar observer is assumed to collect data continuously throughout the day from all parts of the Earth that contribute to Earthshine, the spatial and temporal sampling in this simulation is more complete than the ground-based Earthshine measurements discussed above** [*Pallé et al.*, 2004], which are restricted to a few hours per night and limited to cloud-free conditions at the Big Bear Solar Observatory site. The lunar Earthshine simulation represents ideal sampling conditions: it is analogous to having multiple ground-based Earthshine sites around the globe with no intercalibration differences, no cloud coverage restrictions, and since CERES SW data are considered, no narrow-to-broadband conversion errors.

Figure 1a-b compares the seasonal cycle in simulated

[2] PAR is defined as the solar flux reaching the ocean surface in the 400-700 nm spectral range and is anti-correlated to SW TOA flux.

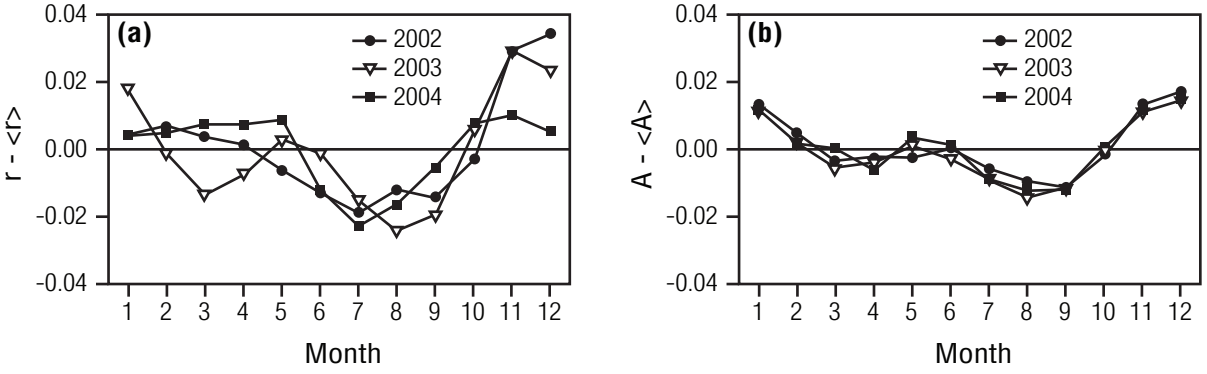

Figure 1. Seasonal variation in **(a)** simulated Earthshine reflectance and **(b)** CERES global albedo expressed as the deviation from the 3-year mean value. Earthshine reflectances are adjusted to a common lunar phase angle of 95°.

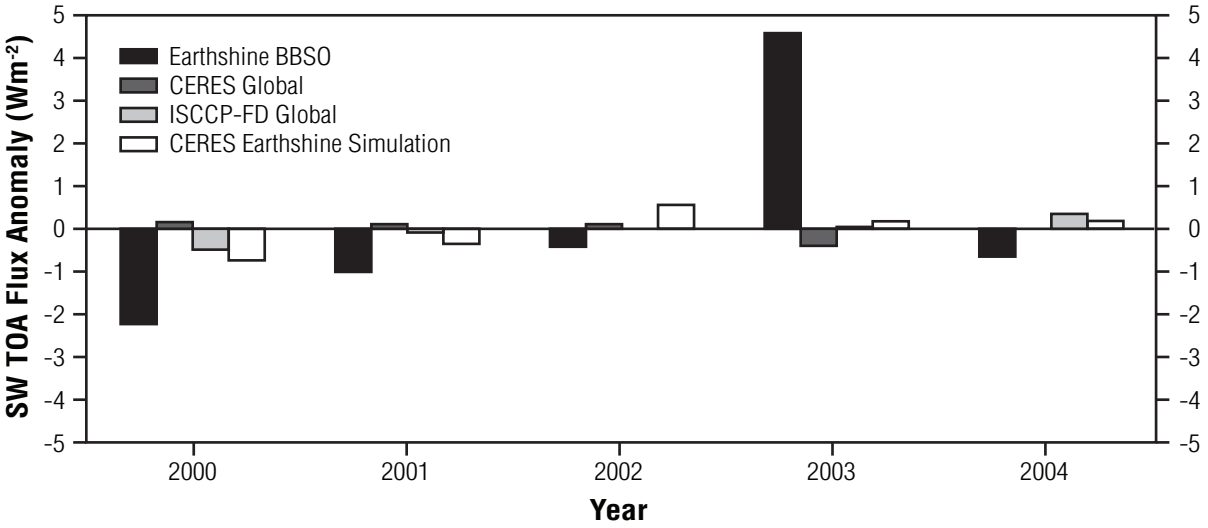

Figure 2. Global annual mean SW TOA flux anomalies from Earthshine BBSO [*Pallé et al.*, 2004], CERES Terra global fluxes, ISCCP-FD, and a simulation of Earthshine.

Earthshine reflectance and CERES global albedo given as the deviation from the mean 3-year value for 2002 through 2004. CERES global albedos exhibit a well-defined seasonal cycle with albedo maxima and minima occurring at the same time of year for each of the 3 years. In contrast, while a seasonal cycle in Earthshine reflectance is apparent, it is highly variable and out-of-phase from one year to the next—see **Figure 1a**. As a result, the year-to-year variability in a given month is typically 4-5 times larger for Earthshine reflectance compared to CERES albedo.

SW TOA Flux Anomalies

Figure 2 shows an overall summary of annual anomalies in SW TOA flux between 2000 and 2004 based on several different approaches. Annual anomalies are determined by differencing the average in a given year from the average of all years between 2000 and 2004. The *Earthshine BBSO* results are from the work done by Enric Pallé and others at Big Bear Solar Observatory [*Pallé et al.*, 2004], while *CERES Global* results are based on global SW TOA fluxes from the SSF data products that have been converted to 24-hr average fluxes by applying diurnal albedo models that account for albedo changes at all times of the day—and assuming the scene at the CERES Terra overpass time remains invariant throughout the day [*Loeb et al.*, 2006]. *ISCCP-FD Global* albedo anomalies are from the work of *Zhang et al.* [2004], while the *CERES Earthshine Simulation* results correspond to simulations described in the previous section. The most striking feature in **Figure 2** is the marked difference between *Earthshine BBSO* anomalies and all other methods. **None of the other methods support the dramatic increase in BBSO Earthshine reflectance between 2000 and 2003.** The standard deviation in the BBSO Earthshine anomalies is a factor of 5 greater than the *CERES Earthshine Simulation* anomalies, and over an order-of-magnitude greater than those from *CERES Global* results. Interestingly, anomalies based on the *CERES Earthshine Simulation* approach bear little resemblance to the *CERES Global* results. In fact, the standard deviation in the *CERES Earthshine Simulation* anomalies is a factor of 2 larger than the *CERES Global* results. While the *ISCCP FD Global* and *CERES Global* SW TOA flux anomalies also differ from one another from year to year, the standard deviation in the anomalies is within 40% of each other.

Figure 3 shows monthly anomalies in CERES SW TOA flux and MODIS cloud fraction. **The strong correlation between the anomalies in these two variables implies that most of the monthly variation in SW TOA flux is associated with changes in cloud cover.** The remaining variability is likely associated with cloud optical depth variations and, to a lesser extent, surface albedo variations.

Conclusions

Monitoring changes in the Earth's SW TOA radiation is critical for understanding climate. However, because of the spatial and temporal scales involved and the need to account for radiant energy across the entire solar spectrum, it presents a significant observational challenge: all methods that attempt to measure the Earth's TOA radiation suffer from sampling errors due to inadequate spatial, temporal or spectral coverage. The Earthshine ground-based approach of *Pallé et al.* [2004] shows the largest variability in annual mean SW TOA radiation, reaching 6 W/m^2 between 1999 and 2003. Simulations of lunar Earthshine measurements show far less variability than those observed from the ground, but still show 4-5 times the variability observed from CERES global data. Furthermore, while CERES

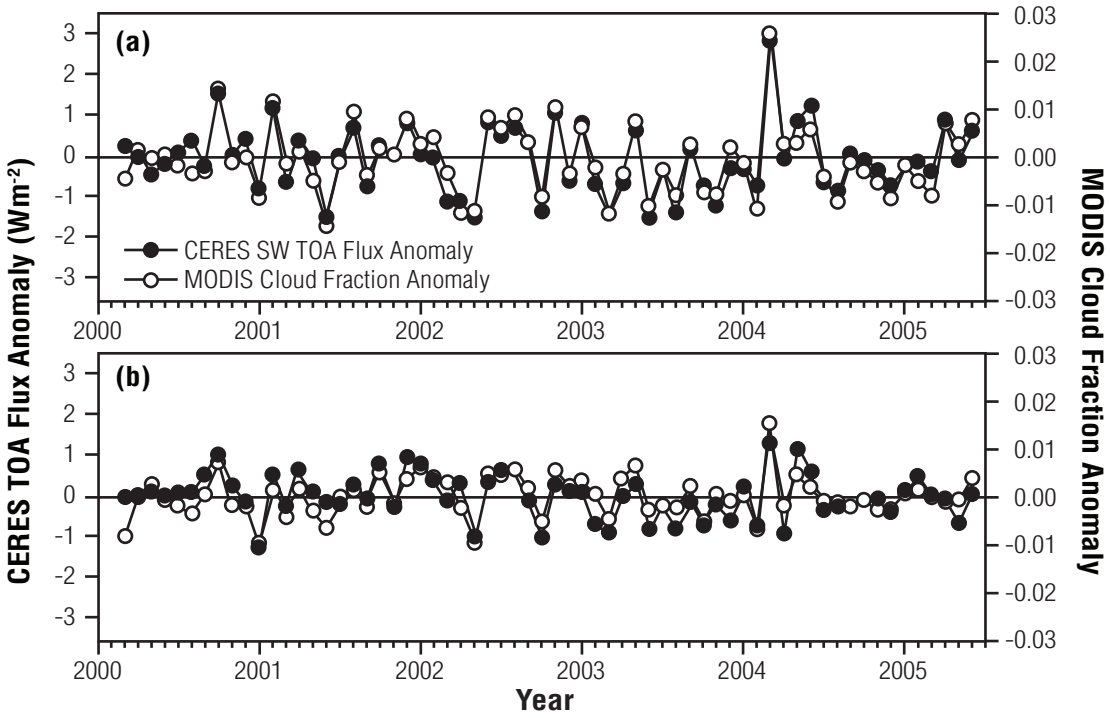

Figure 3. Monthly anomalies in **(a)** tropical and **(b)** global mean CERES SW TOA flux and MODIS cloud fraction.

global albedos exhibit a well-defined seasonal cycle with albedo maxima and minima occurring at the same time each year, the seasonal cycle in lunar Earthshine reflectance simulations is highly variable and out-of-phase from one year to the next.

Acknowledgements

The CERES data are provided by the NASA Langley Atmospheric Sciences Data Center in Hampton, VA. The ISCCP FD data set is obtained directly on-line from the ISCCP web site at *isccp.giss.nasa.gov.* The NASA Science Mission Directorate through the CERES project at Langley Research Center funded this study.

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Release of AIRS Version 5 Near-Real Time Data

AIRS Near Real Time (NRT) data products are currently available for Level-1B and Level-2, and are especially useful for users whose primary interest is low latency for data availability. While operational data are available within 3 days of observation, NRT data are usually available within 3 hours of observation. However, there is no commitment for a complete NRT data record. For example, if NRT data are delayed by more than 24 hours, they will not be processed.

Accuracy of Orbit (impacts geolocation of NRT products): operational data production uses the rectified orbital parameters and satellite position that is accurate to better than 50 meters. NRT data production uses predicted orbital parameters, required to be accurate to 400 meters and generally accurate to 100 meters. Orbital prediction is slightly less accurate towards the end of the day (UTC). Solar flares impact the accuracy of the orbit prediction. An evaluation of the predicted orbital ephemeris for the current day is available after 1600 UT at: *rapidfire.sci.gsfc.nasa.gov/ephdiff/.*

Data Access Information:

- Near Real Time (NRT) Data Products: *disc.gsfc.nasa.gov/AIRS/data_access.shtml#NRT*
- Operational Data Products: *disc.gsfc.nasa.gov/AIRS/data_access.shtml*

meeting/workshop summaries

Summary of the Joint AMSR Science Team Meeting

Elena Lobl, University of Alabama in Huntsville (UAH), Elena.lobl@nasa.gov

The Joint Advanced Microwave Scanning Radiometer—Earth Observing System (AMSR-E) Science Team meeting was held in Missoula, MT on August 14-16, 2007. The Joint AMSR Science Team is made up of the U.S. AMSR-E Science Team, validation and interdisciplinary scientists, and the Japanese AMSR-E Science Team. The meeting usually has the following components: instrument, data processing, archive, and distribution status; science update; and a period for questions and miscellaneous topics. To view full presentations, please visit: ***wwwghcc.msfc.nasa.gov/AMSR****. The next Joint AMSR Science Team meeting will take place in Japan in early January 2008.*

Instrument, Data Processing, Archive and Distribution Status

T. Takeshima [Japan Exploration Agency (JAXA)] explained that since April 15, AMSR-E has been showing some erratic behavior in the torque of the spinning mechanism. Interestingly, the phemonena is very similar to a problem the QuikSCAT scatterometer experienced very early on in its mission. **Figure 1** is a plot of the AMSR-E spinning mechanism torque from the beginning of the mission. The increase in torque is clearly evident, but also notice that values are still much below the maximum allowable value. (Dashed line at the top of the graph.)

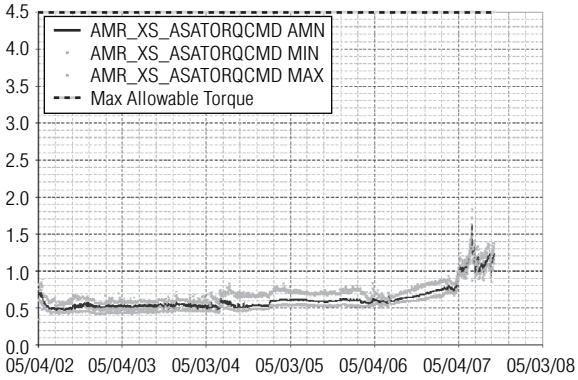


Figure 1. The AMSR-E spinning mechanism torque from the beginning of the Aqua mission. Note the torque has increased since mid-April 2007, but still remains much below the maximum allowable value. **Credit:** J. Pawloski and C. Hester [GSFC].

D. Conway [University of Alabama, Huntsville (UAH)] presented the status of the activities on-going at the Team Lead Science Computing Facility (TLSCF). The major activity at the TLSCF porting algorithms developed by the U.S. Science Team to Linux. This process should be completed by the end of the year and reprocessing with the new algorithms will start shortly after that.

H. Conover [UAH] presented the status of the AMSR-E Science Investigator-lead Processing System (SIPS). The SIPS takes the algorithms from the TLSCF and uses them to process the AMSR-E data. Once processed, the products are sent to the archiving and distribution facility at the National Snow and Ice Data Center (NSIDC) in Boulder, CO.

R. Weaver [NSIDC] presented distribution statistics for the AMSR-E data products.

H. Sasaki [JAXA] and **H. Takezawa** [Remote Sensing Technology Center (RESTEC)] presented the status of the AMSR-E data project at JAXA, in Japan. They also discussed the generation of the Level 2A (L2A) product for the short-lived AMSR-A instrument that flew on Midori 2. Even though Midori 2 ceased operations after only 10 months, there are some advantages to the AMSR-A data, namely the collocation with the SeaWinds scatterometer data, the additional lower tropospheric sounding channels (50 and 53 GHz), and the different ascending node time.

F. Wentz [Remote Sensing Systems (RSS)] showed the different geolocation corrections applied to the AMSR-A dataset that will soon be available at NSIDC.

AMSR-E Science Update

J. Pawloski [NASA Goddard Space Flight Center (GSFC)—Aqua Mission Manager] presented on behalf of Angie Kelly [GSFC] and discussed the status of the A-Train satellites. The idea behind the formation flying of the satellites making up the A-Train was the advantage of a multitude of sensors seeing the same footprint closely spaced in time. AMSR-E data can be combined with data from instruments on the other satellites that make up the A-Train.

C. Kummerow [Colorado State University (CSU)] presented research being done at CSU involving using data from Aqua's AMSR-E and Moderate Resolution Imaging Spectroradiometer (MODIS); Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager (TMI) and Precipitation Radar (PR); and CloudSat's radar. One intermediary conclusion is that CloudSat radar can be used as a *rain screen*—i.e., it observes even the lightest rain amount, much better than the TRMM Goddard Profiling Algorithm (GPROF) products using AMSR-E or TMI observed brightness temperatures.

R. Spencer [UAH] used a multitude of sensors and concluded that the natural climate variability can be

diagnosed only by using multiple satellite instruments and that these satellite measurements can be used to constrain model assumptions.

S-J. Khalsa [NSIDC] showed a plan that was proposed to NASA to provide Aqua/MODIS products subsetted along the CloudSat ground track and the Aura/MLS scan track. The discussions following these presentations made it clear that most of the scientists are involved in research that includes data from numerous space instruments.

T. Wilheit [Texas A&M University] discussed the use of the TRMM-PR to improve the monthly AMSR-E rainfall algorithm. He found that his research calculates different beam filling corrections than those found by his PhD student A. Wang in 1995.

C. Kummerow [CSU] described the changes that are being planned for the instantaneous rainfall (L2B product) algorithm. The rainfall algorithm will become a parametric-type algorithm where the results will vary based on sensor calibration, observation time differences, and capabilities. An *a-priori* climatology of precipitation will be created using the TRMM radiometer and PR. The AMSR-E algorithm will then select a subset of profiles consistent with its observations. There are still some problems to resolve, but Kummerow plans to deliver the new algorithm to the TLSCF in early 2008.

G. Petty [University of Wisconsin, Madison] is working on the validation of precipitation data at high latitudes. Petty showed the statistics of a few of the precipitation algorithm results when compared with data obtained from mid- and high-latitude islands. These data have to undergo a correction process because the islands are *"neither very small nor very flat."* (See Petty's full presentation for the details of his work at *weather.msfc.nasa.gov/AMSR/meetings_2007.html.*)

A. Shibata [JAXA] presented a method for removing the radio frequency interference (RFI) from the AMSR-E sea-surface temperature (SST) product. Even after the corrections are applied there is still a 1-2ºC residual bias.

S. Saitoh [JAXA] looked at the accuracy of the wind speed over oceans from the 6.95 and 10 .7 GHz channels, and concluded that these products are very accurate.

F. Wentz [RSS] presented evidence that the hydrologic cycle is accelerating. Wentz systematically analyzed all 20 years of microwave data (he looked at data from the Special Sensor Microwave/Imager [SSM/I] on the Defense Meteorological Satellite Platform, TMI on TRMM, and AMSR-E on Aqua) and showed that the trends are increasing approximately 1.3% per decade for evaporation, and 1.4% per decade for SSM/I precipitation. These trends are much higher than the ones predicted by climate models. In Wentz's words: *"for a global warming of 3°C by the end of the century, our results would implicate a 20% increase in rain versus a 6% increase predicted by the models."*

M. Brewer [RSS] showed details of the validation process for sea-surface temperatures (SST), oceanic wind speed, and atmospheric water vapor. Brewer presented three movie clips: one showing the global oceanic water vapor (obtained with AMSR-E data), and two SST clips (one showing the SST in the Gulf of Mexico during Katrina's buildup and landfall).

S. Chan [NASA/Jet Propulsion Laboratory] investigated the land-surface moisture variability using the entire AMSR-E dataset. He showed both an annual and inter-annual hydrologic variability. The trend at the 95% confidence level shows areas with both increasing and decreasing surface soil moisture.

J. Kimball [University of Montana] presented part of his ongoing science activity on the carbon cycle. Kimball showed that MODIS gross primary production (GPP), together with the AMSR-E-based soil temperature and moisture inputs, captures the regional patterns and variability in land-atmosphere carbon exchange.

R. Reichle [University of Maryland Baltimore County] presented an adaptive ensemble Kalman filter (EnKF) for AMSR-E soil moisture data assimilation. The premise was that model and observation errors degrade the assimilation estimates. Reichle showed that the assimilation estimates are generally improved when he employs adaptive EnKF. He also introduced a new project that would improve weather and sub-seasonal climate forecast through assimilation of land-surface products (e.g., AMSR-E snow water equivalent and MODIS land-surface temperature) into the NASA Global Modeling and Assimilation Office (GMAO) seasonal forecasting and weather prediction systems.

T. Jackson [U.S. Department of Agriculture (USDA)] talked about the validation of NASA and JAXA soil moisture products at four U.S. watersheds. These watersheds were chosen because each of them had an extensive ground network of ground soil moisture measurements. Jackson concluded that the NASA products generally underestimate the soil moisture, and the JAXA products are generally closer, but at times exhibit erratic behavior. He showed an alternate algorithm, developed at USDA that performed well at all sites.

I. Kaihotsu [Hiroshima University] manages a soil moisture validation site in Mongolia. Kaihotsu presented an update on the validation site status, and then he showed some comparisons of the JAXA soil moisture products and the Ministry for Nature and Environment of Mongolia soil moisture measurements ground network (NAMHEM).

R. Kelly [University of Waterloo, Canada—*AMSR-E U.S. Snow Scientist*] presented the status of the snow water equivalent (SWE) algorithm, and the plans to update the snow detection thresholds. Kelly is also involved in two validation field campaigns planned in Canada in early 2008 which support the further development and validation of the AMSR-E SWE algorithm. Kelly is a Co-Principal Investigator on an ongoing project at GSFC that seeks to merge the MODIS and AMSR-E snow products for a near-real-time application at the Air Force Weather Agency (AFWA).

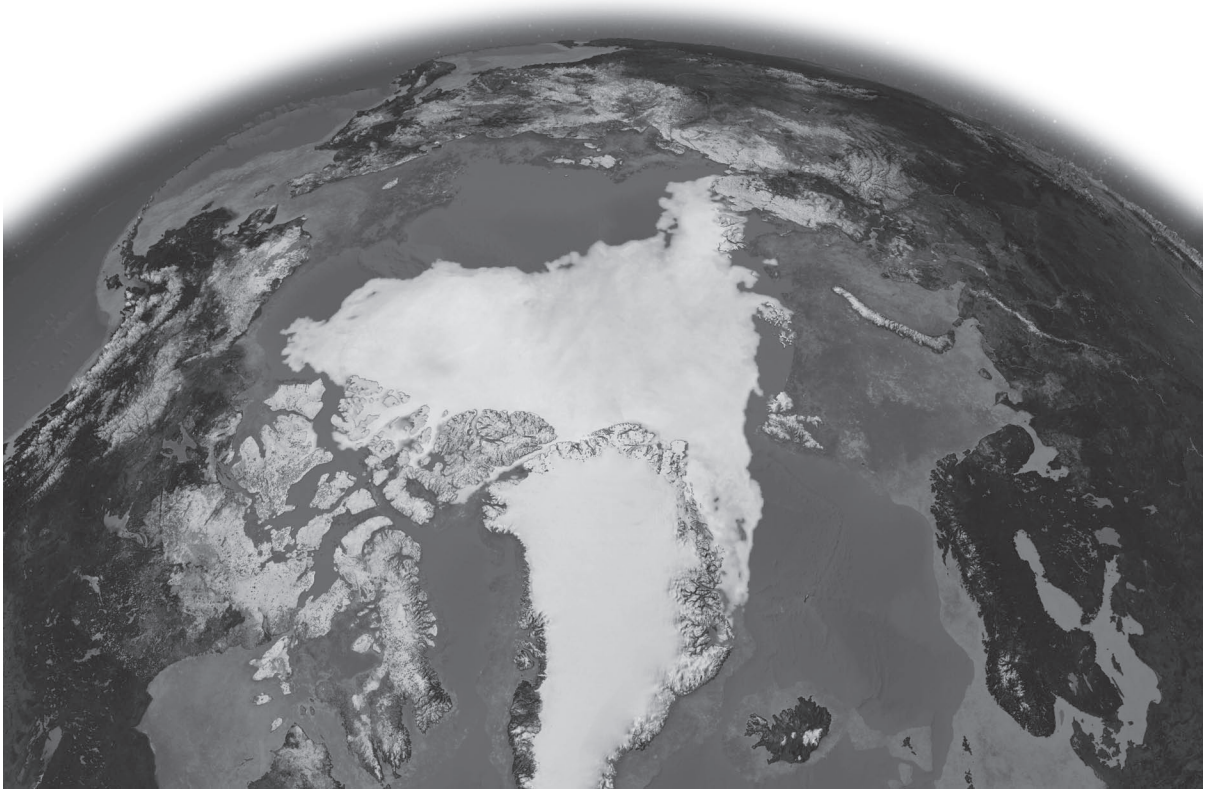
M. Kazumori [Japan Meteorological Agency (JMA)] showed that AMSR-E data are useful in the JMA global data assimilation system.

M. Yamanashi and **Y. Taniguchi** [Mitsubishi Space Software Company, Japan] updated the geolocation correction for the AMSR-E Level 1B data. This correction will be implemented in early 2008.

Future AMSR Mission

K. Imaoka [JAXA/Earth Observation Research Center (EORC)] presented a summary of the next JAXA mission that will fly a follow-on to AMSR-E. The Global Change Observation Mission—Water (GCOM-W) will be the first satellite in the GCOM series, and will be launched in early 2012. The orbit will be close to the current Aqua orbit—i.e., sun synchronous, at 699.6 km altitude, and with a 1:30 PM equator crossing time. Three important changes to AMSR2 are that it will have a larger reflector (2 m), an additional channel at 7.3 GHz for RFI mitigation, and an improved calibration system. ■

The 2007 Arctic summer sea ice has reached the lowest extent of perennial ice cover on record—nearly 25% less than the previous low that was set in 2005. The area of perennial ice has been steadily decreasing since the satellite record began in 1979, at a rate of about 10% per decade. This image was derived from the AMSR-E instrument on NASA's Aqua Satellite and shows the 2007 minimum, reached on September 14, is far below the previous record made in 2005 and is about 38% lower than the climatological average. Such a dramatic loss has implications for ecology, climate and industry. To view the color animation go to: *svs.gsfc.nasa.gov/vis/a000000/a003400/a003466/index.html.* For more details on this year's sea ice minimum see page 38 of this issue. **Credit:** NASA Goddard Space Flight Center Scientific Visualization Studio.



NEESPI/LCLUC Science Team International Regional Meeting on Dryland Processes in Central Asia

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The Northern Eurasian Earth Science Partnership Initiative (NEESPI)/ Land-Cover and Land Use Change (LCLUC) Program Science Team International Regional Meeting on Dryland Processes in Central Asia was held September 16-21, 2007 in Urumqi, China. Xinjiang Institute of Ecology and Geography (XIEG) hosted the meeting. XIEG is an advanced, multidisciplinary institute with a strong focus on ecosystem processes, sustainable development, and resource management in arid lands. Situated in the heart of Central Asia's drylands on the ancient Silk Road, Urumqi was the ideal location for this forum. Over 60 participants joined the meeting representing China, Mongolia, Uzbekistan, Kazakhstan, Tajikistan, Russia, Germany, and the U.S. The objectives of this meeting were to provide an inter-agency and international forum to bring scientists together to discuss drylands research, as well as the importance of data and information sharing. The agenda for this meeting, as well as presentations and posters, can be found on the LCLUC website at: lcluc.hq.nasa.gov.

Science Issues

The focus of the meeting was on global climate change issues relating to and impacting the drylands of Central Asia in particular, with broader application to dryland ecosystems located in other parts of the world. Drylands of Central Asia are *water-limited* ecosystems—i.e., vegetation patterns and ecosystem processes are controlled by water availability. Slight shifts in the water budget can lead to drastic changes in vegetation cover, biodiversity, and ecosystem services in these unique environments. In this manner, drylands are particularly sensitive to the impacts of global climate change and are highly susceptible to substantial, rapid environmental change.

The meeting agenda focused on identifying the data needs for operational monitoring and scientific research, and prioritizing future research objectives in light of the observed and predicted global climate change. Science issues concerning water budgets, water management, soils management, climate change and frequency of extreme events, and Earth system and scale linkages were common themes that ran throughout many of the research presentations. One of the most important science findings highlighted during the meeting is the difference in climate change effects between arid and semi-arid lands in the region. **While semi-arid lands have experienced a decrease in precipitation, arid lands have experienced an increase in precipitation—an unexpected result**. Beyond climate change research, social science issues proved to be the most pressing, with many participants voicing concerns that the social science component necessary for drylands research needs strengthening including local population dynamics, consumption of ecosystem services, agricultural and pastoral systems management, changes in nomadic livelihoods, and inclusion of local stakeholders in scientific research. In addition to data and science needs, speakers emphasized that a key ele-

ment in furthering scientific research and data availability was increased levels of support for international collaboration and regional network-building.

Opening Remarks

Jiyuan Liu [Chinese Academy of Sciences (CAS)], **Chen Xi** [CAS], **Jiaguo Qi** [Michigan State University], and **Hong Li** [CAS] opened the meeting with a warm welcome. They emphasized the importance of research in drylands, in particular those located within Central Asia, throughout the introductions. In addition, they noted challenges of working in the region along with the importance of the meeting in offering opportunity for collaboration and cooperation with other countries, as well as contribution to sustainability science and development research.

Pavel Groisman [NOAA—*NEESPI Program Scientist*] provided an overview of the drylands focus within the NEESPI Program. Groisman placed emphasis on research examining the impacts of climate change, including changes in precipitation patterns leading to prolonged dry episodes. He also stressed the importance of the human dimension, especially as linked to climate change and ecosystem function. Model development—with a focus on feedbacks—and investment in education will both be very important. Looking forward to 2010, he suggested some milestones such as validated, reliable models and increased data support, outreach, and education.

Chris Justice [University of Maryland, College Park (UMCP)—*LCLUC Program Scientist*] provided an overview of the drylands focus within the LCLUC Program. Justice illustrated global distribution and population density within drylands along with reports of climate change impacts in the drylands of Central Asia. In addition, he reviewed LCLUC science themes and program elements and emphasized the six program components. He demonstrated the first component, *regional case studies of land-use change*, showing examples of currently funded regional LCLUC drylands research from case studies around the globe. The second component, *develop and distribute global and regional observations and data sets*, is accomplished through free and open sharing of Earth Observing System (EOS), Landsat *GeoCover*, various Global Land Cover Facility (GLCF), and LCLUC-funded projects datasets. Justice illustrated the third component, *develop conceptual frameworks for LCLUC research*, when he discussed coupled human-environment conceptual frameworks employed in LCLUC-funded sustainability science research and the Global Land Project (GLP). The fourth component, *modeling land-use to understand processes, interactions, and feedbacks*, concentrates on coupled, predictive, and integrated assessment models. The fifth component, *studies providing science underpinning to applications of societal benefit to drylands management*, focuses on water use, shrub encroachment, fire management, livestock management, biodiversity protection, agriculture monitoring, famine early warning, and climate predictions. The sixth component of the LCLUC Program is to *support and promote national and international scientific collaboration through partnerships and linkages*, a goal pursued through venues such as this and future meetings focused on programmatic, scientific, and regional themes.

Garik Gutman [NASA Headquarters—*LCLUC Program Manager*] presented an overview of LCLUC Program linkages to the NEESPI drylands component. Gutman introduced the LCLUC program to attendees who were not members of the Science Team which discussed drivers of disturbance and consequences along with relevant tools (e.g., remote sensing and *in situ* observations, modeling, and data/information systems) for LCLUC studies. He listed NASA and non-NASA systematic and exploratory missions. Gutman outlined LCLUC program contributions to the Global Earth Observation System of Systems (GEOSS) and international projects such as Global Observation of Forest and Land Cover Dynamics (GOFC/GOLD), International Geosphere-Biosphere Programme/ Integrated Land Ecosystem-Atmosphere Processes Study (International Geosphere-Biosphere Programme (IGBP)/iLEAPS), and IGBP-International Human Dimensions Programme (IHDP)/GLP. Further, he described LCLUC support of regional initiatives, putting emphasis on the Monsoon Asia Integrated Regional Study (MAIRS) and NEESPI, explaining the NASA role in these international programs and giving details on the ongoing dryland projects. Gutman stressed the importance for improved programmatic coordination between NEESPI and MAIRS in drylands, and linkages between the LCLUC program and MAIRS in the tropical monsoon region of Asia.

Scientific Presentations

A total of 15 scientific presentations and 16 scientific posters were given during the meeting representing drylands research around the globe. Select presentations and posters have been highlighted.

Chen Xi [CAS] presented an overview of drylands research being conducted at the Xinjiang Institute of Ecology and Geography. The presentation focused on work in Central Asia, with particular emphasis on development and urbanization, land-cover change, desertification processes, sand storms, dune movements, salinization, and water shortages in the region. Xi also emphasized the roles and impacts of human activities on climate and associated regional fluxes in water budget.

Dennis Ojima [H. John Heinz III Center for Science, Economics and the Environment] presented on the effects of climate change and land-use patterns on

pastoral systems throughout Eurasia. Ojima's research focused on nomadic pastoralists in Mongolia and Kazakhstan where socio-economic and lifestyle changes are strongly affecting land productivity and ecosystem sustainability in the region.

Yan Xiaodong [CAS] presented information regarding the role of the iLEAPS project within the IGBP. The objective of the multidisciplinary international research program is to study how interacting physical, chemical, and biological processes transport and transform energy and matter through the land-atmosphere interface.

Lin Zhen [CAS] presented an overview of international collaboration activities and results of research concerning sustainable development of the Mongolian Plateau region. Research focused on climate and land-use change in the region and associated impacts, including accelerated desertification processes, increased soil erosion, a decrease in water availability, loss of livestock, and decreased agricultural yields.

Mutlu Ozdogan [University of Wisconsin, Madison] presented research on the role of remote sensing in irrigation monitoring and management. Remote sensing is a valuable tool for determining the amount of area irrigated and resultant water allocation based on crop type and yield, evapo-transpiration, and soil characteristics. This information helps land managers and irrigation engineers assess the productivity of water use and maximize agricultural efficiency.

Geoffrey Henebry [South Dakota State University] presented research on land surface phenologies, land-cover and land-use change, and regional hydrometeorology in the Eurasian semi-arid grain belt. The research focusses on land-cover and land-use changes following the collapse of the Soviet Union and changes in regional hydrometeorology.

Programmatic Presentations

A total of 10 programmatic presentations were given during the meeting. Two of the presentations are summarized below.

Garik Gutman [NASA Headquarters] presented an overview of global satellite data products for LCLUC research, including the Mid-Decadal Global Land Survey (MDGLS) project and the Landsat Data Gap study. The MDGLS project is developing a global orthorectified data set from Landsat or Landsat-like observations based on measurements during 2004-2006. The project, led in phases by both U.S. Geological Survey (USGS) and NASA, uses Landsat 7 composites as the primary source, and uses data from Landsat 5, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and Earth Observing-1/Advanced Land Imager (EO-1/ALI) to fill remaining gaps. Scene selection for North America and Africa are currently underway, and *GeoCover* images are being reprocessed using Shuttle Radar Topography Mission (SRTM) data for improved and consistent geodetic control.

The objective of the Landsat Data Gap Initiative is to identify, assess, and recommend alternative data sources that can best provide recurring global land observations, sufficiently consistent in terms of acquisition extent, frequency, and quality, as that of the Landsat Program. Systems considered include Indian Remote Sensing Satellite's (IRS) ResourceSat; China-Brazil Earth Resources Satellite (CBERS); MacDonald Dettwiler and Associates' (MDA) RapidEye; Surrey Satellite Technology Ltd's (SSTL) Disaster Monitoring Constellation (DMC); NASA's ASTER; GeoEye's IKONOS; DigitalGlobe's QuickBird; OrbImage's OrbView-3; France's Système Pour l'Observation de la Terre (SPOT); Japan Aerospace Exploration Agency's (JAXA) Advanced Land Observing Satellite (ALOS); and EO-1/ALI, with primary interest in India's ResourceSat-1 launched October 2003 and China/Brazil's CBERS-2 launched October 2003. Gutman presented a case for an international data initiative to generate a decadal data set (2009- 2011) prior to the launch of the Landsat Data Continuity Mission (LDCM).

Ailikun [CAS] presented the objectives and preliminary results of the Monsoon Asia Integrated Regional Study (MAIRS), a new initiative of the Integrated Regional Study under the leadership of the Earth Science Program Partnership (ESSP). The vision of MAIRS is to significantly advance the understanding of the interactions between the human and natural components of the Asian monsoon region (e.g., land-cover/land-use change, increasing aerosol emission, and water-use change) and the implications of these interactions for the global Earth system. MAIRS is also focused on integration of natural and social sciences in order to deliver strategies for sustainable development to the public and policy makers. Ailikun presented the results to date of the MAIRS study within the semi-arid/arid regions of China. She highlighted the discrepancy in precipitation between arid and semi-arid regions—an increase in precipitation and forest density observed in arid lands and a decrease in precipitation in semi-arid lands. The aerosol study concerned itself with the long distance transport of dust and observed that in one case, dusty clouds reduced the instantaneous net top-of-atmosphere cloud cooling effect by 30%. In conclusion, Ailikun recommended collaboration between MAIRS and NEESPI on their mutual regional interests within the drylands of Central Asia.

Breakout Discussion Groups

Four breakout discussion groups met to discuss current research priorities and opportunities for cooperation

and collaboration on the topics of land-use, ecosystems, water cycle, and modeling. In addition, the groups discussed issues such as framing primary research questions, data availability, methodology necessary to advance research in the field, and obstacles towards successful completion of research within their specific program fields.

Land Use

Joseph Messina [Michigan State University] and **Dan Brown** [University of Michigan] co-chaired the Land Use Group. The group devoted significant effort to framing the primary research questions within land-use and land-cover change research as they apply to drylands. Of key importance was identifying thresholds in the natural and/or human components of the natural-human dryland system which affect sustainability. Questions remain concerning the vulnerability, adaptive capacity, and resilience of these systems in the presence of land-use and land-cover change. The degree to which climate variability, water use, and other factors influence local land-cover and climate change must also be analyzed as a coupled system with the broader region. The team also addressed the degree to which social science data must be integrated with land-use and land-cover data. For example, population shifts and political factors may have an effect at the micro-scale and influence or create change on an observable macro-scale.

In order to address these science questions, the team identified the methodologies which would be required, their current deficiencies, the associated data needs, and other obstacles to success. They observed that there was a lack of a consistent methodological framework for interpreting and monitoring land-use on large scales and integrating *People and Pixels* together, but they theorized that inferring land-use from land-cover dynamics and employing data mining and integration methods might be reasonable approaches. Furthermore, they prescribed several methods for forecasting and modeling, including the following: scenarios (e.g., drought and dust), allocation (e.g., Changing Land Use and Estuaries [CLUE]), complex system models (e.g. cellular automata and agent-based models), and Markov and Von Thunen statistical approaches. The team recognized that a significant obstacle to the types of land-use research being discussed is lack of data—i.e., this type of research requires an increase in spatial or temporal detail, longer time series, and common framework for classification which does not mask subtle changes. In addition, researchers will have to deal with inter-annual variability issues, non-standardized multi-scale modeling frameworks, as well as the sometimes difficult issue of separating land-use from land management. These obstacles can significantly impede progress due to a lack of uniform data and models. However, near-term collaboration may help address these research questions and overcome obstacles by harmonizing data sets across international boundaries and enabling foreigners to collaborate within a region.

Ecosystems

Jiyuan Liu [CAS] and **Chen Xi** [CAS] co-chaired the Ecosystems Group. The team felt that the need for improved understanding of long-term ecosystem dynamics and the carrying capacity of ecosystems were key research topics. The group focused on the Millenium Ecosystem Assessment (MA), a five-year program designed to assess the consequences of ecosystem change for human well-being. In addition to the framework established by the MA, they also recommended development of indicator systems for identification of degradation of specific services, unified classifications of ecosystem boundaries, and integration of socio-economic data.

In addition to methodological frameworks, the discussions also highlighted the need for advancement of methodologies relating to scenario analysis, downscaling, and data fusion. Furthermore the most important data needs would seem to be long-term *in situ* and satellite data records, standardized data sources, and spatially-explicit socio-economic data. Difficulty in processing historical 1-km AVHRR data and limited availability of very high spatial resolution data remain as significant challenges to answering science questions. Collaboration between institutions within the region, including field research and observation stations, will enable significant advancement in ecological research. NEESPI can act as a key coordinator between U.S. and Central Asian countries and establish international joint observation stations (e.g., in the Altai Mountains bordering China and Mongolia).

Water Cycle

Natalya Agaltseva [Research Institute Uzhydromet] and **Alexander Shiklomanov** [University of New Hampshire] co-chaired the Water Cycle Group. The group focused on the atmospheric component of the water cycle, surface water, cryospheric water storage, and groundwater sources.

The primary research directions of the atmospheric component focused on weather monitoring and climate projections. The group recognized that *in situ* data are not sufficient in some regions and that current methodological frameworks are not adequate for convection parameterization and precipitation patterns in rough terrain. Further, the lack of high resolution climatic reanalysis data has proven to be a substantial obstacle to progress.

Surface water discussion focused on representation of the regional hydrological cycle and its interaction with

water use and management situations in order to provide reliable estimates of current conditions and future projections. There is a need for improved coherence among regional methodological approaches along with a unified regional hydrological database and reliable information on water and land-use. Major obstacles noted were trans-boundary river problems, lack of joint water management policies, and an overall decline of the observational network. Increased data, methods, and model sharing along with wider use of remotely-sensed data to complement *in situ* measurements could help overcome these obstacles.

The primary research focus of cryospheric water storage is understanding its state and fate. Reliable mountain glacier volume, snow depth, and snow water equivalent measurements are not yet accessible with remotely sensed data. Development of algorithms and methodologies to produce estimates using reasonably-priced data is needed to overcome this obstacle.

The groundwater sources discussion focused on realistic accounting of the clean water supply available for sustainable use and the need for water quality monitoring programs.

Modeling

Yongjiu Dai [Beijing Normal University] and **Dennis Ojima** [H. John Heinz III Center for Science, Economics and the Environment] co-chaired the Modeling Group. Priority areas identified by the group included: 1) the development of an integrated modeling framework; 2) cross-scale linkages and understanding across scale; and 3) further research on knowledge gaps impeding model development. The key issue regarding integrated modeling is developing a framework at an appropriate scale for socio-economic and environmental interactions in order to address science questions regarding regional development, land degradation, and sustainability. There is a need for downscaled climate projections and socio-economic trends to support local and regional scale planning, along with tools to validate models and increased input from stakeholders. A base spatial scale of 1 km was suggested as a starting point for understanding human-environment interactions. Cross-scale integration is also critical in order to improve data sharing and interaction between scale-dependent research communities, which in turn will support research on component linkages to fill current knowledge gaps.

NERIN Workshop

In addition to scientific presentations and breakout discussion groups on drylands research, the meeting also included a special workshop session on the final day regarding LCLUC regional support of both the NEESPI and Northern Eurasia Regional Information Network (NERIN) programs. **Olga Krankina** [Oregon State University] chaired the NERIN workshop that included presentations from:

- **Tatiana Loboda** [University of Maryland, College Park],
- **Jiaguo Qi** [Michigan State University],
- **Nadiya Muratova** [Ministry of Education and Science of the Republic of Kazakhstan],
- **Almaz Torgoyev** [Central Asian Institution of Applied Geocientists, Kyrgyzstan], and
- **Galina Stulina** [Scientific Information Centre of the Interstate Commission for Water Coordination of Central Asia, Uzbekistan].

In addition to the presentations above:

- **Dennis Ojima** [H. John Heinz III Center for Science, Economics and the Environment] led a discussion regarding a preliminary evaluation of the Land Cover Classification System (LCCS) and its application in dryland regions.
- **Chris Justice** [University of Maryland, College Park] and **Alexey Terekhov** [Ministry of Education and Science of the Republic of Kazakhstan] led a discussion on regional requirements for fire monitoring.
- **Jiaguo Qi** [Michigan State University] and **Olga Krankina** led a discussion on regional requirements and data needs for monitoring land-cover.

Recommendations from the fire and land-cover working sessions were as follows:

Fire

- Develop a network of regionally-specific validation sites to evaluate active fire product and burned-area product performances in drylands following international validation protocols.
- Provide coupled daily information on burned area together with active fires as a standard approach to fire monitoring in drylands.
- Include the optical information incorporating smoke as a way to enhance fire observations in drylands.

Land Cover

- Develop a LCCS-compatible map for the dryland areas of Northern Eurasia as a pilot project. The challenge is working together to create a regionally consistent map.
- Provide training through a series of workshops to ensure the correct application of the LCCS to mapping land-cover.

continued on page 35

meeting/workshop summaries

Summary of the Aura Science Team Meeting

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The 2007 Aura Science Team Meeting was held October 1-5, 2007 at the convention center in Pasadena CA. Plenary sessions began on Tuesday afternoon after a day-and-a-half of working group meetings (summarized below).

Ernest Hilsenrath [NASA Headquarters (HQ)—*Aura Program Scientist*] explained the present budget situation at NASA Headquarters.

Mark Schoeberl [Goddard Space Flight Center—*Aura Project Scientist*] updated the team on the status of the special issue of *Journal of Geophysical Research* dedicated to Aura validation, on plans for A-Train sessions at the spring meeting of the American Geophysical Union, and on the Senior Review that will take place when Aura nears the end of its primary mission in 2009. To prepare for the Senior Review, the Aura Project Science Team and some NASA HQ managers will conduct *on-site* reviews of the Aura instruments during late winter of 2008.

The group heard status reports on all four of the instruments on Aura.

- ***Tropospheric Emission Spectrometer (TES)***: **Reinhard Beer** [NASA/Jet Propulsion Laboratory (JPL)—*TES Principal Investigator (PI)*] reported that TES is in good condition, although the current to drive the transport motor is continuing its gradual upward trend. **Annemarie Eldering** [JPL—*TES Deputy PI*] previewed the TES science presentations. (A composite summary of the recent TES Science Team meeting appears on page 33 of this issue.)

- ***Ozone Monitoring Instrument (OMI)***: **Pieternel Levelt** [Royal Dutch Meteorological Institute—Koninklijk Nederlands Meteorologisch Instituut (KNMI)—*OMI PI, Netherlands*] reported improvements in the calibration used to correct for dark current in the new *Collection 3 Level 1B*.

- ***Microwave Limb Sensor (MLS)***: **Nathaniel Livesey** [JPL—*MLS PI*] presented information on the on-going reprocessing using the *Version 2* algorithm. To date, 75 peer-reviewed publications using MLS data have appeared or are *in press*.

- ***High Resolution Dynamic Limb Sounder (HIRDLS)***: **John Barnett** [Oxford University—*HIRDLS PI, U.K.*] showed progress in correcting the HIRDLS radiances to account for the obstruction. **John Gille** [University of Colorado and National Center for Atmospheric Research (NCAR)—HIRDLS PI, U.S.], the second co-PI, showed convincing evidence of high vertical resolution in the temperature and ozone profiles.

The first set of science presentations focused on validation.

John Barnett showed comparisons of HIRDLS temperature profiles with profiles from the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) Global Positioning System (GPS). There are large numbers of profiles that satisfy close coincidence requirements, and comparisons show that the HIRDLS vertical resolution is consistent within 1.2 km of the initial planned resolution.

Thomas Kurosu [Harvard University] showed the present status for the minor species that are observed by OMI, *i.e.*, bromine monoxide (BrO), formaldehyde (HCHO), and chlorine dioxide (OClO). The *Collection 3* distributions compare much more reasonably with distributions retrieved from two European Space Agency instruments: the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography/Chemistry (SCIAMACHY) on ENVISAT, and the Global Ozone Monitoring Experiment (GOME) on the European Remote Sensing Satellite-2 (ERS-2).

Folkert Boersma [KNMI] exploited the different equator crossing times of SCIAMACHY (10:00) and OMI (13:30) to investigate diurnal changes in the OMI nitrogen dioxide (NO_2). In some regions the OMI NO_2 is smaller than SCIAMACHY due to the increased photolysis at 1:30 p.m. compared with 10 a.m. In some regions OMI NO_2 is larger, probably because there are more fires in the afternoon than in the morning.

Kaley Walker [University of Toronto] showed present results from the Canadian Space Agency's Atmospheric Chemisty Experiment (ACE) mission on Sci-Sat, which continues flawless operations. The ACE data are scheduled for public release later this year.

Gerald Nedoluha [Naval Research Laboratory] compared profiles from the water vapor millimeter wave spectrometer (WVMS) with MLS profiles in the 40-80 km region, showing excellent agreement when the WVMS weighting functions are applied to the MLS profiles before comparison.

Robert Stachnik [JPL] showed results from balloon-borne instruments obtained last winter. The researchers launched a balloon into the center of the cold pool of the stratospheric winter vortex, and temperature, ozone

and chlorine monoxide were in excellent agreement with profiles from MLS.

Peter Popp [NOAA Cooperative Institute for Research in Environmental Sciences (CIRES)] organized a large volume of nitric acid (HNO_3) data from the NOAA Chemical Ionization Mass Spectrometer (CIMS) instrument on the WB-57 aircraft, obtained from various Aura validation campaigns by correlating the HNO_3 with ozone (O_3). This technique removes the requirement of coincidence and compares relationships between constituents as seen by satellite and aircraft in similar air masses.

Xiong Liu [GSFC/Goddard Earth Sciences and Technology Center (GEST)] used MLS ozone profiles to soft-calibrate the OMI short-wavelength radiances that are sensitive to stratospheric ozone, with the goal of obtaining an accurate tropospheric ozone distribution from longer wavelengths.

Eric Bucsela [GSFC/GEST] found that the OMI near-real-time NO_2 product developed and produced at KNMI is always larger than the standard OMI NO_2 product. The surface albedo, cloud amount, and stratospheric column all impact the differences in the products.

Shuhui Wang [JPL] compared the hydroxide (OH) column calculated from the MLS profiles (using a model to account for tropospheric and lower stratospheric contributions) with ground-based column measurements. There are differences in the seasonal values due to large disagreements at high solar zenith angle.

Simon Carn [University of Maryland Baltimore County (UMBC)/ Joint Center for Earth Systems Technology (JCET)] showed that the sulfur dioxide (SO_2) measured during the Tropical Composition, Cloud, and Climate Coupling (TC^4) Campaign is too low to validate the OMI SO_2 product for individual fields of view, but the OMI measurements are not inconsistent with the mean of the aircraft measurements.

John Livingston [SRI International/NASA Ames Research Center (Ames)] compared three cases of aerosol observations made during Megacity Initiative; Local and Global Research Observations (MILAGRO)/Intercontinental Chemical Transport Experiment (INTEX) with coincident measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua and from OMI. The analysis required calculations to derive the aerosol absorption from the aerosol optical depth.

Christopher Hepplewhite [Oxford University] compared profiles from the European Space Agency's Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on Envisat with profiles from HIRDLS, exploiting the close coincidence (1° great circle, 12 minutes) that is found near the Poles every few days. Although the viewing geometries still differ, the temperatures compare well throughout much of the stratosphere.

Holger Vömel [University of Colorado, Boulder (CU)/CIRES] showed that the MLS water vapor compares well with profiles from the Cryogenic Frostpoint Hygrameter (CFH). Overall agreement is excellent for pressures less than 215 hPa.

Anne Thompson [Pennsylvania State University] discussed the 2004 and 2006 INTEX Ozonesonde Network Study (IONS) campaigns. This data set of ozonesonde profiles provides information on the variability in the upper troposphere/lower stratosphere.

John Gille [NCAR] gave the first in a series of papers concerning stratospheric chemistry and dynamics, showing an example of an intrusion of air from the upper troposphere into the lowermost stratosphere, producing layers that are seen by the HIRDLS.

David Lary [UMBC/GEST] showed that it is possible to use a neural network to produce a time series of Cl_y using data from the Halogen Occultation Experiment (HALOE) on the Upper Atmosphere Research Satellite (UARS), ACE on SciSat, and MLS on Aura.

Michelle Santee [JPL] used MLS profiles of HNO_3 and meteorological information from the Goddard Modeling and Assimilation Office (GMAO) to examine the lowest levels of the north polar vortex and their influence on transport in the high latitude lowermost stratosphere.

Ross Salawitch [JPL] analyzed the recent behavior of the Antarctic ozone hole, showing that the chemical loss has leveled off in recent years due to the leveling off of the halogen source gases.

Henry Selkirk [Ames] summarized results from the summer 2007 Ticosonde campaign that was part of TC^4. Participants launched Vaisala RS92 radiosondes twice daily at 0000 and 1200 Universal Time (UT) from June 16–30, and then four times daily at 0000, 0600, 1200 and 1800 UT from July 1–August 15. Temperature variability increases markedly in the Tropospheric Transition Layer (TTL).

Tim Canty [JPL] showed that the recent values for the cross sections for dichlorine peroxide (Cl_2O_2) photolysis are not consistent with measurements of chlorine monoxide (ClO) or with observed ozone loss in the Antarctic. (**Mike Kurylo** [NASA HQ] spoke briefly on plans to convene a workshop to consider these results in the context of other measurements and theoretical investigations of chlorine catalyzed ozone loss in the spring polar lower stratosphere.)

Melody Avery [NASA Langley Research Center] investigated the distributions of ozone and carbon monoxide (CO) obtained in the near tropopause region over the Pacific during INTEX B, and comparisons with observations from MLS.

Joan Alexander [Northwest Research Associates] showed that HIRDLS temperature profiles can be used to quantify waves above clouds. Idealized global models of waves generated by convection match mean features obtained from the HIRDLS profiles, but these comparisons suggest that the momentum flux is underestimated by about a factor of two.

[A poster session with more than 60 presentations took place Wednesday afternoon. Many of the posters are available from the Aura Validation Data Center]

The next group of presentations explored connections between Aura observations and climate.

Darryn Waugh [Johns Hopkins University] showed a simple model considering last saturation, advection, and random remoistening can explain observations of water vapor in the tropics.

Andrew Dessler [Texas A&M University] used MLS observations of ice water content to produce a climatology of convective events that pentetrate the TTL. Consideration of the possibility of convective ice with a Lagrangian model makes it possible to explain observations of the ratio of deuterated water (HDO) to water (H_2O).

William Read [JPL] used MLS observations of CO and a convective cold trap model to conclude that convection of ice is needed to reproduce observations of water vapor.

Joanna Joiner [GSFC—*Aura Deputy Project Scientist*] explained that because clouds' interactions with light are a function of wavelength, the OMI cloud pressures are greater (i.e., OMI cloud top heights are lower) than the MODIS cloud tops, so the pressure would be higher.

Omar Torres [UMBC/JCET] showed that OMI's greatest advantage for aerosol remote sensing is its near-ultraviolet (UV) capability to detect and characterize aerosol absorption effects. OMI aerosol absorption measurements complement observations by other A-Train instruments in helping to characterize the aerosol forcing—*e.g.*, OMI can detect absorbing aerosols above clouds. The net absorbing effect (*i.e.*, cooling or heating) depends on aerosol single scattering albedo and cloud fraction. (Non-absorbing aerosol causes cooling.)

Steven Massie [University Center for Atmospheric Research] examined HIRDLS and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) observations of sub-visible cirrus and MLS values of relative humidity with respect to ice along with outgoing longwave radiation from the Climate Diagnostics Center to characterize the climatology of tropical cirrus layers.

Ben Veihelmann [KNMI] showed the potential of the OMI multi-wavelength algorithm that uses 14 bands to derive the aerosol optical thickness by identifying the best fitting aerosol model in terms of aerosol type, refractive index, height, and size distribution.

David Noone [CU] showed how isotopes such as HDO, that can be observed with TES in the mid-troposphere, provide the opportunity to quantify the movement of water in the climate system, and used estimates of the HDO:H_2O ratio to characterize the difference between the hydrologic regimes over tropical continents.

Leonard Pfister [Ames] used trajectory calculations with a simplified convective scheme to explain observations of water vapor and carbon monoxide in the TTL, emphasizing that strong convection will not produce a signature in CO if there is no source of CO in the lower atmosphere.

The final three presentations of the morning concerned assimilation.

Pieternel Levelt—speaking for Henk Eskes [KNMI]—reported on the use of OMI near-real-time NO_2 in a regional air quality model.

Steven Pawson [GSFC] compared results from the GMAO ozone assimilation and a chemical transport model (CTM) simulation using parameterized ozone photochemistry with observations from Measurements of OZone and water vapour by in-service AIrbus airCraft (MOZAIC), showing that there are horizontal scales in MOZAIC data that are better represented in the assimilated ozone than in the CTM.

Kevin Bowman [JPL] compared results for assimilation of TES O_3 and CO with the Goddard Earth Observing System (GEOS)-Chemical (CHEM) model and the IONS ozonesonde profiles, showing a reduction in bias for the assimilated fields in the mid-troposphere.

The first talks of the afternoon sessions were focused on A-Train science.

Fredrick Irion [JPL] presented results from the *Version 5* retrievals of trace gases including O_3, CO and methane (CH_4) from Aqua's Atmospheric Infrared Sounder (AIRS) instrument.

Hui Su [JPL] showed that cirrus clouds accelerate troposphere-to-stratosphere transport in the TTL, interpreting seasonal and spatial variations of TES observations.

Wallace McMillan [UMBC/JCET] combined the spatial coverage of CO from AIRS with the vertical information from TES to interpret observations during a biomass burning event.

Jonathon Jiang [JPL] combined observations from CloudSat, CALIPSO, and MLS to study the vertical and global transport of boundary layer pollution. MLS CO less than (greater than) 30 parts per billion by volume (ppbv) was used to classify ice clouds as clean (polluted). Similar reasoning was used to identify aerosol contaminated ice clouds, and aerosol free ice clouds. Observations support the premise that dirty clouds are associated with reduced precipitation.

The remainder of the meeting focused on tropospheric composition and chemistry.

Randell Martin [Dalhousie University—Canada] noted that the tropospheric NO_2 column is strongly related to ground level NO_2 concentration over land.

Lin Zhang [Harvard University] used OMI observations of NO_2 to constrain NO_X emissions and found that Asian emissions are likely responsible for only 1-2 ppbv of an observed 5 ppbv increase in background ozone on the West Coast.

Greg Osterman [JPL] used the Regional Air Quality Monitoring System (RAQMS) along with observations from TES and AIRS to show that elevated CO and O_3 in the lower troposphere over Houston depend on meteorological conditions and transport from other polluted regions.

Jennifer Logan [Harvard University] used the vertical information from TES observations to expand previous results showing the impact of El Niño on the tropospheric ozone amounts in the tropics.

Ray Nassar [Harvard University] followed Logan's analysis with simulations using GEOS-CHEM to show that the ozone anomalies are related to an increase in biomass burning in Indonesia and also respond to changes in meteorology.

Ron Cohen [University of California, Berkeley] showed evidence that emissions inventories should include the day-to-day variations in NO_X emissions, in particular the Sunday minimum due to reduced truck traffic.

Sunita Verma [Centre for Atmospheric Sciences, Indian Institute of Technology—India] found that O_3 and CO are not correlated in smoke plumes from boreal fires, and that aerosols in the plume have a significant impact on ozone photochemistry.

Yang Chen [JPL] attempted to develop temporal constraints for pyro-convection using data from the Multi-angle Imaging Spectral Radiometer (MISR) to develop a probability distribution function (PDF) for injection heights, and also considering the diurnal variation in wild fires. Simulations from GEOS-CHEM were compared with data from many sources, including satellites MISR, MODIS, and Measurements of Pollution in the Troposphere (MOPITT); the Aerosol Robotic Network (AERONET) ground-based network; and the INTEX field mission.

Ken Pickering [GSFC] used OMI NO_2 to obtain estimates of NO_X produced by lightning. The estimates of NO_X per flash are on the high end of other estimates, and suggest that the amount of NO_X produced per flash may be higher over the U.S. than other areas. This could be due to variations in the meteorology of thunderstorms that lead to somewhat longer flashes in the U.S. than elsewhere.

Jennifer Hegarty [University of New Hampshire] used a synoptic classification scheme to create composite maps of CO and O_3 for the various types of circulation. Maps are related to variations in the export of pollution.

John Worden [JPL] showed TES and Stratospheric Aerosol and Gas Experiment (SAGE) observations of the Middle East ozone maximum. The ozone reaches a maximum in July, and appears to be associated with trapping of pollutants in the Arabian anti-cyclone.

Dylan Millet [University of Minnesota] compared an estimate for the global emission of isoprene derived from OMI HCHO with the Model of Emissions of Gas and Aerosol from Nature (MEGAN) bottom-up estimate. Discrepancies are associated with regions where there is a large contribution to isoprene emissions from broadleaf trees.

Line Jourdain [JPL] showed various tests with different lightning schemes in GEOS-CHEM to identify cases in which ozone enhancements observed by TES could be related to lightning events. These comparisons may result in an improved parameterization for lightning NO_X.

Chenxia Cai [JPL] used MLS and MOPITT measurements of CO to compare longitudinal fluxes of CO at 147 hPa with values produced by GEOS-CHEM.

Pepjin Veefkind [KNMI] compared OMI NO_2 with ground-based measurements that were sorted into types: regional, city, and street. The regional NO_2 is

strongly correlated with the OMI columns, but the city and street observations are not, with more NO_2 seen by the ground-based instruments. The NO_2 at this spatial scale may not be quantitatively related to the OMI columns because the OMI pixels are too large.

Summary reports from the various Working Group Meetings that took place prior to the plenary session were interspersed in the meeting agenda.

- **Angie Kelly** [GSFC] presented the *Mission Operations Working Group* report, and focused on the plans for moving Aura seven minutes closer to Aqua. There is no impact for spacecraft safety and no impact on mission life. OMI has an action item to evaluate the impact of the planned move on their flight software, and a decision regarding this change in the A-Train is needed by December 5.

- **Steven Massie** chaired the *Cloud/Aerosol Working Group* whose discussion focused largely on validation of OMI products. In addition, Curtis Rinsland gave an overview of observations of polar stratospheric clouds by ACE on SciSat.

- **Cheryl Craig** [National Center for Atmospheric Research] reported that the *Data Systems Working Group (DSWG)* discussed each instrument's processing, including highlights of upcoming versions and how each instrument team plans to respond to the new GEOS-5 data version. The DSWG also discussed Aura Guidelines and updates from Goddard and ESDIS.

- **Brook Carter** [GSFC/Science Systems and Applications Incorporated] summarized the *Education and Public Outreach (EPO) Working Group* meeting. EPO plans to develop a roadmap for the future, with a comprehensive portfolio of all accomplishments prior to senior review. They plan to expand their collaborations involving both formal education programs (i.e., the GLOBE program that has contributed to OMI validation) and the informal programs (i.e., the ozone garden at the Goddard Visitors Center, contains a group of ozone sensitive plants that can be used to identify episodes of pollution.)

- **Bryan Duncan** [GSFC] and **Ken Pickering** co-chaired the Tropospheric Working Group, whose discussion focused on "Air Quality (AQ) from Space" and understanding the successes and limitations of using satellite data for AQ applications. NOAA/EPA, state air pollution agencies, and European groups are starting to use Aura satellite data for AQ applications, including estimation of pollutant emissions, tracking long-range transport events, improving air quality forecasts and demonstrating compliance to AQ regulations.

- **Gloria Manney** [JPL] chaired the *Meteorological Products Working Group*. The group learned about updates to the National Centers for Environmental Prediction system. Discussion centered on the new GEOS system (GEOS 5.1.0) that is about to replace the GEOS 5.0.1. Since several of the Aura instruments use GEOS meteorological input in their retrieval system, it is important for a smooth transition and for reprocessing using a constant system for the entire Aura period.

- **Lucien Froidevaux** [KNMI] was co-chair of the *Validation Working Group* and noted that the period of core validation is largely complete and summarized remaining validation needs for each instrument. Some needs will be addressed by the 2008 Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) campaign or from on-going programs such as Measurements of OZone and water vapour by in-service AIrbus airCraft (MOZAIC) or AERONET. There is a continuing need for coincident ozone sondes. It is important to resolve issues concerning the differences among correlative measurements, e.g., CFH and other water measured from aircraft sensors and HCl measured by several sensors on balloons.

The next Aura Science Team Meeting will be held in Fall 2008. The presentations and many of the posters from this meeting are available from the Aura Validation Data Center; several results will be highlighted on the Aura web site: *aura.gsfc.nasa.gov/.* ■

TES Science Team Meeting Overview

Annmarie Eldering, NASA Jet Propulsion Laboratory, Annmarie.Eldering@jpl.nasa.gov

The 31th Tropospheric Emission Spectrometer (TES) Science Team meeting was held on September 6th and 7th at the Harvard University in Boston, MA. There were 30 attendees. The agenda included discussions of project status, algorithms, and science results. Science results addressed current work on regional air quality, global tropospheric composition, and chemistry-climate coupling.

Reinhard Beer [NASA/Jet Propulsion Laboratory (JPL)—*TES Principal Investigator (PI)*] and **Annmarie Eldering** [JPL—*TES Deputy PI*] opened the meeting. Beer welcomed everyone to the meeting and turned the floor over to **Mark Schoeberl** [Goddard Space Flight Center (GSFC)—*Aura Project Scientist*]. Schoeberl discussed the Senior Review of Aura that will be held in 2009, and the preparatory activities planned for 2008. Schoeberl encouraged the TES team to continue their contributions to the *Aura Top 10* Science Results—see *aura.gsfc.nasa.gov*.

Rob Toaz, Jr [JPL—*TES Project Manager*] addressed the meeting, providing an overview of project highlights and instrument operations. TES performed special observations in support of ozone and air quality focused field campaigns. On January 15, *v003* began for the Level 2 products, and Level 3 data production began in March. A new version of Level 2 products (*v004*) will be delivered in Spring 2008. Toaz also pointed out the resources available for users at the Langley Atmospheric Science Data Center (ASDC)—*eosweb.larc.nasa.gov*/—including the TES User's Guide and the validation report.

Greg Osterman [JPL] provided an update on the status of data product validation. Special observation data had been collected for a number of field campaigns, including Sodankylä Total Ozone Intercomparison (SAUNA) and Water Vapor Validation Experiment Satellite/Sondes (WAVES). A reanalysis of validation data sets with *v002* data has been completed. As of September 2007, TES nadir ozone (O_3), carbon monoxide (CO), nadir water vapor (H_2O), atmospheric and sea surface temperature are considered validated (Stage 2), and deuterated water (HDO) is validated (Stage 1). Nadir methane (CH_4), land surface temperature & emissivity, and all limb products are considered provisionally validated. Osterman discussed more details of each data product. This information can be found in the TES validation report at the Langley ASDC.

Susan Kulawik [JPL] provided an update on the upcoming planned data version (*v004)* that will include improvements in the surface temperature retrievals to improve handling of cases where the initial guess is far from true value. The convergence criteria will be tightened and, in an attempt to better capture tropopause latitudinal dependence, the ozone constraints used will have increased latitude dependence. In addition, the carbon dioxide (CO_2) climatology, which impacts the temperature retrieval, will be updated to add time dependence. Kulawik also showed that it is valid to exchange the *a priori* with linear assumptions in science analysis for the vast majority of cases.

Ming Luo [JPL] described the Level 3 data products that are now available. There are gridded data products, produced for daily and monthly data sets from TES Global Survey measurements. There are also browse products that are viewable on the data-ordering page at the Distributed Active Archive Center (DAAC). The TES home page now includes Level 3 plots as well as examples and files used to plot data in *GoogleEarth*.

John Worden [JPL] presented results from an analysis of ozone over the Middle East. TES observations show enhanced upper tropopsheric ozone over northeast Africa, the Mediterranean, and Central Asia, while simulations from the Goddard Earth Observing System-Chemistry (GEOS-Chem) model show a maximum in ozone over the Middle East. TES observations are consistent with earlier measurements—e.g., Stratospheric Aerosol and Gas Experiment (SAGE II). The observations suggest that the Arabian anti-cyclone is driving the ozone spatial distribution, and analysis will continue.

Dylan Jones [University of Toronto] presented further analysis of ozone over the Middle East. Using the Geophysical Fluid Dynamics Laboratory's Atmospheric Model (AM-2) and GEOS-Chem models, Jones showed that transport appears to be the dominant source of O_3 that contributes to the seasonal buildup of O_3 over North Africa, the Middle East, and south/central Asia. The accumulation of ozone across the region reflects the influence of the atmospheric circulation induced by the Rossby-wave response to the Asian monsoon heating. Differences in the spatial distribution of ozone between TES observations and the model results suggest discrepancies in the dynamics in the models.

Sunita Verma [JPL] discussed the chemical evolution of plumes of emissions from the large Siberian boreal fires of July 2006. Verma focused on understanding the photochemical process that governs ozone production in the boreal fire smoke plumes, and the implications for the hemispheric transport that results. Using TES and OMI observations, and the Real time Air Quality Modeling System (RAQMS), she found that the presence of aerosol has a significant impact on ozone

production, and there is little observed enhanced ozone relative to background at high latitudes, despite significant CO concentrations.

Jay Al-Saadi [NASA Langley Research Center] described a global evaluation of near-real-time biomass burning emissions using assimilation of TES observations. Using the RAQMS model, driven by daily global near-real-time biomass burning emission estimates based on Moderate Resolution Imaging Spectroradiometer (MODIS) active fire detections, the assimilation of TES CO observations is used to diagnose biomass burning estimates. Al-Saadi's results suggest that tropical forest emission estimates are shown to have a high bias with this method.

Linda Hunt [NASA Langley Research Center] described upcoming improvements to the data archive, provided statistics on the data downloads from the Earth Observing System Data Gateway (EDG) and the data pool. Hunt described some of the upcoming improvements to the data distribution system.

Susan S. Kulawik [JPL] and **Annmarie Eldering** led a discussion of plans for the next version of TES Level 2 software—*v005*:

The planned improvements for *v005* are:

- better polar land surface characterization (ice/snow/water) to get better throughput at high latitudes;
- reduction of "upper tropopsheric bias" for O_2, H_2O, CH_4 and atmospheric temperature; and
- improved emissivity initial guess and constraints through an updated land-use map and emissivity validation.

Mark Shepard [Atmospheric Environment and Research] presented a study of forward model and calibration systematic errors that propagate to the water and temperature retrievals. No obvious correlations of the water and temperature bias were found with latitude, water vapor amount, and cloud fraction. Potential sources of error in the forward model are spectroscopy (i.e., line and continuum parameters), surface emissivity, and cloud parametrization. CO_2 spectroscopy was updated for *v003* data (i.e., line coupling and continuum) but another CO_2 update is now available, along with new updates for H_2O and O_3—which are still being validated (e.g. with the Scanning High-resolution Interferometer Sounder). Radiance closure experiments were performed with forward model radiances generated from sonde profiles—e.g. during the WAVES field campaign.

Lin Zhang [Harvard] showed aircraft and satellite observations of transpacific transport of ozone pollution during the Intercontinental Chemical Transport Experiment—Phase B (INTEX-B). When Zhang uses the substantially revised estimates of Asian emissions from 2006 (e.g., values of NO_x differ by a factor of 2 from those calculated in 2000) in the GEOS Chem model, he gets reasonable agreement with TES CO-O_3 correlation. Using the revised Asian emission data also increases model-derived values of surface ozone in the U.S.—which is logical, since NO_x is a precursor to surface ozone. Zhang found increases of greater than two parts per billion by volume (ppbV), with highest values over the northwest U.S. Results are consistent with other studies showing minimal descent of polluted air masses from Asia over the U.S.

Juying Warner [University of Maryland, Baltimore County (UMBC)] showed comparisons of measurements of CO from the Atmospheric Infrared Sounder (AIRS) instrument on Aqua and the Measurement of Pollution in the Troposphere (MOPITT) on Terra with those obtained from TES. Using MOPITT data as an *a priori* AIRS "first guess" leads to better agreement between AIRS and MOPITT as well as less variability. Comparison between CO measurements from MOPITT and TES at 500 mb agree within 10 ppbV when AIRS uses MOPITT data as a "first guess," but with stronger disagreement in the southern hemisphere. Warner also compared the Differential Absorption CO Measurement (DACOM) CO measurement (from March 4, 2006) with those from AIRS and TES combined and saw improved agreement.

Changsub Shim [JPL] showed results of a study to characterize *megacity* pollution using TES O_3-CO correlations in outflow from Mexico City. Correlations are in good agreement with aircraft measurements and GEOS-Chem predictions. Shim also described preliminary results from an adjoint inversion of global NO_X emissions compared to NO_2 measurements from Scanning Imaging Absorption Spectrometer for Atmospheric Chartography/Chemistry (SCIAMACHY) on Envisat and the Global Ozone Monitoring Experiment (GOME) on the European Remote Sensing Satellite-2. The model uses 10 emission variables and full chemistry with a 4°x5° horizontal resolution. In general, *a posteriori* NO_X emissions are higher by ~20-30%.

Helen Worden [National Center for Atmospheric Research] showed a study of TES infrared (IR) flux and O_3 measurements combined to estimate the downward IR flux due to upper tropospheric ozone. This study also shows the dominance of water vapor in the outgoing longwave radiation (OLR) at higher sea-surface temperatures even for the relatively small spectral range near 10 μm for ozone absorption.

Annmarie Eldering presented results of the Southeast U.S. ozone study. The study used the FLEXPART model for trajectory analysis and to derive maps of TES upper tropospheric (UT) O_3 with stratospheric influ-

ence removed. This approach will complement analysis based on sondes and provide more insight to the flow of ozone off the shores of the U.S.

Jennifer Logan [Harvard University] presented her analysis of the global impacts of the 2006 El Niño on biomass burning in Indonesia, and how the emission impacts propagated around the globe. The El Niño results in convection moving to the east, and in addition, there were large, drought-induced fires in Indonesia. Looking at the differences between 2005 and 2006, Logan sees that the CO anomaly over Indonesia persisted for two months, and the O_3 anomaly for three months.

Ray Nassar [Harvard University] followed Jennifer Logan's talk with a discussion of model simulations and causes for the anomalies observed in 2006. Using GEOS-Chem simulations, he found that the October/November 2006 anomalies clearly relate to increased Indonesian biomass burning during dry El Niño conditions. The persistent December O_3 anomaly may relate to lightning changes associated with the 2006 El Niño.

Gregory Osterman [JPL] reported on analysis of the impact of the Esperanza fire on Los Angeles air quality, and the use of TES data to support the Texas Air Quality Study. In close collaboration with the Texas state agency, analysis of Houston summertime events showed that a number were impacted by long-range transport of pollutants.

Line Jourdain [JPL] presented results of her research on the strength of lightning NO_x source over the U.S. Layers of enhanced ozone due to lightning NO_x are evident in the TES observations, and GEOS-Chem can replicate the spatial and temporal distribution of the ozone, but the magnitude is not replicated unless the lightning emissions are scaled. ■

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- A draft report on the findings of this workshop will be provided to the participants, and their input will be solicited and included in the final report.

Closing Remarks

Garik Gutman [NASA Headquarters] wrapped up the meeting with a review of NASA programmatic linkages, including Applications, Biodiversity, Terrestrial Ecosystems, and Water and Energy Cycle, as well as external national and international linkages, including the U.S. Climate Change Science Program (CCSP), GOFC/GOLD, and the IGBP-IDHP/GLP and iLEAPS under which NEESPI and MAIRS fall. Ongoing projects were noted, with new rounds of Interdisciplinary Science (IDS), EOS, and Achieving Competence in Computing, Engineering, and Space Science (ACCESS) projects, Water Cycle, Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), and Climate/LCLUC projects in their second year, and Carbon Cycle/LCLUC projects in their third year. New Carbon Cycle selections are being made now, and new LCLUC proposals were due October 1. Future directions for the LCLUC Program include integration of LCLUC processes in climate models and assimilation schemes, climate impact on land-use in terms of vulnerability, resilience, and adaptation, and enhancement of the social science component. Future plans for the program include an additional LCLUC call in ROSES-2008 to be published in January/February and due in October/November, increased LCLUC-MAIRS coordination, and further development of GOFC/GOLD regional networks, such as NERIN.

Future Meetings

The upcoming Spring LCLUC Science Team Meeting will be held May 1-2, 2008 in conjunction with the NASA Carbon Cycle and Ecosystems Focus Area Joint Science Workshop (April 28-30, 2008) at the University of Maryland University College (UMUC) Conference Center. More information concerning this meeting along with presentations from the Urumqi meeting can be found on the LCLUC website at: *lcluc.hq.nasa.gov.* The Fall 2008 LCLUC Science Team meeting will be organized jointly with the MAIRS program and held in Southeast Asia. The focus of the meeting will be on LCLUC in the Asian tropics. The NEESPI Plenary (all-hands) Science Team meeting will be held in Helsinki, Finland on June 2-6. Details on this and other NEESPI meetings can be found at: *neespi.org.* ■

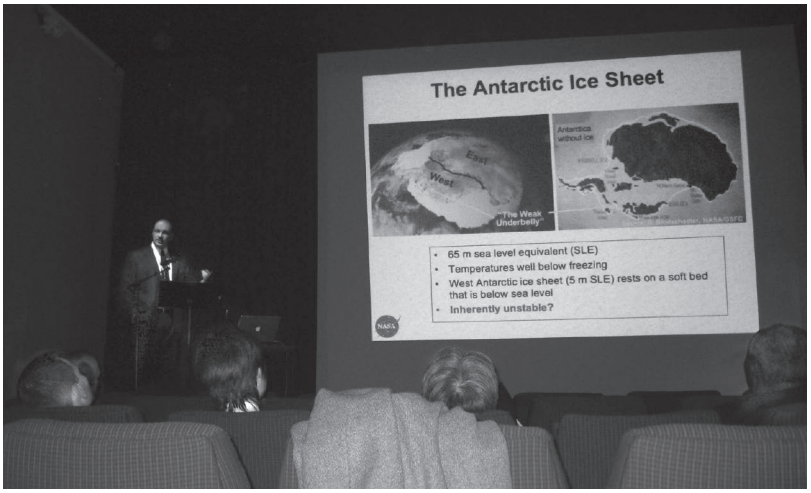
On the Ground: NASA Lands on Planet UNESCO

Inconvenient Truths About Global Warming

Anne Candau, UNESCO, a.candau@unesco.org

Imagine watching a space-based view of melting polar icecaps from the comfort of a seat in the United Nations Educational Scientific and Cultural Organization (UNESCO) Cinema. The images and animations are spectacular but, unlike the seats, the underlying message is far from comfortable.

Non-scientific conference participants embarked on a steep learning curve on October 25th and 26th when NASA's **Waleed Abdalati**, Head of the Cryospheric Sciences Branch at Goddard Space Flight Center, presented "Dramatic Changes in Polar Ice: A Global Perspective."



NASA scientist **Waleed Abdalati** shares the *inconvenient truth* that changes that happen in a remote place like the Antarctic can't be ignored. In fact, climate is changing most rapidly in Polar Regions and these changes could have far-reaching impacts on the world's climate. Says Abalati, *"What happens there matters here."* **Credit:** Steve Graham.

At times the presentation resembled science fiction, with nightmare scenarios of an ice-free Arctic, rising sea levels, a nonexistent Gulf Stream and trans-Pole shipping lanes. This is no fiction: participants learned that people were sailing through the Northwest Passage last summer. As Abdalati succinctly put it, "What happens there matters here."

What use can UNESCO make of this information? "The first step to any progress on global challenges is awareness," Abdalati replies. "All other activity springs from that. Our contribution is fundamental information from a global perspective which we communicate through these powerful tools."

The other NASA scientist to visit UNESCO was **Michael D. King**, Senior Project Scientist of the Earth Observing System at the Goddard Space Flight Center. What does he think UNESCO can do with NASA's space-based data? "Developing countries particularly can apply it to health, education, social welfare, and agriculture—to all fields in fact," he answers. "The correct use of information has great economic value provided you have people to interpret the data."

King came down from space with a down-to-Earth anecdote: "To keep the elephants out of the cornfields, Kenyan farmers used to stay awake for three weeks every year. When satellites predicted the three exact nights the corn would be ripest, the farmers could sleep easily again."

NASA's eTheater Earth Observations of the Global Environment was a side event of the 'Planet Earth: from Space to Place' exhibition, which also featured its "*Magic Planet*" interactive globe. ■

In addition to the visits from the conference delegates, kids from UNESCO's day care facility took time to come by and experience NASA's *Magic Planet*. **Credit:** Steve Graham.

NASA Data Reveals 'Average' Ozone Hole in 2007

Maria Frostic, NASA Goddard Space Flight Center, Maria.T.Frostic@nasa.gov

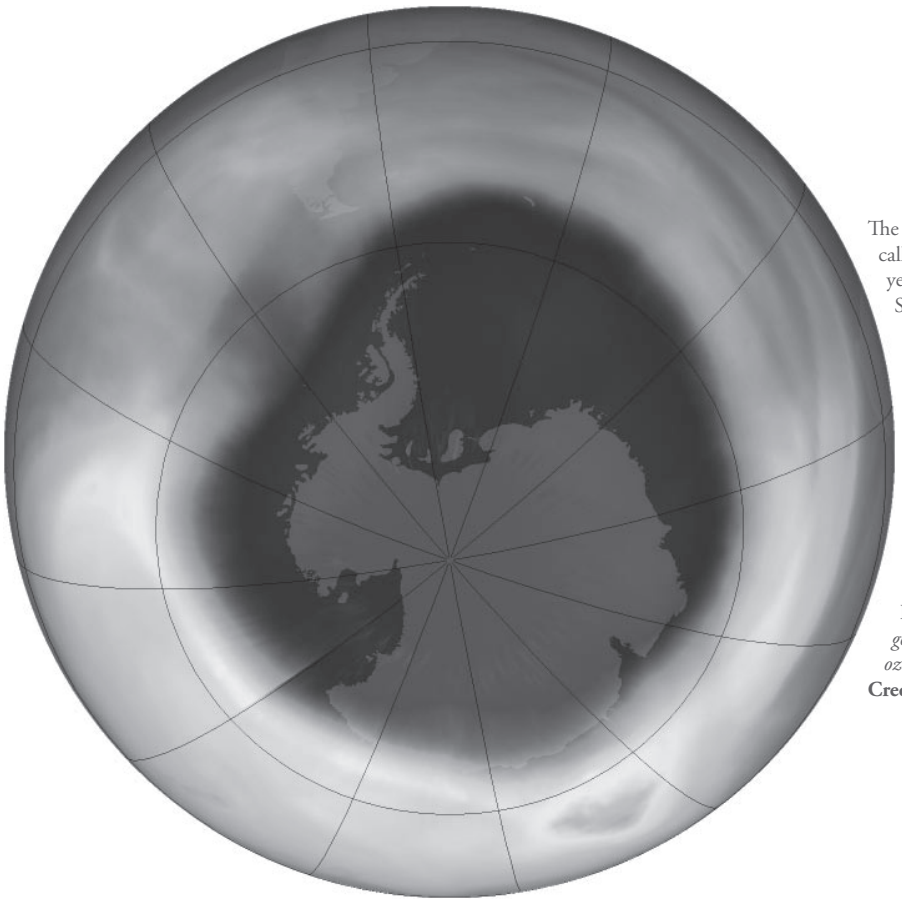
Each year, the depleted region in Earth's protective ozone layer over the Antarctic, known as the "*ozone hole*," reaches its largest size during a period in September. Data from a NASA satellite are now in, and images created from the data reveal the extent of the hole in 2007 was about average when compared to measurements from the last few decades.

Data from NASA's Aura satellite show that the ozone hole peaked in size on September 13, reaching a maximum area extent of 9.7 million mi^2 (25.1 million km^2) just larger than the size of North America. "That's pretty average," says **Paul Newman**, an atmospheric scientist at NASA Goddard Space Fight Center, when compared to the area of ozone holes measured over the last 15 years. Still, the extent this year was "very big," he says, compared to the 1970s when the hole did not yet exist.

In comparison, 2002 and 2004 turned up weak ozone holes with maximum areas of about 8.3 million mi^2 (21.5 million km^2) and 8.7 million mi^2 (22.5 million km^2), respectively. The hole in 2006, however, reached a record-breaking maximum area of 11.4 million mi^2 (29.5 million km^2).

The ozone hole reaches its maximum area in September when cold temperatures and sunlight beginning to appear over the Antarctic horizon start to drive chemical reactions that destroy ozone. The chlorine in these reactions comes from man-made chlorofluorocarbons (CFCs). By October, the ozone-destroying chemical reactions stop, and the hole shrinks in area and depth. During the period from October to December, the ozone depleted region is "stirred up like a can of paint" into the mid-latitudes, depleting atmospheric ozone there.

Despite successful measures that have stopped production of CFCs, scientists don't expect to see the hole significantly reduce in size for about another decade, Newman says. This is due to the long lifetimes of CFCs already in the atmosphere, ranging from 40 to 100 years. Full recovery is expected in about 2070. But even that prediction is tentative, he says, because scientists remain uncertain about how a changing climate will come into play, as warming temperatures could act to speed up recovery of the ozone hole. ■



The area of the Antarctic atmosphere called the *ozone hole* opens up each year in mid-August and peaks in September. This year the ozone hole reached its peak on September 13, appearing as the darkest areas in this image created with data collected from the Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite. NASA atmospheric scientist Paul Newman describes this year's hole as "average," peaking at 9.7 million mi^2 (25.1 million km^2), roughly the size of North America. For full color image see: *www.nasa.gov/vision/earth/environment/ozone_2007.html*
Credit: NASA

in the news

Arctic Sea Ice Shatters All Previous Record Lows

Diminished summer sea ice leads to opening of the fabled Northwest Passage

The following article originally ran as a press release from the National Snow and Ice Data Center (NSIDC), which is part of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder. Media Relations Contact: Stephanie Renfrow, National Snow and Ice Data Center, srenfrow@nsidc.org

Arctic sea ice during the 2007 melt season plummeted to the lowest levels since satellite measurements began in 1979. The average sea ice extent for the month of September was 4.28 million km^2 (1.65 million mi^2), the lowest September on record, shattering the previous record for the month, set in 2005, by 23%—see **Figure 1**. At the end of the melt season, September 2007 sea ice was 39% below the long-term average from 1979 to 2000—see **Figure 2**. If ship and aircraft records from before the satellite era are taken into account, sea ice may have fallen by as much as 50% from the 1950s. The September rate of sea ice decline since 1979 is now approximately 10% per decade, or 72,000 km^2 (28,000 mi^2) per year—see **Figure 3**.

Arctic sea ice has long been recognized as a sensitive climate indicator. NSIDC Senior Scientist **Mark Serreze** said, "Computer projections have consistently shown that as global temperatures rise, the sea ice cover will begin to shrink. While a number of natural factors have certainly contributed to the overall decline in sea ice, the effects of greenhouse warming are now coming through loud and clear."

One factor that contributed to this fall's extreme decline was that the ice was entering the melt season in an already weakened state. NSIDC Research Scientist **Julienne Stroeve** said, "The spring of 2007 started out with less ice than normal, as well as thinner ice. Thinner ice takes less energy to melt than thicker ice, so the stage was set for low levels of sea ice this summer."

Another factor that conspired to accelerate the ice loss this summer was an unusual atmospheric pattern, with

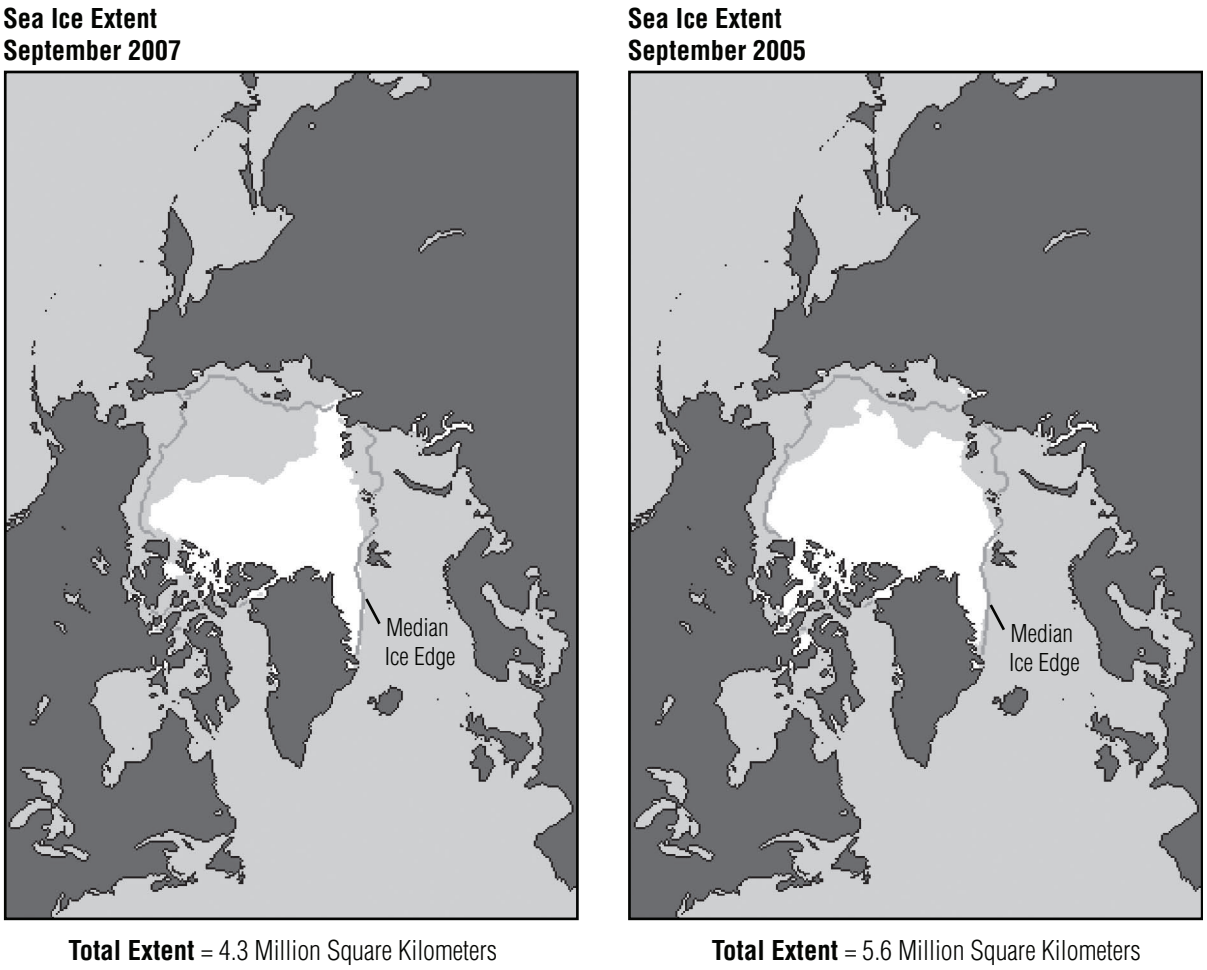


Figure 1. This image compares the average sea ice extent for September 2007 to September 2005; the line marked "Median Ice Edge" indicates the long-term median from 1979 to 2000. September 2007 sea ice extent was 4.28 million km^2 (1.65 million mi^2), compared to 5.57 million km^2 (2.14 million mi^2) in September 2005. **Credit:** National Snow and Ice Data Center.

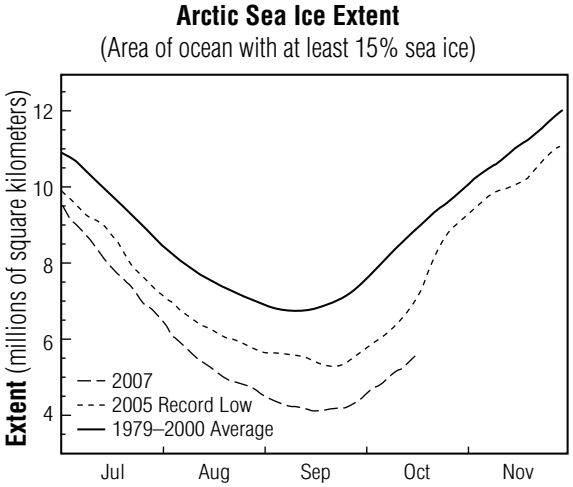


Figure 2. The updated time series plot puts this summer's sea ice extent in context with other years. 2007, shown in a large dashed line at the bottom, is far below the previous record year of 2005, shown as a small dashed line; September 2007 was 39% below where we would expect to be in an average year which is shown in a solid black line at the top. Average sea ice extent from 1979 to 2000 was 7.04 million km^2 (2.70 million mi^2). **Credit:** National Snow and Ice Data Center.

persistent high atmospheric pressures over the central Arctic Ocean and lower pressures over Siberia. The scientists noted that skies were fairly clear under the high-pressure cell, promoting strong melt. At the same time, the pattern of winds pumped warm air into the region. While the warm winds fostered further melt, they also helped push ice away from the Siberian shore. NSIDC Research Scientist **Walt Meier** said, "While the decline of the ice started out fairly slowly in spring and early summer, it accelerated rapidly in July. By mid-August, we had already shattered all previous records for ice extent."

Arctic sea ice receded so much that the fabled Northwest Passage completely opened for the first time in human memory—see **Figure 4**. Explorers and other seafarers had long recognized that this passage, through the straits of the Canadian Arctic Archipelago, represented a potential shortcut from the Pacific to the Atlantic. Roald Amundsen began the first successful navigation of the route starting in 1903. It took his group two-and-a-half years to leapfrog through narrow passages of open water, with their ship locked in the frozen ice through two cold, dark winters. More recently, icebreakers and ice-strengthened ships have on occasion traversed the normally ice-choked route. However, by the end of the 2007 melt season, a standard ocean-going vessel could have sailed smoothly through. On the other hand, the Northern Sea Route, a shortcut along the Eurasian coast that is often at least partially open, was completely blocked by a band of ice this year.

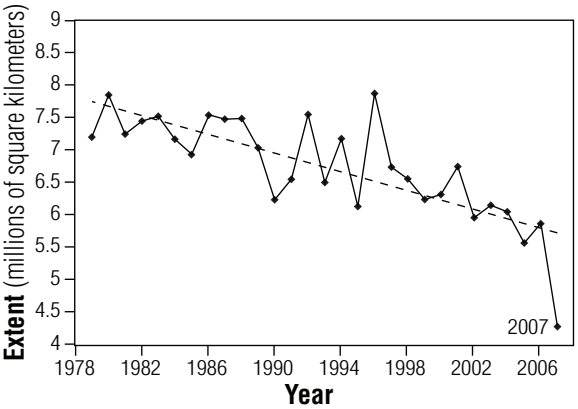


Figure 3. September ice extent from 1979 to 2007 shows an obvious decline. The September rate of sea ice decline since 1979 is now approximately 10% per decade, or 72,000 km^2 (28,000 mi^2) per year. **Credit:** National Snow and Ice Data Center.

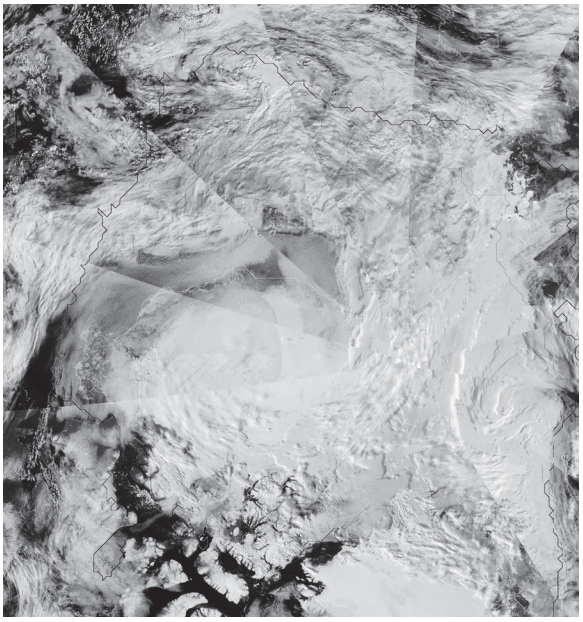


Figure 4. Arctic sea ice reached its lowest annual extent—the absolute minimum—on September 15, 2007. This image is a composite image taken by the MODIS satellite on September 15–16, 2007, during a relatively clear-sky period. The Northwest Passage, through the channels of the Canadian Archipelago at bottom left, opened for the first time in human memory, this melt season. The Northern Sea Route, to the right around the coast of Siberia, remained blocked by a large mass of ice. **Credit:** National Snow and Ice Data Center.

In addition to the record-breaking retreat of sea ice, NSIDC scientists also noted that the date of the lowest sea ice extent, or the absolute minimum, has shifted later in the year. This year, the five-day running minimum occurred on September 16; from 1979 to 2000, the minimum usually occurred on September 12. To view an animation that depicts this visit: *nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html*—see **Figure 5** in the article on the web. NSIDC Senior Scientist **Ted Scambos** said, "What we've seen this year fits the profile of lengthening melt seasons, which is no surprise. As the system warms up, spring melt will tend to come earlier and autumn freezing will begin later."

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in the news

Amazon Forest Unexpectedly Resilient to Drought

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

The extensive forests of South America's Amazon are turning out to be tougher than expected when it comes to withstanding the onslaughts of a changing climate. A team of U.S. and Brazilian scientists using the insightful eyes of two NASA satellites has shown that one of the worst droughts in decades could not stop the undisturbed regions of the Amazon forest from *greening up*.

The Amazon drought of 2005 reached its peak just as the region's annual dry season was beginning, from July through September. Although the double whammy of the parched conditions might be expected to slow the growth of the forest's leafy canopy, in much of the drought-stricken areas the canopy became significantly *greener*—an indication of increased photosynthetic activity.

"Instead of 'hunkering down' during a drought as you might expect, the forest responded positively to drought, at least in the short term," said study author **Scott R. Saleska**, an assistant professor of ecology and evolutionary biology at the University of Arizona. "It's a very interesting and surprising response."

The new finding contradicts a prominent global climate model that predicts the Amazon forest would begin to *brown down* after just a month of drought. The model also predicts an eventual forest collapse, shifting the ecosystem permanently from a thick, evergreen, broad-leaved forest to a grassy savanna.

"No one had looked at this issue with observations that are available from satellites," said co-author **Kamel Didan**, an associate research scientist in the University of Arizona's Department of Soil, Water and Environmental Science. "We took the opportunity of the most recent drought, the 2005 drought, to do so."

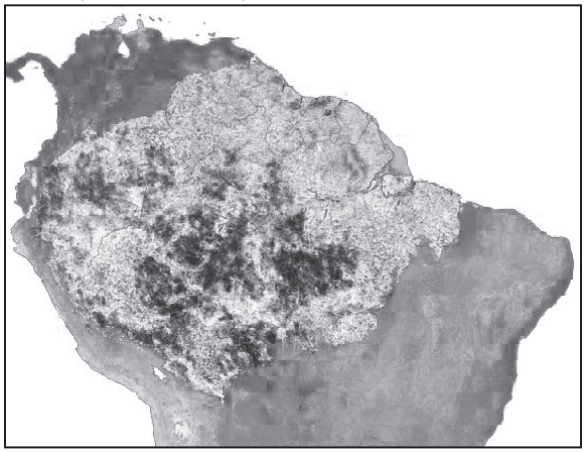
"A big chunk of the Amazon forest—the southwest region where the drought was severest—reacted positively," said Didan. "The forest showed signs of being more productive. That's the big news." The new study, which was supported by NASA research funding, was published on September 20 in *Science Express*, the online version of the journal *Science*.

The researchers and their colleagues already knew the Amazon forest took advantage of the annual dry season's relatively cloudless skies to soak up the sun and grow. From a previous study that used NASA satellite data combined with additional field measurements, the researchers found that intact Amazon forest increases photosynthesis, actually *greening up*, during the dry season.

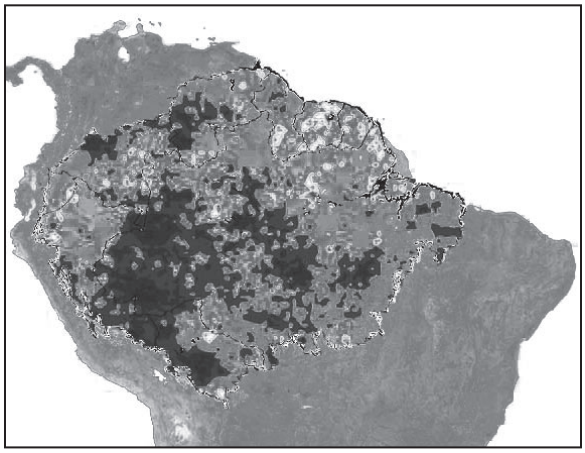
The severe 2005 drought and the detailed, long-term observations from two NASA satellites—one that maps the greenness of vegetation, one that measures rainfall in the tropics—gave the researchers what they needed to see how the Amazon forest responds to a major drought.

One of the instruments on NASA's Terra satellite, launched in 1999—the Moderate Resolution Imaging Spectroradiometer (MODIS)—provides month-to-month maps of changes in vegetation status across the Amazon (and the world). The one-of-a-kind Tropical Rainfall Measuring Mission spacecraft, launched in 1997, collects observations of rainfall.

Photosynthetic Activity



Rainfall



During the 2005 drought in the Amazon, intact primary forest showed an increase in photosynthetic activity (left image) despite below-average rainfall (right image). In the left image, data from NASA's Terra satellite showed areas of high growth (darkest pixels) during the peak of the drought (July-September). In the right image, data from the Tropical Rainfall Measuring Mission satellite showed areas of severe rainfall reduction (darkest pixels) due to the drought. To view these images in color please see: *www.nasa.gov/vision/earth/environment/amazon_green.html*. **Credit:** Kamel Didan, University of Arizona Terrestrial Biophysics and Remote Sensing Lab.

The scientists used the seven-to-nine years of observations from these satellites to map "normal" rainfall and greenness conditions in non-drought years. When they compared those conditions to the same months of the 2005 drought, the researchers found that areas of Amazon's intact forests that had received below-normal rainfall in 2005 also had above-average *greenness*.

Global climate models predict the Amazon forest will cut back photosynthesis quickly when a drought starts. That slowdown in plant growth would create a positive feedback loop: as the forest shuts down more and more, it removes less and less carbon dioxide (CO_2) from the atmosphere. The CO_2 ordinarily sequestered by growing trees would remain in the atmosphere, increasing global warming and further accelerating the forest's decline and additional CO_2-fueled warming.

By contrast, the research team's findings suggest the opposite happens, at least in the short-term. The drought-induced flush of forest growth would dampen global warming, not accelerate it. During the 2005 drought, Amazon forest trees flourished in the sunnier-than-average weather, most likely by tapping water sources deep in the forest soil. To grow, trees must take up more CO_2, thus drawing down the levels of atmospheric CO_2. ■

Arctic Sea Ice Shatters All Previous Record Lows

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Changes in sea ice extent, timing, ice thickness, and seasonal fluctuations are already having an impact on the people, plants, and animals that live in the Arctic. NSIDC Research Scientist and Arctic resident **Shari Gearheard** said, "Local people who live in the region are noticing the changes in sea ice. The earlier break up and later freeze up affect when and where people can go hunting, as well as safety for travel."

NSIDC scientists monitor and study Arctic sea ice year round, analyzing satellite data and seeking to understand the regional changes and complex feedbacks that we are seeing. Serreze said, "The sea ice cover is in a downward spiral and may have passed the point of no return. As the years go by, we are losing more and more ice in summer, and growing back less and less ice in winter. We may well see an ice-free Arctic Ocean in summer within our lifetimes." The scientists agree that this could occur by 2030. Serreze concluded, "The implications for global climate, as well as Arctic animals and people, are disturbing."

Further Reading

Meier, W.N., J. Stroeve, and F. Fetterer, 2007. Whither Arctic sea ice? A clear signal of decline regionally, seasonally and extending beyond the satellite record, *Ann. Glaciol.*, vol. 46, pp. 428-434.

Serreze, M.C., M.M. Holland, and J. Stroeve, 2007. Perspectives on the Arctic's shrinking sea-ice cover, *Science*, vol. 315, pp. 1533-1536, doi: 10.1126/science.1139426.

Stroeve J., M.M. Holland, W. Meier, T. Scambos, and M. Serreze, 2007. Arctic sea ice decline: Faster than forecast, *Geophys. Res. Lett.*, vol. 34, L09501, doi: 10.1029/2007GL029703. ■

in the news

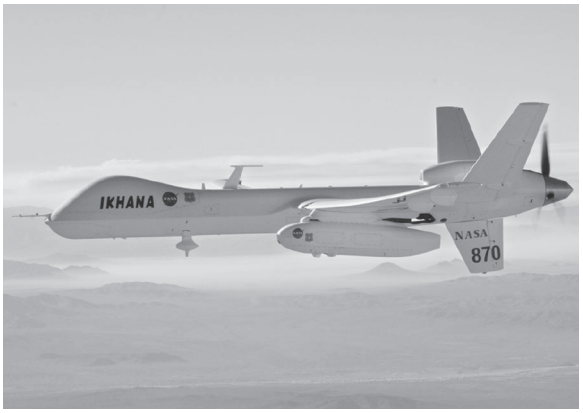
NASA Airplane Joins California Fire Battle

Frederick A. Johnsen, NASA, Dryden Flight Research Center, Frederick.A.Johnsen@nasa.gov

A high-tech NASA research airplane helped firefighters in southern CA get better up-to-the-minute information about the status of the blazes they faced. It was a bittersweet moment for the NASA technicians and pilots who fly the *Ikhana* aircraft remotely. Sweet, because they got to use cutting edge technology in a real-world application that could help save lives and property. Bitter, because this mission was born from tragedy, as more than 13 fires swept across southern California.

In a cavernous white hangar bay at NASA's Dryden Flight Research Center on Edwards Air Force Base in California's Mojave Desert, technicians hovered over computer screens Tuesday afternoon, October 23, preparing Ikhana to mount its important mission Wednesday morning. Outside, Ikhana waited for the order to fly. On the horizon in front of the aircraft a huge billow of smoke snaked ominously westward from the Arrowhead fire, 70 mi distant.

Ikhana is a special NASA civil variation on the Predator B remotely piloted aircraft. A pod weighing more than 400 pounds is carried externally on the white *Ikhana*, bearing thermal-infrared sensors that can electronically see through smoke, revealing fire hotspots. Images downlinked from Ikhana are superimposed over *Google Earth* maps of the fire area, giving fire commanders almost instant feedback on the intensity of the blazes, and allowing them to make informed decisions on how best to fight the fires.



With smoke from the Lake Arrowhead area fires streaming in the background, NASA's *Ikhana* unmanned aircraft heads out on a Southern California wildfires imaging mission on Oct. 24, 2007. **Credit:** Jim Ross

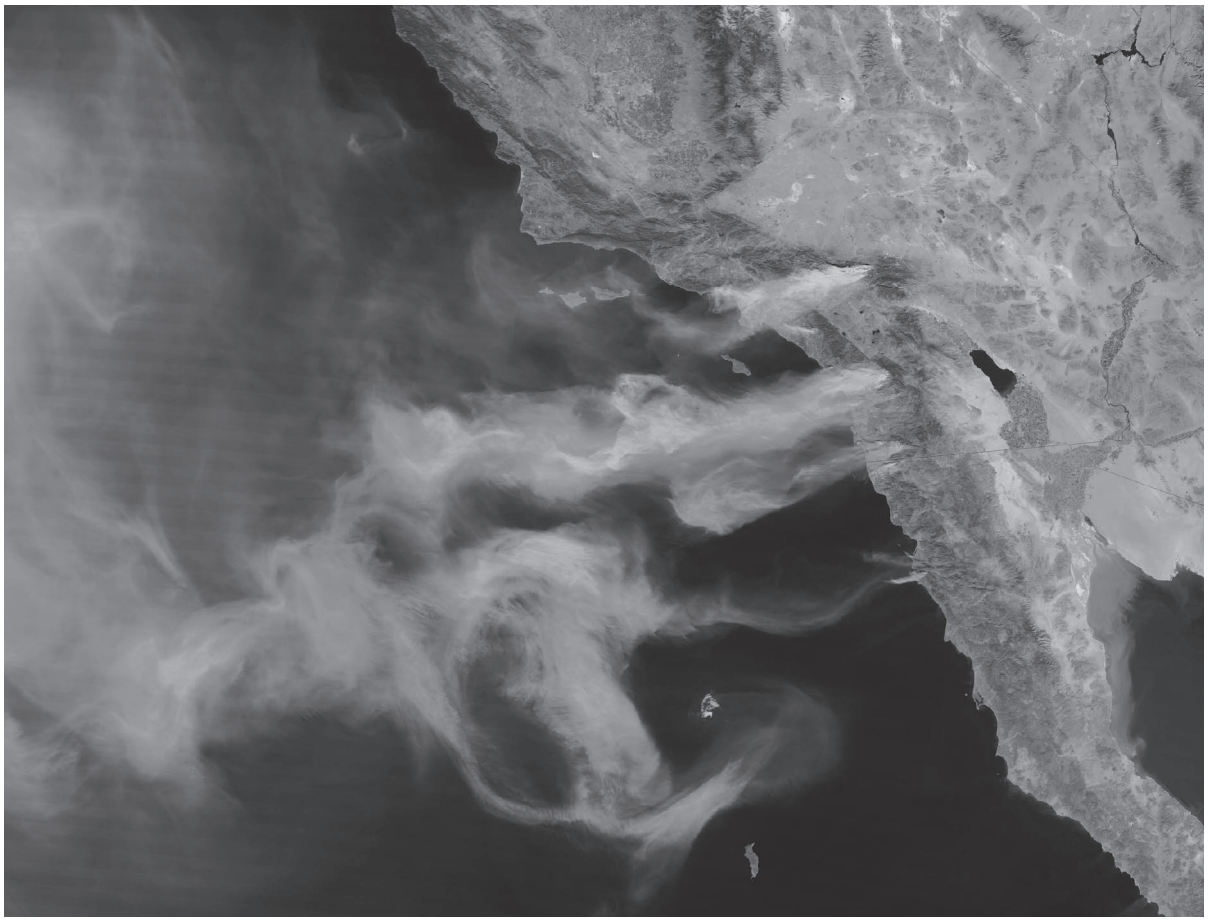
Ikhana's gracefully flexed wings took the scientific airplane aloft at 8:45 a.m. Wednesday, October 24. The blue desert sky was bordered by a pall of white smoke on the southern horizon. Time for *Ikhana* to go to work.

The flight plan for the *Ikhana* UAV Wildfire Imaging Mission on Friday October 26 was prominently displayed in the San Diego Emergency Operations Center's Situation Room. The flight plan overlaid on a *Google Earth* map of the fire area is active on the left-hand screen, with other data layers, including imagery from *Ikhana*, displayed on other screens. **Credit:** NASA

NASA's Dryden and Ames Research Centers each share in the success of *Ikhana*. Conceived as a research platform, *Ikhana* has been pressed into real-world service several times this year in support of firefighters. The newest sortie responded to a call from the California Governor's office. NASA, state officials, the Federal Aviation Administration (FAA), the U.S. Forest Service, and *Ikhana's* manufacturer, General Atomics Aeronautical Systems Inc., all leaned forward to make this flight happen.

Ikhana can stay aloft for many hours, while its Earth-bound pilots switch out in shifts as needed. Its use in the national airspace system is closely coordinated with the FAA to ensure safe operations. ■

NASA research pilot **Mark Pestana** flies the *Ikhana* unmanned aircraft remotely from the ground control station at NASA Dryden. **Credit:** Tom Tschida.



Fueled by the powerful Santa Ana winds that whip from the high-altitude deserts of the Great Basin toward the Pacific Ocean, 12 large wildfires raged in California on October 23, 2007. The fires clouded the air over the Pacific with dense plumes of smoke that stretched across hundreds of miles. This photo-like image, captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on October 23, illustrates the immensity of this historic fire event. At the time the image was taken, the fire had burned 145,000 acres, destroying hundreds of homes and commercial buildings, and threatening thousands more, said the National Interagency Fire Center. **Credit:** MODIS Rapid Response Team, NASA Goddard Space Flight Center.

EOS Scientists in the News

Stephen Cole, NASA Earth Science News Team, Stephen.E.Cole@nasa.gov
Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

More Rainfall Lands in Tropics, Sept. 3; *Washington Post*. Previous predictions suggested that the tropics would see increased rainfall. Now a study by **Robert Adler** (NASA GSFC) and colleagues using data from satellites and other sources revealed a 5% increase in tropical rainfall since 1979, with slight decreases elsewhere on Earth.

Heat Blamed in Deaths of 16, Sept. 5; *Los Angeles Times*. **William Patzert** (NASA JPL) called the September heat wave in California, responsible for the deaths of 16 people, "modest," compared to the hot and long heat waves more than a decade ago.

TemperaTour, Sept. 8; *National Public Radio*. **William Patzert** (NASA JPL) drove around with host John Rabe, collecting temperature and humidity data in cities around southern California, highlighting the region's many microclimates.

Greenland Ice Melt Shocks Scientists, Sept. 9; *The Oregonian*. Greenland's ice sheets are melting at an accelerated rate that has "astonished" some researchers, said **Robert Bindschadler** (NASA GSFC). The extent of acceleration was unforeseen by models.

Tracking Pollution From Earth Orbit, Sept. 15; *Earth & Sky Radio*. A team including **Ralph Kahn** (NASA JPL) is using remote-sensing instruments aboard Earth-orbiting satellites to track pollution particles from above, allowing them to map the aerosols and describe the type of aerosol.

Forest Service Tests *Predator* B, Sensors for Fire-Mapping, Sept. 17; *Aviation Week*. **Vincent Ambrosia** (NASA Ames) and **Greg Buoni** (NASA Dryden) described what it took to get an unmanned aircraft flying and collecting images in what became the first concerted use of an unmanned aircraft to map wildfires as firefighters battled their way though an unusually dry summer.

Scientists Hopeful Despite Climate Signs, Sept. 23; *Associated Press*. Despite all the bad news that global warming has served up, many climate scientists, including **James Hansen** (NASA GISS), cite various reasons as to why they have hope that society can rally to avoid catastrophic consequences of climate change.

Parts of Greenland Ice Melting at Faster Rate, Sept. 25; *MSNBC*. High-altitude areas of the ice sheet covering Greenland saw melting rates at 150% of the two-decade average, according to a study co-authored by **Marco Tedesco** (NASA GSFC).

Vanishing Ice Worries West, Sept. 27; *San Diego Union Tribune*. Some climatologists say that the loss of Arctic ice will change weather patterns, as evidenced by severe droughts in the U.S., but **Ronald Kwok** (NASA JPL) notes that too few observations exist to confirm the extent that Arctic ice loss is linked to drought.

NASA Releases Some Global Warming Images, Sept. 27; *ABC 7 (San Francisco, Oakland, San Jose)*. Time-lapse satellite images released by NASA show an unprecedented amount of sea ice melt in the Arctic Ocean, and **Lenny Pfister** (NASA Ames), not associated with the study, says he is "somewhat alarmed by the mechanisms involved."

Venturing Into Space and Finding Earth, Sept. 30; *Globe and Mail (Canada)*. In a look at how NASA has influenced Earth science, **Ramakrishna Nemani (**NASA Ames) suggests that satellites helped confirm how much of Earth was covered by forests, desert or savannah, while **DeWayne Cecil** (NASA HQ) notes how satellites have helped researchers document change on Earth, and **Waleed Abdalati** (NASA GSFC) cites the break up of an ice shelf in Antarctica as an example of such change.

Five Essential Things to do in Space, October; *Scientific American*. In a story about the future of space-related research, "monitoring Earth's climate" was listed first. **Bob Cahalan** (NASA GSFC) and **Drew Shindell** (NASA GISS) discuss the looming gaps in critical satellite observations of Earth.

Arctic Melt Unnerves the Experts, Oct. 1; *The New York Times, International Herald Tribune, Globe and Mail*. A study led by **Son Nghiem** (NASA JPL) used satellites and buoys to show that winds since 2000 had pushed huge amounts of thick, old ice out of the Arctic basin past Greenland into open water, where the ice floes melted faster or were expelled by wind.

Moving Sea Ice Feels Like 'Walking on the Moon', Oct. 15; *Earth & Sky Radio*. **Thorsten Marcus** (NASA GSFC) was on location in Antarctica collecting *in situ* sea ice measurements that will be compared with satellite data to help researchers understand sea ice thickness and the amount of snow on top of it.

Naked Science: Hyper Hurricanes, Oct. 18; *National Geographic Channel*. Hurricane scientist **Owen Kelley** (NASA GSFC) is interviewed in this hour-long program that delves into some of Earth's most destructive past hurricanes, whether or not intensification of current storms are linked to global warming, and how scientists are working to predict future "hyper" hurricanes.

NASA: Ozone Hole Returns to Average Size, Oct. 19; *Associated Press*. The size of the 2007 ozone hole was average when compared to the last few decades, according to **Paul Newman** (GSFC). While the hole is smaller than last year's maximum extent, it is still about the size of North America. See page 37 of this issue.

Heroes of the Environment: Scientists and Innovators, Oct. 22; *TIME*. **James Hansen** (NASA GISS) was named by *Time* as a "hero of the environment" for his role in climate change research and being "not only a great scientist but also a great scientist-statesman." ■

First Public Release of Aura OMI Radiance and Irradiance Data Products

Aura OMI Level-1B Radiance and Irradiance Data Products (*version 3*) are now released to the scientific community for environmental monitoring and global climate change studies. Four standard radiometric calibrated and geolocated (Level-1B) Radiance data products *OML1BRUG*, *OML1BRUZ*, *OML1BRVG*, *OML1BRVZ*, and the Solar Irradiance data product *OML1BIRR* are now available from the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). *disc.gsfc.nasa.gov/Aura/OMI/*

The Ozone Monitoring Instrument (OMI) has been providing global measurements of stratospheric and tropospheric ozone, clouds, aerosols and smoke from biomass burning, sulfur dioxide (SO_2) from volcanic eruptions and other sources, and key tropospheric pollutants formaldehyde (HCHO) and nitrogen dioxide (NO_2) and ozone depleting gases chlorine dioxide (OClO) and bromine monoxide (BrO) since its launch aboard the EOS-Aura satellite (1:38 pm equator-crossing time, ascending node on the day side) on July 15, 2004. OMI, with its 2600 km viewing swath width (60 cross track pixels, spatial resolution of 13 x 24 km at nadir), provides almost daily global coverage.

OMI is a contribution of the Netherlands Agency for Aerospace Programs (NIVR) in collaboration with Finnish Meteorological Institute (FMI), to the Aura Mission. Aura is part of the A-Train series of satellites, 15 minutes behind the Aqua satellite. The Royal Netherlands Meteorological Institute (KNMI) is the principal institute for the OMI instrument and **Pieternel Levelt** is the OMI Principal Investigator.

The Level-1B Radiance and Irradiance data products available from GES DISC, contain calibrated and geolocated earth view spectral radiances and incoming solar spectral irradiances, for 716 ultraviolet channels in the spectral region of 264 to 383 nm, and 751 visible channels in the spectral region of 349-504 nm. OMI also provides spatial *zoom-in* measurements (nadir ground pixel size 13 x 12 km) one day per month. *Version 3* is the first 'public release' of OMI Radiance and Irradiance data products. The lead algorithm scientist for the Level-1B radiance and irradiance products is **Marcel Dobber** [KNMI].

For the full set of Aura products available from the GES DISC, please see the link below.
disc.gsfc.nasa.gov/Aura/data_products.shtml.

NASA Science Mission Directorate – Science Education Update

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SUN-EARTH DAY 2008 WEBSITE IS LAUNCHED!

The website for *Sun-Earth Day: Space Weather Around the World* is now online at *sunearthday.nasa.gov/*. Here you will find a new calendar that features upcoming mission launches, conferences, NASA events, amateur astronomer events and star parties, museum exhibits and local happenings relating to Sun-Earth Day. Next year's Sun-Earth Day main event will be on March 20, 2008.

2008 GLOBE INTERNATIONAL CONFERENCE
June 22-28, 2008, Cape Town, South Africa

The GLOBE Learning Expedition and Annual Partner Conference in South Africa is the largest international event currently planned by the GLOBE Program with more than 300 students, and 200 scientists and educators, from 109 partner countries expected to attend. The theme will be GLOBE Research for Sustainable Communities. Students will present their research on topics such as environmental impacts on the quality of life (including water quality issues and malaria), regional impacts of climate change and GLOBE Earth System Science Projects. Sustainable communities balance the fulfillment of human needs with the protection of the natural environment, and the upcoming event in South Africa will encourage students from around the world to examine this fundamental issue. For more information, visit *www.globe.gov*.

2007-2008 EARTH SCIENCE EDUCATION BROCHURE

The cover of this colorful, foldout brochure features a high-resolution image of Antarctica's Ferrar Glacier created from Landsat satellite data. Inside is a guide to NASA Earth science education programs and resources, including descriptions and Web sites. The brochure also includes a chart that lists NASA Earth science satellite missions according to the components of Earth observed—air, land, water, ice and life—with links to learn more about the missions and their educational programs. To download the brochure as a PDF, visit: *science.hq.nasa.gov/education/catalog/index.html*.

SPACE PLACE LIVE! MEET A SPACE ARCHITECT!

The Space Place introduces a new episode of *Space Place Live!*, the cartoon talk show where the Space Place kids, Kate and Kyo, chat with real NASA scientists and engineers about their jobs, the excitement of working in the space program, and what else they like to do for fun. The latest show features **Linda Herrell**, a space mission architect. Who knew space missions require an architect just as much as buildings do? Visit *spaceplace.nasa.gov*, and find out how Linda's love of French and Spanish led her to a love of computers and space technology—and what artistic hobby she picked to practice her design skills.

NASA CONTRIBUTES TO GOOGLE EARTH

New NASA content is available at *Google Earth*, including photographs taken by NASA astronauts and imagery from NASA's Earth observing satellite sensors, such as the Sea-viewing Wide Field-of-View Sensor, Landsat, and the Moderate Resolution Imaging Spectrometer.

Astronaut photography was developed in collaboration with the Crew Earth Observations team, part of the Image Science and Analysis Laboratory at NASA's Johnson Space Center, Houston. Satellite imagery of Earth was developed in partnership with the Earth Observatory team at NASA's Goddard Space Flight Center. For more information on *Google Earth*, visit: *earth.google.com*.

21st CENTURY EXPLORER PODCAST COMPETITION
Deadline: January 4, 2008

Students are asked to create an audio recording or video short that answers the question: *What do you think is NASA's greatest exploration achievement in the past 50 years and why?* The competition is open to U.S. citizens between 11-18 years of age. For more information, visit: *www.explorationpodcast.com/*.

NASA LAUNCHES EARTH SCIENCE EXPERT DIRECTORY FOR MEDIA
experts.nasa.gov

This directory includes NASA scientists and NASA-funded researchers from over 30 scientific disciplines who have expressed an interest in working with the news media. Journalists can do a targeted search by name or by keyword, or by browsing a list of scientists by field. ■

EOS Science Calendar

2008

January 8-10
Landsat Science Team Meeting, USGS EROS Data Center, Sioux Falls, SD. Contact: Thomas Loveland, *Loveland@usgs.gov*

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/*

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*

Global Change Calendar

2007

December 10-14
American Geophysical Union (AGU) Fall Meeting, San Francisco. URL: *www.agu.org/meetings/fm07/*

2008

January 20-24
American Meteorological Society (AMS) Annual Meeting, New Orleans, LA. URL: *www.ametsoc.org/meet/annual/index.html*

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 22-28
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.*

Release of CloudSat R04 version of the Cloud Water Content (CWC) Product

The CloudSat Data Processing Center (DPC) has released, to the General Science Community, the R04 version of the *2B-CWC-RO* product. This is the Cloud Water Content (liquid and ice) generated from Radar-Only (a later version will use the *2B-TAU*, visible optical depth retrieval from CloudSat, and will be identified as *2B-CWC-RVOD*).

The current schedule calls for the generation and release, to the science team, of the R04 version of the *2B-TAU* product, within the next month, followed by the *2B-CWC-RVOD* (CWC using the Radar Visual Optical Depth output from *2B-TAU*), and then a subsequent rerun of *2B-FLXHR* using *2B-CWC-RVOD* as input. Watch the DPC website for news and current status of these R04 product releases.

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

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

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

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

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Greenbelt, MD 20771

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The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 610, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available on the World Wide Web at *http://eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php* or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call Steve Graham at (301) 614-5561, or send a message to *steven.m.graham.2@gsfc.nasa.gov*, or write to the address above.

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