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Editor's Corner

Steve Platnick
EOS Senior Project Scientist – Acting

In this first issue of 2009 [**Volume 21**], we are pleased to have another installment in our periodic *Perspectives on EOS* series. In this series, we've been presenting a variety of personal experiences on the history of the Earth Observing System Program. Our objective with this series is twofold: (1) to share the fascinating story of the *"difficult journey of a good idea"* as the vision of a series of satellites that would study our home planet evolved and eventually became reality; and (2) to provide a historical perspective that helps inform those involved in developing future Earth science missions (such as those now in the planning stages initiated in response to the National Academy's Earth Science Decadal Survey).

In this issue, we hear from **Piers Sellers**. Sellers is now a Mission Specialist Astronaut at the Johnson Space Center. Before he became a "satellite" himself, Sellers had his feet firmly planted on *Terra firma* as he worked in the Biospheric Sciences Branch at Goddard Space Flight Center from 1982–1996, and was actively involved in numerous field experiments. While at Goddard, he also became involved in the early development of the concepts that would eventually become EOS. Sellers' article fills in more of the *backstory* of how the program we now know came to be, and complements previous articles in the series by **Darrel Williams** [May–June 2008—**Volume 20, Issue 3**] and **Dixon Butler** [September–October 2008—**Volume 20, Issue 5**]. We think you'll agree that it is both an informative article and an enjoyable read.

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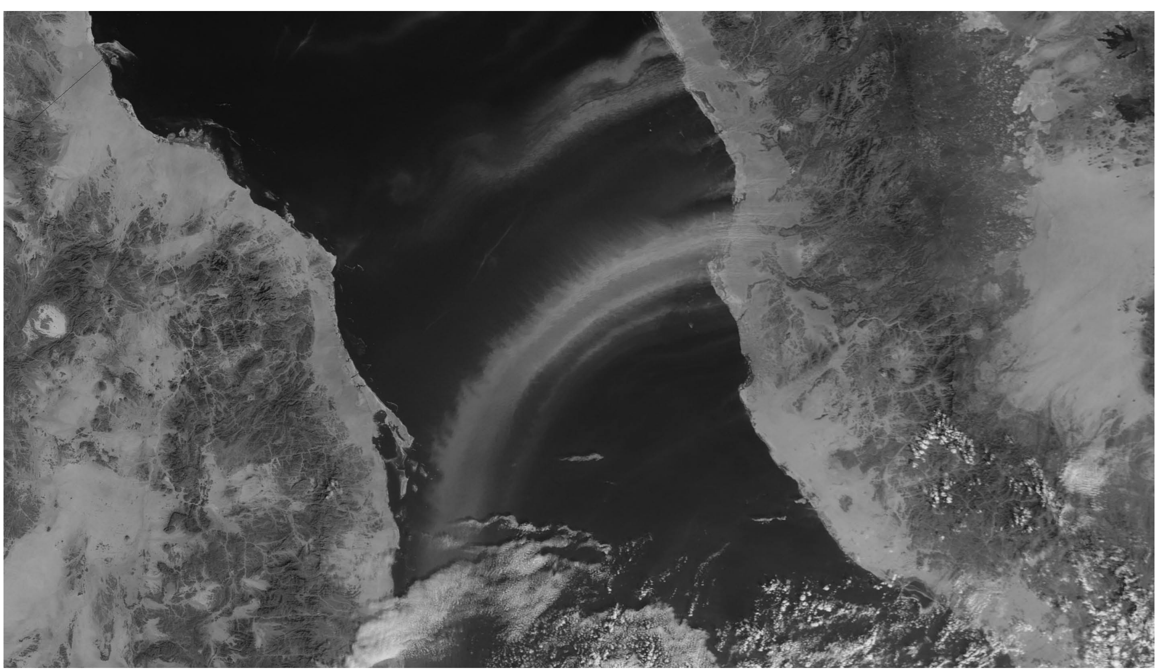

The Earth Observer is pleased to recognize **Vince Salomonson** as he steps aside from his role as Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team Leader after more than 20 years. Salomonson oversaw the development of MODIS and the successful launches of Terra and Aqua, both of which carry a MODIS instrument. MODIS now routinely captures vivid images of Earth such as the one shown here. The image comes from MODIS on Terra and shows dust plumes blowing off the coast of Saudi Arabia and over the Red Sea on January 15, 2009. For more details and to view the image in color please visit: earthobservatory.nasa.gov/IOTD/view.php?id=36668. **Image Credit**: MODIS Rapid Response Team, NASA GSFC.

eos.nasa.gov

In This Issue

On a related note, **Mary DiJoseph** has written an article updating us on the status of the various *Tier 1* and *Tier 2* missions identified in the Decadal Survey. DiJoseph is the Technical Deputy in the Earth Systematic Missions Program Office in Code 420 at Goddard that has programmatic responsibility for managing Decadal Survey missions.

As planning continues for these future missions, 13 existing Earth Science missions will be writing proposals for the upcoming biannual Senior Review. The proposals are due March 23, and are for missions that are, or soon will be, beyond their Prime Mission lifetimes. The objectives of the Senior Review are to identify those missions whose continued operation contributes cost-effectively to both NASA's goals and the nation's operational needs, and to identify appropriate funding levels for extended missions. This Senior Review will provide detailed science and budgetary recommendations for the period FY2010–FY2013. Two separate panels (the Science and Core Mission Review panels) will be convened to evaluate the proposals in the April–May timeframe. Earth science missions in this year's review are ACRIMSAT, Aqua, Aura, CALIPSO, CloudSat, EO-1, GRACE, ICESat, Jason-1, QuikSCAT, SORCE, Terra, and TRMM.

I draw your attention to several feature articles in this issue:

- **Christopher Funk** of the U.S. Geological Survey's Center for Earth Resource Observations and Science has written an article describing how NASA data from the Atmospheric Infrared Sounder (AIRS) and SeaWinds are being entered into the U.S. Agency for International Development's Famine Early Warning System Network to forecast drought in Eastern and Southern Africa.
- **Christopher Neigh** of the Biospheric Sciences Branch at Goddard has written an article describing his research to use Normalized Difference Vegetation Index (NDVI) measurements from the NOAA Advanced Very High Resolution Radiometer (AVHRR) to study vegetation changes in North America.

In this issue, we also include another in our series of science blogs that give a sense of what it is like to be a scientist in the field. This time, we return to the remote reaches of Siberia for a series of entries from **Jon Ranson** of the Biospheric Sciences Branch at Goddard and **Slava Kharuk** of the Sukachev Forest Institute in Russia as they co-led an expedition this past summer to make field measurements to help validate forest height measurements made by the Geoscience Laser Altimeter (GLAS) on the Ice, Clouds, and land Elevation Satellite (ICESat) and also to help inform the design of future laser altimeters. The expedition took place this past summer and the full version of the blog was posted on *The Earth Observatory* website: *earthobservatory.nasa.gov/Features/SiberiaBlog2008/page1.php*. (The September–October 2007 issue of *The Earth Observer* contained a report on this group's previous expedition to Siberia—**Volume 19, Issue 5,** pp. 13–21.)

Our EOS Project Science Office (EOSPSO) education and outreach group (**Winnie Humberson,** Task Lead) had another successful outreach effort at the Fall Meeting of the American Geophysical Union (AGU). Four team members traveled to San Francisco last month to help staff the NASA Science Mission Directorate (SMD) exhibit. The exhibit space, which was coordinated and planned by the EOSPSO, encompassed all four divisions of the SMD—Earth Science, Heliophysics, Planetary Science, and Astrophysics. The exhibit space included a presentation/demo area where NASA scientists and data experts presented brief 20-minute presentations on relevant SMD topics and programs throughout the week. In all, 24 presentations were given at the exhibit, including several related to Earth Sciences; all of the presentations were well attended.

Finally, I wish to recognize **Vince Salomonson** on the occasion of his stepping aside from his role as the Team Leader for the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument. In this capacity, Salomonson led a team of over 90 science investigators, providing some 40 data products enabling studies of global and regional land, ocean, and atmospheric processes and trends.

Previously, Salomonson served NASA with distinction for nearly 40 years. During his long tenure at Goddard, Salomonson was the Project Scientist for Landsat-4 and Landsat-5 (1977–1989) and became involved with MODIS from its inception in 1988. He led MODIS through the ups and downs of the development phase and guided the team through the successful launches of Terra and Aqua. Along the way, while the team grew significantly, Salomonson always provided excellent leadership. On behalf of everyone involved in MODIS and EOS over the years, I thank Salomonson for his many years of faithful service to NASA and to the MODIS Science Team, and wish him the very best in his retirement.

Conference attendees fill the presentation area of the NASA exhibit at the fall meeting of the American Geophysical Union held in San Francisco, CA. **Photo credit:** Winnie Humberson

Reflections on the Early Days of EOS: A Biased and Unexpurgated History

Piers J. Sellers, NASA Johnson Space Center, piers.j.sellers@nasa.gov

Sellers was actively involved in many different field experiments, getting up close and personal with the land surface and atmosphere he sought to understand. But now as an astronaut, he has glimpsed a perspective that few humans ever see; he has seen the Earth as satellites "see" it.

This article continues our ongoing *Perspectives on EOS* series. In this series, we have asked a variety of individuals who were actively involved in the early years of the EOS Program and/or who are involved today to share their particular *perspective* on EOS. We hope these reports help to shed light on the history of NASA's Earth Science Program while also providing some lessons-learned for future Earth observing missions.

For this issue, *The Earth Observer* is pleased to offer the perspective of **Piers Sellers**. Sellers worked at Goddard Space Flight Center from 1982–1996 and his research focused on how the Earth's biosphere and atmosphere interact. His work involved computer modeling of the climate system, satellite remote sensing studies, and fieldwork utilizing aircraft, satellites, and ground teams in places such as Kansas, Russia, Africa, Canada, and Brazil. Sellers briefly served as Deputy EOS Project Scientist under **Jerry Soffen** in 1988, and later served as Project Scientist for EOS AM-1 from 1992–1996. In 1996, Sellers was selected as an astronaut candidate, and left Goddard to, as he describes it below, "*pursue my own career as a satellite*." Sellers completed two years of astronaut training at Johnson Space Center, and went on to participate in two space shuttle flights, where he logged almost 42 hours of extravehicular activity in six spacewalks.

Sellers offers a unique perspective on EOS; in fact he can truly "see" Earth (and EOS) from a variety of perspectives. He was actively involved in many different field experiments as an Earth scientist at Goddard, getting up close and personal with the land surface and atmosphere he sought to understand. But now as an astronaut, he has glimpsed a *perspective* that few humans ever see; he has seen the Earth as satellites "see" it. This gives him a unique *window* to comment on the significance of NASA Earth science and of the EOS Program in particular. We are happy he has agreed to share some of his reflections with us and we hope you find them insightful.

Once upon a time (in the mid- to late-1980s to be precise) there was a bunch of us young (well, we were young back then anyway) scientists working in and around the Biospheric Sciences Branch—the branch formerly known as Code 923, and now known as Code 614.4 recurring—in the Laboratory for Terrestrial Physics at Goddard Space Flight Center (GSFC). Just like now, it was a mixed crowd of home-grown Americans—e.g., **Compton Tucker**, **Brent Holben**, **Forrest Hall**, **Tom Schmugge**—with a sprinkling of barely legal immigrants—e.g., **Chris Justice**, **Yoram Kaufman**, **Inez Fung**, myself, and others. It was a time of tremendous innovation and opportunity, with a colorful cast of characters and an eclectic music scene to set it all in context: *The Clash*, *Sex Pistols,* and *The Police* were established, borderline respectable bands while *U2* was considered a fringe group with some potential.

Compton Tucker and his tribe of vegetation mappers were accelerating the whole business of global vegetation monitoring and coming to grips with the global carbon cycle. They were doing this with the NOAA Advanced Very High Resolution Radiometer (AVHRR) instrument, which was originally designed for cloud detection, but also turned out to be a pretty good "veggie detector". (**Editors' Note**: The article on page 28 of this issue discusses this use of AVHRR and other data to deduce the causes of vegetation changes in different regions of North America.) A lot of this work involved staying up all night in the lab, mounting and running thousands of NOAA raw data tapes, crunching numbers, and registering bits. Compton claimed that it kept him out of the nightclubs and turned him towards clean living. The rest of us think it's still too early to tell.

Piers Sellers

Meanwhile, in the Laboratory for Atmospheres at Goddard, a different bunch of people was trying to push forward numerical climate models: **Yale Mintz**, **Jagadish Shukla**, **Dave Randall**, **Eugenia Kalnay**, and others. This was a much "rougher" science back then with very coarse resolution models running on archaically slow machines—i.e., "*I hope this model run finishes before I die*." I had the good fortune to "commute" between both the land and atmosphere camps, and was trying—with a lot of help from my colleagues—to put a model of the terrestrial biosphere into one of these atmospheric models. This work would test the patience of my climate friends, my family, and the funding agencies for many years. But the great thing about Goddard was that if you didn't know the answer to something, there was almost always someone in the next building or corridor who did know—it was like having continuous access to an Earth Science brain trust. So the work proceeded and my friends and I were happily occupied in some of the most interesting science of that time or any time. **And along the way, everyone involved in the business of global modeling or climate change was beginning to recognize that an interdisciplinary approach would be needed to understand the Earth System.**

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As things evolved, and we all got to know each other better, we figured out that we really didn't know much about how the land surface interacted with the atmosphere on regional and continental scales, and that methods for quantifying important land surface properties— e.g., albedo, roughness, evaporation rate, photosynthesis—from satellite data were pretty much in the "hand-waving" stage of development. We expressed this view to NASA Headquarters (HQ). They feigned appropriate shock and dismay. Next, we—we being principally the Code 923 crowd and fellow-travelers—proposed that HQ should give us access to the cream of the NASA research aircraft, a lot of money, a lot of University scientific support and NASA people, and abscond with all of this stuff to Kansas. ("*Kansas! Are you serious?!*") There, we boasted, we would run a large-scale field experiment[1] to see how well we could observe and model land-surface atmosphere interactions, and also how well we could measure the important parameters from space, all at the same time. Amazingly, HQ gave us the "keys" to the goodies, and so a large chunk of the international land climate science community went off to Kansas in 1987, looking for adventure and enlightenment. So it was, while we were out there, fighting off the chiggers, heat rash, and curious cows, that we first heard of something called the Earth Observing System (EOS).

Up until about that time, there had been an internal NASA proposal for a large "Global Habitability" satellite, called *System Z*. This was a long skinny platform with a large L-band radiometer on it (Tom Schmugge's amour proper) and several other visible-infrared sensors scattered around on it; my memory is a bit dim here about what was exactly on it. In any case, *System Z* had gone some way in setting out the

[1] The experiment would come to be known as the First International Satellite Land Surface Climatology Project Field Experiment (FIFE) and would run from 1987-1989. For more details please visit: *http://www.esm.versar.com/fife/FIFEHome.htm*.

arguments for a large integrated measurement system for looking at the Earth's health. While all this was going on, the whole global climate argument was cranking up in the media and it became apparent that there would be political enthusiasm for "something big" to be done by NASA. Hence, a lot of the thinking that went into *System Z* was morphed into EOS[2].

In 1988, during a break between Kansan field campaigns, we caught an EOS briefing given by **Dixon Butler**, who was armed with a stack of mind-blowing view-graphs. We marveled at the heft and bulk of the proposed *EOS-A* platform, bristling with 17 instruments. "*Egad! This thing will blot out the sun whenever it comes over*." The first EOS designs thus became known as "Galactica." We all wondered what would happen next…

Then, seemingly all at once, we found out… Calls for proposals came out, and so we were all busy writing proposals for 10 years worth of supporting research—an unthinkable amount of money and resources in those days. Dixon Butler and friends were touring the country like a small rock group trying to drum up support from a flagging Earth science community who had long been used to hearing of grandiose NASA projects that never came to fruition. As a result, a large part of the research funding went to younger scientists who were too innocent or ignorant to know of the long track history of dry boreholes in new funding initiatives, but wrote proposals anyway and lucked out. I had been on various "flavors" of soft money for the first 8 years that I worked in and around Goddard so, not unusually, I was moving between institutions at the time of the proposal announcement. As a result, I ended up writing a "freelance" proposal (i.e., no fixed address) with Compton Tucker, Inez Fung, Dave Randall, and Chris Justice using our own resources: we each invested $60 for the typing, duplication, and postage of the proposal. As a result, we received several million dollars of funding over the next decade—a reasonable return on our investment.

I ended up writing a "freelance" proposal with Compton Tucker, Inez Fung, Dave Randall, and Chris Justice...we each invested $60 for the typing, duplication, and postage of the proposal. As a result, we received several million dollars of funding over the next decade—a reasonable return on our investment.

Meanwhile, the design of the instruments and buses for EOS was proceeding rapidly. Around this time, Gerald "Jerry" Soffen was appointed as Project Scientist for EOS at Goddard, and he snagged me to be his Deputy Project Scientist. Heady stuff! Jerry was an interesting character—he was a biologist and to prove this, he had a picture of himself wrestling with an anaconda on his wall—and he had also been the Project Scientist for *Viking*, the first Mars soft lander. He was very articulate, very proud of being a part of NASA, and had an impressive Amish-style beard. He asked me to do a quick review of the proposed EOS satellite hardware and get back to him with a short report.

So I pulled a little team together—dubbed the EOS review group (a.k.a: the "erg")—with Dave Randall, Steve Wofsy, Inez Fung, and a couple of others. Our group met a few times and talked about the proposed EOS architecture, including the data system—the EOS Data and Information System (EOSDIS). It was all very interesting. The group concluded that we should prioritize the proposed suite of instruments, and bundle them into launches of 3 to 5 instruments per platform. The thinking here was to prevent a sad day at the launch pad if "Galactica" blew up on ascent, taking all 17-odd instruments and the entire Earth Science budget with it and simultaneously hurling the Earth science community into the ranks of the unemployed. We also agreed that EOSDIS should start small, be under the governance of the EOS scientists, and other such subversive stuff.

Well, our group wrote up our conclusions and I presented an overview to Dixon in a large EOS forum. Poor Dixon nearly had an infarction on the spot. He had managed to sell the idea of this large *new start* to various political bodies on the basis of very large new systems that seemed attractive and irreducible to the various committees, and now here was a bunch of wild-eyed scientists, smoking heaven knows what,

[2] Dixon Butler discusses the origins of the idea for *System Z*, its proposed design, and how it "paved the way" for EOS in his article in the *Perspectives on EOS* series: "The Early Beginnings of EOS: *System Z* Lays the Groundwork for a Mission to Planet Earth" in the September–October 2008 issue of *The Earth Observer* [**Volume 20, Issue 5**, pp. 4-7.]

telling him that "smaller was beautiful," and that the proposed "Galactica" could actually end up suffering the same fate as the "Death Star". Needless to say, there was bad "juju" all round, and all this resulted in my being rotated out of the Deputy Project Scientist slot pretty quickly, with **Darrel Williams** (I think) taking over.

Another year or so passed. We were very busy in Code 923 with finishing up the Kansas experiment and trying to pull together another large international field experiment, this time in Canada—Saskatchewan and Manitoba to be precise[3]. (We scientists always pick the most interesting places to visit and study!) Most of the Kansas experiment veterans in Code 923 were rolling into the new experiment, which was a huge relief as their experience was invaluable, and so things were motoring along quite happily with EOS in the background. Then I got a call from **Vince Salomonson** to rejoin the EOS team, but this time as Project Scientist for the first EOS platform, EOS-AM, which was renamed *Terra* in due course. This appointment proved that Goddard was very short of available bodies at the time: I was pretty much let go and rehired into EOS within the space of 18 months.

The intrepid crew (left to right, Piers Sellers, Forrest Hall, and Andy Black) prepare to board a small *Cessna* at the Prince Albert airport during the BOREAS campaign. Piers would pilot the plane while Forrest and Andy mapped potential tower sites. **Photo courtesy:** Forrest Hall.

Upon joining EOS-AM, I met with **Chris Scolese**, the Project Manager, and his team for the first time and immediately took a liking to them—a really great bunch of young can-do engineers. They were housed in the infamous Building 16W at Goddard, a building which was basically a non-converted warehouse. In spite of the inhuman conditions, they were already beavering away on integrating the first 5 EOS instruments onto a long flat launch bus. I was surprised; what had happened to "Galactica?" Chris explained how that after everyone had bought into the EOS concept, a bunch of the wise and powerful had decided to split up the EOS payload into smaller bundles. I am pretty sure to this day that the recommendations put forth by our "erg" had little or no influence on this process, but you never know.

The first meeting of the EOS-AM science team came around. A team of scientists was assembled for each instrument. There was the Moderate Resolution Imaging Spectroradiometer (MODIS) Team (whose mantra was "Moderation in all things"), the Multi-angle Imaging Spectroradiometer (MISR) Team ("Les Miserables"), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Team ("The Asteroids"), and the Measurements of Pollution in the Troposphere (MOPPIT) Team, and the Clouds and the Earth's Radiant Energy System (CERES) Team. The CERES team was known as "Infinite CERES" on account of their proposed long-term multi-generational program which would extend until the collapse of the solar system.

For a while, it looked as if Landsat-7 might be put on the bus as well[4] but in the end it flew in formation with *Terra*. Right from the beginning, the science team was

[3] This experiment was called the Boreal Ecosystem–Atmosphere Study and campaigns took place in 1994 and 1996. For more details please visit: *daac.ornl.gov/BOREAS/bhs/BOREAS_Home.html.*

[4] Darrel Williams discusses this short-lived "Landsat on AM-1" idea in his article in the *Perspectives on EOS* series: "Reflections on the Early Days of EOS: Putting Socks on an Octopus" in the May–June 2008 issue of *The Earth Observer* [**Volume 20, Issue 3**, pp.4-5.]

There was almost total silence as we all looked at this thing: after all, abstract discussions are one thing, and that's how we scientists spent a lot of our time, but real hardware was somehow uncompromisingly deserving of attention.

confronted with a whole raft of problems: there were worries about the platforms pointing accuracy, (which turned out to be okay); the quality of the MODIS mirror (ditto); the solidity of EOSDIS (this turned out to be a real problem, and it took many management efforts to get this into shape); and the science team's desire to periodically point the instrument cluster at the moon for calibration ("*You want to do what?!*"). As time went on, the project team crunched their way through these problems and kept drilling ahead towards the launch date.

One of the EOS-AM team meetings was held in King of Prussia, PA, where the bus structure was being made. I borrowed a light aircraft and flew myself up there. Chris Scolese got us invited to visit the facility where the bus was being put together and so we went into a *clean room* and there got our first glimpse of the beast: it was very different from what I'd expected. The overall effect was of a slender black and silver lattice work, about 15 feet tall. The bus structure itself consisted of a trusswork of black composite beams held together by shiny alloy nodes, with little baseplates mounted here and there to hold the instruments and avionics boxes. It looked delicate, exotic, and expensive. There was almost total silence as we all looked at this thing: after all, abstract discussions are one thing, and that's how we scientists spent a lot of our time, but real hardware was somehow uncompromisingly deserving of attention. I think we were all wondering if the spacecraft would get safely into orbit and how it would fare spending year after year sailing quietly around the planet. When we got out from the meeting, it was dark. I offered to fly Chris back to College Park, not far from Goddard, and he trustingly agreed to be my navigator/bomb-aimer for the trip home. It was a beautiful clear night as we took off, and soon we were flying along, dodging the congested airways over Pennsylvania and Maryland, looking at the brightly-lit cities of Baltimore and Washington, DC as they crept towards us over the horizon. All the way back we talked about how the project was going and how ***real*** the whole thing had suddenly become.

Piers next to his supercomputer at the Snow Drifter's Lodge in Saskatchewan during the BOREAS campaign, where ground and aircraft operations were coordinated in conjunction with simultaneous measurements. The "MM" on Piers' chair stands for Mission Manager. **Photo courtesy:** Forrest Hall.

I left Goddard in 1996 to pursue my own career as a satellite. It was a very hard wrench as I'd been so happy and engaged at Goddard, and had worked with so many interesting and entertaining people. Looking back, it's clear that the years of hard and painstaking work by all the teams was absolutely critical in getting EOS started, designed, and launched, but it took years for me to realize how remarkable and rare a success the whole project was. **Dixon Butler**, **Berrien Moore**, **Francis Bretherton**, **Shelby Tilford**, **Michael King** and many others deserve enormous credit for making EOS a reality. ■

Return to Siberia: The 2008 Kotuykan River Expedition

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*In the September–October 2007 issue of **The Earth Observer** [**Volume 19, Number 4**, pp. 13-21] we presented an article entitled "Expedition to Siberia: A Firsthand Account." In that article we shared excerpts from a blog that chronicled the adventures of a team of scientists from NASA and Russia's Academy of Science as they embarked on a three-week adventure in the wilds of Siberia in hopes of collecting measurements to validate data from satellites flying 700 km overhead. The same team, plus a couple new participants, headed back to Siberia this past summer and we are now pleased to present the continuation of their story. For more background details on the expedition to Siberia or if you missed the first part of the story, please refer to the previous article. (PDFs of back issues of **The Earth Observer** are available for download at the following URL: eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php.)*

Wednesday, July 9
Joanne Howl

To most people, the word Siberia evokes images of a frigid land of extreme cold… and that is certainly true… but Northern Siberia is also a climatic *hot spot*—meaning it is an area that is warming faster than the rest of the planet. In the past 30 years, average temperatures across the region have risen 1–3°C (3–5°F), while the worldwide average increase in that time is about 0.6°C (1°F).

Again, that's not to say that it's time to break out the beach blankets. The region remains fiercely cold. The average wintertime low in Khatanga, a small village in Northern Siberia, is -34°F and can drop to -63°F. Yet the warming trend is so rapid here that scientists are curious to watch the effects on the land.

With such dramatic changes afoot, scientists from all over the world are now looking at Siberia. But some scientists, including **Jon Ranson**, Head of the Biospheric Sciences Branch at NASA's Goddard Space Flight Center and **Slava Kharuk**, Head of the Biological Laboratory of the Sukachev Institute of Forests, have been studying Siberian forests for decades. Starting July 10, 2008, they led a team of American and Russian scientists on a research mission to an extremely remote and harsh section of northernmost central Siberia.

What did these scientists discover? What challenges awaited them? Read the following blog for a peak into their research during an exciting two weeks. [**NOTE**: The following article is a condensed version of the expedition blog that was originally posted on *The Earth Observatory*; for the full version please visit: *earthobservatory.nasa.gov/Features/SiberiaBlog2008/*.]

Thursday, July 10

Jon Ranson
From Taymyrskiy Region, Siberia
8:15 PM local time [USZ6S] (8:15 AM EDT)

Our trip from the U.S. to Khatanga went very smoothly. There were few delays. All the bags arrived with their respective owners, on time. Our equipment got through customs without comment. Everybody met as we planned, and everyone arrived on time and healthy.

Maybe things were going too well. I guess we needed a little excitement—and we got it today.

Last year we'd loaded the helicopter down pretty heavily with our gear. This year we had two more people and plenty of extra gear to support them, plus we added some heavy "comfort" items, like a generator. We were pretty certain we would not be overweight, but we knew we'd have little room to spare. Or so we believed…

As we were stowing our gear aboard the helicopter, four Russians appeared. They said very little, but threw a bunch of their own gear onboard, then climbed in along side us. Somehow, everyone got squeezed inside and the pilot took off. When we landed, the four hurriedly inflated a boat, grabbed their gear and took off downriver without a backwards glance.

In steady rain, a Russian M-8 helicopter drops the scientists off on the banks of the Kotuykan River in northern Siberia. In the foreground, scientists cover gear with plastic. This is the first campsite of the expedition, and it will not be a soft one. The beach is covered with marble- to microwave-sized stones. **Photo Credit:** Jon Ranson.

Slava later explained that it's a custom for locals to catch rides when they can. Apparently these were Siberian "good old boys," out for a week of fishing. As he talked, we slowly realized that we were missing a bag—a bag that contained truly vital equipment, including our global positioning system (GPS). We figured it must have gone downriver with the fishermen! All hands scurried to get one boat inflated. We launched the craft, Mukhtar leapt in and sped off, hoping to catch up with the fishermen. Fortunately, the fishermens' boat did not have a motor, so he was able to catch the group, retrieve the wayward bag, and return everything back to camp safely.

It was such an odd experience. We have traveled so far and gone to such great expense to get to this truly remote area of the world, and expected to be completely alone. We certainly never expected to have locals vacationing with us! I guess it is a reminder that, no matter where you travel nor how remote the region, you are always in someone's back yard.

It is fantastic to be here. Everyone is excited to get started. We've set up camp on the beach next to this beautiful river. It's just across the river from several dozen Geoscience Laser Altimeter System (GLAS) footprints, so we are perfectly situated. [One of the expedition's objectives is to collect ground-truth data for comparison with satellite data from GLAS on the Ice, Clouds, and land Elevation Satellite (ICESat)]. The only hitch is that beaches in this region are stony—no sand at all. Our campsite is filled with stones ranging in size from a marble to a microwave, all mixed together.

At their first campsite, the team assembles for a group photo in front of one of the not-yet-inflated rafts. Back row from left to right: Guoqing Sun, Mukhtar Naurzbaev, Slava Kharuk, Jon Ranson, Pasha Oskorbin, and Sergei Im. Front row from left to right: Ross Nelson and Paul Montesano (Nelson and Naurzbaev are new team members for this year's expedition.) **Photo Credit:** Jon Ranson.

We've caught three nice fish this afternoon. It would have been four, but mine slipped away as I was making my way back to shore. We've got about three pounds of meat and our Russian friends have made a large batch of fish soup. That's basically the entire fish cut into chunks and put into water with some flavorings, then boiled over a campfire until it is declared done. Fresh protein is hard to come by out in the Arctic wilderness, so it is wholesome and healthy food.

We have landed in a wonderful area for our studies; the forests surround us. The trees are relatively small and far apart, but they have been extensively measured by the GLAS lidar. We know that the instrument gives us fairly accurate information [about biomass] farther south, where the trees are larger. We also know that here, where the trees are small, that the measurements are fairly inaccurate. We are not sure why. So to be able to get into these forests, where we know we have difficulties, and make truly accurate measurements is a wonderful opportunity. I think this is going to be a very worthwhile expedition, with plenty of good data to bring home.

Friday, July 11

Jon Ranson
From Taymyrskiy Region, Siberia
8:05 PM

It's been quite an interesting day, starting with a bit of excitement. For some reason I woke up around 5 a.m., curious to take a look outside. What I saw was alarming: the river we camped beside had begun to rise rapidly. It looked like some of our things were about to be swept away. I began pulling some things inland, as I could. Soon Guoqing, always the early riser, came out of his tent to help. Before long we decided we'd better wake up the camp. Together we managed to pull everything up on land and to safety.

When we returned from making measurements around noon, the river had risen again. We estimated it had risen about 1.5-m (5 ft) since I woke up at 5 a.m.! It was rainy here last night, but not that rainy. There must have been really big rains upstream to make such a difference.

We thought the river was finished rising, but in the afternoon Slava and Mukhtar, whose studies kept them near the camp, saw it rising again. They had to stop their work to move our things and raise the camp even higher. Gosh, I'm really glad we didn't come in the "rainy season" this year!

Today there's not much rain, but it is cloudy and cool.….probably in the low fifties, but the wind feels cold in this damp weather. Despite the cool and the breeze, there are still enough mosquitoes to go around. We wear head nets and insect repellant and stay covered from head to toe. With that, they are tolerable.

Mosquitoes and dampness not withstanding, it was a wonderful day for work. We were able to complete a lot of GLAS plot measurements. What we do is go to the center of the GLAS footprint and outline a 10-m (32.8 ft) circle within that *footprint*—the total area the satellite "sees" in a single image. Then we measure every single tree we find within that circle. We do standard forestry measurements, such as diameter at breast height and height of the tree. We also note the species. Then we move out of the circle and measure the tallest trees outside the circle for additional information.

This year we are 3–4º further north than last year. The elevation is different—lower—than last year, too. Compared to the sites we observed last year, there are about one-fourth the number of trees in the same area here.

Life is very harsh up here; there is no doubt about it… but life is also very vigorous and pervasive. Every bit of ground that can support life is covered. There is moss and lichen as well as these small trees. And there are flowers everywhere—flowers of every kind. We're disappointed that there are no blueberries yet; they won't be ready for a few more weeks. But it is a very beautiful time to be in Siberia.

Saturday, July 12–Monday, July 14

Jon Ranson
From Taymyrskiy Region, Siberia
9:05 PM

Since our last entry, we've broken camp twice and spent one day working in the woods on our various studies. It's been an intensely busy time, but not without some unexpected pleasures. Our last camp was a real treat. We chose the site for its proximity to our research areas, but were pleased to find a little wooded area, up an embankment next to the river, with the ground carpeted by moss and lichens. Not many bare rocks at all! It was soft! What a great night's rest.

Because my tent was in the woods and on high ground, I stayed snug and dry, despite being awakened in the middle of the night to the sound of a hard rain. But a few folks had set their tents in the low land by the side of the river. The runoff from the rain went down our hill and right into one of their tents, just like little fast-flowing streams. So not everyone had a good night's sleep.

Since we arrived, we've had no shortage of sites we can measure. We are traveling right through areas surveyed by the GLAS instrument in 2003, 2005, and 2006.

Today we've stopped at what appears to be the beginning of a canyon. There are a couple of pretty steep hills on each side of the river. We're excited about this, because it gives the U.S. team an opportunity to make measurements on steeper slopes than we have seen this trip. And it gives the Russian team a great place to gather data on the effect of elevation on treelines. It's a good spot, and we'll work it hard tomorrow.

Ross Nelson (right) and Gouqing Sun (left) clean and scale the day's catch. Fish are the only fresh protein available to the expedition, so they eat it as frequently as possible. On this day, the scientists set out nets in the morning and returned, hungry from a hard day's work, to a good catch. Twenty-five fish went into a soup and, for variety, some others were seasoned and fried over the campfire. **Photo Credit:** Jon Ranson.

I should mention what an incredible group we have here. We all get along well and each person has so much talent. It's always interesting when we have a chance to stop and talk together.

The newest Russian among us, Muhktar Naurzbaev, is an expert at *dendrochronology*. He dates the trees, of course, by looking at the tree rings: one ring equals one year's growth. In good years, the rings are far apart; in tough years, they are very close together. Because the climate is so extreme here, Muhktar must use a microscope to evaluate the width of the tree rings. Some of the rings are no more than 200 μm wide—just over the width of two human hairs. That represents how much the tree grew in an entire year! That's so incredibly little! But the point is, they may have barely grown—but they did grow. **The land is extreme, but life won't quit.**

These small trees here, in this tough land, can be very ancient indeed. Muhktar tells me that he has seen larch trees over 1,000 years old. The diameters are small, yes, but the trees have lived a very long time.

Yesterday we had a real treat. The sun came out for the afternoon! How wonderful to see that brilliant blue Arctic sky and feel the warmth of sunlight again! But the sunshine was short-lived; it's overcast again. At least we know the sun is really up there trying to shine on us 24 hours each day. I'm sure we'll see it again, soon.

Tuesday, July 15

Jon Ranson
From Taymyrskiy Region, Siberia
9:30 PM

It was an interesting day here. The morning started bright and beautiful, with no rain, no clouds. I went out with Guoqing, Paul, and Ross to take measurements of the GLAS footprints nearby, which were across the river and on a mountain.

The mountain is typical for the region: the elevation gain isn't huge, but the slope is fairly steep. These mountains, called the Siberian Traps, have flattened tops and are made of basalt. They were created from the eruption of volcanoes in the area about 250 million years ago. That timing coincides with the Permian extinction, when many forms of life died out. The basaltic flows at that time were huge. Some estimate they may have covered up one to four million square miles. It must have been a world-changing event. It certainly changed this part of Siberia, leaving these magnificent mountains behind. [The Permian-Triassic Extinction was the worst mass extinction in Earth's history. Fossils suggest that between 90-96% of all marine species and 70% of all land species died out.]

There were several GLAS lines along the mountainside. The larch trees were all less than 10-m (32.8 ft) tall. We actually saw a few willows, but none big enough to meet the criteria for measurements; they were so small they could be defined as "shrubs," not trees.

Jon Ranson comments on…

…How a Spaceborne Lidar Works…

Let me explain how this all works a bit more. GLAS is a *lidar*—like a *radar*, except it uses laser light instead of radio waves. The ICESat satellite moves along in an orbit up above the Earth and GLAS fires a laser pulse to the Earth at specific intervals. The pulses hit the Earth about every 170 m (558 ft), and some of the energy is scattered back from the surface. GLAS measures the intensity of the return signal, which is called a *waveform*.

Unlike the beam of a flashlight, the laser pulse stays in a narrow beam as it travels from space to the surface of the Earth. The area *illuminated* by the laser pulse—the GLAS footprint—is roughly circular. When we put the shot locations on a map, it's just like a dotted line across the Earth, with each dot representing a footprint and the line representing the path of the satellite overhead.

The return *waveforms* are affected not only by the height of the trees, but also the branches, the underbrush, the ground, and anything else that exists there. We can calculate tree height from the *waveform* data by subtracting the first return (tops of trees) from the last return (ground). We also use these *waveforms* to calculate *biomass*—the amount of plant material present in the area.

…How Trips to the Field Can Help Improve the Accuracy of Future Lidar Measurements...

Siberia isn't at the top of most people's vacation wish list. We come with a purpose in mind… In some areas on Earth, our calculations using GLAS data match closely to what we measure when we are on the ground. But, when we look at the GLAS data from Siberia, what we see are *waveforms* that are characteristic of bare hillsides, not forest. Yet there is forest here. I see it with my own eyes, and we're measuring it.

We hope that measurements like the ones we are taking here in remote Siberia help us to see what's really going on and, thus, do a better job interpreting the GLAS data. We may then be able to interpret the data we have more accurately, so we may recognize these small forests. If not, we can certainly use the data we're gathering to put into our models, so that in the future, we can build an instrument that will measure these areas more accurately.

One of the issues may be that the measurements in this region are most often taken during the winter. ICESat is an ice mission, after all. These larch trees, although conifers, lose their needles in the winter. Without the leaves on the trees, we may get less return signal from the trees, and this may well alter our ability to interpret whether we have sparse forest or bare ground.

A view of the campsite taken from across the Kotuykan River. In the background are the flat-topped mountains known as the Siberian Traps. The slope in the foreground is littered with basaltic rocks formed from lava flows about 250 million years ago. The campsite was originally set up next to the riverbank. It is now on high ground; the river dropped about 6.6 ft (2 m) overnight. **Photo Credit:** Jon Ranson.

After this successful start, we found a nice lunch spot near a cliff. We enjoyed the view as we ate our lunch of canned fish and crackers. We were in a great mood and enthusiastic for the rest of the day's work.

As we made our first afternoon measurements, the sky darkened and a sudden thunderstorm moved in. So there we were, at the top of this mountain with thunder and lightening all around us. And the rain pouring down. What could we do? We just kept working.

I should mention something we've seen here that is pretty interesting. The Russians call it a "tree in a skirt." And, with just a little imagination, that's what it looks like. Basically, the top of the tree is the typical sparse-needled shape of the larch as it grows in this extremely harsh climate. Then, lower down, is a lush green growth. The branches are so heavy with needles that they sag down towards the ground. So it looks like a thin woman wearing a heavy green skirt.

A photograph of a tree near the campsite shows a growth pattern that Siberians call a "tree in a skirt." During Siberian winters, the bottom parts of trees can be covered by snow, which protects the branches from damaging winds. **Photo Credit:** Jon Ranson.

This happens because of the winter weather. When it snows, the bottom of the tree is covered up. This blanket of snow is actually very protective, keeping the lower branches safe. The part of the tree that sticks out of the snow is unprotected, so it is buffeted by the winds, which carry ice-crystals that can act like knives as they slice past the tree all winter long. It makes for an interesting-looking tree in summer! And is another testament to how incredibly harsh the conditions are here in the winter.

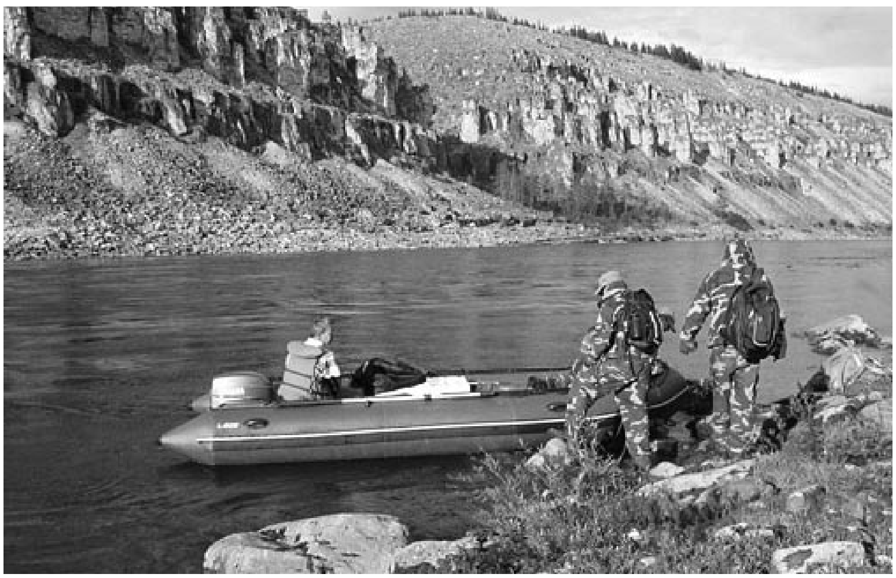
This campsite is beautiful tonight. The rains have cleared now. We can see downstream, where the river flows between more mountains. There is a fog rising up from the river between those mountains—a wonderful sight! Yes, we are sleeping on rocks again, but I doubt any of us will complain much—we're tired and should sleep well.

Wednesday, July 16–Thursday, July 17

Jon Ranson
From Taymyrskiy Region, Siberia
10:45 PM

This part of Siberia is incredibly beautiful. Our new camp, where we set up on Tuesday, is right where a smaller tributary river flows into the Kotuykan. When we look downriver, we can see the Kotuykan flowing swiftly between the stark mountains. Larch trees grow well on the top of the mountains, so they appear green and soft. The sides of the mountains are a real contrast. They are dark and sheer, made up of crumbling rock. In some places, where the rock is more weather-resistant, there are formations that look like columns and fortresses that jut out of the side of the mountain.

Yesterday started out nice and dry—a pleasant thing, since we had to break camp and move downriver. Just as soon as we got into our boats and began to move, it just poured down on us. We had rain all day, until we prepared to pull to shore. Then the skies began to clear. As we set up our camp, I heard someone tell us to look downriver. A gorgeous, huge rainbow stretched over the river. With the green trees, the dark mountains, the blue river, and the clearing sky as background, the rainbow was an amazing thing to see.



The expedition's camp is on the opposite side of the river from the study sites. The team uses the largest boat on the expedition, which has a 40-horse-power motor, to ferry people and gear. Paul Montesano and Guoqing Sun have just disembarked at their study site, while Mukhtar Naurzbaev prepares to return the boat to camp for the day. **Photo Credit:** Jon Ranson.

It was nice to have a peaceful day yesterday, because today was much more exciting. From our maps, we knew that we'd have a tough time getting to our GLAS points to do our measurements today. There were a lot of points, but they were on a sheer-sided mountain. We knew this was not going to be a stroll, but a real challenge. We were more right than we imagined!

As usual, our measurement sites were across the river from camp. We asked Mukhtar, who was staying to work with his colleagues on their studies in the mountains on the camp side of the river, to ferry us across. He took us where we asked: near the entry of a small, steep-sided canyon. We believed that near there the mountain's edge would flatten enough to be safely climbable.

Friday, July 18–Saturday, July 20

Jon Ranson
From Taymyrskiy Region, Siberia
11:57 PM

It's midnight at the oasis here. I'm in my tent, surrounded by a hoard of bloodthirsty mosquitoes all waiting for a drink. Lucky for me they are all outside, so they will have to stay thirsty.

This was a travel day [July 20]. Even though we have to tear down and set up the entire camp, we consider travel days "easy" days, because we do get to sit down for a few hours while we're in the boats. We needed to find a large, flat site for tonight because this will be our last camp. Two days from now we will have a helicopter come pick us up from here.

We found good spots for our tents about 200 meters away and about 10 meters above from the rocky river bank. It's a little climb from the river, where we are cooking, to our tents. But it's worth it. The view of the Kotuy river and sheer cliffs on the other side is spectacular. The ground up here is less rocky and covered with a bit of grass, so it should be comfortable sleeping.

We got into camp early, about 7 p.m. When we got here, Slava said there might be a good fishing spot nearby and thought we should try to catch something for dinner. The spot was good: Slava caught several really nice fish. And I hooked "Bubba."

I hadn't had much luck using the small silver spoons that had netted me so many fish upriver. So I broke out a *muskie-killer*—a lure with giant hooks and a greenish skirt. It was huge and new. A fish store near my home had suggested it; I figured they did it just because it was so expensive!

Well, I tossed it about twice, then on the next cast I got a fantastic strike. It was clearly far too much fish for my 10-lb test line, but I managed to play it just fine for quite awhile. Then it leapt from the water and twisted sideways—what a huge fish! Slava thought so too; he said it must've weighed about 20 lbs!

I guess the fish didn't like the way we looked, because when it hit the water it took off straight downstream. My drag was whining as the line went out. I had been teetering on loose rocks on an embankment, while playing the fish, but now I needed to adjust my footing—and I slipped. The rod tip flipped up and I felt the line snap. My giant fish was gone.

Needless to say, I spoke some fine American slang, sitting there on the bank. Also needless to say, fishermen can't walk away when they spot a *Big One*. There are rumors of truly giant fish—taimen over 100 lbs—in the Kotuy River, so mine might have actually been a "Small One!" So we fished until far too late, basking in the sunlight of the Siberian night. I didn't come here to fish, so I can't complain, but it would have been fun to have landed my Siberian "Bubba."

Yesterday we worked in the field. Our measurement sites were at the top of a mountain but we were able to climb up the back side, so no big excitement, just steady going. We ate our standard sardine, cracker, and candy bar lunch perched on a cliff looking over the river. Just a wonderful sight. It's interesting; we are seeing small patches of snow on the north side of the mountains. It's too warm to snow on us, but too cold for all of the snow to have melted. It may stay here all summer.

A nice spot for lunch, on the Siberian Traps, that overlooks the Kotuy River. The freeze/thaw cycle cracks and crumbles the rocks. The weather and the river have eroded the mountains into spectacular formations and sheer drop-offs. **Photo Credit:** Jon Ranson.

We were able, at last, to go from the forest all the way upslope until we were in tundra. The forest trees became smaller and more sparse very quickly as we gained elevation. The tundra was interesting to see. No trees there, but we did see a lot of caribou skulls and antlers. Some of the guys thought these were fantastic—so fantastic that they carried them all day long and brought them into camp. I'm curious to see if they try to get them on the airplanes going home.

Slava has been working hard on several studies. Today was a really good day for him. I think he should have a chance to talk about his side of things.

Slava Kharuk:

We were working today on looking at the effect of changes in climate on the growth of trees. We went up a mountain where there were very old, dead trees. These so-called *fossil trees* are ancient. They died in the 13th or 14th century, in the time of the *Little Ice Age*. Before that, they were growing at the edge of their territory. They were maybe 200 – 400 years old (yet still very small from the hard climate) when the climate got too cold, and they died.

Forest ecologist Slava Kharuk called this a photo of Siberia's "bones and flesh." The "bones" are the skeletons of fossil trees that died prior to the extremely frigid climate of the *Little Ice Age*. Although they died hundreds of years ago, the frigid climate has prevented them from decaying.

The "flesh" is the new trees that are colonizing the area as the climate warms. These trees are growing far above the "fossil" tree line, which is evidence that the current warming trend is very strong. Scientists will use data on the ages of both old and new trees to create a timeline of climate change in this part of Siberia. **Photo Credit:** Jon Ranson.

These *fossil trees* don't decompose because it is so cold here, but they have fallen over in the last few hundred years. All around them now are younger trees, green and tall. These young trees are evidence that the climate has warmed a lot, so that now conditions will allow trees to grow here again. The young trees are now growing further upslope than the old tree line. That means that this area is warmer now than it was in the warm time before the Little Ice Age.

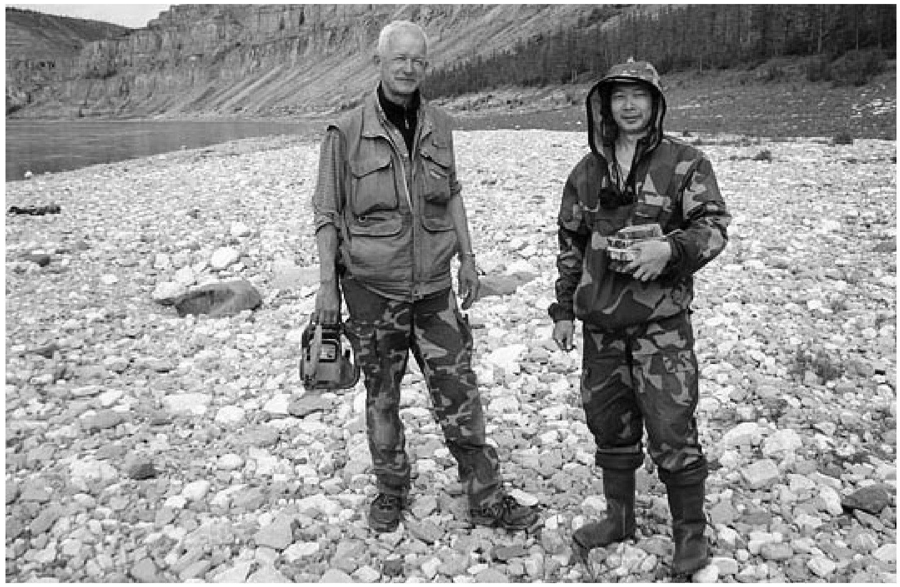
The climate has changed many times in this area. Once, the climate was much warmer. There were trees growing all the way to the Arctic Sea. But then it got cold and those trees died off. Since then, there have been waves of warmth and waves of cold. **Now we see warming that lets trees grow where they haven't grown for a long, long time. If this warming continues, we may again see trees growing all the way to the Arctic Sea.**

Monday, July 21–Tuesday, July 22

Jon Ranson
From Taymyrskiy Region, Siberia
9:05 PM

The time is rushing by like lightning. We stay so busy, and the experience is so intense that I can't believe this year's trip is almost over. It seems like we just began a day or two ago. But when I think about my home, my friends, and my family, it seems like forever that I've been gone. On the river it seems almost as if that life is just a dream. But the fact is we're done with the river. And I'm only a half-a-world and four days away from my home.

Yesterday was our last day in the forest. It was a pretty routine day, no special excitement. The weather was cooperative, and the mosquitoes a steady backdrop, just music to measure trees by. We went up the back of the mountain and worked down slope. The trees there were small and far apart. We made a ton of measurements so it was a highly successful, long day's work.



Slava Kharuk (left) and Sergei Im (right) return to camp after a day collecting transects from larch trees. Sergei is holding some of the transects, or cross-sections while Slava holds the chainsaw they used to collect them. These cross-sections will be studied in the laboratory at the Sukachev Institute of Forests. Each one will give the scientists a wealth of information: the age of the tree, climate conditions throughout its lifetime, dates of fires that left scars, and changes of growth rate in response to climate warming. **Photo Credit:** Jon Ranson.

Slava and his team worked the other side of the river. Today they took transects of trees for their fire-return studies. Fire has always been a part of life in the forest. The larch trees actually benefit from smaller fires. The larch resist the heat of fire that burns the underbrush, so a fire will allow the seeds more fertile ground with less competition. And it helps the cones to release their seeds, too. But large and extremely hot fires will damage and often kill larch—so fire is a mixed blessing to this forest.

From his prior work, it appears that fire is occurring much more frequently in recent years, possibly as a consequence of the warming of the region. It also appears that these fires are much larger than in the past, affecting and killing many more trees. To continue these studies, Slava's team cuts slices across the tree and takes these discs back to the lab to analyze. If there has been a fire in the tree's lifetime, it will leave a scar on the tree. Each fire leaves a different scar on a different growth ring. The collected transect of the tree not only can date the fires the tree has lived through, but they are also analyzed to study the effects of the climate on growth and the age of the trees in the forest. So one tree gives a wealth of information for many studies.

Cooking for a team of hard-working scientists in the field is a challenge. Pasha Oskorbin, the primary camp cook, uses his secret ingredient to enhance a meal. He says, "*There is nothing inedible on this expedition. There may just be too little ketchup*." The label is from an American company, with the brand name written in English. The rest of the label is in Russian Cyrillic: an appropriately international condiment for this American/Russian expedition. **Photo Credit:** Jon Ranson.

The last night in camp was quiet. And yes, fish was on the menu again. We eat a lot of fish here. By this time last year, I was having cravings for borscht, and Paul was constantly reciting a mantra that sounded something like "pizza, pizza, pizza." This year no one is complaining much, although Paul has just begun talking about craving some of his special, secret tacos. I guess we're more satisfied with our diet this year. I'm not sure why. Maybe it's Pasha's secret ingredient—ketchup. He uses a lot of it when he cooks for us.

Early this morning we ate a fast breakfast then hurriedly broke down our tents and boats. We piled our gear near the edge of the flattened area we'd selected as the wilderness helipad. The helicopter was only a couple of hours late—a long time when you are wondering if your ride is really going to show up, but not so long for a connection in the wilderness.

The big MI-8 made a memorable arrival. We crouched down next to our gear, expecting some prop wash to blow on us. We sure got that and more! Apparently the pilot wanted to make it as easy on us to load up, because he came down within five feet of our pile.

Within an hour we were loaded and a few more hours found us in Khatanga. It's a small town, but it seems pretty big now, after coming out of the wilderness. We'll spend two nights here, in a small house that we rented. It's comfortable: no rocks under our beds tonight!

Even though we have soft beds, fresh food, and a roof to sleep under, there's no mistaking that we are still in a different land. This evening I saw a load of caribou meat being trucked to market out of town. The carcasses had been skinned, beheaded, gutted, and frozen. They were piled in the back of a slat-sided, open truck. It was bizarre to see the legs sticking every which-way. Of course, the truck was not refrigerated, other than by natural means. Yes, it's pretty cold here even now—in mid-summer—so I guess they take advantage of the weather. I'm sure it's perfectly safe and edible meat. Still, I think I'm glad I'm not on the receiving end of that load of caribou!

Friday, July 25

Jon Ranson
From Krasnoyarsk Krai, Siberia
9:10 PM

We're in Krasnoyarsk now—no longer in the wilderness and no longer above the Arctic Circle. This is the third largest city in Siberia, with a population of just over 900,000. To put that in perspective, that's a bit less than the size of the caribou herd in the Taymyrskiy Region.

It's nice to have the amenities that civilization brings, especially being free to make a phone call or hook up to Internet without hanging off the side of a mountain! But there is an adjustment to be made. After our time out camping, I'm finding it hard to get used to a real bed. The first night it felt good to snuggle into a mattress—but I woke up with every muscle in my body aching. I guess my body liked hard rocks better!

Today we'll work at the Sukachev Institute of Forests. I'll have a chance to look at some data and to do some work on a scientific paper with Slava. Then it will be early to bed, and very, very early to rise. Tomorrow, Saturday, we'll begin our journey home. We'll arrive at our home airport on Saturday night. No, that's not just a few hours flight, as it seems. We lose twelve hours coming home, so it's 26 hours of travel.

This has been an exhausting, but rewarding science adventure. The whole team worked very well together, with the Russians and Americans helping each other and enjoying each other's company. The two new members of the team, Ross and Muhktar, became good friends during the two weeks on the river.

Ross Nelson, Guoqing Sun, and Paul Montesano holding reindeer antlers. They found these antlers on the tundra at the top of a mountain, carried them all day, then brought them back to camp strapped on the bow of the boat. To many Russians, the reindeer is a symbol for wanderers, or nomads—a meaningful souvenir for these three scientists, who have wandered a half-world away from their homes in search of knowledge. **Photo Credit:** Jon Ranson.

When we come to the field, we work intensely to gather a lot of very valuable data. **From space, we can gather a huge amount of data to review, but there is always a question of how accurate that data may be under these extreme conditions.** In the field we can touch and measure only a relatively small amount of forest, but it's essential work. This is how we learn to better understand and use our satellites and models—and learn how to improve the instruments, too.

You know, it is really so very, very essential that this *ground work* gets done. Not just for my own studies or for the studies of the members of this expedition. But there is so much to learn, so much that is critical to life on Earth—to our lives and to the lives of generations to come.

I'd really like to emphasize, especially to the younger folks, that **science is a living, exciting, and important career.** Yes, scientists spend a lot of time working with papers and mathematics and meetings in conference rooms. Yeah, if you want to do science, you've got to study hard and make the grade. It's hard work.

But, for those willing to do it, **science offers true adventure**—both intellectually and hands-on. You can explore anything you want, anywhere in the world—or in the universe. And your results can be extremely important. Scientists commonly uncover information that helps us change the way we think about the world. **From time to time, scientists have uncovered information that has literally changed the world.**

I've been asked if I'm coming back to Siberia again next year. Right now, I don't know. We sometimes joke that science expeditions must be sort of like giving birth. I've been told that after such an intense experience that many women swear, right there in the delivery room that they are done, **forever**. But then, soon, they're fantasizing about another new baby.

Right now I'm tired; it's been intense and exhausting. Right now I'm focused on getting home and attending to the new data we've gathered. Right now I just can't imagine going back to that river again. But give me a few months … or a few weeks. I'll make a bet that I'll be looking over maps and planning the next trip to Siberia before too long. ■

Progress Update on NASA's Earth Science Decadal Survey Missions

Mary DiJoseph, NASA Goddard Space Flight Center, Mary.S.DiJoseph@nasa.gov

In 2008, NASA formally initiated work on its Earth Science Decadal Survey missions. The NASA Decadal Survey missions are directed missions managed by the Earth Systematic Missions (ESM) Program Office at NASA's Goddard Space Flight Center (GSFC). The survey is comprised of 15 missions—prioritized by the National Research Council (NRC) in its 2007 report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*—that will enable NASA to provide ongoing information about global climate and climate change. The mission launches are organized into three time-phased tiers, with each mission having a study management team led by a Program Scientist and Program Executive from the Earth Science Division at NASA Headquarters (HQ). These teams have been diligently working—conducting workshops, science simulations and analyses, and conceptual design studies; defining schedules; and developing cost estimates and management structures.

On February 14, 2008, NASA provided the Soil Moisture and Precipitation (SMAP) and Ice, Cloud, and land Elevation Satellite II (ICESat II) mission teams—two of the four *Tier 1* missions discussed below—with directions to immediately start *Pre-Phase A* activities for target launch dates of 2012 and 2015, respectively. On March 7, NASA formally initiated *Pre-Phase A* activities for the other two *Tier 1* missons, the Climate Absolute Radiance and Refractivity Observatory (CLARREO) and Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) missions, and directed teams to complete study activities for a Mission Concept Review early in Fiscal Year (FY) 2010. NASA also initiated *Pre-Phase A* activities on the *Tier 2* missions of the survey, directing mission teams to conduct studies that improve the understanding and scope of the missions.

The following paragraphs summarize the current status of the *Tier 1* and *Tier 2* missions. **Table 1** shows an overview of the schedules for these missions.

Tier 1 Missions

SMAP

The SMAP mission—designed to measure surface soil moisture and freeze-thaw state—is assigned to NASA's Jet Propulsion Laboratory (JPL). SMAP, which was previously competitively selected as the Hydros mission under the Earth System Science Pathfinder (ESSP) Program, conducted Mission Concept Review on June 24, 2008, and was formally approved to initiate *Phase A* on September 24, 2008. Mission Definition Review for SMAP is planned to be conducted from February 24-26, 2009, with a target Launch Readiness Date (LRD) of Spring 2013. The LRD will be finalized at the Mission Confirmation Review that is tentatively planned for March 2010. The SMAP instrument radar will be built at JPL, the radiometer will be built at GSFC, and other instrument components will be procured from industry. The spacecraft will be built in-house at JPL.

ICESat II

ICESat II—the follow-on mission to ICESat—is assigned to GSFC. ICESat II will continue the measurement of ice sheet mass balance, cloud and aerosol heights, and land topography begun by ICESat. It will also measure vegetation canopy heights. The Mission Concept Review for ICESat II is scheduled for February 5, 2009. This should result in formal approval to begin *Phase A* in March 2009. A report on the ICESat mission has recently been completed by the *ad-hoc* Science Definition Team and will soon be available for distribution. The Science Definition Team selection announcement was made on December 16. ICESAT II hopes to be ready for launch no later than 2014; the mission team is currently evaluating whether an earlier launch date is possible. The laser altimeter instrument will be built in-house at GSFC with the help of a competitively selected industry partner. The spacecraft will most likely be procured competitively.

DESDynI

JPL, in partnership with GSFC, is assigned the DESDynI mission. DESDynI will study the probability of natural hazards, such as earthquakes, volcanic eruptions, and landslides. It will also track fluids that impact hydrocarbon production and groundwater resources and examine the effect of climate change on ice sheets, sea level, species habitats, and the carbon budget. A hydrology applications workshop for DESDynI took place in October 2008 and trade studies are currently being conducted to evaluate different measurement approaches. These include trades on the radar design, the lidar design, and the number of spacecraft and the orbit for each. The mission team is also conducting discussions with the German Aerospace Center (DLR) on a potential partnership with the TerraSAR-X add-on for Digital Elevation Measurement (TANDEM-L) mission. DESDynI's Mission Concept Review is targeted for Fall 2009.

CLARREO

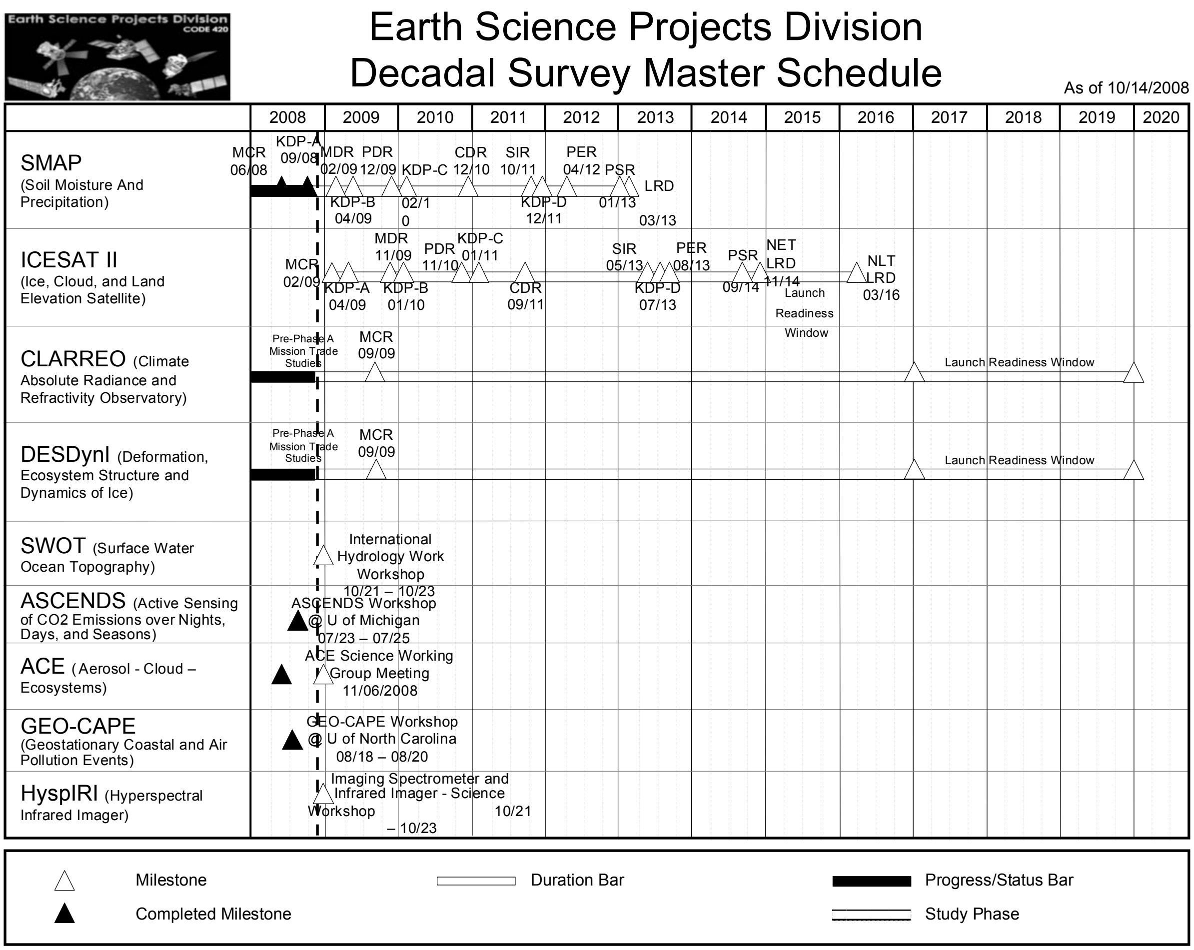
CLARREO is a key mission that will serve as a primary measure of atmospheric and climate change, and is assigned to NASA's Langley Research Center (LaRC). A science team meeting in April 2008 and a community workshop in October 2008 further refined the science objectives and measurement requirements of the mission. The CLARREO team initiated detailed mission design studies early in November. A Fall 2009 Mission Concept Review is targeted for CLARREO.

Tier 2 Missions

In 2008, mission teams conducted community workshops for all of the Tier 2 missions—ACE, ASCENDS, GEO-CAPE, HyspIRI, and SWOT (see **Table 1** for full names). An additional workshop for each mission is planned in 2009. Team members are conducting a wide range of science modeling and analysis combined with selected instrument technology development efforts to further mature the mission concepts and better prepare them for *Phase A* activities.

More information on the science objectives and the status of each mission is available at: *decadal.gsfc.nasa.gov.* This website also includes information on the proposed *Tier 3* missions.

TABLE 1. Master Schedule for *Tier 1* and *Tier 2* Decadal Survey missions.



CDR = Critical Design Review
KDP-A = Key Decision Point (-A, -B, -C, -D)
LRD = Launch Readiness Date
MCR = Mission Concept Review
MDR = Mission Design Review
NET = No Earlier Than
NLT = No Later Than
PDR = Preliminary Design Review
PER = PER Pre-Environmental Review
PSR = Pre-Ship Review
SIR = System Integration Review

New Satellite Observations and Rainfall Forecasts Help Provide Earlier Warning of African Drought

Chris Funk, USGS Center for Earth Resource Observations and Science, cfunk@usgs.gov

The poor nations of sub-Saharan Africa face a constant struggle against weather and climate. The outcome of that struggle profoundly influences these nations' economic growth, health, and social stability. Advances in climate monitoring and forecasting can help African nations and international aid organizations reduce the impact of these natural hazards. Satellites play a crucial role in this effort as they enable scientists to track climate conditions over data-sparse land and ocean areas. **In this article, I discuss how a multi-organizational group of scientists use satellite data and statistical forecasts to provide earlier and more accurate early warning of potential drought conditions.** We frame our discussion in a specific, timely context—that of probable dramatic food insecurity in Zimbabwe, Eastern Kenya, and Somalia. As this article was being prepared in mid-December, very warm conditions in the Indian Ocean appear likely to produce below normal December–January–February rainfall in both Eastern Kenya/Somalia and Zimbabwe.

Food Insecurity, Early Warning Systems, and Earth Observations

When the price of food spikes sharply—making food too expensive for poor people—famine conditions may result. These humanitarian disasters evolve slowly, and primarily take their toll by undermining nutritional condition, leading to outbreaks of disease and increased mortality. Acute malnutrition first strikes those with the most immediate and time-critical needs—such as pregnant and lactating mothers and their children. These *at-risk* populations are the first impacted by limited access to food [*Natsios & Doley*, 2009].

As the number of urban poor around the world rises rapidly and global grain prices soar due to increased competition by biofuels and livestock, there has been a broad increase in three classic coping mechanisms: food hoarding, migration, and increased banditry. This expanding *food stress* disrupts societies and contributes to political unrest. Over the next decade, we are likely to see *food coups* emerge as modern counterparts to the famines of the past. While international aid, urbanization, remittances, and increasingly dense food markets are reducing the frequency of death from acute malnutrition, chronic and accelerating food shortages may contribute to rising political instability in many nations.

Early Warning Systems, such as the U.S. Agency for International Development's (USAID) Famine Early Warning Systems Network (FEWS NET), can help mitigate the political and humanitarian impacts of food shortages by identifying appropriate food, health, and market-related interventions. Satellite observations can contribute substantially to both the contingency planning and disaster response planning phases of FEWS NET (**Figure 1**), supporting decisions that save lives and lessen the impacts of drought. During the contingency planning phase, relatively uncertain information, such as climate forecasts [*Funk et al.*, 2006] and climate indicators (**Figure 1, Box A**), can help guide scenario building and food security outlooks. This typically occurs before or during the early phase of the crop growing season. In the middle of the season (**Figure 1, Box B**), satellite rainfall fields may be used to monitor crop growing conditions. These simple water balance models use grids of rainfall and potential evapotranspiration [*Verdin and Klaver*, 2002; *Senay and Verdin*, 2003] to estimate whether sufficient soil moisture exists for crop growth. At the close of the crop growing season, satellite-observed vegetation may be used to assess crop production and/or yield [*Funk and Budde*, 2009].

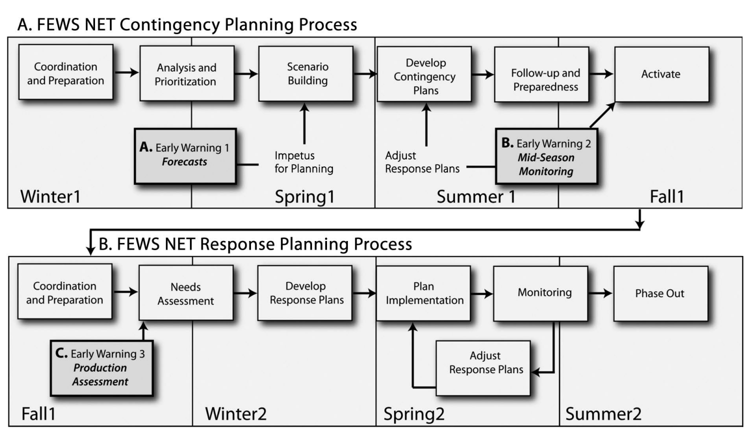


Figure 1. FEWS NET Contingency Planning and Response Planning Schema. Adapted from *www.fews.net*. Inputs related to Earth observations are shown with *shaded* boxes.

Table 1. Current food security situation and worst case scenario (from FEWS NET Executive Overview at *www.fews.net*)

Region	Current Food Security Situation	Potential Worst Case Scenario
Eastern Africa	"Fifteen to 18 million people are currently highly or extremely food insecure due to below-normal rains, poor crop and pasture production, civil conflict and insecurity, abnormally high food prices … Near-normal October to December rains would improve livestock production, but high/extreme food insecurity would remain."	"Below-normal October-December rains provide marginal, short-lived improvements in pasture and water availability in pastoral areas and crop failure in agro-pastoral areas of East Africa. The January-March dry season will thus be more severe than normal, reducing prospects for improvements in child malnutrition and overall food security."
Zimbabwe	"Approximately four million people are food insecure in Zimbabwe due to poor 2008 harvests, slow progress of food imports, weak internal distribution, hyperinflation, high unemployment, shortages of foreign and local currencies, and political instability."	"Over five million people will be dependent on emergency food assistance in Zimbabwe and, in the worst case, if commercial and humanitarian imports are inadequate, they could become highly food insecure. Maize planting is expected to be delayed and, in key cropping areas, followed by inadequate rainfall at critical growth stages."

In this report we will focus on early-to-mid-season analysis of conditions late in 2008 in Eastern Kenya, Somalia, and Zimbabwe. While improved monitoring tools cannot compensate for inadequate *agricultural inputs* (i.e., seeds and fertilizer) or rainfall, they can help guide the early identification of agricultural drought—leading to more timely and effective intervention.

Current Food Security Conditions in Eastern Kenya, Somalia, and Zimbabwe

In December 2008, two highly food insecure regions are in the midst of their main growing seasons. Eastern Africa, following the twice-yearly passage of the sun, has two main growing seasons, known as the *long* and *short* rains and covering March-July and October-December, respectively. For Eastern Kenya and Somalia, the *short* rains tend to be the most important. Southern Africa, on the other hand, has a different climate, and typically has a single monsoonal rainy season, during the Southern Hemisphere summer (October–April). In this area, most of the moisture necessary for flowering and grain growth and, hence, successful harvests falls during the latter half of the rainy season (i.e., during December–January–February).

Both Eastern Africa and Zimbabwe currently face dangerous food availability challenges. Excerpts from a recent (November 26, 2008) FEWS NET Executive Overview are shown in **Table 1**. FEWS NET country-level analyses (based on reports by in-country food security analysts) indicate that Kenya faces unprecedented escalations in the price of corn (*maize*), the main food crop. In Ethiopia, significant price inflation has also occurred since 2007, and the southeastern Somali region is still extremely food insecure. In Somalia, October–November rains were near normal, but high prices and civil unrest persist. In Zimbabwe, poor harvests in 2006–07 and 2007–08 have combined with hard currency shortages and outbreaks of cholera. Agricultural inputs for the current season are limited, and the pipeline of food aid may experience breaks in January. Availability of seeds and fertilizer has been very poor, almost ensuring very low crop production.

Monitoring the Current Climate

While rainfall is only one factor in a complex tableau of factors that influence global climate, it plays an important role in regulating the climate of Eastern and Southern Africa. Satellites help us monitor the climate by tracking atmospheric conditions over the Indian Ocean, which strongly influences rainfall in this part of the world. Using satellites, we can also estimate rainfall over land and observe vegetation responses in crop growing areas.

Before looking at the current climate anomalies (mid-December 2008), we need to briefly review *normal conditions* for the Indian Ocean. **Figure 2** shows satellite-observed Global Precipitation Climatology Project rainfall and surface winds for December–January–February. The rainy intertropical front typically stretches from Southern Africa east across the southern tropical Indian Ocean, with rainfall peaks near Indonesia and Madagascar. Across the northern Indian Ocean the monsoonal winds blow from north to south (black arrows pointing toward the Equator in **Figure 2**). Along the southern Indian Ocean steady easterly trade winds (another black arrow in **Figure 2**) bring moisture into Southern Africa, feeding the main rainy season. In recent years, surface winds have tended to flow southward (gray arrows in **Figure 2**), into the warming south-central Indian Ocean and away from Africa. We have suggested that this *warm south-central Indian Ocean* pattern is related to recent greenhouse gas-related global warming [*Funk et al.*, 2008]. This climate shift tends to draw moisture away from Africa, reducing December–January rains in parts of Southern Africa and March-May rains in parts of Eastern Africa.

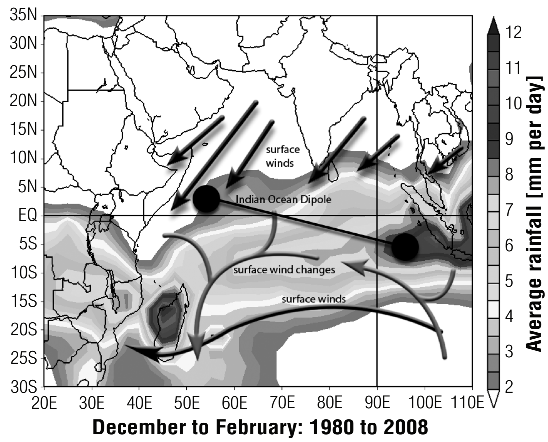


Figure 2. Average rainfall (shading) and surface wind conditions (black arrows) for December-January-February. Also shown are recent changes (1993-2007 minus 1979-2002) in surface winds. Images were obtained from the Climate Diagnostic Center.

The large connected black dots in **Figure 2** demarcate a second important source of climate variation in these regions: the *Indian Ocean Dipole*. When sea surface temperatures are relatively warm in the northwestern Indian Ocean and cold in the southeastern Indian Ocean, Eastern Africa is relatively wet and Southern Africa is relatively dry—and vice versa. Taken together, the *warm south-central Indian Ocean* and *Indian Ocean Dipole* patterns can tell us a lot about December–January–February rainfall in Eastern and Southern Africa. Some seasons, we shall see, are affected by warming in both the south-central and south-eastern Indian Ocean.

Satellite Observations of November Climate Conditions

As part of our ongoing research for USAID's FEWS NET activity, the U.S. Geological Survey, and NASA, we have been using two new satellite data products to track moisture and wind conditions over the Indian Ocean and Africa. These new observations allow us to examine water vapor over the land and ocean, as well as the direction and speed of surface winds over the ocean. **Water vapor images tell us where the atmospheric water *is*, while surface wind observations over the oceans tell us where it's *going*.** The combination helps us understand *cause and effect*, and anticipate hydrologic conditions in the coming months.

The left panel of **Figure 3** shows water vapor observations from the Atmospheric Infrared Sounder (AIRS). Launched in 2002 aboard the Aqua satellite, AIRS provides 3-dimensional (3-d) maps of air temperature, water vapor, cloud properties, and greenhouse gases. Adding up all the water vapor from the surface to the top of the atmosphere gives us *total precipitable water*. This is the amount of liquid water that would fall to the ground if all the water vapor in the sky suddenly precipitated. To quickly compare different regions, we can express the total precipitable water vapor as standardized anomalies.

These are calculated by: i) subtracting the monthly inter-annual mean from the current monthly average; and ii) dividing the resulting anomaly by the inter-annual standard deviation. These maps, in units of *standard deviations* or σ, allow us to quickly identify abnormally wet and dry locations. Locations with more than ± 1σ are exceptionally wet or dry. In the left panel of **Figure 3**, dark areas indicate regions of below-normal water vapor while white areas depict areas with above-normal water vapor.

The right panel of **Figure 3** depicts November *surface wind anomalies* (i.e., observed monthly winds minus the average monthly observed winds) obtained from the SeaWinds scatterometer aboard NASA's QuikSCAT mission. SeaWinds is a radar sensor used to measure the reflection or scattering from the surface of the world's oceans. The instrument has been specially designed to retrieve surface wind direction and speed.

Putting the precipitable water and wind images together (as we do in **Figure 3**), we see strong moisture *convergence* to the east of Madagascar and to the north-west of Australia—meaning that the wind is acting to "pile up" moisture in these areas. Of particular interest are those anomalies near the equator (the equator is shown with a black line in **Figure 3**). Low-latitude anomalies have a strong influence on tropical Africa. The strong (> +1σ)

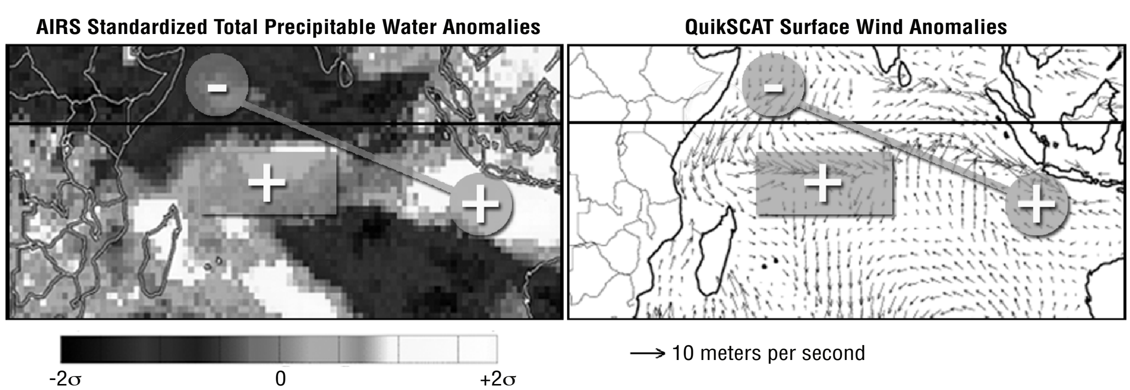


Figure 3. The panel on the left shows standardized November precipitable water anomalies from AIRS on Aqua. The panel on the right shows near-surface wind anomalies from SeaWinds on QuikSCAT. These data were mapped by Pete Peterson, University of California Santa Barbara.

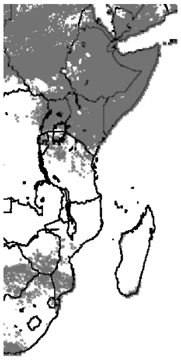


Figure 4. Shaded areas have November 17th–December 18th rainfall of less than 50% of normal. Source: *www.cpc.noaa.gov.*

precipitable water anomalies to the east of Madagascar (the gray boxes in **Figure 3**) correspond with a strong *warm south-central Indian Ocean event*, linked to drought across Southern Africa [*Funk et al.*, 2008]. The strong (> +1σ) precipitable water anomalies to the north of Australia, combined with the -1σ precipitable water anomalies to the east of Kenya, correspond to a fairly vigorous Indian Ocean Dipole structure. **Thus, the above-normal moisture convergence in both the south-central and south-eastern Indian Ocean could result in below-normal rainfall for both Eastern Africa and Southern Africa.**

Over Eastern Africa, both the precipitable water image (see **Figure 3**) and recent satellite-observed rainfall (shown in **Figure 4**) have been very low (<50% of normal) across Kenya, southern Somalia, Uganda, and southern Ethiopia. For eastern Kenya, north-eastern Tanzania, and southern Somalia, the *short rainy season* has been diminished. Over Southern Africa, rainfall (shown in **Figure 4**) has been less than half of normal across the *drought alley* stretching across southern Mozambique, southern Zimbabwe, the northern portion of the Republic of South Africa's *maize triangle*, and into Botswana—see **Figure 4**.

A logical next question: *Are these dryness tendencies likely to persist?* To assess this risk, we turn to statistical rainfall forecasts, based on November rainfall data—i.e., using the conditions the month before December–January–February to estimate what will come.

The Matched Filter Forecast Technique

In remote sensing applications, *matched filters* are sometimes used to measure the strength of a given target signal [*Funk et al.,* 2001]. In simple cases, the optimal filter is very similar to a correlation calculation. Standardized versions of the data and the signal are multiplied against each other and normalized by a constant. Building on this concept (shown schematically in **Figure 5**), we can *filter* a set of climate fields—e.g., surface wind observations—to isolate variability associated with our "target of interest". In this case, our "targets" are December–January–February rainfall in Zimbabwe and Eastern Kenya/Somalia. We use sea surface temperatures and winds and rainfall (obtained from *www.cdc.noaa.gov*) as our predictors. We next standardize the time series of predictors at each grid cell by first subtracting the mean and then dividing by the standard deviation. All predictors now have a mean of zero and a standard deviation of 1. Next, each predictor time series is scaled by its correlation with the target time series—i.e., either Zimbabwe or Eastern Kenya/Somalia rainfall. This dampens the variance of locations historically unrelated to our target. Finally, two standard statistical manipulations (*principal components* and *regression*) are then used to produce forecasts for all seasons. Accuracy assessments are carried out by *take-one-away cross-validation*. (This means that for the analysis of each year, November's data are removed, the entire estimation procedure recalculated, and the corresponding December–January–February seasonal rainfall estimated.) This *cross-validation* provides a relatively unbiased way to assess forecast accuracy.

Figure 6 shows time series of our forecasts for Eastern Kenya, Somalia, and Zimbabwe for late 2008 and early 2009. The forecasts are based on November climate data. We have expressed the December–January–February totals as *Standardized Precipitation Index* (SPI) values, with an average of zero and an inter-annual standard deviation of 1. Values of ±1σ indicate particularly good or bad seasons. **While the cross-validated forecasts do not catch every good and bad season, they do capture the sign of the rainfall anomalies, and have reasonably good skill, with a cross-validated forecast correlation of ~0.6 for both regions**. The standard error for both estimates is about ±0.8, indicating a modest level of precision sufficient to bracket the likely outcome. For both regions, the statistical forecasts for the 2008–2009 season are moderately pessimistic (about -0.5σ) with a level of uncertainty that embraces both well-below and slightly-above normal rainfall totals (see dark vertical bars at far right of each graph, indicating the 2008–2009 forecast).

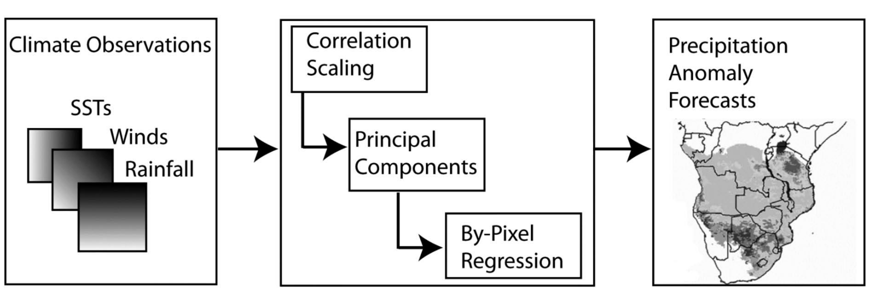


Figure 5. Matched Filter Forecast technique.

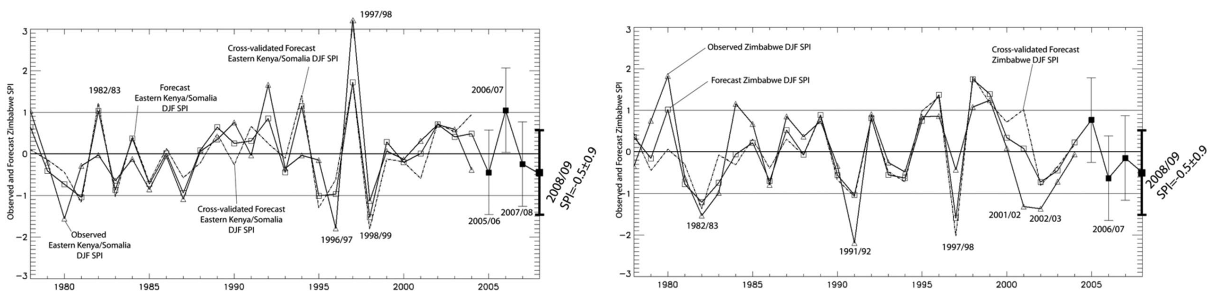


Figure 6. Time series of December-January-February rainfall totals for Eastern Kenya/Somalia (left panel) and Zimbabwe (right panel). Rainfall time-series are expressed in terms of the SPI with a mean of zero and standard deviation of 1. Observed data are marked with triangles, and end in 2004 or 2005. See *Funk et al.*, 2008 for details. Full matched filter forecasts are marked with boxes. Cross-validated estimates are shown with dashes.

Conclusions

While the future is always uncertain, we can learn from patterns of the past. As Mark Twain put it, *"History doesn't repeat itself, but it does rhyme."* Using a combination of satellite-based Earth observations and historic rainfall archives, we are slowly learning to reveal those patterns in climate and follow the complex interplay of mass and energy within tropical ocean-atmosphere dynamics. New observations of atmospheric water vapor and near-surface winds (**Figure 3**) help us watch the seasons reveal their character, and we can now peek ahead, making educated guesses about the next few months (**Figure 5** and **Figure 6**). **When these forecasts and satellite-observed rainfall (Figure 4) are combined with in-country analyses of prices, grain stores, political conditions, and agricultural inputs, we can provide effective early warning of potential food shortages related to drought.** The food aid community has already mitigated the impact of very large droughts (such as that of 2002–03 in Ethiopia—an event similar in magnitude to the 1984–85 event that cost a million lives). While these are real and positive steps forward—putting Earth observations into service for the poorest nations on earth—**we must remember that humanitarian crises are fundamentally caused by a failure of human institutions**. True progress will require improving the agricultural capacity and early warning systems of these African nations. This will allow them to better harness the power of satellites, improving their food security and resilience. Rising food costs and drought induced by a warming Indian Ocean make these objectives increasingly important.

List of Related Web Sites

- *eospso.gsfc.nasa.gov/eos_observ/pdf/Nov_Dec08final.pdf*: Previous article written by Molly Brown describing the Famine Early Warning System that appeared in the November–December 2008 issue of *The Earth Observer* [**Volume 20, Issue 6,** pp. 4–9].

- *www.fews.net*: Central FEWS NET website, where information from a large network of in-country observers and satellite observations is synthesized.

- *earlywarning.usgs.gov*: USGS web site containing satellite observations and crop/pasture model analyses.

- *www.cpc.ncep.noaa.gov/products/fews/briefing.html*: NOAA Climate Prediction Center website containing satellite rainfall and related weather analysis.

- *www.cdc.noaa.gov*: NOAA Climate Diagnostic Center, where reanalysis data are archived and climate conditions monitored.

- *airs.jpl.nasa.gov/* and *winds.jpl.nasa.gov/*: NASA satellite websites describing the AIRS and QuikSCAT winds.

- *www.pnas.org/content/105/32/11081.full.pdf+html*: Link to our *Proceedings of the National Academies* paper on climate change and agricultural capacity trends.

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Determining Carbon Consequences of Vegetation Change Dynamics in North America with Long-Term Multi-Resolution Data

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Scientists use many different types of data to help them in their efforts to study the sources and sinks of carbon in North America, but one of the most important sources of data comes from Earth observing satellites.

Introduction

Over the past two centuries, scientists estimate that the *terrestrial biosphere*—i.e., the Earth's land surface—has sequestered or stored ~150 gigatons (Gt) of carbon in the form of biomass and carbon contained in soils through the process of *photosynthesis*—in which plants "breathe," "inhaling" carbon dioxide and "exhaling" oxygen vital to the survival of life on Earth. About half of that massive amount of carbon is believed to be stored in the vegetation and soils of North America [*King et al*. 2007; *Goodale et al. 2002; Gurney et al.* 2002; *Pacala et al.* 2001; *Sabine et al.* 2004]—meaning North America's land surface plays an extremely important role in the global carbon cycle. In simple terms, minimizing climate change requires minimizing the amount of additional greenhouse gases that enters the atmosphere—in this case—carbon dioxide. That means finding ways to maximize carbon storage in biomass and soils while, at the same time, minimizing the release of carbon dioxide from fossil fuels, vegetation, and soils to the atmosphere. Since such a large portion of the currently estimated terrestrial carbon *sink* resides in North America, it is essential that scientists understand the role that North American terrestrial carbon storage plays in the global carbon budget. Toward that end, NASA and other federal agencies have implemented a science program to determine the status of *sources* and *sinks* of carbon in North America (*www.nacarbon.org*). Scientists use many different types of data to help them in their effort, but one of the most important sources of data comes from Earth observing satellites.

A long-term, multi-satellite, and multi-resolution remote sensing investigation has been underway at NASA's Goddard Space Flight Center (GSFC) utilizing the National Oceanic and Atmospheric Administration's (NOAA) long-term series of Advanced Very High Resolution Radiometers (AVHRR). These instruments, now in use for three decades, were not advanced nor high resolution, but nevertheless have provided vital climate quality data.

Compton Tucker and his coworkers in the Biospheric Sciences Branch at Goddard first "stumbled" upon the utility of this instrument for quantifying photosynthetic capacity almost three decades ago and started the Global Inventory Modeling and Mapping Studies (GIMMS) group. This group has now produced six iterations of normalized difference vegetation index (NDVI) photosynthetic capacity data derived from seven AVHRR instruments [*Tucker et al.*, 2005] and has published numerous journal articles using these data. In fact, NDVI is now one of the most widely used remotely sensed products and more than 2,000 scientific papers have been published using these data for various applications.

GIMMS group members use these NDVI data to study climatically-linked infectious diseases, global photosynthesis, carbon accumulation in forests, and many other processes that require time-series understanding of dynamic vegetation on the Earth's land surface.

Assimilating Efforts

In 2001, I (Christopher Neigh) joined the GIMMS group. Prior to my arrival, some questions began to arise as to just how reliable the NDVI data were for climate research. Numerous corrections had been applied to the data over the years and it was also difficult to understand the coarse-resolution satellite data. This led to the question of: **What really causes large scale NDVI anomalies?** Are they caused by climate variations, disturbances such as fire or insect outbreaks, and/or changes in the landscape due to human activities? The GIMMS group was trying to answer all these questions.

When I arrived at Goddard, I began to investigate the long-term AVHRR NDVI trends to determine if they were caused by climate, disturbance, human land-cover land-use change, or if they were artifacts in the data. I welcomed the challenge of studying several regions throughout North America. It provided a fascinating study topic for my graduate degrees while allowing a unique multi-resolution, multi-satellite perspective of our changing planet. I was fortunate to work with **John Townshend** of the Department of Geography at the University of Maryland, College Park, as well as Compton Tucker at Goddard.

This task was challenging, to say the least. We needed to come up with methods to reduce the spatial complexity of vegetation dynamics that was occurring in anomalous areas in different periods of our 1981–2005 satellite record. We set *thresholds* to limit our regions of interest, focused on marked anomaly areas, and, at least at first, only addressed positive trends in NDVI (**Figure 1**).

Prior studies implied the Earth was warming and there was more terrestrial photosynthesis at higher northern latitudes [*Myneni et al.*, 1997; *Zhou et al.*, 2003], but was that the case throughout North America? We set out to test this hypothesis; to do so required acquisition of multi-resolution remote sensing data and ground data available for the specific regions selected for study. Our first step was to acquire more than 150 moderate-resolution NASA *GeoCover* Landsat data scenes for the six unique regions we selected. Next, to validate our land cover maps, we acquired high-resolution data from a number of different sources: IKONOS satellite data (IKONOS is a commercial Earth observing satellite whose name derives from the word *icon*, which in Greek, means image); historical aerial photography (from the U.S. Geological Survey (USGS) and the Canadian National Air Photo Library); and a collection of our own oblique aerial photographs linked to global positioning system (GPS) data. To complement our satellite data, we obtained approximately 250 daily meteorological station records from which we calculated climate variability and growing season length. We also obtained records of fire disturbed areas, harvest from logging, and agriculture production. All of the ancillary data we used came from the Canadian Forest Service and U.S. Department of Agriculture.

What really causes large scale NDVI anomalies? *Are they caused by climate variations, disturbances such as fire or insect outbreaks, and/or changes in the landscape due to human activities? The GIMMS group was trying to answer all these questions when I arrived at Goddard and started my graduate work.*

What is Normalized Difference Vegetation Index?

The Normalized Difference Vegetation Index (NDVI) is a simple numerical indicator that can be used to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not.

Live green plants strongly absorb photosynthetically active radiation (PAR) and scatter near-infrared radiation (NIR). Thus, they appear relatively dark when viewed in visible light and relatively bright when viewed in the near-infrared. Scientists like Compton Tucker realized that they could exploit this strong difference in plant reflectance between these wavelengths by using satellites to measure how much green vegetation was present.

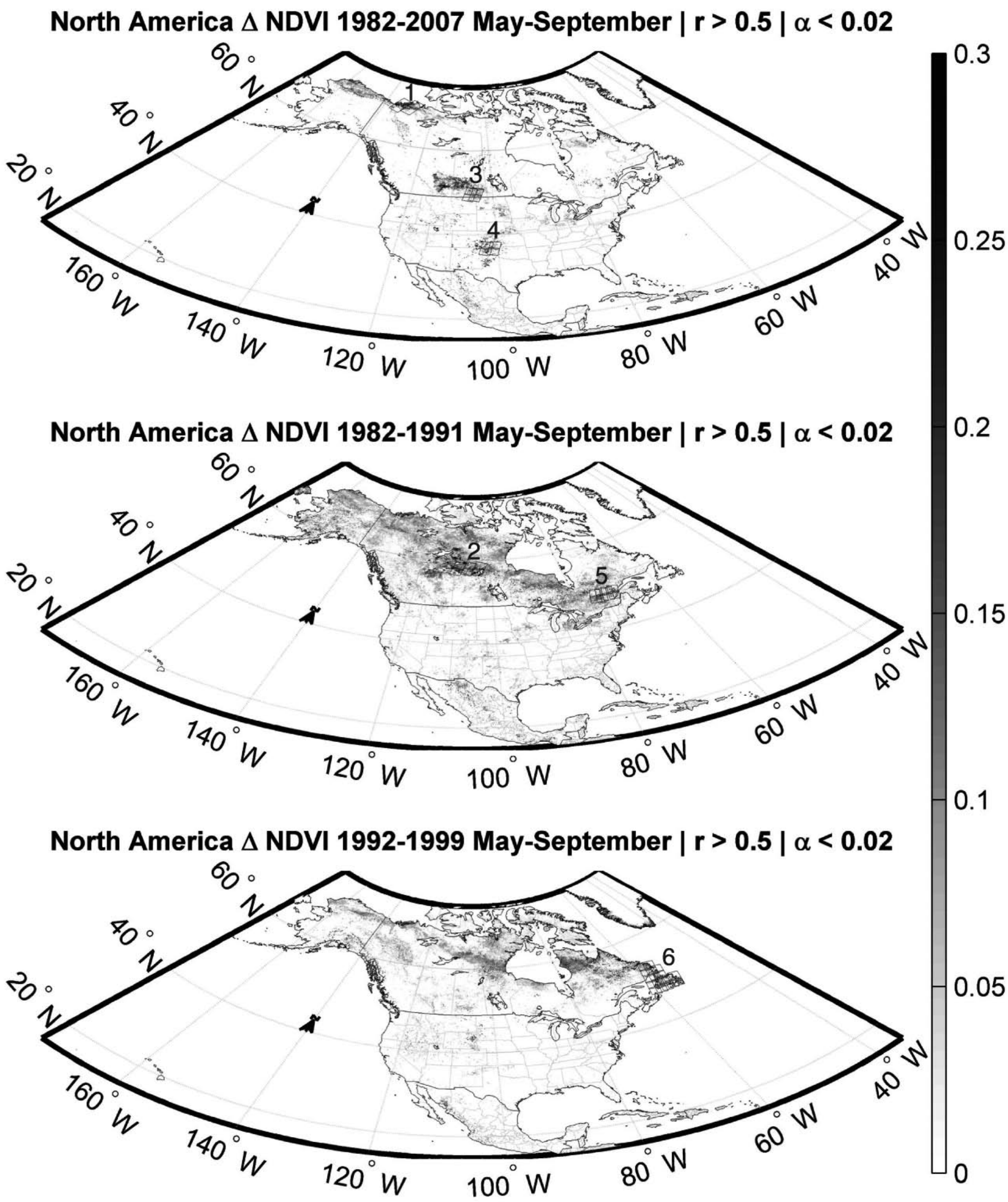
NDVI is a ratio created by comparing the reflectance of vegetation at two different wavelengths. Typically, one wavelength is chosen in the visible (VIS) spectrum—usually red—and the other is chosen in the NIR region of the electromagnetic spectrum:

$$NDVI = (NIR-VIS)/(NIR+VIS)$$

So, for example, for data used in this article, the NDVI ratio is from AVHRR Channel 1 (0.55 – 0.68 μm) and Channel 2 (0.73 – 1.1 μm).

Methods of reprocessing the satellite data have been implemented to extract reliable multi-sensor measurements of photosynthetic capacity while minimizing solar zenith angle variation, cloud and volcanic aerosol contamination, and sensor degradation.

Figure 1. ΔNDVI anomalies used to determine regional study sites for investigation based upon a least squares linear fit per pixel (trends with a correlation r < 0.5 and significance α > 0.02 excluded from analysis). Dark grey and black areas indicate strong positive anomalies. Numbers indicate locations of study sites and correspond to key below.



Key to Study Sites

1 – Yukon, Northwest Territories
2 – Northern Saskatchewan
3 – Southern Saskatchewan and North Dakota
4 – Texas and Oklahoma Panhandle
5 – Southern Quebec
6 – Newfoundland

First Stop: Newfoundland

Of the six regions of interest we identified, the first we chose to study in detail was Newfoundland (**Figure 1, Region 6**) as it showed the most dramatic increase in NDVI from 1992–1999 compared to any other region in North America and, thus, stood out as the first place to stop and explore. We collected *GeoCover* Landsat data; acquired logging, fire, and insect outbreak records from the Canadian forest service; and investigated 32 meteorological stations.

Figure 2. Arriving in Port aux Basque, Newfoundland from Sydney, Nova Scotia onboard the Canadian Marine Atlantic Ferry, *Caribou*, Summer 2002.

Figure 3. Aerial photograph of spruce forest logging for pulp and paper production on the west coast, near Stephenville, Newfoundland, Summer 2002.

Newfoundland is located along the east coast of Canada and has a maritime climate influenced by the presence of two nearby ocean currents—the warm Gulf Stream and the cold Labrador Current. During the period 1992–1999, the Gulf Stream strengthened and seemed to have warmed the climate, allowing for a 17-day increase in the length of the growing season across the entire island [*Neigh et al.*, 2007]. Meanwhile, during the same period, we discovered land cover change impacted less than 6% of the 100,000 km^2 total area of the Province of Newfoundland. **Thus, our research showed that the primary cause (or *driver*) of NDVI change in Newfoundland from 1992–1999 seemed to be related not to land cover change, but rather to change in climate related to a stronger Gulf Stream influence.**

To get a better feel for the actual conditions in Newfoundland, myself, Compton Tucker, and **Diane Pitasy** from the Biospheric Sciences Branch at Goddard took a ~1,500 km *in situ* excursion from Halifax, Nova Scotia throughout Newfoundland in Summer 2002 (see **Figure 2**). We collected aerial GPS photos to develop a validation dataset for our land cover change maps and to derive a geographical understanding of the vegetation distribution density relative to the observed AVHRR anomaly. We traveled over a week and a half observing from the roadside and from small aircraft searching for logging sites for pulp and paper production (see **Figure 3**). Our travels took us from the west coast to widespread barren desolate lands devoid of human influence throughout the interior.

Thus, our research showed that the primary cause (or driver) of NDVI change in Newfoundland from 1992–1999 seemed to be related not to land cover change, but rather to change in climate related to a stronger Gulf Stream influence.

Our initial study found climate variability to be a marked *driver* of Northern Hemisphere vegetation production. **But considering Newfoundland was an island with maritime climate devoid of extensive human influence, were conditions there indicative of other hotspots in North America?** We needed to study other areas across the continent to find out.

Every Pixel has Its Own Story

In addition to Newfoundland, five additional regions were added to our investigation through our studies: 1) Yukon, Northwest Territories; 2) Northern Saskatchewan; 3) Southern Saskatchewan and North Dakota; 4) Texas and the Oklahoma Panhandle; and 5) Southern Quebec. (All six regions are shown in **Figure 1**). The regions were selected based on three criteria: 1) each had different NDVI behavior over various periods from 1982–2005; 2) the size of the anomaly area and; 3) the availability of ancillary data for analysis. **Each of the selected regions, through analysis of ancillary data, was found to have a different *dominant driver* of change in photosynthetic capacity.**

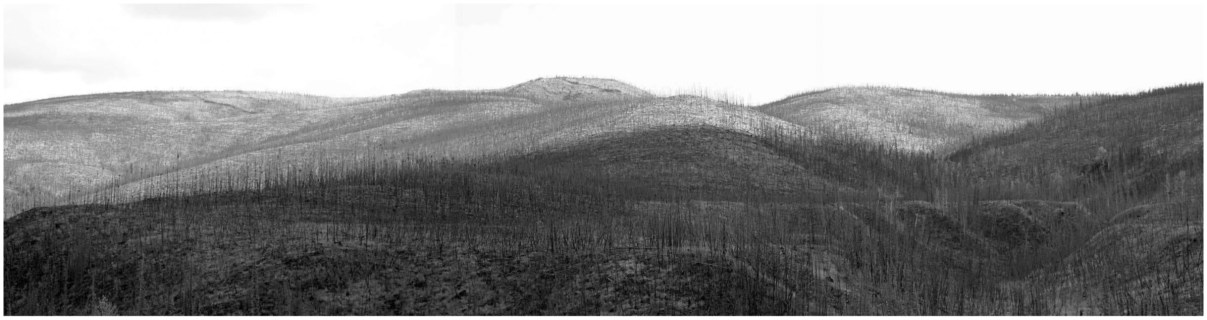


Figure 4. Three stitched photos of 2004 burn near Tok, Alaska off the Taylor Highway, Summer 2008. The year 2004 was the most active fire season in Alaska on record, and this fire burned 115,000 hectares from June 2004 through November 2004.

Dominant Change Drivers

Consistent with the results we obtained in our earlier work in Newfoundland, climate warming was the *dominant change driver* for NDVI in higher latitude regions—e.g., earlier start of spring, increased precipitation, and longer growing season (Yukon, Northwest Territories—**Figure 1, Region 1**). The mid-latitudes, on the other hand, were dominated by a variety of land-cover, climate, and land-use changes including: severe drought and subsequent recovery (Southern Saskatchewan—**Figure 1, Region 3**); expansion of center pivot irrigated agriculture (Texas and Oklahoma Panhandle—**Figure 1, Region 4**); herbivorous insect outbreak followed by salvage logging (Southern Quebec—**Figure 1, Region 5**); and forest fires with post fire regeneration (Northern Saskatchewan—**Figure 1, Region 2**) [*Neigh et al.*, 2008]. We have made some progress in identifying *dominant change drivers* for NDVI in North America, but a question still remains: **What is happening in the regions of North America where NDVI trends are negative?**

What about Areas With Negative Photosynthetic Capacity Trends?

When we started out, we focused only on areas with positive NDVI trends, but now we are expanding our analysis and investigating four additional regions with negative photosynthetic capacity anomalies to determine *dominant change drivers* for these areas. We are currently investigating four regions: 1) Interior Alaska; 2) Southern Northwest Territories; 3) Western Oregon and Northern California mountains; and 4) Wisconsin agricultural lands. Prior studies have suggested negative trends in NDVI may be due to the expansion of western bark beetle from climate warming [*Hicke et al.,* 2006]; increased boreal forest fire activity due to warming and drying [*Stocks et al.*, 2003]; and reduced productivity from long-term drought [*Piao et al.*, 2006]. We are currently investigating all of these processes and simulating them in numerical models in collaboration with **G. Jim Collatz** at the Biospheric Sciences Branch at Goddard

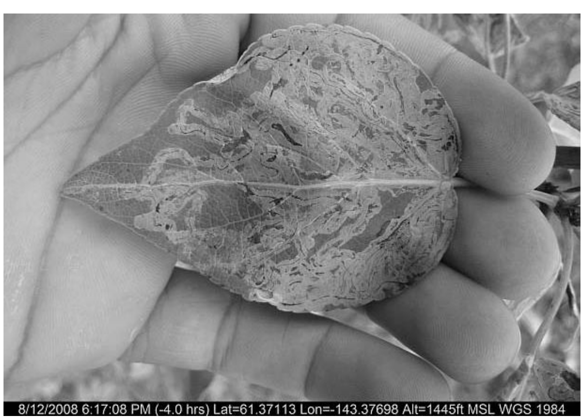


Figure 5. Aspen leaf miner trails in the dermis layer. Outbreak was observed throughout lowlands of interior southeastern Alaska. This photo was taken outside the Copper River Lodge near Wrangell St. Elias National Park, Summer 2008.

Figure 6. Aerial GPS photo from a *Cessna 172* of permafrost active layer creep down slope or *cryogenic solifluction lobes* from a 2004 burn in Alaska, near the Steese Highway north of Fairbanks, Summer 2008.

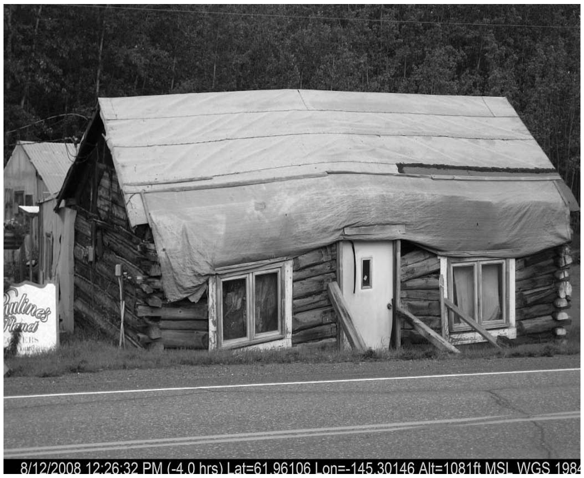


Figure 7. A log cabin in Copper Center, Alaska sinking from thawing soil, Summer 2008. The warm interiors of old buildings built on untested soil typically melt underlying rock hard permafrost with time.

Figure 8. Alaskan moose enjoying an aquatic lunch in a *thermokarst* pond West of Tok, Alaska on highway Ak-1, Summer 2008. Tilted and submerged trees indicate lakes are undergoing rapid enlargement.

and with **Nuno Carvalhais** from the Department of Environmental Sciences and Engineering at the New University of Lisbon in Portugal. Our goal is to quantify the impact of these processes on the regional carbon cycle.

As we did in Newfoundland, to get a better understanding of the lay of the land and of the large-scale processes at work in one of our study areas, Compton Tucker and I undertook a field visit to Alaska in Summer 2008. We embarked on a ~2,900 km journey through interior Alaska where we observed from the roadside and on foot thawing permafrost, widespread fire disturbance, and insect outbreak. We also flew in a small aircraft to investigate areas around Fairbanks. Spending so many hours in a car would typically be drudgery, but with endless views of Alaskan beauty on all horizons, a trusty little *Subaru Impreza*, excellent conversation, and a long playlist of *MP3*s, we didn't mind racking up the miles. We also dodged moose and bald eagle while negotiating very bumpy highway—made bumpy from melting permafrost and resulting subsidence. The scale and extent of forest fire burns in Alaska dwarfed anything that we had previously observed. With no human intervention, lightning-induced boreal fires can burn millions of hectares if dry conditions are present. The fires leave behind a desolate, charred, spindly black-spruce-stem landscape with an odd porcupine texture (see **Figures 4–8**). **Our work is ongoing, but we currently believe NDVI decline in interior Alaska is a result of a greater than 2°C warming over the past 25 years. This warming-drying climate has reduced the carbon *sink* potential of the boreal forest, and is not a direct result of increased fire disturbance.**

Our investigation has taken us from validating long-term satellite measurements to understanding and identifying carbon dynamics and consequences of major terrestrial vegetation changes driven indirectly by climate warming or directly through human land-cover conversion.

Conclusion

Assimilating multiple satellite and ground datasets to understand 25+ years of vegetation dynamics is a daunting task. But we have made significant progress. We continue to work to quantify climate and anthropogenic changes to the North American terrestrial carbon budget. It has been suggested that the long-term North American sink may saturate in the coming decades [*Canadell et al.*, 2007], necessitating immediate mediation of land-cover change processes that could maximize carbon sequestration. Our investigation has taken us from validating long-term satellite measurements to understanding and identifying carbon dynamics and consequences of major terrestrial vegetation changes driven indirectly by climate warming or directly through human land-cover conversion. Our efforts intend to resolve some of the unknown dynamics that are modifying the terrestrial carbon balance while improving future datasets to understand our changing planet.

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The Atmospheric Sounding Science Team Meeting

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The first NASA-sponsored Atmospheric Sounding Science Team Meeting was held on October 13-17, 2008, in Greenbelt, MD. The meeting took place in coordination with the National Oceanic and Atmospheric Administration (NOAA) to include science from the Atmospheric Infrared Sounder (AIRS) on Aqua, the Infrared Atmospheric Sounding Interferometer (IASI) on the European Space Agency's polar-orbiting meteorological (MetOp) satellite, and the Cross-track Infrared Sounder (CrIS) planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and its predecessor, the NPOESS Prepatory Project (NPP). Over 113 participants attended and over 68 presentations were made.

Introduction

Mous Chahine [NASA/Jet Propulsion Laboratory (JPL)—*AIRS Science Team Leader*] presented a new challenge to the AIRS science team. As the AIRS science supports more climate-related applications Chahine's challenge is that we "*make every milli-Kelvin count.*" Small changes in instrument calibration and retrieval response with time must be differentiated from true climate trends.

Ramesh Kakar [NASA Headquarters (HQ)—*Aqua Program Scientist*] is pleased the project is going strong and expressed interest in hearing about CrIS and IASI at this meeting.

Chris Barnet [NOAA] presented an overview of the sounding activities at NOAA and mentioned that AIRS has taught us a great deal, and with CrIS and IASI, we now have an opportunity to achieve at least a 20-year continuous data set from these instruments. NOAA can now process AIRS, CrIS, and IASI retrievals.

Tom Pagano [JPL] presented the status of the AIRS instrument and highlighted recent science results in the published literature. Pagano also presented results of a survey taken on the AIRS website that indicated most users are interested in the AIRS Level 2 products and improving their accuracy and resolution.

Claire Parkinson [NASA Goddard Space Flight Center (GSFC)—*Aqua Project Scientist*] presented the status of the Aqua spacecraft and key science highlights from the other instruments on Aqua. The good news is that there is enough fuel on the spacecraft to last beyond 2016.

Hyperspectral Infrared Science

George Aumann [JPL] discussed how the frequency of deep convective clouds (DCC) is affected by seasonal variation in the average surface temperature of the tropical oceans, published in the October 3, 2008 issue of *Geophysical Research Letters (GRL)*. Based on the current rate of global warming of 0.13 K per decade, the frequency of DCC will increase by 6% per decade. DCC are strongly linked with severe storms, torrential rain, hail, and tornadoes.

Ramesh Kakar addresses the AIRS Science Team.

Breno Imbiriba [University of Maryland, Baltimore County] discussed the September 2008 *GRL* paper (by Larrabee Strow *et al.*) that derived a four-year tropospheric ocean carbon dioxide (CO_2) climatology (from observed radiances minus calculated radiances), using the European Center for Medium Range Weather Forecasting (ECMWF) analysis temperature and moisture profiles. The results in the 400–550 mb range agree well in amplitude and phase with the Carbon Tracker (CT) for the tropics and 20–50° N, but capture only the trend, and not the seasonal modulation of CO_2 for the 20–50° S latitude zone.

Brian Kahn [JPL] presented *A Global Climatology of Temperature and Water Vapor Variance Scaling*. The variance of temperature and moisture derived from AIRS data as a function of length scale (150–1300 km) follows power law scaling consistent with previous observational, modeling, and theoretical studies. However, this is the first comprehensive global-scale survey for both temperature and water vapor, and it has shown significant clear/cloudy, land/ocean, seasonal, altitude, and regional variations.

Ramesh Singh [George Mason University] showed how the AIRS data available at different pressure levels can help to understand land–ocean–atmosphere coupling associated with earthquakes, volcanoes, and dust storms. He showed changes in surface skin temperature, relative humidity, and air temperature using AIRS data prior to the Sumatra earthquake of December 26, 2004, and the Wenchuna earthquake (China) of May 12, 2008.

Trace Gas Products and Science

There were more than the usual number of talks on studies of trace gases using AIRS data, so the sessions were split into two days.

Day 1

Bill Irion [JPL] compared AIRS total column ozone measurements in the tropical ocean to those measured using the Ozone Monitoring Instrument (OMI) on Aura. Retrievals generally compared well, except where there were low quality ocean skin temperature retrievals. Biases in the ocean temperature—as compared to the Advanced Microwave Scanning Radiometer–Earth Observing System (AMSR-E)—tended to produce a low bias in AIRS ozone columns compared to OMI.

Breno Imbiriba [UMBC] used a clear subset of the Level 1b data to compute CO_2 retrievals using the 791 cm^{-1} channel and the 2400 cm^{-1} region. He compared the CO_2 retrieved maps to the CT model, showing the correct seasonal patterns.

Juying Warner [UMBC] updated AIRS carbon monoxide (CO) validation by using the latest aircraft *in situ* measurements from the NASA Tropospheric Chemistry Program, from the Intercontinental Chemical Transport Experiment–Phase B (INTEX-B) campaign, and the Arctic Research of the Composition of the Troposphere Aircraft and Satellites (ARCTAS) campaign. The performance of AIRS CO retrievals is similar in the Northern Hemisphere mid- and high-latitudes during the summer season. Retrievals tend to underestimate the tropospheric CO in the North Pole region in early spring due to the tropopause being at low altitudes this time of year and also because of very cold surface temperatures.

Jasna Pittman [National Center for Atmospheric Research (NCAR)] examined AIRS and IASI ozone (O_3) measurements in the tropopause region using aircraft *in situ* data from the Stratosphere-Troposphere Analyses of Regional Transport 2008 (START08) campaign. The IR sounders showed significant capabilities of observing large-scale, dynamically-driven horizontal gradients in O_3, and provide a good qualitative distinction of the troposphere–stratosphere transition region.

Wallace McMillan [UMBC] presented validation results for *Version 5 (V5)* of the AIRS data CO retrievals using INTEX-A and INTEX-B *in situ* profiles showing that AIRS is biased high by 8% from 300–900 mb. A candidate optimal estimation retrieval algorithm for *Version 6 (V6)* of the AIRS data appears to have much less bias between 300–700 mb. New correlation studies of AIRS CO with Aura OMI nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and formaldehyde (HCHO) indicate the large CO emissions from China are related to human activity.

Day 2

Bob Vincent [Bowling Green State University] pointed out that surface temperature rises of greater than 1°F per year have been recorded in ice cores from Antarctica and Greenland, caused by destabilization of methane (CH_4) clathrates (a.k.a., methane ice). He described a compelling case for satellite imaging of lower tropospheric methane along continental slopes offshore and in high-latitude tundra regions onshore, for early detection of methane clathrate destabilization.

Xiaozhen Xiong [NOAA] presented new validation results for the AIRS CH_4 product at NOAA using recent aircraft campaign data. Some improvements for *V6* have been proposed, including adding three more functions, a better first-guess, and *tuning* of the spectroscopy used in *V5*.

Leonid Yurganov [UMBC/Joint Center for Earth Systems Technology (JCET)] compared AIRS *V5* Level 3 CH_4 data with independent surface measurements in Siberia. Both AIRS and surface data indicate a maximum of emission from wetlands in Western Siberia in

July. AIRS data show a September maximum of CH_4 —that has shown some growth during the last 2 years— over permafrost areas in Eastern Siberia.

Sergio DeSouza-Machado [UMBC] showed detailed evaluations of retrieved dust heights and optical depths for a February 2007 dust storm that blew over the Sahara and Mediterranean. He compared AIRS data with data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua, Polarization and Directionality of the Earth's Reflectances (POLDER) on Polarization & Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL), the Cloud–Aerosol Lidar with Orthogonal Polarization (CALIOP) on the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), and OMI on Aura. The results show that AIRS data can be used day and night, over ocean and land, to obtain results that compare very well against other passive and active instruments.

Fred Prata [Norwegian Institute for Air Research] concluded the trace gas talks with a presentation on new work on the retrieval of SO_2 column abundance using the strong vibration absorption band near 7.3 µm. Despite the presence of water vapor absorption across the band, the retrievals give values that compare favorably with SO_2 retrieved from OMI. These AIRS IR retrievals are being used to identify volcanic clouds that are hazardous to passenger jet aircraft, and to quantify volcanic SO_2 that enters the stratosphere and, hence, is important to climate.

Education and Public Outreach & Data Support

Sharon Ray [JPL—*AIRS Outreach Coordinator*] reported on the newly redesigned AIRS web site—*airs.jpl.nasa.gov/*. The site has a new look, new organization, and many new features, including an AIRS Publications Database, a Science News section which highlights news/events and announces new papers, a FAQ for data users, an image archive of 10 geophysical products that plays from the beginning of the AIRS mission, and satellite-feed maps of six AIRS geophysical products that will soon be available.

Mike Theobald [GSFC] discussed the status of AIRS data processing at the Goddard Earth Sciences Data Operations and Services Center. The center has completed *V5.0* reprocessing with a net rate of 13x and have integrated *V5.2* algorithms and reprocessed from the start of the Advanced Microwave Sounding Unit (AMSU) Channel 4 degradation.

Andrey Savtchenko [GSFC] reported on simple AIRS applications at the Goddard Earth Sciences Data and Information Services Center (GES DISC). There are new data access features in Mirador, including a conversion to *NetCDF*, a standard retrieval browse, and new web map and coverage services.

Data Assimilation

Seven speakers covered topics ranging from progress at operational weather prediction centers to experimental developments.

Tony McNally [ECMWF] reported *(via phone)* on experimental use of AIRS cloudy radiances (i.e., radiances not filtered to remove cloud effects) at ECMWF. Results show positive impact in the tropics only, but the work continues with the expectation that significant impact will eventually result.

Ed Pavelin and **Stephen English** [U.K. Meteorological Office] reported *(via phone)* on efforts at the U.K. Met Office to assimilate AIRS cloudy radiances. Their approach is a two-step one: first retrieve a few cloud parameters (using 1D-Var), then do a full 4D-Var from the cloudy radiances plus the retrieved cloud parameters. The results are very promising, with significant positive impact over the baseline method of filtering out cloudy data.

Eugenia Kalnay [University of Maryland, College Park] reported on assimilating AIRS radiances as well as retrievals (temperature and water vapor) with the Local Ensemble Transform Kalman Filter (LETKF) method that she and her colleagues at Maryland have developed. Adding the geophysical parameters improves the forecast, especially for zonal wind. This will soon be implemented by Brazil's Centro de Previsão de Tempo e Estudos Climáticos (CPTEC).

Brad Zavodsky and **Will McCarty** [both at NASA Marshall Space Flight Center] reported on progress at the Short-term Prediction Research and Transition Center (SPORT), where AIRS retrieved profiles are also being assimilated—now using the WRF-Var data assimilation system. The impact of the AIRS data is to reduce Temperature (T)-bias by 0.5–1 K throughout the troposphere, while Humidity (q)-bias is only moderately improved. They have already established that AIRS radiances have a significant impact.

Bryan Baum [University of Wisconsin] reported on efforts to develop and improve scattering models. Analysis of Afternoon Constellation (*A-Train*) data has raised issues regarding differences between inferred cloud parameters that require refinement to existing bulk ice-scattering models. Such models, which use microphysics from various field campaigns, are now under development and are expected to become available soon and applied to hyperspectral sounders such as AIRS and IASI.

James Jung [University of Wisconsin] reported on water vapor from IASI radiance assimilation experiments using the Global Data Assimilation Global Forecast System (GDAS/GFS) and a subset of IASI data (using 165 long-wave channels + 86 water vapor channels thinned to 180 km). Results are mixed, with only slight improvement of the 500-mb anomaly correlation in the Southern Hemisphere (and none in the Northern Hemisphere).

Oreste Reale [GSFC] reported on using AIRS observations—both clear-sky radiances and retrieved profiles—to improve tropical cyclone forecasts. A number of cases have been analyzed, with an emphasis on difficult Indian Ocean cases, including Nargis (which devastated Myanmar earlier in 2008). In all cases, and particularly Nargis, significant positive impact was found.

Temperature & Water Vapor Validation

Joao Teixeira [JPL] presented the plans for an AIRS *V5* data release validation report. This report will address the AIRS core products, as defined by the January 2007 Senior Review comments. He also presented results from the Rain in Shallow Cumulus Over the Ocean (RICO) experiment which show that the AIRS support product is capable in many circumstances to capture key characteristics of the trade-wind boundary layer, such as the boundary layer depth.

Mitch Goldberg [NOAA] presented the Global Space-Based Inter-Calibration System (GSICS) activities. GSICS provides a framework for coordination of international satellite calibration and exchange of critical data sets, ultimately resulting in improved sensor characterization for numerical weather prediction (NWP) and climate.

Murty Divakarla [NOAA] presented an evaluation of the IASI and AIRS retrievals at NOAA using matched global radiosonde (RAOB) measurements, and ECMWF and National Centers for Environmental Prediction Global Forecast System (NCEP-GFS) forecasts. Differences due to algorithm differences (e.g., channels, cloud-clearing), sounding geometry, and spatial sampling of the matched data sets were discussed.

Bill Irion [JPL] presented a comparison of AIRS temperature and water vapor profiles with 880 dedicated radiosondes. His method involves use of *averaging kernels* resulting in much better agreement between AIRS and the sondes.

Ju-Mee Ryoo [Johns Hopkins University] compared tropospheric relative humidity measurements made by AIRS and by the Microwave Limb Sounder (MLS) on Aura with a simple statistical model. The probability density functions (PDFs) from the two instruments showed good agreement except in the tropical convective regions where the PDFs from MLS are much broader than those from AIRS.

John Forsythe [Cooperative Institute for Research in the Atmosphere (CIRA)/Colorado State University and Science and Technology Corporation (STC)–METSAT, Inc.] discussed the NASA Water Vapor Project (NVAP) global water vapor data set status and plans for improvement and extension from 1987–2010. A new NASA Making Earth Science Data Records for Use in Research Environments (MEaSURES) initiative will allow a reanalysis of NVAP to remove time-dependent biases, and extend the data set into the Aqua era.

David Whiteman [GSFC] discussed on-going satellite validation activities at the Howard University Beltsville Campus (HUBC). In the Water-vapor Variability Satellite/Sondes (WAVES) field campaigns, more than 75 ozonesonde launches were coordinated with Aqua/Aura overpasses both day and night and in varying seasons and pollution conditions. These launches were supported by numerous backscatter and Raman lidar measurements as well as the suite of other active and passive and *in situ* sensors that populate the site.

Glynn Hulley [JPL] presented results of comparison of AIRS *V5* retrieved emissivity with measurements from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra and with *in-situ* observations. AIRS and ASTER agree to within 1.5% in the 8–12 µm region, but AIRS underestimates the emissivity in the 6–8 µm region by about 5%.

Bob Knuteson [University of Wisconsin] showed results of comparison of AIRS Total Precipitable Water (TPW) with ground-based microwave radiometer data at the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) Site. Results show a small seasonal bias in the day-night ratios.

Nick Nalli [NOAA] provided an overview of an on-going series of validation cruises-of-opportunity over the tropical Atlantic, called the Aerosol and Ocean Science Expeditions (AEROSE). Although the latest campaign, RB-08-03, conducted in April–May 2008, was descoped from its original plan due to severe ship mechanical problems, *in situ* data were successfully acquired from multiple instruments, including dedicated radiosondes (funded by the AIRS Science Team) and ozonesondes at IASI and AIRS overpass times, under a wide range of atmospheric conditions.

NPP CrIS/ATMS/Cal/Validation Plans and Readiness

Heather Kilcoyne [NPOESS Integrated Program Office] stated that the NPP Calibration and Validation Program objectives are to ensure the data provided meet civilian and military requirements and to support the fullest possible exploitation of the data by the users. The program leverages subject matter and heritage program experience through the use of community experts to lead and participate on the discipline teams. The NPOESS Community Collaborative Calibration/Validation Plan details the calibration/validation (cal/val) discipline teams and their plans for NPP pre- and post-launch cal/val activities.

William Blackwell [Massachusetts Institute of Technology] presented an overview of the effort to conflate the NASA and Northrop Grumman Space Technology (NGST)/Integrated Program Office (IPO) Advanced Technology Mircowave Sounding (ATMS) Sensor Data Record (SDR) cal/val plans. The ATMS cal/val activities were divided into two phases: *Activation and Checkout*, consisting of about five days immediately after sensor activation where basic sensor functionality and health is assessed, and *Intensive Cal/Val*, consisting of about six months of detailed cal/val tasks culminating in a coordinated aircraft underflight campaign.

Gail Bingham [Utah State University] presented a summary of the CrIS sensor data record (Level 1B) cal/val plan, including both the pre-launch and post-launch plans. The presentation included teaming arrangements and top level assignments for the effort, the software tools being developed to support the effort, and the procedures to be used by the IPO and contractor team to implement calibration changes post-launch.

Chris Barnet [NOAA] presented an overview of the NOAA CrIS Environmental Data Record (EDR) Cal/Val Plan. The CrIS/ATMS sounding EDR validation needs to incorporate lessons learned from AIRS IASI, for example, concentrating on data sets proven valuable for global validation (e.g., ECMWF, NCEP/GFS, RAOBs, etc), along with experiments-of-opportunity for detailed characterization of products.

Denise Hagan [NGST] said the NPP Cross-track Infrared Sounder (CrIS) is in the final stages of thermal vacuum testing at ITT Fort Wayne, Indiana. Test results show better than expected noise performance for all measurement bands, and high spectral accuracy and radiometric stability.

Larrabee Strow [UMBC] presented an independent assessment of the CrIS Neon spectral calibration system performance during thermal vacuum testing of flight model one (FM-1) in Spring 2008. Comparison of gas cell spectra to the Neon measurements indicates that the Neon calibration should be accurate to 1 part per million (ppm) in frequency under a wide range of orbital conditions, well within specification.

William Blackwell [MIT] discussed a selection of three ATMS SDR-related activities currently undertaken by the MIT-Lincoln Laboratory (LL) group, including an update on the generation of ATMS proxy data at the Raw Data Record (RDR), Temperature Data Record (TDR), and Sensor Data Record (SDR) levels; proposed additional pre-launch testing for the ATMS Flight Unit 2 (FU-2) (scheduled to fly on NPOESS–Charlie 1) including a focus on the calibration implications for the ATMS NPP unit; and finally, plans and progress for a comprehensive ATMS/CrIS SDR/EDR error model.

David Staelin [MIT] showed the first-ever wide-area images of precipitation (measured in mm/h at 15-km resolution) over the full Arctic, which were obtained using AMSU on NOAA-16 and validated using CloudSat radar data; they reported nearly full visibility for about 120 summer days annually since 1999. Simulations using the model MM5 for 106 representative global storms suggest that ATMS on NPP will perform even better because of its superior spatial resolution near 50 GHz and increased number of channels.

Sid Boukabara [NOAA] presented NOAA plans to make use of the Microwave Integrated Retrieval System (MiRS) within the NPOESS Data Exploitation (NDE) program. The MiRS algorithm is already operational for NOAA-18, MetOp-A and will soon be operational for the Defense Meteorological Program's F-16 Special Sensor Microwave Imager and Sounder (SSMIS) as well.

Stephen Beck [Aerospace Corp.] discussed Defense Meteorological Satellites Program (DMSP) SSMIS sounding channel cal/val activities including methods of cal/val and results.

Lars Peter Riishojgaard [GSFC—*Director of the Joint Center for Satellite Data Assimilation (JCSDA)*] presented JCSDA plans for contributions to the NPP cal/val effort. He stressed the importance of a close involvement of the numerical weather prediction (NWP) community right from the instant when the instruments are turned on and pointed out that in the past, successful early implementations have happened whenever this model has been followed.

Joel Susskind [GSFC] showed the methodology used to generate a proxy CrIS and ATMS data set based on AIRS/AMSU/Humidity Sounder for Brazil (HSB) observations. Such a *proxy* data set is more realistic than one generated using simulated radiances because it uses satellite observations affected by real physics, real atmospheres (including cloud structures), and real surfaces including sub-pixel variability.

Nikita Pougatchev [Utah State University, Space Dynamics Laboratory] presented the Validation Assessment Model developed for the CrIS sounder on NPP/NPOESS. Its application to the IASI temperature and water vapor profiles retrievals validation against radiosondes demonstrated that under the clear sky condition the sounder performs to the expected level. The results also reveal the need for more accurate account for low level clouds and surface properties.

Bill Smith [Hampton University] showed that spatially and temporally consistent mesoscale features of the atmospheric temperature and moisture field could be retrieved with IASI data. These small-scale thermodynamic features were validated using analyses of high-density aircraft dropsonde temperature and moisture measurements.

AIRS/IASI/CrIS Accuracy for Climate

Hyperspectral sounders have the potential of creating a climate data record of unprecedented 100 mK accuracy and mK/year stability. In order to validate that these data are accurate enough to use in climate research, it will be necessary to compare AIRS data with IASI (present) and with CrIS and possibly the Climate Absolute Radiance and Refractivity Observatory (CLARREO; future).

George Aumann [JPL] presented results of using the double difference between AIRS and IASI of the surface temperature derived from the 2616 , 1231, and 961 cm^{-1} window channels under cloud-free conditions. The NCEP Real-Time Global Sea Surface Temperature Product (RTGSST) and the automatic weather station *AWS8989* on *DomeC* in Antarctica were used to show the differences between IASI and AIRS and are of the order of less than 100 mK.

Larrabee Strow [UMBC] presented the results of the *double difference* between IASI and AIRS using the ECMWF temperature and moisture profiles in the calculation of brightness temperatures (observed minus calculated) under night cloud-free tropical ocean conditions for the 30 days from May 2007. Uncertainty in the ECMWF temperature and moisture profiles cancels in the *double difference*. The agreement is typically within 100 mK.

Dave Tobin [University of Wisconsin] used Simultaneous Nadir Overpasses (SNO) to compare IASI and AIRS radiances under uniform (i.e., not totally cloud-free) conditions. Based on preliminary analysis of 284 matchups of AIRS and IASI observations collected between May 2007–January 2008, no significant trends were observed and the AIRS and IASI agree within the estimated uncertainty of about 100 to 150 mK.

Hank Revercomb [University of Wisconsin] gave an update on the proposed CLARREO, the new climate benchmark observatory being pursued by NASA as a *Tier 1* mission following recommendations of the 2007 National Research Council's Decadal Survey. CLARREO emphasizes measuring spectrally resolved IR/solar radiances and GPS-based refractivity. As defined for CLARREO, this set of observations will provide high information content about climate with 30 mK absolute accuracy that is referenced to Standard International units on-orbit.

NPP Data Systems

NASA is developing a Science Data Segment (SDS) to support evaluation of and improvement of the quality of NPP retrieved products.

Bob Schweiss [GSFC] presented an overview of the SDS and the division of responsibility between the five Product Evaluation and Analysis Tool Elements (PEATEs) and one Climate Research Analysis System (CARS). Schweiss described the need for the PEATEs to work closely with their respective Science Teams and to report findings to the NPP program through the NPP Program Science Office Element.

Steve Friedman [JPL] presented details and plans for development of the NPP Sounder PEATE and its support role for the Sounder Science Team. The Sounder PEATE will support the Sounder Science Team by developing tools and data products which will enable them to assess the climate quality of EDRs.

AIRS Version 6 Planning

Steve Friedman [JPL] reviewed current progress on development and testing of the planned *V6* upgrade. Two significant work efforts were identified as needing to be completed before the release of *V6*: (1) the removal of time-dependent bias trends in AIRS Level 2 temperature products; and (2) mitigation of the potential loss of additional AMSU-A channels (AMSU-A channel 4 is already lost).

Evan Manning [JPL] explained that total retrieval yield has often been described as a measure of the accuracy of the retrieval process, but he proposed that another measure, one that compares the ability of various retrieval methods to be more accurate when compared to the best forecast should be considered. This quantification measure is referred to as a *skill* instead of *yield* measure, and can indicate whether a particular retrieval product adds value or replicates already known information about a particular forecast.

Joel Susskind [GSFC] updated his group's status and plans for contributing to the *V6* software update. He identified several algorithmic improvements already completed including: (1) improved determination of

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Aura Science Team Meeting Summary

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An Aura Science Team Meeting took place from October 27-30, 2008, in Columbia, MD. The plenary session ran from Tuesday morning until noon on Thursday and featured reports from each of the instrument Principal Investigators (PIs). The meeting also featured science presentations, including a large poster session on Wednesday afternoon, and summaries of the working group meetings that were held on Monday.

Mark Schoeberl [NASA Goddard Space Flight Center (GSFC)—*Aura Project Scientist*] opened the plenary session, introducing representatives of NASA Headquarters [HQ]. **Ernest Hilsenrath** [HQ—*Aura Program Scientist*] reported on the Committee on Earth Observation Satellites (CEOS) workshop that was held earlier in the month at the Goddard Institute for Space Studies (GISS). That workshop identified gaps in the planned program of constituent observations. **David Considine** [NASA Langley Research Center (LaRC)] was introduced as the new manager for the Atmospheric Chemistry Modeling and Analysis Program (ACMAP). There are plans for a Research Opportunities in Space and Earth Science (ROSES) call for proposals in fiscal year 2009. **Cheryl Yuhas** [HQ] presented guidelines for *Senior Review* as it has been more than four years since Aura launch.

The PIs reported on the current status of each of the Aura instruments and data sets.

High Resolution Dynamic Limb Sounder (HIRDLS): **John Barnett** [Oxford University—*HIRDLS PI, U.K.*] gave details of the stalled chopper on HIRDLS and automatic procedure attempts to restart the chopper about 1000 times per day. **John Gille** [University of Colorado and National Center for Atmospheric Research (NCAR)—*Aura HIRDLS PI, U.S.*] presented some results from the HIRDLS *Version-4 (V4)* retrieval. Previously released products [Temperature (T), ozone (O_3), and nitric acid (HNO_3)] have all improved substantially relative to correlative observations, and this release also includes chlorofluorocarbons $CFCl_3$ and CF_2Cl_2.

Microwave Limb Sounder (MLS): **Nathaniel Livesey** [NASA/Jet Propulsion Laboratory (JPL)—*MLS PI*] reported that the MLS operations are nominal, although there are some signs of aging. For example, the primary band for hydrochloric acid (HCl) measurements is no longer operational, although HCl is still retrieved using information from a different band. Work is ongoing to reconcile the trends derived from the two channels for the times both were operational. There is a high bias for carbon monoxide (CO) measured in the upper troposphere that is due to a slope feature across the 240 GHz band. An *ad-hoc* correction improves the retrieved CO, and work is ongoing to understand the source of the slope.

Ozone Monitoring Instrument (OMI): **Pieternel Levelt** [Royal Netherlands Meteorological Institute (KNMI)—*OMI PI*] reported that OMI has shown very little optical degradation. The latest version of the data products is produced using *Collection 2*, which includes a highly accurate correction of the unavoidable charge-coupled device (CCD) degradation. OMI data retrieved from *Collection 2* are superior, and previous data versions should be discarded. There are several row anomalies in the CCD—these produce poor data and must be accounted for by the user when using OMI fields.

Tropospheric Emission Spectrometer (TES): **Reinhard Beer** [JPL—*TES PI*] reported that TES operations are nominal. TES would like to include ammonia (NH_3) and methanol (CH_3OH) as standard products. TES life is known to be limited by the amount of lubricant in the translator that must "travel" during each measurement. The TES team had already eliminated routine limb scans which require long movements of the translator in order to extend the instrument life for nadir operations. Other strategies to prolong TES life and maximize science return include reduction of the number of high latitude measurements—as these contain minimal information—or replacement of complete global surveys with special observing periods or locations.

Working Groups

Air Quality: Bryan Duncan [GSFC] and **Ken Pickering** [GSFC] led the working group on air quality (as observed from Aura), discussing the potential of: 1) several techniques to measure lower tropospheric ozone; 2) several methods to gain information about the photochemical environment of the boundary layer; and 3) sulfur dioxide (SO_2) as a precursor for aerosol and converting observed aerosol optical depth (AOD) to surface fine particulate matter (PM2.5).

Clouds and Aerosols: Steven Massie [NCAR] led the working group. **John Livingston** [Stanford Research Institute (SRI)/NASA Ames Research Center (Ames)] stated that agreement between the AOD measurements obtained during OMI and the Moderate Resolution Imaging Spectroradiometer (MODIS) from the Intercontinental Chemical Transport Experiment/Megacity Initiative: Local and Global Research Observations (INTEX-B/MILAGRO) and those measured by the Airborne Sunphotometer (AATS-14) during Arctic Research of the Composition of the Troposphere from

Aircraft and Satellites (ARCTAS) campaign improves if the OMI aerosol model optical constants are changed from biomass burning to weakly absorbing values. **Michael Garay** [JPL] reported that OMI SO_2 and Multiangle Imaging Spectroradiometer (MISR) aerosol are analyzed jointly along the western coast of South America where a metal smelter in Peru is a dominant source of aerosol. Presentations with a focus on retrievals included: preliminary results for ice crystal effective diameters by **Dong Wu** [JPL]; a technique for SO_2 and O_3 that extends the range of SO_2 column and solves for the SO_2 plume height by **Kai Yang** [Goddard Earth Sciences and Technology Center (GEST)/University of Maryland Baltimore County (UMBC)]; and improvements in the retrieval characteristics of the HIRDLS experiment by **Steven Massie**.

Data Systems: The Aura Data Systems Working Group (DSWG), led by **Cheryl Craig** [NCAR], met and discussed each instrument's processing and highlights of current and upcoming versions. Presentations given provided information on Aura guidelines and updates from the Goddard Earth Sciences Data and Information Services Center (GES DISC), the Langley Atmospheric Sciences Data Center (ASDC), and the Earth Science Data and Information System (ESDIS) Project.

Education and Public Outreach (E/PO): The E/PO working group, led by **Brooke Carter Hsu** [Science Systems and Applications, Inc. (SSAI)], met to discuss current and future E/PO goals, review ongoing E/PO efforts, and give an overview of new E/PO partnerships—both within and outside of NASA institutions. **Sarah DeWitt** [GSFC] represented the Office of Public Affairs.

Mission Operations Working Group (MOWG): Angelita Kelly [GSFC] led the MOWG, where the Aura Instrument Operations Teams, Instrument Project Scientists, Ground System, and Flight Operations Team (FOT) personnel participated. These groups focused on the current state of the instruments and steps to ensure continued operations. Instrument-specific sessions later in the week considered red limit responses, flight dynamics questions, and contingency procedures. OMI, MLS, and TES are operating nominally. HIRDLS is not producing science data products due to the chopper anomaly. The HIRDLS team and the FOT are continuing efforts to restart the chopper.

The remainder of the meeting focused on science presentations and posters. These can be obtained from the Aura Validation Center website: *avdc.gsfc.nasa.gov/*

The next science team meeting will be hosted in the Netherlands by the OMI team from September 14-17, 2009. Information will be available by late spring at the Aura web site: *aura.gsfc.nasa.gov/*. ■

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Glory Science Team Meeting

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Meeting Overview

The Glory Science Team and Science Advisory Group met for the second time on November 17–18, 2008, at the Goddard Institute for Space Studies (GISS) in New York, NY. The meeting featured status reports from the Glory management, as well as presentations and discussions about the scientific instruments the satellite will carry. These instruments include the following:

- **Aerosol Polarimetry Sensor (APS),** an instrument that will enable the retrieval of aerosol and cloud particle microphysical properties by inverting multiangle and multispectral radiance and polarization measurements;
- **Total Irradiance Monitor (TIM),** an instrument that will provide measurements of total solar irradiance (TSI) with extremely high accuracy and precision; and
- **Cloud Camera,** an instrument that will provide cross track coverage over a finite swath of aerosol and cloud fields.

Ultimately, the Glory mission aims to increase the understanding of aerosols as agents of climate change and to clarify the sun's direct and indirect effects on climate. The mission is intended to produce data that will help scientists understand the degree to which climate change is *anthropogenic*.

Welcome/Introduction

Michael Mishchenko [GISS—*Glory Project Scientist*] began the meeting by offering information about Glory's history. In early 2003, he explained, NASA received funds to build an advanced APS instrument. In Fall 2003, the TIM instrument was included in the mission as well. In November 2005, NASA Headquarters [HQ] officially confirmed a stand-alone mission. And, in January 2006, the first Glory science meeting occurred.

Mission Status

Bryan Fafaul [NASA Goddard Space Flight Center (GSFC)—*Glory Project Manager*] updated meeting attendees on various aspects of mission logistics. He reported that the integration, baseline performance testing, and environmental testing of the APS instrument have been completed. Likewise, the TIM instrument has been delivered to the Orbital Sciences Corporation, integrated onto the Glory spacecraft, and undergone supporting pre-APS observatory environmental testing. In addition, the spacecraft integration is complete. Fafaul also noted that the ground system is progressing as planned, and the *Taurus XL* launch vehicle is on track to support Glory's scheduled June 15, 2009 launch from Vandenberg Air Force Base in California.

TIM Overview

Greg Kopp [Laboratory for Atmospheric and Space Physics (LASP), University of Colorado—*TIM Instrument Scientist*] described the status of the TIM instrument in more detail. He also provided an overview of the data products that the TIM will help generate and gave an overview of the algorithms that will be used to produce them.

APS Overview

Brian Cairns [GISS—*APS Instrument Scientist*] described the status of the APS instrument—built by Raytheon—in more detail. Cairns described the data products that the APS will help generate and the algorithms that will be used to produce them.

Data Analysis Funding Discussion

Hal Maring [HQ] explained that all of the post-launch processing of the APS data will be limited to the first year. Given the time constraints, he noted, the amount of *Level 2* data will be limited and, in all likelihood, no *Level 3* data will be produced. Maring advised attendees that funding might be reinstated if the data prove particularly valuable. He encouraged attendees to brainstorm ways to quickly present the value of APS products so additional data analysis funding can be gained. The following day Maring presented ideas that included conducting field campaigns and comparing APS results to other satellite sensors, the Aerosol Robotic Network (AERONET), and model outputs.

APS Topics

Members of the Science Advisory Group offered short presentations on topics related to the APS. **Ralph Kahn** [GSFC] discussed how to measure aerosol optical depth (AOD) and how to validate particle properties. **Omar Torres** [Hampton University] explained how ground-based observations, specifically data from AERONET, will be useful in evaluating APS data products. **Chris Hostetler** [NASA Langley Research Center (LaRC)] discussed APS validation and synergistic lidar-polarimeter retrieval studies. **Eric Shettle** [Naval Research Laboratory (NRL)] discussed potential applications of APS aerosol products, including the study of smoke in the upper troposphere and lower stratosphere. **Norman Loeb** [LaRC] highlighted synergies between the

TIM, APS, and Clouds and the Earth's Radiant Energy System (CERES). **Beat Schmid** [Pacific Northwest National Laboratory] explained how climatologists at his organization collect data from sun photometers mounted on aircraft. **Ellsworth Dutton** [NOAA Earth Systems Research Laboratory] discussed ongoing ground-based aerosol column observations from NOAA and highlighted potential areas of collaboration with the Glory mission. **John Seinfeld** [California Institute of Technology] explained the global climate response to anthropogenic aerosol indirect effects in the present day and the year 2100. **Joyce Penner** [University of Michigan] provided the results of research that has compared the Integrated Massively Parallel Atmospheric Chemical Transport (IMPACT) aerosol model with satellite data. Penner also suggested ways to improve the model. **Oleg Dubovik** [University of Lille] explained how researchers optimized aerosol retrievals from the French satellite that collects information on aerosols, called the Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL). In addition, meeting attendees discussed the APS algorithm and how to most efficiently calibrate and validate APS products.

TIM Topics

Members of the Science Advisory Group offered short presentations on topics related to the TIM instrument. **Judith Lean** [NRL] gave a presentation on TSI in the past, present, and future. She explained ways in which solar irradiance influences the climate system. **Joe Rice** [National Institute of Standards and Technology (NIST)] reported on the results of scale comparison between the radiometer at the TSI Radiometer Facility (TRF) radiometer—a new facility at LASP developed to perform pre-flight calibrations of the TIM instrument—and the Primary Optical Watt Radiometer (POWR) at NIST. The new TRF radiometer, the research found, has an uncertainty of 98 parts per million (ppm). **Greg Kopp** explained how the new TRF at LASP can help validate the TIM instrument once the spacecraft is in orbit. Meeting attendees also discussed the TIM algorithm and other ways to efficiently calibrate and validate the instrument.

Data Utilization Maximization Discussions

Meeting attendees discussed various ways to maximize the utility of the data Glory will collect. **Judith Lean** led the discussion on the potential effect of TIM data on our understanding of climate and heliophysics. **Norman Loeb** discussed Glory's potential contribution to the study of the Earth's radiation budget. **Ralph Kahn** moderated the discussion on how multi-sensor data and models might be used to better understand the relationship between aerosol concentration and air quality. **Joyce Penner** discussed some reasons for discrepancies between models and satellite data found in estimates of aerosol forcing. Later in the day, **Jacek Chowdhary** [Columbia University—*APS Science Team*] discussed how the concentration of *chlorophyll a* in the ocean and the shape of non-spherical aerosol particles affect polarization measurements. **Otto Hasekamp** [Netherlands Institute for Space Research (SRON)] described the outcomes of aerosol retrievals using data taken by the European instrument the Global Ozone Monitoring Experiment-2 (GOME-2). **Pavel Litvinov** [SRON] discussed the testing of Bidirectional Reflectance Distribution Function (BRDF) models for soil and vegetation surfaces using airborne photopolarimetric data. **Kirk Knobelspiesse** [Columbia University] discussed the potential of using the APS to validate surface BRDF measurements. **Waquet Fabien** [University of Lille] discussed issues with the use of polarization measurements in remote sensing of aerosols over land.

Outreach Update

Sarah DeWitt [GSFC] shared plans to publicize the Glory mission and showed recently completed video animations at the conclusion of the meeting. ■

CERES Science Team Meeting

Jim Closs, NASA Langley Research Center/Science Systems and Applications, Inc., james.w.closs@nasa.gov

The Fall 2008 meeting of the Clouds and the Earth's Radiant Energy System (CERES) Science Team was held jointly with the Geostationary Earth Radiation Budget (GERB) International Science Team (GIST) meeting from October 27-31, 2008, at the Goddard Institute for Space Studies (GISS) in New York City. **Norman Loeb** [NASA Langley Research Center (LaRC)—*CERES Co-Principal Investigator*] led the meeting. A more detailed summary and full presentations are available on the CERES web site at: *science.larc.nasa.gov/ceres*.

Major objectives of the meeting included the review and status of CERES instruments and data products including:

- Status of NASA/U.S. Climate Change Science Program (CCSP)/Earth Observing System (EOS)/Senior Reviews and CERES on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) and NPOESS;
- Terra and Aqua shortwave (SW)/longwave (LW)/TOTAL channel calibration for *Edition 3*; Flight Model (FM)-5 and FM-6 Update;
- Evaluation of Global Modeling and Assimilation Office (GMAO) G5-CERES Assimilated Global Datasets;
- *Edition 3* cloud algorithm development and validation;
- Clouds and Radiative Swath (CRS) *Edition 2* Validation;
- Surface radiation budget (SRB) average data product (SRBAVG) production of daily means in addition to monthly means;
- New International Satellite Cloud Climatology Project (ISCCP)-like Moderate Resolution Imaging Spectroradiometer (MODIS) and geostationary-enhanced (GEO) Data Products;
- Synoptic Radiative Fluxes and Clouds (SYN) and Regional Radiative Fluxes and Clouds (AVG): the *Level 3* Gridded Version of CRS Data Product;
- Extending SRBAVG, ISCCP-like-GEO and SYN/AVG/Monthly Zonal and Global Radiative Fluxes and Clouds (ZAVG) to December 2007;
- New adjusted SRBAVG dataset for climate modelers;
- Global Energy and Water Cycle Experiment (GEWEX) Radiative Flux Assessment (RFA);
- GERB Status Update;
- Earth Observing System Data and Information System (EOSDIS) evolution activities at the Langley Distributed Active Archive Center (DAAC): transition from the Langley Tropical Rainfall Measuring Mission (TRMM) and Terra Information System (LATIS) and Silicon Graphics, Inc. (SGI) toward the Archive Next Generation (ANGE) software and commodity cluster computing; and
- CERES-specific co-investigator (Co-I) reports.

Bruce Wielicki (LaRC) presented a "big-picture" perspective on the U.S. CCSP, EOS, CERES, NPP/NPOESS, National Research Council (NRC) Decadal Survey missions, and the Afternoon Satellite Constellation (*A-Train*) constellation. The CCSP Observation Working Group (OWG) is planning a second observation requirements workshop, with the purpose of evaluating new tools for both science community guidance and for climate model Observing System Simulation Experiments (OSSEs). An NRC review of CCSP is underway. Preliminary indications are that good science is resulting, but that it is poorly funded and the space-borne climate observing system is in danger of collapsing. Despite these set-backs, the new Obama administration holds promising changes for improved climate science support.

The Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4 (AR4) confirms that cloud feedback remains the largest uncertainty in climate sensitivity, and that low clouds dominate the uncertainty. Changes in NASA Earth Science program management include Ed Weiler as the new Associate Administrator (AA) for Earth Science, and Steve Volz as Earth Science Deputy for Missions. Mike Freilich remains the Director of the Earth Science Division, and Don Anderson and Hal Maring are Modeling and Radiation Science Leads, respectively.

For the CERES program, the Terra and Aqua Senior Review in 2007 went very well. The Aqua End of Prime Mission Review was held in December 2008, and the next *Senior Review* will be in 2009 with funding decisions in September. For the future of CERES, the FM-5 instrument has been integrated onto the NPP spacecraft, and plans are beginning for the FM-6 instrument on NPOESS. A CERES follow-on will be the next generation CERES instrument and will go beyond FM-6 in calibration improvements. The follow-on design will assure its ability to inter-calibrate with future missions, such as the Climate Absolute Radiance and Refractivity Observatory (CLARREO).

Kory Priestley and **Susan Thomas** (Both at LaRC) gave an overview and update of the CERES Instrument Working Group, CERES flight schedules, and *Edition 2* and *3* data product status. The FM-5 instrument recently completed mechanical and electrical integration on the NPP spacecraft—currently scheduled to launch no earlier than June 2010. The FM-5 ground calibration was the most extensive to date in the CERES program, with 33 days under continuous vacuum and 6 additional tests beyond the legacy procedure. CERES FM-6 will be built from spare parts as part of the payload on NPOESS Charlie 1 (C1), and a CERES follow-on instrument is planned for an undetermined platform in the 2018 timeframe. Residual calibration errors in CERES *Edition 2* data products are dominated by spectral degradation of sensor optics in the reflected solar bands. The CERES team is pursuing options to characterize spectral degradation for *Edition 3* data products.

Updates were given on several CERES subsystem activities, including:

- Cloud algorithm activities, by **Patrick Minnis** [LaRC];
- Surface-only flux algorithms (SOFA), by **Shashi Gupta** [LaRC]**;**
- Surface and Atmosphere Radiation Budget (SARB) products, by **Thomas Charlock** [LaRC];
- Time Interpolation and Spatial Averaging (TISA) Working Group and Time-averaged Flux Product, by **David Doelling** [LaRC];
- ISCCP-D2-like CERES data product, by **Moguo Sun** [Science Systems and Applications, Inc. (SSAI)];
- Preliminary results for time-averaged computed top-of-atmosphere (TOA), atmospheric and surface flux products, by **Fred Rose** [SSAI]; and
- CERES data processing status, by **Lisa Coleman** [SSAI].

The second day of the meeting began with break-out Working Group sessions, including the Angular Modeling Working Group led by **Norman Loeb**, the SARB/SOFA Working Group led by **Thomas Charlock**, and the Cloud Working Group led by **Patrick Minnis**.

A group of **invited presentations** highlighting exciting new science followed, including:

Dave Turner [University of Wisconsin/Madison] presented recent activities of the Atmospheric Radiation Measurement (ARM) Program's Radiative Processes Working Group. This group is investigating alternate methods of correcting for infrared (IR) loss for use when collocated pyrgeometer information is not available, improving cirrus cloud characterization with Raman lidar measurements, and assessing ARM clear sky broadband heating rate profile with CERES and Atmospheric Infrared Sounder (AIRS). This work reinforces that the ARM's spectrally resolved and broadband radiance/flux observations have led to important new insights into cloud/aerosol/water vapor/radiation interactions.

Anthony Del Genio [GISS] spoke about the importance of deep convective clouds on climate sensitivity. He showed that general circulation model (GCM) cumulus parameterizations are not sensitive enough to free troposphere humidity to capture the transition from shallow to mid-level to deep convection. In addition, most GCMs use a precipitation efficiency tuning knob to discern large (precipitated) and small (lifted) water particles. He cautioned that while existing cumulus parameterizations may be useful, height variation must be added to buoyant energy consumption. He concluded by stating that the IPCC AR4 consensus about deep convective cloud feedback hides many shortcomings in cumulus parameterizations.

Gavin Schmidt [GISS] reported on remaining uncertainties of the IPCC AR4, and strategies for reducing these uncertainties. He suggested that climate projections would be more credible if a bottom-up approach (which tests process parameterizations against observations) is combined with a top-down approach (to test emergent properties such as overall sensitivity) and improvements in conformability of modeled variables and observations. He concluded that models are the bridge between observables and processes, and more complete and forward models are needed—along with more data synthesis.

Dave Randall (Colorado State University) reported on lessons learned from super-parameterization with the Multiscale Modeling Framework (MMF), which utilizes improved periodic boundary conditions and individual realizations over conventional parameterizations. Despite identical dynamical cores, the super-parameterization makes a robust Madden–Julian Oscillation (MJO), while the conventional parameterization does not. He summarized that preliminary MJO forecasting experiments using MMF look very promising.

A series of **Co-I reports** with updates on new data products and science results followed, including:

- Status report on the Student's Cloud Observations On-line (S'COOL) project, by **Lin Chambers** [LaRC]**;**
- GEWEX RFA update, by **Takmeng Wong** [LaRC];
- Status of a Cloud-Aerosol Lidar and Infrared Pathfinder Satellite (CALIPSO)/CloudSat, CERES/MODIS merged data product, by **Seiji Kato** [LaRC];
- Evaluation of tropical cloud simulations in forecasts with Community Atmosphere Model (CAM3) using A-Train data, by **Jerry Potter** [Lawrence Livermore National Laboratory (LLNL)];
- Evaluation of cloud physical properties of the European Centre for Medium-Range Weather Forecasts (ECMWF) re-analysis against CERES tropical deep

convective cloud object observations, by **Kuan-Man Xu** [LaRC];

- Recent studies of cloud pertubation, energy balance, and feedback, by **Bing Lin** [LaRC];
- Evaluation of GISS Single Column Model (SCM) simulated cloud and radiative properties using both surface and satellite observations, by **Aaron Kennedy** [University of North Dakota];
- Requirements for a Climate Observing System and a CLARREO mission update, by **Bruce Wielicki**;
- CERES-Single Scanner Footprint (SSF)- and MODIS-derived properties for deep convective clouds, by **James Coakley** [Oregon State University];
- The degradation pattern of the Earth Radiation Budget Experiment (ERBE) Wide Field-of-View Radiometer on NOAA-9, by **Takmeng Wong** and **Lou Smith** [LaRC];
- A study on the influence of gaps in Earth radiation budget climate data records, by **Norman Loeb;**
- Consistency of TOA fluxes from CERES and the Multiangle Imaging Spectroradiometer (MISR), by **Wenbo Sun** [Hampton University];
- How smoke from the 2008 Evans Road and Great Dismal Swamp fires in North Carolina affected the CERES Ocean Validation Experiment, by **Brian Fabbri** [LaRC]; and
- Measurement of the Earth radiation budget imbalance, citing calibration and sampling challenges in the measurement, by **Steven Dewitte** [Royal Meteorological Institute of Belgium].

Norman Loeb led a final wrap-up and discussion of action items from the meeting. He congratulated the team on CERES FM-5 and emphasized the importance of being ready for *Edition 3* data processing; the submission of Clouds, SARB, and SOFA papers; the SYN/AVG/ZAVG delivery; and preparation for the Terra and Aqua Senior Review in 2009. The Spring 2009 CERES meeting will be held from April 28-30, 2009, at the City Center Marriott in Newport News, VA. ■

The Atmospheric Sounding Science Team Meeting

continued from page 40

surface skin temperature and spectral emissivity; and (2) an improved outgoing longwave radiation radiative transfer algorithm (OLR RTA). Susskind also described plans for handling the loss of additional microwave channels, including improvements to the microwave retrieval and plans for an improved infrared-only retrieval fallback, in case the AMSU-A unit became non-operational.

Meeting Summary

Having the AIRS Science Team Meeting in conjunction with the NASA/NOAA NPP Cal/Val and readiness meetings significantly improved the interaction and dialogue among the participants. The wide range of uses of sounder data from weather and climate to atmospheric composition was evidenced by the colorful and insightful presentations of the participants. There is a significant amount of work to be done with the atmospheric sounders in all areas. Although weather forecast improvement has already been demonstrated in the operational system, presenters showed there is considerable further improvement possible using different assimilation methods. Meeting the needs of the climate community for improving process definition in climate models and for trending atmospheric geophysical variables is the next big challenge for the atmospheric sounding community. AIRS and IASI have each demonstrated excellent performance, and having these two instruments has allowed cross-comparison for subtle differences important to weather and climate. The work performed to date on AIRS and IASI should help greatly in the operational implementation of CrIS and the definition of requirements for CLARREO.

The meeting agenda and presentations can be found at the AIRS website: *airs.jpl.nasa.gov/documents/science_team_meeting_archive/science_team_meeting_2008.10.14/* ■

New Satellite Data Reveal Impact of Olympic Pollution Controls

Adam Voiland, NASA Goddard Space Flight Center, avoiland@sesda2.com

Chinese government regulators had clearer skies and easier breathing in mind in the summer of 2008 when they temporarily shuttered some factories and banished many cars in a pre-Olympic sprint to clean up Beijing's air. And that's what they got.

They were not necessarily planning for something else: an unprecedented opportunity to use satellites to measure the impact of air pollution controls. Taking advantage of the opportunity, NASA researchers have since analyzed data from NASA's Aura and Terra satellites that show how key pollutants responded to the Olympic restrictions. The two maps on page 49 illustrate the results showing the conditions before the restrictions were imposed (top) and while the restrictions were in place (bottom).

According to atmospheric scientist **Jacquelyn Witte** and colleagues from NASA's Goddard Space Flight Center, the emission restrictions had an unmistakable impact. During the two months when restrictions were in place, the levels of nitrogen dioxide (NO_2)—a noxious gas resulting from fossil fuel combustion (primarily in cars, trucks, and power plants)—plunged nearly 50%. Likewise, levels of carbon monoxide (CO) fell about 20%.

Witte presented the results on behalf of the team on December 16 at the fall meeting of the American Geophysical Union in San Francisco.

Some scientists have questioned whether Beijing's highly publicized air quality restrictions actually had an impact. These new data show clearly that they did. "After the authorities lifted the traffic restrictions, the levels of these pollutants shot right back up," Witte noted.

The steep decline in certain pollutants surprised the researchers. In a preliminary analysis of the data, the effect seemed to be minimal, explained **Mark Schoeberl—**Project Scientist for the Aura mission and a contributor to the study. The reductions only became noticeable when the investigators focused tightly on the Beijing area.

"If you take a wide view, you start to pick up long distance transport of pollutants," Schoeberl said. That seemed to be the case with sulfur dioxide (SO_2), which has a longer lifetime in the atmosphere. Although satellites detected reductions in levels of SO_2—a major byproduct of coal-fired power plants and a key ingredient of acid rain—the decline was more widespread due to a larger effort to reduce SO_2 emissions across China, explained **Kenneth Pickering**, another Goddard scientist involved in the research.

Witte and colleagues presume that winds carried SO_2 in from the heavily industrialized provinces to the south of Beijing. However, she cautions that it is difficult to capture accurate readings of SO_2 from the satellites due to difficulties detecting the gas low to the ground, where it is most abundant. It's best to consider the SO_2 measurements a work in progress, emphasized Pickering.

Ultimately, researchers aim to use satellite data to evaluate and refine local and regional models that predict how pollution levels respond to changes in emissions. Such models are important for understanding the integrated Earth system and aiding policymakers considering ways to reduce pollution.

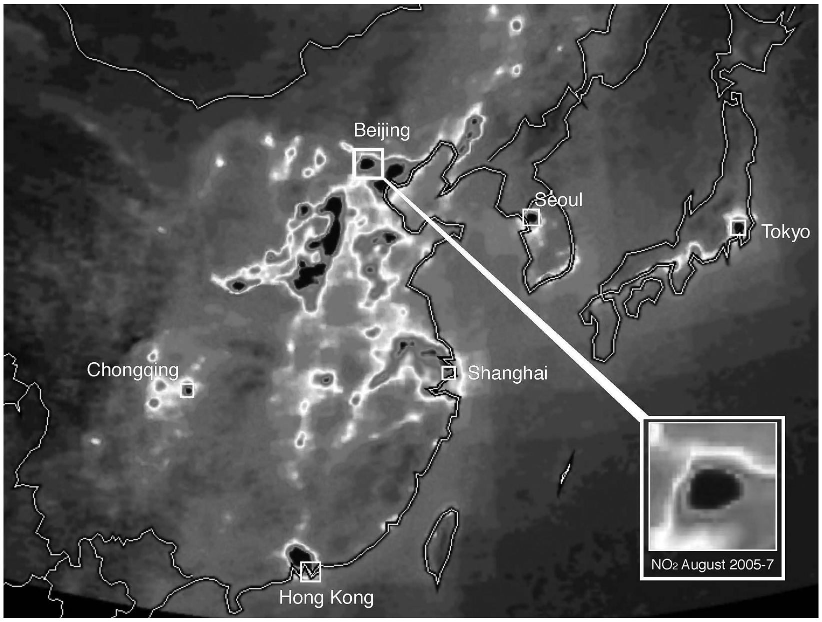
Until recently, it's been difficult to improve atmospheric composition and chemistry models because scientists have had trouble correlating "bottom up" estimates of total emissions—tallies of likely pollution sources, such as the number of cars on the road or the amount of coal burned—with "top down" observations from instruments on satellites. According to Pickering, data from the Netherlands-supplied Ozone Monitoring Instrument (OMI) on Aura and the Measurement of Pollution in the Troposphere (MOPITT) instrument on Terra help significantly.

Still, it will take a few years for the research team—which includes investigators from the University of Iowa and Argonne National Laboratory in Illinois—to perfect and finalize the models.

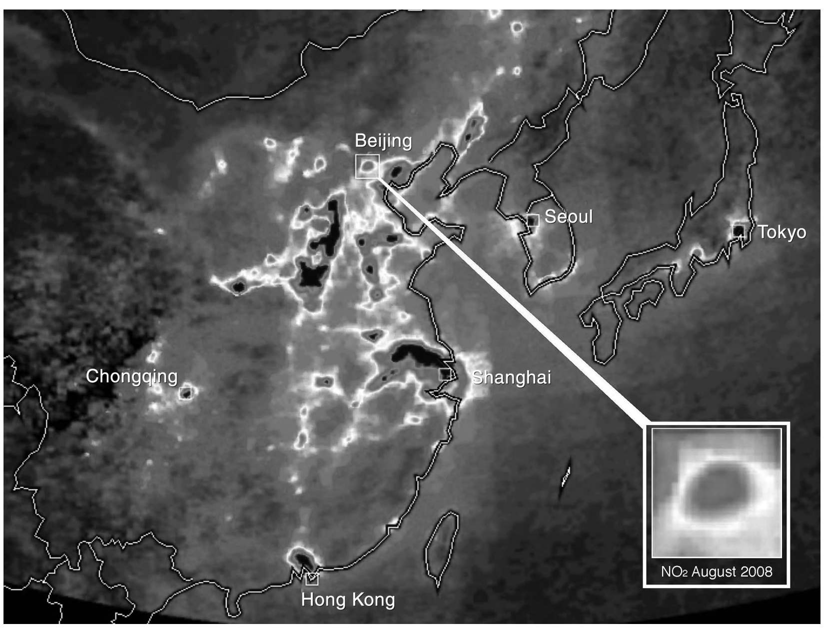
The team is sharing its findings with colleagues from Tsinghua University in China. "They are very interested in what we're finding," says Pickering, noting that the data from Aura and Terra are unique and will help scientists devise more accurate ways to quantify and evaluate ongoing efforts to reduce emissions.

China is currently in the midst of a sustained effort to reduce SO_2, according to the Xinhua News Agency. Officials recently decided to reinstitute a less stringent version of the Olympic driving restrictions, requiring most cars to stay off the road at least one day each week, the agency reported in October.

Sorting out what's happening over Beijing is just the beginning, says **Greg Carmichael**, a professor of chemical and biochemical engineering at the University of Iowa. The procedures demonstrated here, he said, offer the capability to detect emission changes and improve models the world over. ■



This map shows nitrogen dioxide (NO_2) levels based upon an average of monthly data from August 2005 through August 2007. This gives an idea of what the conditions are typically like in China. Notice the high levels of pollution in Beijing and other areas of eastern China as indicated by the darkest shading. The inset shows a close-up of the area around Beijing and the high concentrations of NO_2 around the city. For color image, go to: www.nasa.gov/topics/earth/features/olympic_pollution.html **Credit:** NASA



In contrast, levels of NO_2 plunged nearly 50% in and around Beijing in August 2008 after officials instituted strict traffic restrictions in preparation for the Olympic Games. Notice in the inset image that the shaded areas are lighter indicating less NO_2. For color image, go to: www.nasa.gov/topics/earth/features/olympic_pollution.html **Credit:** NASA

Modeling Radiation Exposure for Pilots, Crew and Passengers on Commercial Flights

Patrick Lynch, NASA Langley Research Center,

A group of researchers led by NASA, in collaboration with Space Environment Technologies, Inc., the National Center for Atmospheric Research (NCAR), and Dartmouth College, are building a model that can predict the solar and cosmic radiation exposure for crews and passengers on commercial airline flights. Researchers presented their preliminary work at the American Geophysical Union's fall meeting in San Francisco on December 19.

While it may not be commonly known, airline flight crews are currently classified as "radiation workers," a federal designation that means they are consistently exposed to radiation. Flight crews on high-latitude routes, in fact, are exposed to more radiation on an annual basis than nuclear plant workers.

But unlike in other fields, radiation exposure is not measured in the airline industry, nor are there standards or limits regarding exposure.

A NASA Applied Sciences project, called Nowcast of Atmosphere Ionizing Radiation for Aviation Safety (NAIRAS), seeks to build tools that use real-time data and modeling to estimate radiation exposure. The issue has been of concern to pilots, crews, and scientists for some time, but this will be the first real-time, data-driven, global model to predict not just cosmic background radiation, but also radiation during solar storm events.

Passengers and flight crews are exposed to radiation because the shielding from Earth's atmosphere against high-energy solar particles and cosmic rays is weaker at normal cruising altitudes than at the surface. The threat is even greater for flight paths that take planes near the poles, because the momentum shielding by Earth's magnetic field is weaker at high latitudes. The concern is greatest for flight crews and frequent flyers because of their consistent exposure over long periods.

Christopher Mertens, a senior research scientist at NASA Langley Research Center and the NAIRAS Principal Investigator, said the model should provide the most accurate estimations yet of the biologically damaging radiation doses received by airline crews and passengers. The model will use measurements from ground-based neutron monitors, atmospheric temperature and density, solar particle flux and solar wind parameters to "nowcast" exposure levels. Measurements from the NASA Advanced Composition Explorer (ACE) spacecraft and NOAA Geostationary Operational Environmental Satellites (GOES) satellites are used in the model.

"The idea is you combine real-time data with accurate models to predict," said Mertens, who helped develop a radiation dosage model for light-ion radiotherapy. "We need an ability to measure and predict."

John Murray, a Langley research scientist who specializes in satellite aviation-weather products, said including solar, atmospheric and magnetosphere activity into the model will make it stand apart.

"This will help the Federal Aviation Administration to determine what standards may be needed in order to address the increasing concerns that the industry and public have over human exposure to ionizing radiation," Murray said.

Most aviation-related research on cosmic radiation has focused on the potential damage to communication and navigation technology, Mertens said. But little has centered on human health impacts.

NASA first investigated the issue in the 1960s and 1970s when it was studying the feasibility of high-altitude supersonic commercial aviation transport, Mertens said. At the time, radiation exposure during flight was deemed a negligible health concern for commercial aircraft at cruising altitudes given what was known about radiation and the number and types of flights common at that time.

Concerns have grown for three primary reasons. Pilots log twice as many flight hours now as then, while flight attendants typically log more hours than pilots. Epidemiological studies have shown this type of exposure to be more damaging than previously thought. And, the number of polar flights is increasing, Mertens said.

Airlines prefer polar routes—for instance, for certain U.S.-to-northern Europe or U.S.-to-Asia routes—because it's a shorter route with reduced head winds, creating fuel savings of tens of thousands of dollars per flight.

Preliminary research indicates that passengers and crews are being exposed to more radiation than previously thought, especially during significant solar events. Mertens analyzed data from a strong solar storm around

Halloween 2003 and found that passengers on polar flights—for example, from Chicago to Beijing—were exposed to radiation higher than the limit recommended by the International Commission on Radiological Protection. In addition, not including new features in the model such as magnetic storm effects on Earth's magnetic field underestimated the exposure during that storm by a factor of four.

"People on that flight exceeded their radiation exposure limit, and they don't even know it," Mertens said.

The system could also eventually be used to log radiation exposure for flight crews by year and even by career, so that pilots and attendants can keep track of their personal risk.

NAIRAS, funded in the spring of 2008 by NASA's Applied Sciences Program, is scheduled to be a three-year program. Mertens said he hopes the research will lead to improved methods for measuring radiation, predicting radiation levels and a better system to mitigate exposure for passengers, pilots and flight attendants. The research could also lead to the development of onboard instruments that would give pilots real-time radiation estimates on their control panels, alongside the rest of their instruments.

Murray said the model will be available upon completion to the Centers for Disease Control's National Institute for Occupational Safety and Health (NIOSH), the NOAA's Space Weather Prediction Center, the Air Force Research Laboratory and the FAA. ▬

ESIP Federation Elects New Officers

The Federation of Earth Science Information Partners ("ESIP Federation") is a consortium of Earth science data centers, scientists, technologists, educators, and applications developers. The Federation promotes increased accessibility, interoperability, and usability for Earth science data and derivative products. NASA initiated the Federation in 1997 to provide data, products and services to decision makers and researchers in public and private settings. On January 12 at their winter meeting, the Federation elected new officers to serve one-year terms.

Officers

*President**: **James Frew** [Bren School, University of California, Santa Barbara]
*Type I Representatives**: **Steven Kempler** [NASA Goddard (Executive Committee)] and **Marilyn Kaminski** [National Snow and Ice Data Center (Foundation Board)]
*Type II Representative**: **Peter Fox** [Rensselaer Polytechnic Institute]
*Type III Representative**: **Tamara Shapiro Ledley** [TERC]

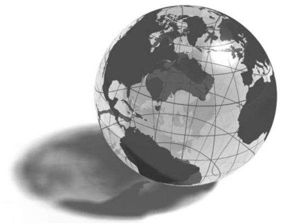
Committee Chairs

*Finance & Appropriations**: **Charles Hutchinson** [University of Arizona]
Partnership: **Danny Hardin** [University of Alabama in Huntsville]
Education: **Margaret Mooney** [Space Science and Engineering Center, University of Wisconsin]
Information Technology and Interoperability: **Karl Benedict** [University of New Mexico]
Products and Services: **Robert Raskin** [NASA/Jet Propulsion Laboratory]

*: These individuals also serve on the Board of Directors of the Foundation for Earth Science.

Frew, who is serving his first term as President will preside over the ESIP Federation's Assembly and its Executive Committee. Frew was the ESIP Federation's founding Vice President, and described his vision for the ESIP Federation. "*As the ESIP Federation enters its second decade, the original vision for the ESIP Federation is being realized. With a community of more than 100 partners, multi-agency involvement, and robust distributed governance, the ESIP Federation is both an incubator and an [example of] the kinds of multi-disciplinary collaborations essential to addressing the grand challenges in Earth science.*"

For additional information about the ESIP Federation please visit their website: *www.esipfed.org* and/or contact **Carol Meyer**, Executive Director of the Foundation for Earth Science, *carol.meyer@earthscience-foundation.org*.



EOS Scientists in the News

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

NASA at 50: Colloquium Series, October 24; *HearSay with Cathy Lewis (WHRV)*. **Joel Levine** (NASA LaRC) discussed the "NASA at 50" lecture series and promoted the final lecture, "50 Years of NASA Aeronautical Research."

October 2008: The Warmest on Record in L.A., October 31; *Los Angeles Times*. October 2008 was Los Angeles' toastiest year in history. **William Patzert** (NASA/JPL) equates California's climate system to a Big League slugger "on steroids," and notes that breaking records in a warming world can be expected.

NASA Spots Jump in Atmospheric Methane, November 4; *Aviation Week*. Climate modeler **Drew Shindell** (NASA GISS) explains how the surprising rise in global atmospheric methane in 2007 contributes to total greenhouse gas emissions, noting that more modeling is needed to explain the cause of the jump and to predict future trends.

NASA Scientist Honored by State Department, November 6; *Yahoo Politics*. **Richard Eckman** (NASA LaRC) helped organize the March 2008 Washington International Renewable Energy Conference (WIREC). On October 31, he was presented with the State Department's Group Superior Honor Award, along with other WIREC conference organizers, at an award ceremony in Washington, DC.

Gulf of Alaska Glacier Melt is Studied, November 10; *United Press International*. A team of researchers including **Scott Luthcke** (NASA GSFC) used satellite data to establish the most precise measurements to date of global warming effects in Gulf of Alaska. They found that Gulf of Alaska glaciers have lost about 84 gigatons of ice annually—about five times the average annual flow of the Colorado River through the Grand Canyon and equal to the entire amount of water in the Chesapeake Bay.

Jon Ranson Calculates Earth's Carbon Budget in a Warmer World, November 11; *Earth & Sky Radio*. **Jon Ranson** (NASA GSFC) describes Earth's carbon cycle and how disruptions to the cycle cause global warming.

'Sundowner' Winds Fuel SoCal Fire, November 14; *Associated Press*. The wildfire that exploded along California's Central Coast and destroyed more than 100 homes was fueled by evening winds known as *sundowners*. Unique to the Santa Barbara area, the winds are shaped by the region's topography, according to **William Patzert** (NASA JPL), who says the fires "get compressed and burst out of the canyons like a fire hose."

Subglacial Lakes Flood, Glaciers Speed Up, November 16; *Science News*. Using satellite observations, researchers linked a flood of water beneath Antarctica to a 14-month–long acceleration of one of the region's largest glaciers. Glaciologist **Robert Bindschadler** (NASA GSFC) declares the findings to be "smoking gun" evidence for the link between floods and glacier movement.

Water Vapor a 'Major Player' in Global Warming, November 19; *USA Today*. Researchers including **Andrew Dessler** (Texas A&M) used NASA satellite data to confirm the heat-amplifying effect of water vapor. **Eric Fetzer** (NASA JPL) explains that water vapor plays a significant part in climate dynamics.

Pollution Causes Most Lightning Strikes at Midweek, November 26; *Discovery News*. New research by **Thomas Bell** (NASA GSFC) shows that the middle of the week is the worst time for lightning, with 10-20% more strikes on Wednesdays and Thursdays than on weekends.

Trimming Smog and Soot Offer Immediate Impact on Climate Change, December 12; *The Mercury News*. **Drew Shindell** (NASA GISS) and colleagues bolstered the link between air quality and climate, finding that across-the-board cuts in air pollution can spur "substantial, simultaneous improvement" in local air quality and near-term mitigation of climate change. Curbs on smog and soot represent an alternate and far more immediate global warming solution for regulators stymied by the complexities of other greenhouse gases such as carbon dioxide.

Ice Melting Across Globe at Accelerating Rate, NASA Says, December 17; *CNN International*. Between 1.5

trillion and 2 trillion tons of ice in Greenland, Antarctica and Alaska have melted since 2003 as the rate of melting accelerates, according to research by **Scott Luthcke** (NASA GSFC). The losses amounted to enough water to fill the Chesapeake Bay 21 times, reflecting previous findings by **Jay Zwally** (NASA GSFC).

Coal Should Be Warming Concern, December 18; *Reuters*. **Pushker Kharecha** (NASA GISS) explains scenarios that show how carbon dioxide can be kept below levels considered dangerous for climate—now set at 350 parts per million—as long as emissions from coal are phased out globally within the next few decades.

NASA Set to Launch CO_2 Hunter, December 18; *BBC News*. **David Crisp** (NASA JPL), principal investigator of NASA's Orbiting Carbon Observatory (OCO) mission, explained how the spacecraft will map Earth's carbon dioxide.

****China Successfully Cut Pollution During Olympics, Finds NASA**, December 18; *Mongabay.com*. **Jacquelyn Witte** (NASA GSFC) and colleagues found that efforts to clean up Beijing's skies during the Olympics seemed to have worked, with levels of nitrogen dioxide (NO_2)—a noxious gas resulting from fossil fuel combustion—falling nearly 50% during the two months when restrictions were in place.

Hansen Calls for Carbon Tax to Drop CO_2 Below Today's Levels, December 18; *Greentechmedia*. At the American Geophysical Union's meeting in December, **James Hansen** (NASA GISS) explained that a carbon tax is the only way to reduce atmospheric carbon dioxide below today's levels and avert a potential disaster.

Global Warming Causing More Tropical Storms: NASA, December 19; *Agence France-Presse*. Global warming is increasing the frequency of extremely high clouds in the Earth's tropics that cause severe storms and rainfall, according to a NASA study presented by **Hartmut Aumann** (NASA JPL) at the American Geophysical Union's fall meeting.

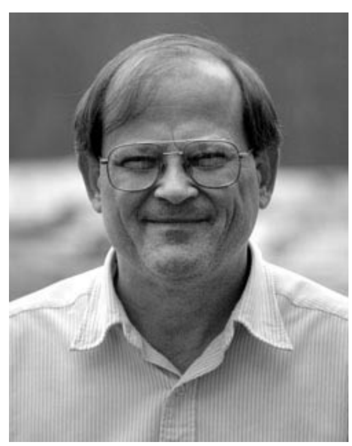
NASA Ducks Dive Under Greenland Ice, December 20; *BBC News*. Ninety bathtub toys were hurled into a drainage hole on the Greenland ice in September to see how melt waters find their way to the base of the ice sheet. At the American Geophysical Union's fall meeting, **Alberto Behar** (NASA JPL) explained the duck experiment and other, more advanced, techniques used to explore crevasses on Greenland's ice.

Interested in getting your research out to the general public, educators, and the scientific community? *Please contact Kathryn Hansen on NASA's Earth Science News Team at khansen@sesda2.com and let her know of your upcoming journal articles, new satellite images, or conference presentations that you think the average person would be interested in learning about.*

** For more details on this topic, see News Article in this issue.*

EOS Scientist Receives 2008 Presidential Rank Award

Bruce A. Wielicki, [Langley Research Center, *Principal Investigator for Clouds and the Earth's Radiant Energy System*], was a recipient of the 2008 Presidential Rank Award for Distinguished Service Professionals. Each year, the President recognizes and celebrates a small group of career Senior Executives with the Presidential Rank Award for exceptional long-term accomplishments.



Award winners are chosen through a rigorous selection process. They are nominated by their agency heads, evaluated by boards of private citizens, and approved by the President. The evaluation criteria focus on leadership and results. To learn more about Presidential Rank Awards, please visit: *www.opm.gov/ses/performance/presrankawards.asp*.

The *Earth Observer* staff and the entire scientific community congratulate Wielicki on this outstanding achievement. Wielicki was also a recipient of the 2006 Presidential Rank Award for Meritorious Senior Professionals.

NASA Science Mission Directorate – Science Education Update

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

Stockman is New E/PO Lead for SMD

Beginning the week of November 23, Stephanie Stockman became the new Science Mission Directorate (SMD) Education Public Outreach lead at NASA Headquarters (HQ). For the past 16 years, Stephanie has played a leadership role in NASA Earth and space science education at Goddard Space Flight Center (GSFC). She has been the education lead for several NASA science missions, including the Lunar Reconnaissance Orbiter (LRO), the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) mission, Aura, and Landsat-7.

A planetary geologist and science educator by training, Stephanie has a B.S. in Natural Science/Geology Concentration from Towson University, an ABD in Geology (Structure and Tectonics) from the University of Maryland, College Park, and an M.Ed. in Science Education from the University of Maryland, College Park.

K-12 Teachers: Apply to be a NASA Endeavor Fellow

Applications for the September 2009 cohort are due March 6, 2009 (open to in-service, alternative-route and pre-service teachers).

As part of NASA's commitment to the effective preparation of K-12 science teachers, formal educators are invited to apply to become a NASA Endeavor Fellow. Each Fellow will be fully funded to complete a unique Online Certificate in Applied Science Education with Teachers College, Columbia University. The goal of the project is to ensure that teachers across the country can use the discoveries that NASA makes on a daily basis to inspire the next generation of explorers, engineers and astronauts.

For more information and to apply, visit *www.nasa.gov/audience/forstudents/postsecondary/programs/Endeavor_Science_Teaching_Certificate_Project.html.*

Upcoming Educator Launch Conferences

These educational programs are geared to K-16 educators and administrators and will provide a general introduction to the specific NASA mission and a variety of K-12 Science, Technology, Engineering, and Math (STEM) education workshops and specific science behind the satellites. All K-12 educators will be provided learning opportunities as well as a teacher's guide, a classroom poster, and mission CD for classroom use. For more information and to register, visit *endeavours.org/sec/.*

GLOBE Announces Student Research Campaign on Climate Change

Planning for the GLOBE Student Research Campaign on Climate Change will occur over a 2-year period, beginning in January 2009, and will enlist the support of internationally renowned climate change scientists, science educators and educational outreach experts, as well as businesses, foundations, and policy makers. Student research activities will commence in 2011, with final results of the campaign to be presented at an international student conference in 2013.

The campaign goals are to: (1) involve over 1,000,000 students in climate change research; (2) enhance environmental and climate literacy for millions of people around the world; (3) empower students, teachers, and community members to take action on climate-related environmental issues; and (4) create a compelling model for 21st century environmental science education based on grade-level appropriate research and learning experiences.

The project is currently developing strategic collaborations to make this campaign a success. For more information, go to: *globe.gov/r/html/climatechange or email: ClimateChangeCampaign@globe.gov.* ■

EOS Science Calendar

2009

March 31-April 2
LCLUC Science Team Meeting, Bethesda North Marriott, Bethesda, MD, URL: *lcluc.umd.edu/Program_Information/meeting-registration_spring09.asp*

April 28-30
CERES Science Team Meeting, Newport News, VA. URL: *science.larc.nasa.gov/ceres/meetings.html*

July 19-29
SORCE Science Team Meeting will be held in conjunction with the IAMAS 2009, Montreal, Canada. URL: *iamas-iapso-iacs-2009-montreal.ca/e/99-home_e.shtml*

September 14-17
Aura Science Team Meeting, Netherlands. URL: *aura.gsfc.nasa.gov/*

Global Change Calendar

2009

April 26-30
7th International Science Conference on the Human Dimensions of Global Environmental Change (Open Meeting), Bonn, Germany. Contact: *openmeeting@ihdp.unu.edu*; URL: *www.ihdp.org/*

May 4-8
41st International Liege Colloquium on Ocean Dynamics, Liege, Belgium. URL: *modb.oce.ulg.ac.be/colloquium/*

May 4-8
33rd International Symposium on Remote Sensing of Environment, Stresa, Lake Maggiore, Italy. URL: *isrse-33.jrc.ec.europa.eu/index.php?page=home*

May 18-20
International Conference on Land Surface Radiation and Energy Budgets, Yingdong Hall, Beijing Normal University, China. URL: *www.landenergybudget.org/LED/default.htm*

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