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Editor's Corner

Steve Platnick

EOS Senior Project Scientist

NASA recently completed the Global Hawk Pacific Mission (GloPac). Flying out of the Dryden Flight Research Center (DFRC), GloPac was the first mission to use the *Global Hawk* unmanned aircraft system (UAS) for NASA science. GloPac objectives were to explore trace gases and aerosol patterns, and the dynamics of the remote upper troposphere and lower stratosphere. Between April 2–30, five flights took place, logging a total of 82.5 hours of flight time mostly over the Pacific Ocean. One of these flights lasted 28.6 hours, making it the longest flight ever conducted for Earth Science. **Paul Newman** [Goddard Space Flight Center—*GloPac Co-Project Scientist*] said, “*The preliminary results are outstanding and include the observation of polar ozone vortex fragments, dust plumes from the Gobi Desert (as predicted by GSFC models), and stratospheric trace gas distributions.*” With an unprecedented capability for observing across large spatial and temporal scales, the *Global Hawk* ushers in a new era in airborne Earth sciences. The success of the GloPac autonomous flight mission is a credit to the 10 instrument teams, two project scientists (Newman and **David Fahey** of the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory), as well as to the NASA HQ Airborne Sciences and the Upper Atmosphere Research and Radiation Sciences Programs, DFRC, and many other organizations and individuals. We plan to include a feature article on GloPac in an upcoming issue. In the meantime, please see page 18 for more information about the mission.

Two major environmental stories have been in the news headlines in recent weeks—one natural and one man-made. Both have provided opportunities to put into practice some of the tools that NASA and its partners in government and academia have developed to respond to disasters such as these.

continued on page 2



The GloPac team poses for a group photo in front of the *Global Hawk* in the hangar at NASA Dryden Flight Research Center at Edwards Air Force Base in California.

the earth observer

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The second explosive¹ 2010 eruption of Iceland's Eyjafjallajökull volcano began on April 14, with fine ash significantly disrupting air travel in Western and Central Europe. Beginning in 2007, NASA-funded scientists at the University of Maryland-Baltimore County (**Nick Krotkov, Arlin Krueger, Kai Yang, and Simon Carn**—now at Michigan Tech) in coordination with NOAA/NESDIS scientists (**Gilberto Vicente and Eric Hughes**) have used data from the Ozone Monitoring

¹ The first eruption of Eyjafjallajökull (in the modern era) took place on March 20, but the ongoing eruption is 20 times more powerful, and has had a much more significant impact on air travel.

Instrument (OMI) on NASA's Aura satellite to provide the United States' Volcanic Ash Advisory Centers (VAACs), located in Washington, DC and Anchorage, AK, with near real time regional updates on volcanic ash and sulfur dioxide² plumes. During the height of the European air traffic shutdown, for the first time, NASA began providing similar customized products for affected European air spaces (see *satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2*).

NASA and NOAA also support ongoing research efforts at the University of Wisconsin to develop new techniques for distinguishing volcanic ash from clouds and estimate the height of ash plumes using data from MODIS on Aqua and Terra. These data products, led by **Mike Pavolonis** (NOAA/NESDIS, CIMSS), still in the prototype stage, were supplied to the London VAAC (under the jurisdiction of the U.K. Met Office). The U.S. advisory centers also use the MODIS volcanic ash data. Additionally, ash plume heights have been obtained from the MISR instrument on Terra and the CALIOP lidar onboard CALIPSO (see page 22 of this issue and the *Earth Observatory* Eyjafjallajökull collection at *earthobservatory.nasa.gov/NaturalHazards/event.php?id=43253*).

On April 23, the *Deepwater Horizon* oil rig collapsed and sank into the Gulf of Mexico several days after an explosion and fire caused by an *oil blowout*. As of this writing, an official estimate of 5,000 barrels of oil per day are believed to be spewing into the gulf from the mile-deep well. There is an understandable fear about the environmental impact on coastal and underwater ecosystems coming in contact with the oil.

At the request of NOAA, the lead agency for tracking the spill, NASA sent the high-altitude ER-2 aircraft outfitted with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) [NASA/JPL] and the Digital Camera System [NASA Ames] to collect detailed images of the Gulf of Mexico and its threatened wetlands. These data have been provided to NOAA and USGS. In addition, data from the aircraft observations, MODIS (Terra, Aqua) and ASTER (Terra) satellite instruments, and the Advanced Land Imager (ALI) and Hyperion instruments on NASA's Earth Observing-1 (EO-1) satellite have been made available to the USGS Hazards Data Distribution System (see example on page 27 of this issue). See the side bar for more details on these and other NASA responses to the oil spill.

NASA participated in the 40th Anniversary celebration of Earth Day at the National Mall in Washington DC, April 17–25. **Jack Kaye** [NASA HQ—Associate Direc-

² Sulfur dioxide can be a marker for fresh volcanic ash clouds under clear skies especially in the early days of a high-altitude eruption. It can at times indicate the presence of ash when the ash cannot be visually detected from space.

tor of Research] opened the NASA exhibit with a Ribbon Cutting Ceremony. The *NASA Village* was made up of three large tents and drew thousands of visitors to interact with our scientists and outreach educators. A Cinema tent was used for scientific presentations and to engage the public in open discussions on important Earth Science issues such as climate change. The Earth tent was used for numerous displays and family/student activities. A Technology tent included information related to NASA airborne and spaceflight activities. On Earth Day (April 22), the Office of Education

organized a “student day” that included over 320 local middle and high schoolers. The students participated in hands-on activities, and spoke with and heard from many scientists.

Many thanks to all who helped make this a successful and rewarding event. More information about the activities and presentations that took place in the NASA Village can be found at eosps0.gsfc.nasa.gov/EarthDay/index.php; photos and videos are at www.flickr.com/photos/scienceatnasa. ■

NASA Responds to the Gulf Oil Spill

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Since the failure of the *Deepwater Horizon* oil rig on April 20, NASA has flown solar reflectance imager, synthetic aperture radar, and lidar instruments to identify the location and extent of the oil slick and possibly the oil concentration.

NASA's Earth observing satellites have been continuously monitoring the disaster. The Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua observes the Gulf of Mexico at local mid-morning and mid-day respectively, and again at night. MODIS has a large swath width (~2300 km) so each image provides a synoptic view of the region. In contrast, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra has a smaller swath width (60 km) and as such it only views the oil slick every two to five days depending upon the orbit. Similarly, the Advanced Land Imager and Hyperion hyperspectral instruments on the Earth Observing-1 satellite have very high spatial resolutions but narrower fields of views (37 and 8 km respectively) and thus are limited in the area of the slick that they may view.

NASA's spaceborne instruments are primarily detecting the extent of the slick. NASA also has airborne instruments that can provide much higher resolution observations and have the ability to make frequent passes over the shoreline, wetlands and the oil slick. At the request of NOAA, NASA is flying the high altitude *Lockheed ER-2* aircraft with the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) and the Cirrus Digital Camera System. AVIRIS measures how water absorbs and reflects light in order to map the location and concentration of oil, which has separated into a widespread, thin sheen and ribbons of concentrated oil streams. Satellites can document the overall extent of the oil but have difficulty distinguishing between the sheen and concentrated oil. AVIRIS should be able to identify the oil concentrations. The AVIRIS team is providing calibrated radiance cubes to the U.S. Geological Survey's Spectroscopy Lab in Denver CO, which is using experimental algorithms to identify the oil concentration volumes observed in the AVIRIS scenes. The intent is for the USGS-derived oil concentration product to be provided to the NOAA Office of Response and Restoration for use as inputs into the NOAA oil trajectory models. Trajectory models help guide recovery efforts by identifying which locations are most likely to need resources, such as booms and skimmers, to protect the shoreline.

The NASA Langley Research Center (LaRC) *King Air* B200 aircraft also flew three flights over the spill between May 10–11. There are two remote sensors on the aircraft: the LaRC High Spectral Resolution Lidar (HSRL), and the Goddard Institute for Space Studies Research Scanning Polarimeter (RSP). The flights over the gulf are exploratory in nature with the intention to determine what can be inferred about the oil slicks using the HSRL and RSP aircraft instruments as well as the lidar on Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite, and the Aerosol Polarimetry Sensor on the future Glory mission.

Airborne researchers also plan to measure changes in vegetation along the coastline and assess where and how oil may be affecting marshes, bayous, and beaches that are difficult to survey on the ground. NASA is deploying the Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR), which currently flies on a manned Gulfstream-III aircraft, to contribute to studies of ecosystem response and recovery. The approach is to monitor the region on seasonal to annual time scales in order to differentiate ecosystem response of oil impacted areas from nominal seasonal behavior. The combination of satellite and airborne imagery will assist the federal and state agencies in documenting changes in the ecosystem. It is critical to make observations of the coastal zone before the oil inundation. Subsequent post-inundation measurements will enable the assessment of the extent of the oil infiltration into the coastal wetlands and its ecological impact. ■

The Origins and Implementation of Operation IceBridge

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

Bridging the Gap...

Let's say that you are a scientist, working on an eminently important and productive satellite-based remote sensing mission to explore the cryosphere. The mission is going well, but the orbiting sensor—while exceeding its planned operational lifetime—is beginning to show signs of failure, and no follow-on mission is planned for another six years. The data and their continuity are important, as polar regions are sensitive to changes in climate, and a several-year hiatus would severely undermine your ability to track such changes. What do you do?

The answer has come from a team at NASA that has developed a mission using instrumented aircraft to bridge that gap.

Operation IceBridge is a five-year field campaign designed to provide a series of aircraft-based measurements of sea ice and ice sheets in the Arctic and Antarctic regions of our planet. It is the largest airborne survey of Earth's polar ice ever flown. IceBridge representatives from NASA and partnering universities will watch changes to these critical regions by taking aircraft measurements at the snow and ice surfaces and through the ice using ice-penetrating radars and gravimeter measurements.



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Scientific Foundations

Earth's cryosphere is comprised of water in its frozen phase (e.g., snow and ice), and the regions in which such frozen water is found. Typically, frozen water is found at Earth's surface where temperatures drop to (or below) freezing, such as mountaintops and—characteristically—the Arctic and Antarctic regions at the Earth's poles. Ice and snow have strong effects on Earth's albedo: snow- and ice-covered regions reflect sunlight back into the atmosphere; conversely, as temperatures rise and snow and ice melt, darker surface features are revealed, thereby absorbing sunlight. Together, both conditions affect Earth's *energy balance*—the balance between incoming and outgoing solar radiation. Further, *meltwater*—pools of water sitting atop the ice surface—affects the hydrosphere; the presence or absence of snow or ice affects plant and animal habitats, in turn affecting the biosphere; and, as glaciers erode their rock beds and walls, the geosphere is also affected. Studying the cryosphere, then, is a necessary component for understanding Earth's interlocking systems. These studies entail acquiring data on snow, ice, sea ice, glaciers, ice shelves, ice sheets, and frozen ground.

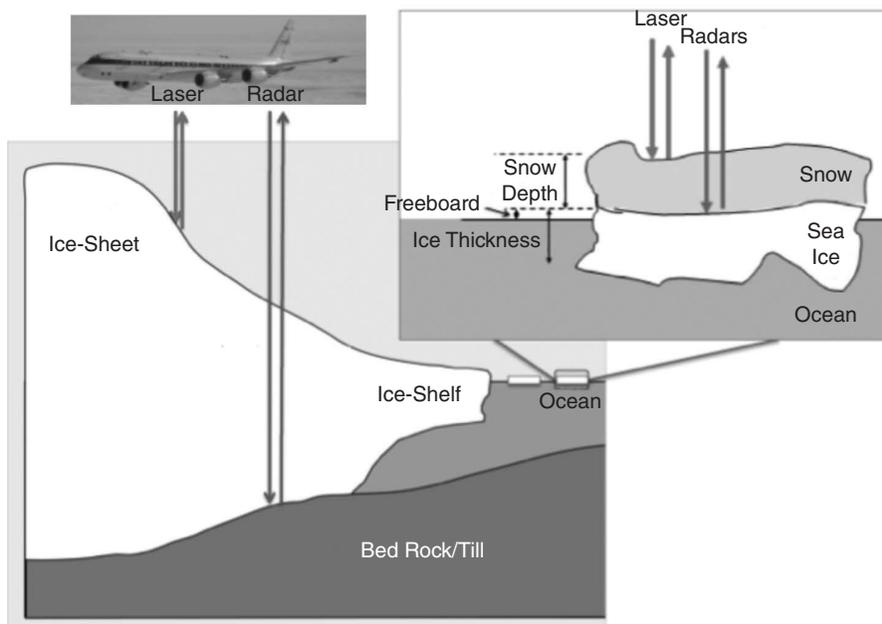
To help acquire such data, the Ice, Cloud, and Land Elevation Satellite (ICESat) mission was developed to be part of NASA's Earth Observing System (EOS). Launched in January 2003, ICESat used three Geoscience Laser Altimeter System (GLAS) lasers to measure ice sheet mass balance, sea-ice *freeboard*—the amount of ice and snow that protrudes above the water surface, cloud and aerosol heights, and land topography characteristics. Designed for a three-to-five year lifetime, the mission's data acquisition ended in October 2009 when the last of the GLAS lasers stopped working; the mission was declared completed in February 2010. A follow-on mission, ICESat-2, is currently in the works, but its launch is not planned until 2015. *Operation IceBridge* allows scientists to mitigate the impacts of this hiatus.

Operation IceBridge Objectives

Operation IceBridge is designed to bridge the data gap between ICESat-1 and -2 by characterizing changes to Earth's polar ice sheets, and using relevant data to improve predictive cryospheric models. To ensure data continuity, aircraft flights will replicate previous flight lines and ICESat groundtracks; new points of interest will be targeted as well. Calibration of the data will be maintained into the ICESat-2 era, based on IceBridge flights that were undertaken before completion of ICESat's mission.

The science objectives for IceBridge are fourfold. According to **Seelye Martin** [University of Washington], **Lora Koenig** [NASA Goddard Space Flight Center] and **Michael Studinger** [University of Maryland Baltimore County Goddard Earth Science and Technology Center], *Operation IceBridge* will:

- (1) Make airborne laser altimetry measurements over the ice sheets and sea ice to fill in the data gap between ICESat-1 and the launch of ICESat-2;
- (2) Link measurements made by ICESat, ICESat-2, and the European Space Agency's CryoSat-2 (launched on April 8, 2010) to allow for their comparison and the production of a long-term record of ice-sheet observations and sea ice altimetry measurements;
- (3) Use airborne altimetry and radar to monitor key, rapidly changing areas of ice—including sea ice, ice sheets, and glaciers—in the Arctic and Antarctic to maintain a long-term observation record, that will improve understanding of glacial dynamics and augment predictive models of sea-level rise and sea-ice cover; and
- (4) Collect other remotely sensed data in conjunction with altimetry measurements, including ice-sheet thickness, structure, and extent; bed topography underlying land-based ice; bathymetry beneath floating ice shelves; and snow accumulation and firn structure.



Data Acquisition

To acquire the necessary data, two NASA aircraft, the Wallops P-3B and the Dryden DC-8, have been instrumented for specific surveys with laser altimeters, near-surface and depth-sounding radars, a gravimeter, and a high-resolution digital camera. In its current Greenland campaign, the NASA DC-8 carries two NASA laser altimeters [the Airborne Topographic Mapper (ATM) and the Land, Vegetation and Ice Sensor (LVIS)]; three radars from the

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Operation IceBridge instruments will map ice sheet surface elevations, the underlying bedrock, sea-ice freeboard, and the thickness of overlying snow. Shown here is the DC-8 that has been specially equipped for Operation IceBridge. Credit: NASA

Notably, the gravity and ice-penetrating radar measurements will provide the necessary bedrock and bottom topography measurements required for input to numerical ice-sheet models. Toward this end, detailed surveys have been done of the Pine Island Glacier floating ice tongue, and of some of the rapidly changing Greenland glaciers.

University of Kansas Center for Remote Sensing of Ice Sheets (CREGIS) [a Ku-band altimeter, the Snow Radar, and the Multichannel Coherent Radar Depth Sounder (MCoRDS)]; a gravimeter; and a high-resolution stereographic camera. At the completion of the DC-8 mission, the instruments will be transferred at Wallops to the P-3B, with the absence of the LVIS laser, and the addition of an improved antenna array for MCoRDS radar.

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Implemented and Planned Activities

Operation IceBridge began with the Arctic 2009 campaign, with P-3B flights over the Greenland ice sheet and the Arctic Ocean. Instruments flown over Greenland in 2009 included the LVIS, Airborne Topographic Mapper (ATM), Pathfinder Airborne Radar Ice Sounder (PARIS), and the CREGIS MCoRDS radars. While logging over 150 hours of flight time, sea ice freeboard, and snow depth were determined for first-year and multiyear ice, and ice-sheet surface elevation and bedrock topography were measured. These laser data will allow intercalibration between ICESat-1 and -2.

During the Fall Antarctic 2009 campaign, the Dryden DC-8 was equipped with the LVIS, ATM, the CREGIS Radar Suite (Ku-band altimeter, Snow Radar, and the MCoRDS ice-penetrating radar), the Digital Mapping System (DMS), and the gravimeter. The 250 hours of flight time provided data from the first successful flights over sea ice in the Weddell Sea, and provided LVIS swath altimetry data mapping of Crane Glacier on the Antarctic Peninsula and gravity anomaly measurements over the Pine Island Bay region.

Analysis of these data are currently underway.

In the Field with IceBridge: Reporting the Rare and Routine

NASA's P-3B aircraft, scientists, and crew planned to begin their journey back from Greenland no later than May 28, concluding the Arctic 2010 *Operation IceBridge* campaign. Throughout the campaign, scientists, engineers, and crew shared their personal accounts of working—and living—in the Arctic.

Some of those experiences ranged from the mundane routine of a successful flight ...

"As I write this we are conducting our 11th flight of the campaign, part of a four-mission effort to survey the lower Northeast Greenland Ice Stream in unprecedented detail. And things are going smoothly and well. They are going so well, in fact, that many of the scientists and engineers are battling drowsiness as they monitor their instruments, and those who are off-duty are often napping."

— **John Sonntag** [NASA Wallops Flight Facility—ATM Senior Scientist and IceBridge Management Team]

... to the excitement of ground-based crew at Summit Camp, participating in IceBridge instrument calibration, who witnessed the DC-8 overflight ...

"During the winter, the last brush with the outside world (not including the World Wide Web and telephone, that is) is the Twin Otter flight that comes to pick up the outgoing crew after a week of turnover. So, seeing the NASA DC-8 plane was the first reassurance that people are in fact still out there. Maybe we are geeks, but it was exciting and fun for us to be a part of the IceBridge project."

— **Christina Hammock** [Johns Hopkins Applied Physics Laboratory] and **Sonja Walker** [NOAA Carbon Cycle/Greenhouse Gases Group]

To read the complete archived posts from *Operation IceBridge's* first flights to Greenland and Antarctica in 2009, or catch up on the latest from the current Arctic campaign, visit the mission blog: blogs.nasa.gov/cm/blog/icebridge/.



Sonja Wolter from Greenland's Summit Camp was working in the field on April 14 when NASA's DC-8 passed overhead. **Credit:** Christina Hammock

The ongoing Arctic 2010 campaign—see sidebar opposite page—has been designed to monitor the Greenland ice sheet and Arctic sea ice, with particular attention to mapping sea ice, bedrock topography beneath the ice sheets, and outlet glaciers. To this end, the aircraft were transferred to Thule, Greenland in March 2010. Some 200 hours of flight time are planned during about 20 flights, using NASA's DC-8 and P-3B. The main instruments include the laser altimeters, near-surface and depth-sounding radars, a gravimeter, and the high-resolution digital camera. As of April 10, eight flights had been completed, with all instruments productively gathering data.

Ultimately, *Operation IceBridge* data will be available at the National Snow and Ice Data Center site.

Synergistic Collaboration

In the best of scientific traditions, the scope of *Operation IceBridge* has been expanded beyond its original purview by funding of teams from the University of Texas/Austin (UT) and the University of Alaska/Fairbanks. The addition of these teams augmented the existing roster of NASA scientists and instrument principal investigators by adding to other efforts, funded by other agencies, already in progress. The UT team is providing altimetry data for East Antarctica; the UA team is providing data for Southeast Alaska glaciers. This spreads the spatial extent of the *Operation IceBridge* studies in a way that NASA would not be able to do on its own. The mutual sharing of data thus provides relevant and important data for both groups, and expands our knowledge of the changes in the ice sheets and glaciers.

Bridging the Gap

Operation IceBridge is well under way, and the data collected thus far clearly shows the utility of aircraft overflights. With a suite of instruments that will continue the data stream begun with ICESat-1, augmented with data acquired by other satellite missions—including Cryosat-2, launched in April 2010—IceBridge will provide continuity of observations through the launch of ICESat-2.

Additional Resources

Operation IceBridge Home Page—www.espo.nasa.gov/oib/

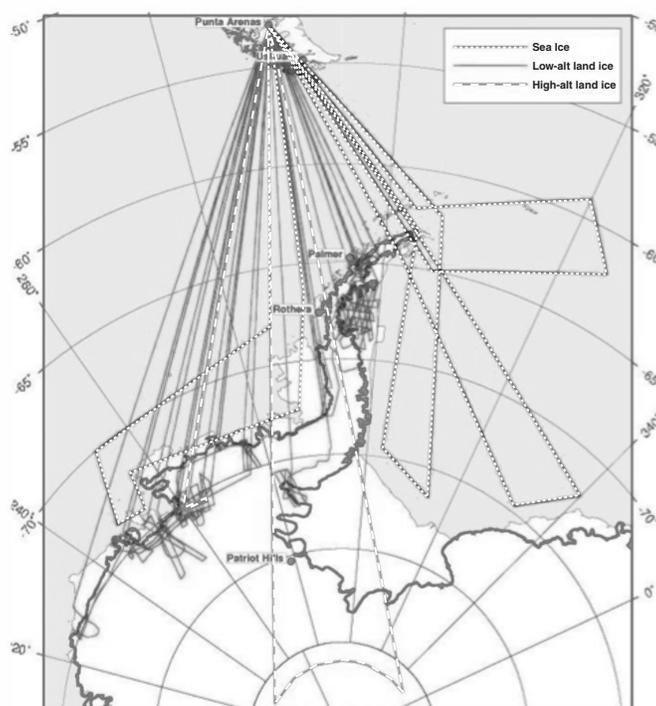
Operation IceBridge: Using Instrumented Aircraft to Fill the Observational Gap between ICESat-1 and ICESat-2—soa.arcus.org/abstracts/operation-ice-bridge-using-instrumented-aircraft-fill-observational-gap-between-icesat-1-a

Latest IceBridge Campaign News—www.nasa.gov/mission_pages/icebridge/index.html

ICESat Home Page—icesat.gsfc.nasa.gov

IceBridge Data at the National Snow and Ice Data Center—nsidc.org/data/icebridge/index.html

Acknowledgments: Lora Koenig, Seelye Martin, and Kathryn Hansen [Wyle Information Systems—*Earth Science News Team*] provided significant aid and guidance in generating this article. ■



Flight paths for the Antarctica 2009 campaign of *Operation IceBridge*. Flights originated from Punta Arenas, Chile. Sea-ice targets are largely to right of center; land-ice targets are largely to left of center. Courtesy NASA.

Arctic Sea Ice News & Analysis: Cold Snap Causes Late-Season Growth Spurt

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Early in March, Arctic sea ice appeared to reach a maximum extent.

However, after a short decline, the ice continued to grow. By the end of March, total extent approached 1979–2000 average levels for this time of year.

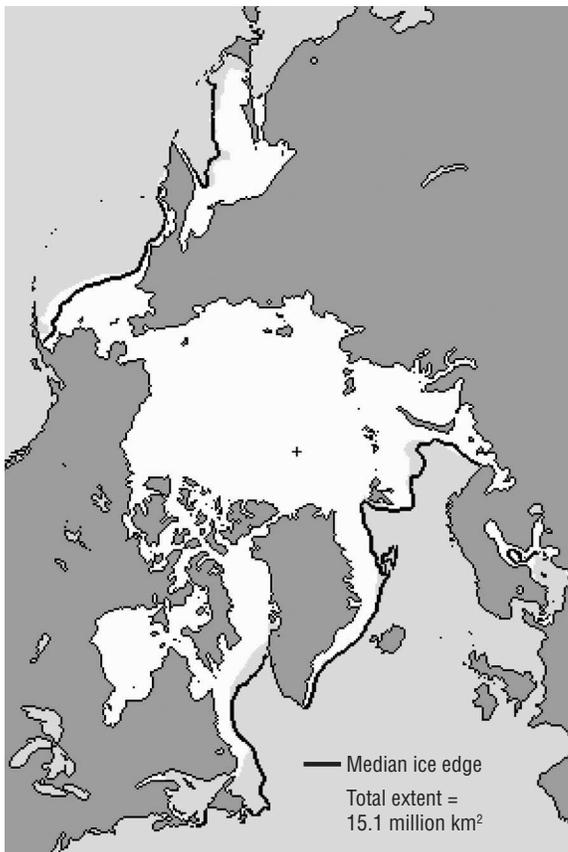
Arctic sea ice reflects sunlight, keeping the polar regions cool and moderating global climate. According to scientific measurements, Arctic sea ice has declined dramatically over at least the past thirty years, with the most extreme decline seen in the summer melt season.

The National Snow and Ice Data Center (NSIDC) provides an update of sea-ice conditions during the first week of each month, or more frequently as conditions warrant. NSIDC scientists provide Arctic Sea Ice News & Analysis, with partial support from NASA.

The images shown in Arctic Sea Ice News & Analysis are derived from the Sea-Ice Index data product. The basis for the Sea-Ice Index is the dataset, “Near Real-Time Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) Daily Polar Gridded Sea-Ice Concentrations” and the NASA-produced “Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I Passive Microwave Data.”

Arctic sea ice reached its maximum extent for the year on March 31 at 5.89 million mi² (15.25 million km²). This was the latest date for the maximum Arctic sea-ice extent since the start of the satellite record in 1979.

Sea Ice Extent for March, 2010



Average Arctic sea-ice extent for March 2010 was 5.83 million mi² (15.10 million km²). The black line shows the 1979–2000 median extent for that month. The black cross indicates the geographic North Pole. Sea-Ice Index data. Credit: National Snow and Ice Data Center

Early in March, Arctic sea ice appeared to reach a maximum extent. However, after a short decline, the ice continued to grow. By the end of March, total extent approached 1979–2000 average levels for this time of year. The late-season growth was driven mainly by cold weather and winds from the north over the Bering and Barents Seas. Meanwhile, temperatures over the central Arctic Ocean remained above normal and the winter ice cover remained young and thin compared to earlier years.

Arctic sea-ice extent averaged for March 2010 was 5.83 million mi² (15.10 million km²). This was 250,000 mi² (650,000 km²) below the 1979–2000 average for March, but 260,000 mi² (670,000 km²) above the record low for the month, which occurred in March 2006.

Ice extent was above normal in the Bering Sea and Baltic Sea, but remained below normal over much of the Atlantic sector of the Arctic, including the Baffin Bay, and the Canadian Maritime Provinces seaboard. Extent in other regions was near average.

Sea ice reached its maximum extent for the year on March 31—the latest maximum date in the satellite record. The previous latest date was on March 29, 1999. The maximum extent was 5.89 million mi² (15.25 million km²). This was 260,000 mi² (670,000 km²) above the record low maximum extent, which occurred in 2006.

Sea-ice extent seemed to reach a maximum during the early part of the month, but after a brief decline, ice ex-

tent increased slowly and steadily through the end of the month. By the end of the month, extent had approached the 1979–2000 average. During March 2010, ice extent grew at an average of 5100 mi² (13,200 km²) per day. Usually there is a net loss of ice through the month.

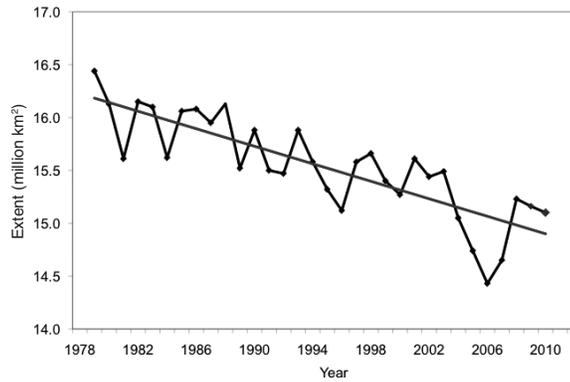
The average ice extent for March 2010 was 260,000 mi² (670,000 km²) higher than the record low for March, observed in 2006. The linear rate of decline for March over the 1978–2010 period is 2.6% per decade.

The maximum Arctic sea-ice extent may occur as early as mid-February to as late as the last week of March. As sea-ice extent approaches the seasonal maximum, extent can vary quite a bit from day to day because the thin, new ice at the edge of the pack is sensitive to local wind and temperature patterns. This March, low atmospheric pressure systems persisted over the Gulf of Alaska and north of Scandinavia. These pressure patterns led to unusually cold conditions and persistent northerly winds in the Bering and Barents Seas, which pushed the ice edge southward in these two regions.

This winter's strong negative mode of the Arctic Oscillation was moderated through the month of March. Average air temperatures for the month nevertheless remained above average over the Arctic Ocean region. Overall for the winter, temperatures over most of the Arctic were above average, while northern Europe and Siberia were colder than usual.

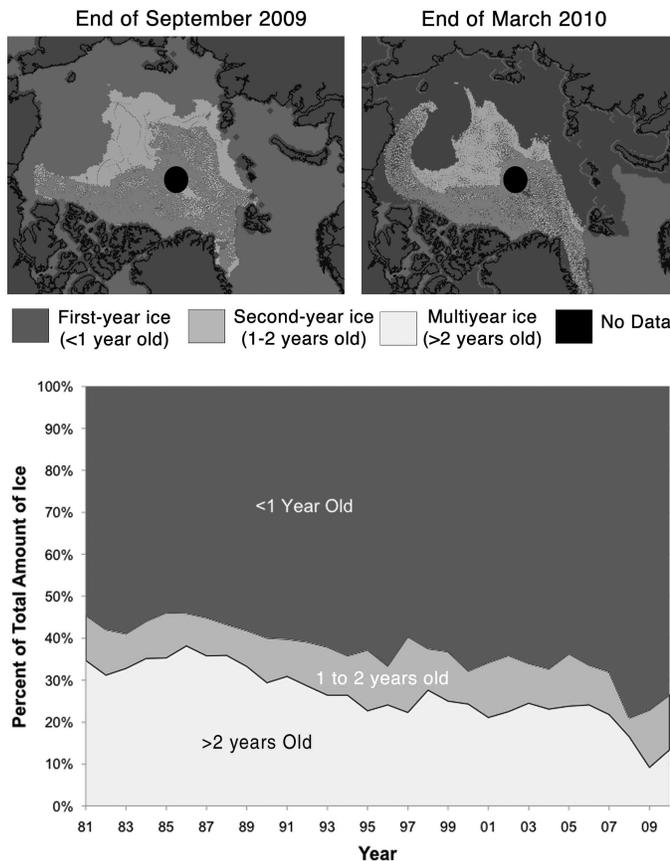
The late date of the maximum extent, though of special interest this year, is unlikely to have an impact on summer ice extent. The ice that formed late in the season is thin, and will melt quickly when temperatures rise.

**Average Monthly Arctic Sea-Ice Extent
March 1979–2009**



Monthly March ice extent for 1979–2010 shows a decline of 2.6% per decade. **Credit:** National Snow and Ice Data Center

**Arctic Sea-Ice Age Change
2009–2010**



These images show the change in ice age from Fall 2009–Spring 2010. The negative Arctic Oscillation this winter slowed the export of older ice out of the Arctic. As a result, the percentage of ice older than two years was greater at the end of March 2010 than over the past few years. **Credit:** National Snow and Ice Data Center, courtesy J. Maslanik and C. Fowler, CU Boulder

Scientists often use ice-age data as a way to infer *ice thickness*—one of the most important factors influencing end-of-summer ice extent. Although the Arctic has much less thick, multiyear ice than it did during the 1980s and 1990s, this winter has seen some replenishment: the Arctic lost less ice the past two summers compared to 2007, and the strong negative Arctic Oscillation this winter prevented as much ice from moving

The larger amount of multiyear ice could help more ice to survive the summer melt season. However, this replenishment consists primarily of younger, two- to three-year-old multiyear ice; the oldest, and thickest multiyear ice has continued to decline.

out of the Arctic. The larger amount of multiyear ice could help more ice to survive the summer melt season. However, this replenishment consists primarily of younger, two- to three-year-old multiyear ice; the oldest, and thickest multiyear ice has continued to decline. Although thickness plays an important role in ice melt, summer ice conditions will also depend strongly on weather patterns through the melt season.

At the moment there are no Arctic-wide satellite measurements of ice thickness, because of the end of the NASA Ice, Cloud, and land Elevation Satellite (ICESat) mission last October. NASA has mounted an airborne sensor campaign called IceBridge to fill this observational gap.

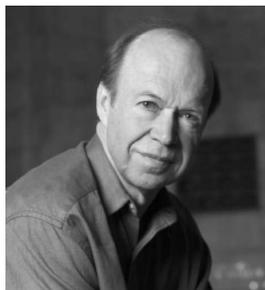
To view images from this story in color, please visit: nsidc.org/arcticseaicenews/. Continuing updates on Arctic sea ice and previous analyses are also available at this site. ■

KUDOS

Moustafa Chahine [Jet Propulsion Laboratory—*Science Team Leader for the Atmospheric Infrared Sounder (AIRS) on Aqua*] recently received the 2010 George W. Goddard Award, in recognition of his exceptional achievement in optical science and instrumentation for aerospace and atmospheric research. The award is given annually by Society of Photo-Optical Instrumentation Engineers (SPIE) for the invention and development of a new technique, photonic instrumentation, instrument, or system. Chahine received the award for his development of an inversion algorithm called the *relaxation method*. To read the full announcement, please visit: spie.org/x39353.xml.



Moustafa Chahine



Jim Hansen
Photo Credit: Arnold Adler

Jim Hansen [Goddard Institute for Space Studies (GISS)—*Director*] recently received the 2010 Sophie Prize, an international award for environment and sustainable development. The prize is awarded annually to one or several persons, or an organization, which has created awareness of alternatives to modern-day development and/or initiated such alternatives in a pioneering or particularly inventive manner. Hansen received the award for his clear communication of the threat posed by climate change and for his genuine commitment to future generations. To read the full announcement, please visit: www.softeprisen.no/.

Claire Parkinson [NASA Goddard Space Flight Center—*Aqua Project Scientist*] has been elected to membership in the American Philosophical Society, the oldest learned society in the United States. Founded in 1743 by Benjamin Franklin with the express purpose of “*promoting useful knowledge*,” the society elected 38 new members at their recent annual meeting, with Parkinson being one of seven elected to the Mathematical and Physical Sciences section. Although known in the EOS community mostly for her role as the Aqua Project Scientist and in the polar science community mostly for her research on sea ice, Parkinson has also written a book on the history of science and has a new book out entitled *Coming Climate Crisis? Consider the Past, Beware the Big Fix* (published May 2010). The new book places current climate change issues and proposed geoengineering solutions in the context of 4.6 billion years of Earth system history and the limitations of our models and understandings.



Claire Parkinson
Photo Credit: Steve Graham

The Earth Observer and the entire scientific community congratulate Chahine, Hansen, and Parkinson on their accomplishments!

NASA DEVELOP Students Apply Science and Technology to Public Health

Nathan Renneboog, DEVELOP National Program, Marshall Space Flight Center/University of Alabama at Birmingham, nrennebo@uab.edu

The DEVELOP National Program is a student-led Applied Sciences research internship focused on training and development that originated at Langley Research Center in 1998. As a part of NASA's Applied Sciences Program, DEVELOP provides students with remote sensing experience and the opportunity to work with NASA and partner agency scientists. Students conduct research projects in partnership with communities and local organizations¹.

The Marshall Space Flight Center (MSFC) in Huntsville, Alabama partnered with the Laboratory for Global Health Observation at the University of Alabama at Birmingham (UAB) to establish a new DEVELOP team in the summer of 2008. The team, led by graduate student **Jeff DeGraffenried** [UAB] and mentored by **Jeffrey Luvall** [MSFC—*Physical Scientist*], studied the West Nile Virus (WNV) risk in Auburn, AL, using geolocated mosquito population data in combination with Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and QuickBird imagery to create predictive risk models. The team presented the project at NASA Headquarters and, in the fall term, expanded it to include Tuskegee, AL in the predictive model. In addition, **Scott Silver** [UAB—*Student*], **David Gathings** [UAB—*Student*], and **Nathan Renneboog** [UAB—*Student*] presented results to the local public health department.



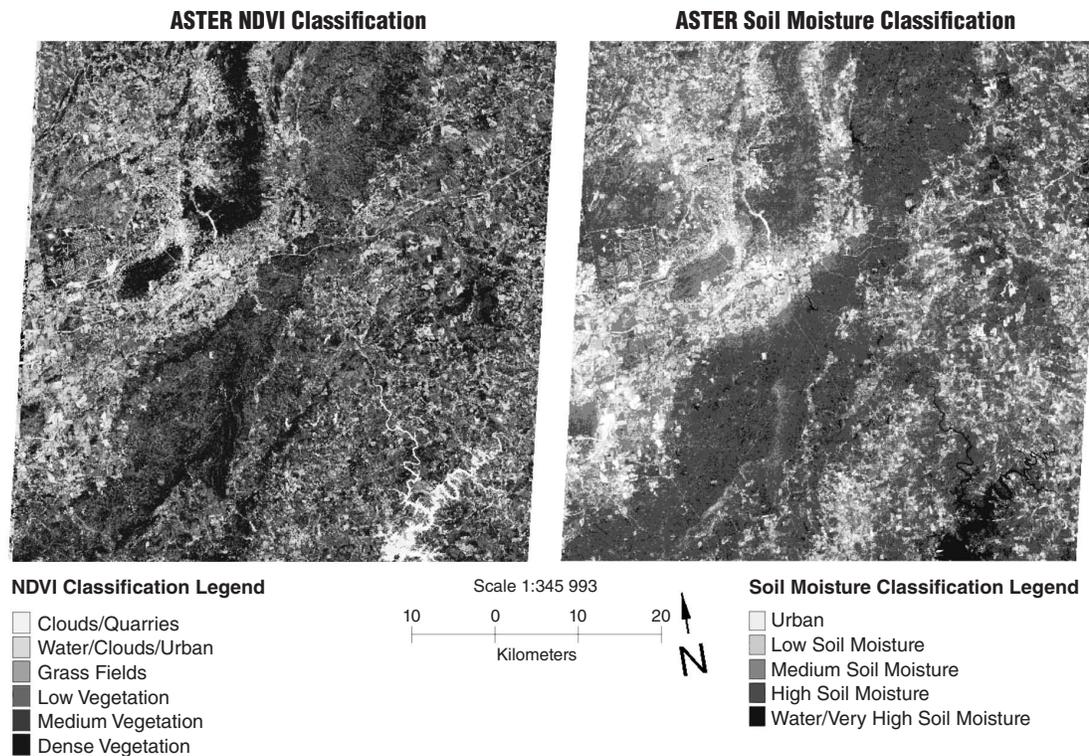
As a part of NASA's Applied Sciences Program, DEVELOP provides students with remote sensing experience and the opportunity to work with NASA and partner agency scientists. Students conduct research projects in partnership with communities and local organizations.

The NASA DEVELOP MSFC-UAB 2009 summer team. [Standing row from left] Shveta Setia, Emily Capilouto, Donna Burnett, Kyle Levy, and Stephen Firsing. [Seated row from left] Lili Xie, Nathan Renneboog, and Kathryn Roa.

Renneboog, a student in the UAB Science and Technology Honors Program, became *Team Lead* in the spring of 2009. The team moved the WNV model to Cook County, IL and expanded on the study by including other environmental variables such as daily precipitation and temperature data. The team also utilized normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), atmospherically resistant vegetation index (ARVI), digital elevation models (DEM), ordinary kriging, and inverse distance weighting² models to map mosquito hot spots. The project won first place at the University of Alabama at Birmingham School of Public Health Graduate School Research Day, and was also presented at the American Association for the Advancement of Science (AAAS) annual meeting in San Diego, CA in February 2010.

¹ To read more about the DEVELOP program, see pages 7-9 in the March-April 2010 issue of *The Earth Observer* [Volume 22, Issue 2].

² Ordinary kriging and inverse distance weighting are two well-known geostatistical modeling techniques.



Satellite views of Talladega National Forest obtained on September 20, 2006: [right] Unsupervised Soil Moisture Classification [left] Unsupervised Normalized Difference Vegetation Index Classification for Anniston, Alabama (Cherokee, Calhoun, Talladega, and Clay Counties)

Since the DEVELOP team identified the presence of the Lyme disease chain of infection and numerous tick habitats, there is good reason to believe the disease is more prevalent in Alabama than currently reported.

In the Summer 2009 term, the team began a new project studying Lyme disease in the state of Alabama. This disease is rarely reported in the state even though ticks (*Ixodes scapularis*) are present. Using ASTER and QuickBird satellite imagery, the students created NDVI and soil moisture classification maps by combining the respective algorithms with unsupervised classifications. This resulted in maps indicating vegetation and soil moisture levels—see example above—as both of these environmental variables are closely related to *Ixodes scapularis* populations. Likely tick habitats are identified as areas containing both high vegetation and soil moisture levels. The project also identified the presence of the Lyme disease vector, *Ixodes scapularis*, and hosts such as white-tailed deer and cotton mice. Literature also identified the presence of the *Borrelia spirochetes* in the state of Alabama. Since these factors as well as numerous tick habitats were identified in Alabama, there is a good reason to believe the disease is more prevalent than currently reported.

During the Fall 2009 term, the Marshall DEVELOP team set up a partnership with **Robert Carter** and his students from Jacksonville State University. Carter's team has been studying tick ecology in Alabama for years by conducting tick drags and collecting *in situ* soil moisture data. The DEVELOP team is currently using this geolocated data and combining it with remotely-sensed data to test the predictive model's accuracy. They have also set up a Lyme disease stakeholder event at the UAB School of Public Health, and partnered with the local Girl Scouts to give a number of Lyme disease presentations at summer camps in Alabama during the 2010 Summer term.

Renneboog presented the Lyme disease project at NASA Headquarters to the Applied Sciences Program Director and Managers, the Director of Earth Science, and other NASA executives. Due to the promising preliminary results, NASA authorized the team to expand the project. Well received by the media, the University of Alabama at Birmingham posted a video and article of the project on its home page (main.uab.edu/Sites/MediaRelations/articles/66245/). The local newspaper, *The Birmingham News*, also published an article on the team's research on the front page of its health section and posted the article on its webpage. The article has been hosted on a number of other websites including

www.medicalnewstoday.com, *www.GISuser.com*, *www.gisdevelopment.net*, and *www.gisand-science.com*. The *Space News* magazine published an article on the Lyme disease study in its August 2009 issue. **Daniel Cameron** [International Lyme and Associated Diseases Society—*President*] invited **Renneboog** and **Stephen Firsing** [Marshall DEVELOP—*Assistant Lead*] to give a plenary presentation on this research at the International Lyme Disease Conference in October 2009, in Washington, DC.

The high level of stakeholder interest in this project led to an invitation to present on the Alabama Lyme disease project, and the West Nile Virus project, at the 2009 NASA Public Health Program Review in Savannah, GA. The team expanded on the Lyme disease project in the Fall 2009 term by analyzing all available ASTER imagery for the state and mapping all likely tick habitats in Alabama. A survey to analyze the risk perceptions, behaviors, and general knowledge of Lyme disease in Alabama's high-risk population of citizens participating in outdoor recreational activities will be conducted during the summer of 2010. The results of this study will assist with the creation of a more effective community outreach message for Lyme disease risk in Alabama.

For more information about the NASA DEVELOP National Program, go to the DEVELOP website at develop.larc.nasa.gov. ■

The high level of stakeholder interest in this project led to an invitation to present on the Alabama Lyme disease project, and the West Nile Virus project, at the 2009 NASA Public Health Program Review in Savannah, GA.

New Datasets Available from NSIDC

The National Snow and Ice Data Center (NSIDC) is pleased to announce the release of three new datasets:

Canadian Meteorological Centre (CMC) Daily Snow Depth Analysis Data

Ross Brown and **Bruce Brassnet** have provided a dataset that contains a Northern Hemisphere subset of the global daily snow-depth analysis produced by the Canadian Meteorological Centre since 1998. The daily snow-depth analyses are based on the optimal interpolation of real-time snow-depth information from surface synoptic observations, meteorological aviation reports, and special aviation reports. The dataset also includes monthly mean snow depth and derived monthly mean snow-water equivalent estimated using a monthly mean snow density look-up table. The dataset covers the period from April 1998–December 2009 and will be updated annually while the operational analysis is maintained. For more information on this dataset, please see: nsidc.org/data/nsidc-0447.html.

Co-Registered AMSR-E, QuikSCAT, and WMO Data

Marco Tedesco and **Jeffrey Miller** have provided a dataset that contains the following spatially and temporally co-registered data: Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) brightness temperatures for all channels, Quick Scatterometer (QuikSCAT) backscattering coefficients, and World Meteorological Organization (WMO) ground observations acquired from more than two thousand stations. These data are available from January 1, 2002–March 19, 2009 with AMSR-E data included from June 19, 2002–March 19, 2009. For more information on this dataset, please see: nsidc.org/data/nsidc-0450.html.

Daily Global Land Surface Parameters Derived from AMSR-E

Lucas A. Jones and **John S. Kimball** have provided a dataset that contains satellite-retrieved geophysical parameters generated from the AMSR-E instrument on the NASA Aqua satellite. Parameters include: air temperature minima and maxima at approximately two meters in height, fractional cover of open water on land, vegetation canopy microwave transmittance, surface soil moisture at less than or equal to two centimeters soil depth, and integrated water-vapor content of the intervening atmosphere for the total column.

The daily parameter retrievals extend from June 19, 2002–December 31, 2008. The global retrievals were derived over land for non-precipitating, non-snow, and non-ice covered conditions. The primary input data were daily AMSR-E dual polarized multi-frequency, ascending and descending overpass brightness temperature data. For more information regarding this dataset, please see: nsidc.org/data/nsidc-0451.html.

If you have any questions, please contact NSIDC User Services at nsidc@nsidc.org.

Road Transportation Emerges as Key Driver of Warming in New Analysis from NASA

Adam Voiland, NASA's Earth Science News Team, avoiland@sesda2.com

For decades, climatologists have studied the gases and particles that have potential to alter Earth's climate. They have discovered and described certain airborne chemicals that can trap incoming sunlight and warm the climate, while others cool the planet by blocking the Sun's rays.



Motor vehicles produce significant amounts of pollutants that warm climate, such as carbon dioxide, black carbon, and ozone, while giving off only minimal amounts of pollutants that cool climate, such as sulfates and nitrates. **Credit:** NASA's Langley Research Center

Now a new study led by **Nadine Unger** of NASA's Goddard Institute for Space Studies (GISS) offers a more intuitive way to understand what's changing the Earth's climate. Rather than analyzing impacts by chemical species, scientists have analyzed the climate impacts by different economic sectors.

Each part of the economy, such as ground transportation or agriculture, emits a unique portfolio of gases and aerosols that affect the climate in different ways and on different timescales.

"We wanted to provide the information in a way that would be more helpful for policy makers," Unger said. "This approach will make it easier to identify sectors for which emission reductions will be most beneficial for climate and those which may produce unintended consequences."

In a paper published online on February 3 by the *Proceedings of the National Academy of Sciences*, Unger and colleagues described how they used a climate model to estimate the impact of 13 sectors of the economy from 2000–2100. They based their calculations on real-world inventories of emissions collected by scientists around the world, and they assumed that those emissions would stay relatively constant in the future.

Snapshots of the Future

In their analysis, motor vehicles emerged as the greatest contributor to atmospheric warming now and in the near term. Cars, buses, and trucks release pollutants and greenhouse gases that promote warming, while emitting few aerosols that counteract it.

The researchers found that the burning of household *biofuels*—primarily wood and animal dung for home heating and cooking—contribute the second most warming. And raising livestock, particularly methane-producing cattle, contribute the third most.

On the other end of the spectrum, the industrial sector releases such a high proportion of sulfates and other cooling aerosols that it actually contributes a significant amount of cooling to the system. And *biomass burning*—which occurs mainly as a result of tropical forest fires, deforestation, savannah and shrub fires—emits large amounts of organic carbon particles that block solar radiation.

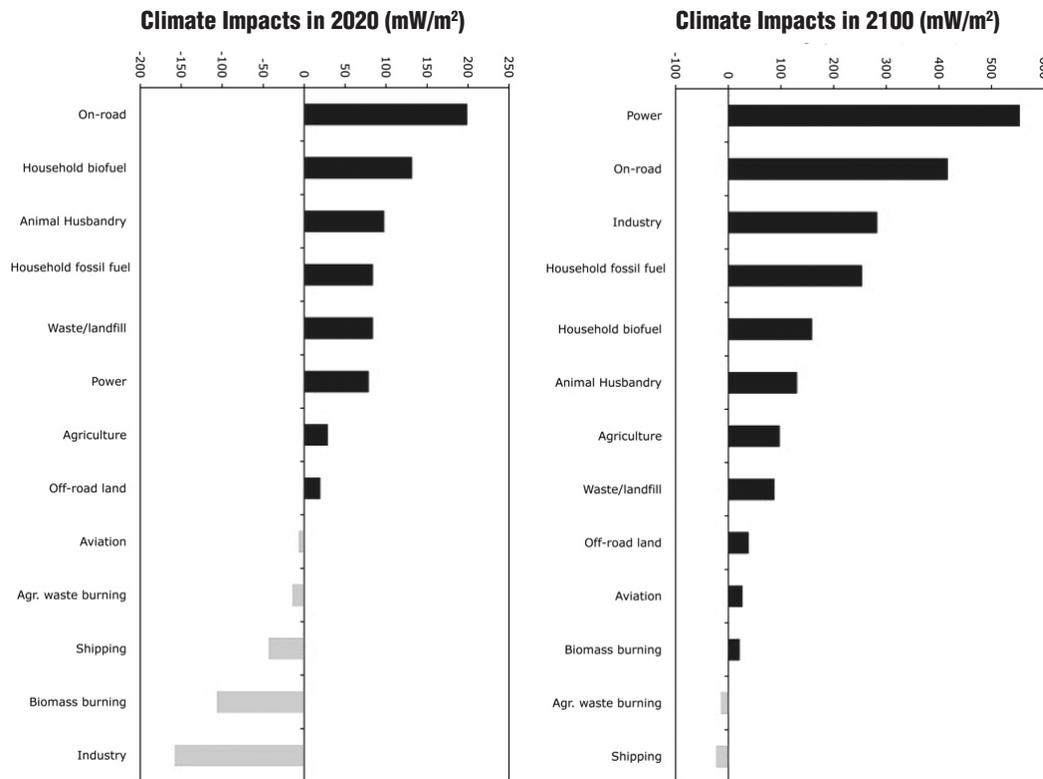
The new analysis offers policy makers and the public a far more detailed and comprehensive understanding of how to mitigate climate change most effectively, Unger and colleagues assert. "Targeting on-road transportation is a win-win-win," she said. "It's good for the climate in the short term and long term, and it's good for our health."

Due to the health problems caused by aerosols, many developed countries have been reducing aerosol emissions by industry. But such efforts are also eliminating some of the cooling effect of such pollution, eliminating a form of "inadvertent geoengineering" that has likely counteracted global warming in recent decades.

"Warming should accelerate as we continue to remove the aerosols," said Unger. "We have no choice but to remove the aerosol particulate pollution to protect human and ecosystem health. That means we'll need to work even harder to reduce greenhouse gases and warming pollutants."

By the year 2100, Unger's projections suggest that the impact of the various sectors will change significantly. By 2050, electric power generation overtakes road transportation as the biggest promoter of warming. The industrial sector likewise jumps from the smallest contribution in 2020 to the third largest by 2100.

"The differences are because the impacts of greenhouse gases accumulate and intensify over time, and because



Unger's model finds that in 2020 [left], transportation, household biofuels, and animal husbandry will have the greatest warming impact on the climate, while the shipping, biomass burning, and industrial sectors will have a cooling impact. By 2100 [right], the model finds that the power and industrial sector will become strongly warming as carbon dioxide accumulates. **Credit:** NASA GISS/Nadine Unger

they persist in the atmosphere for such long periods," said Unger. "In contrast, aerosols rain out after a few days and can only have a short-term impact."

Factoring in Clouds

For each sector of the economy, Unger's team analyzed the effects of a wide range of chemical species, including carbon dioxide, nitrous oxide, methane, organic carbon, black carbon, nitrate, sulfate, and ozone.

The team also considered how emissions from each part of the economy can impact clouds, which have an *indirect effect* on climate, explained **Surabi Menon**, a coauthor of the paper and scientist at the Lawrence Berkeley National Laboratory in Berkeley, CA.

Some aerosols, particularly sulfates and organic carbon, can make clouds brighter and cause them to last longer, producing a cooling effect. At the same time, one type of aerosol called black carbon, or soot, actually absorbs incoming solar radiation, heats the atmosphere, and drives the evaporation of low-level clouds. This process, called the *semi-direct effect*, has a warming impact.

The new analysis shows that emissions from the power, biomass burning, and industrial sectors of the economy promote aerosol-cloud interactions that exert a power-

ful cooling effect, while on-road transportation and household biofuels exacerbate cloud-related warming.

More research on the effects of aerosols is still needed, Unger cautions. "Although our estimates of the aerosol forcing are consistent with those listed by the International Panel on Climate Change, a significant amount of uncertainty remains."



Unger's analysis is one of the first of its kind to incorporate the multiple effects that aerosol particles can have on clouds, which affect the climate indirectly. **Credit:** NASA's Johnson Space Center

Q & A with Nadine Unger

In the article on the preceding pages, Nadine Unger describes results of a recent study that analyzed how different human activities impact climate. Unger also spoke with the Earth Science News Team about her findings and expanded on some of the ideas mentioned in the article.

NASA's Earth Science News Team: Your research suggests that the climate science community ought to shift its focus from looking at the impacts of individual chemicals to economic sectors. Why?

Unger: There's nothing "wrong" with dividing climate impacts up by chemical species, but it's not particularly useful for policy makers. They need to know which human activities are impacting the climate and what the effect will be if they attempt to curb emissions from a particular sector. Also, there's a great deal of complexity in our emissions that they need to be mindful of if we want to mitigate climate change efficiently.

NASA: What sort of complexity?

Unger: Some sectors of the economy produce a mixture of pollutants—particularly aerosols—that cause cooling rather than warming in the short term. Since warming can accelerate as we remove aerosols, we've been inadvertently geoengineering for decades with aerosol emissions.

Take the heavy industry and shipping sectors, for example. These sectors burn a great deal of coal and bunker fuel, which release carbon dioxide, which causes greenhouse warming. But they also release sulfates, which cause cooling by blocking incoming radiation from the sun and by changing clouds to make them brighter and longer-lived. In the short term, the cooling from sulfates actually outweighs the warming from carbon dioxide, meaning the net impact of the shipping and heavy industry sectors today is to cool climate.

Compare that to cars and trucks, which emit almost no sulfates but a great deal of carbon dioxide, black carbon, and ozone—all of which cause warming and happen to be very bad for human health. Cutting transportation emissions would be unambiguously good for the climate in the short term, while cutting heavy industry emissions would have less of an impact right now.

NASA: You keep mentioning "short-term" impacts. Could the climate impacts of some sectors of the economy change over longer time periods?

Unger: Yes. Greenhouse gases have a much longer *lifespan*—or residence time—in the atmosphere than aerosols, which typically rain out after a few days or weeks. This means that the impact of greenhouse gases can accumulate and intensify over time, while the aerosol effects become comparatively less important on longer time scales due to the accumulation of carbon dioxide.

NASA: You've mentioned industry, shipping, and on-road transportation. What other sectors of the economy did you analyze?

Unger: Aviation, household fossil fuels, railroads, household biofuels (mainly wood and dung used for home cooking and heating), animal husbandry, the electric power sector, waste and landfills, agriculture, biomass burning...



NASA's Goddard Institute for Space Studies scientist Nadine Unger **Credit:** NASA's Goddard Institute for Space Studies

NASA: What is *biomass burning*?

Unger: Mainly tropical forest fires, deforestation, and savannah and shrub fires. We also looked at agricultural waste burning, which relates to seasonal clearing of the fields common in many countries in Africa and South America.

NASA: So, does this mean that pollution from industry and biomass burning is good for the climate?

Unger: No, not at all. Both of those sectors contribute to warming over the long term, so we'll have no choice but to reduce our emissions over time. But these sectors do mask warming from greenhouse gases in the short term. **Just because an activity causes cooling in the short-term does not mean that it is 'good' for the climate.** The emissions might disturb other aspects of the climate system including the amount of rainfall in a region and, therefore, the water supply to humans.

NASA: Where did you get all the information about emissions?

Unger: We used emission inventories assembled by colleagues. For instance, a colleague from the University of Illinois—**Tami Bond**—has some of the best information on some types of aerosols, such as black carbon.

NASA: But how can you estimate the impacts of emissions that haven't happened yet?

Unger: We used a computer model at GISS to look at future climate impacts if we continued emitting pollutants at today's rate. Using this approach, we looked specifically at two snapshots in time: 2020 and 2100.

NASA: What can we do if we want to minimize climate change in the near term?

Unger: Well, our analysis suggests that on-the-road transportation and household biofuels are very attractive sectors to target. We can reduce human warming impacts most rapidly by tackling emissions from these sectors. In order to protect climate in the longer term, emissions from power and industry must be reduced.

NASA: Are there any uncertainties in your results?

Unger: There are. There's a large amount of uncertainty about how aerosols affect climate, especially through the indirect effects on clouds. Hopefully, NASA's Glory mission will help reduce the uncertainties associated with aerosols.

NASA: What direction do you see your research going next?

Unger: Our focus has been on global climate so far, but in future work we'll assess regional climate impacts, as well as other disturbances to the climate system, such as effects on the water supply and land ecosystems.

In addition, we plan to investigate many of the sectors in greater detail. In the power sector, for example, we might look specifically at power stations that operate with coal or natural gas. And in the on-road transportation sector, we might break out heavy- from light-duty vehicles.

Finally, we're planning to partner with environmental economists to determine the damage costs of emissions from all the sectors due to both climate and air quality impacts—results that we can use to develop alternative mitigation scenarios. ■

Blog Log

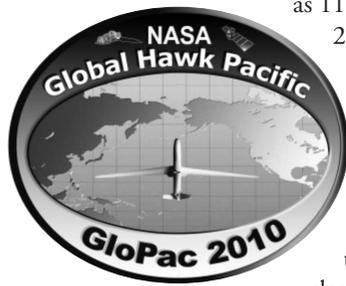
Nicole Miklus, NASA Goddard Space Flight Center, nmiklus@sesda2.com

Blog introductions modified from text on the Earth Observatory, images also from the Earth Observatory, earthobservatory.nasa.gov/blogs

In our November-December 2009 [Volume 21, Issue 6] issue of *The Earth Observer*, we introduced you to the *Blog Log*. This periodic installment features new blogs about NASA Earth science research and fieldwork and provides links where you can access the full story and view color photographs online. In this issue, we highlight two blogs and provide an update on one. We hope you'll bookmark these and check back frequently for updates. And if you know of a blog that perhaps deserves some attention (maybe your own!), please let us know.

Global Hawk Pacific (GloPac)

The Global Hawk Pacific (GloPac) mission is the first science use of NASA's new unmanned aircraft system (UAS). The Global Hawk is a robotic plane that can fly for more than 30 hours at a time, as high as 65,000 feet, and as far as 11,000 nautical miles (12,659 miles). The GloPac field campaign began in March 2010 out of NASA's Dryden Flight Research Center in CA. GloPac will consist of



four or five science flights that will take the Global Hawk over the Pacific Ocean and Arctic regions. The plane will carry ten science instruments to sample the chemical composition of stratospheric and tropospheric air and observe cloud and particle distributions in the troposphere. To read about the

campaign, go to: earthobservatory.nasa.gov/blogs/fromthefield/category/glopac/.



The *Global Hawk* is sheltered in a hangar at NASA's Dryden Flight Research Center.

Climate Q & A

The questions people have about climate change are limitless. Some are scientific, some are economic, some are political, and some are moral. Some questions have answers today, and some won't be answerable for decades. This column offers answers to some of the questions people ask about the science of global warming and climate change. Questions and answers to climate science topics that are frequently misunderstood are included, as well as questions particularly relevant to NASA Earth science research. All posts are written or reviewed by Earth and climate scientists. To check out the questions and see how much you know, go to: earthobservatory.nasa.gov/blogs/climateqa/.

Operation IceBridge Update



Sea ice is visible from the window of the DC-8 during a mission to map the ice near Canada's Ellesmere Island. **Credit:** NASA/Michelle Williams



On April 14, 2010, NASA's DC-8 flew over Summit Camp, Greenland. **Credit:** Christina Hammock

The *Operation IceBridge* blog, reported in our November-December 2009 issue, chronicles NASA's field campaign to complete the largest ever airborne survey of Earth's polar ice. The campaign began in March 2009 and has used NASA's P-3B and DC-8 research

aircrafts to measure glacier and ice sheet thickness in Greenland and Antarctica. The Arctic 2010 campaign, which runs through May, is monitoring changes in the Greenland ice sheet and Arctic sea ice. The DC-8 recently completed the first half of the campaign and now the P-3B will fly for the remainder of it. In this issue of *The Earth Observer*, **Mitchell Hobish** provides an overview of the campaign and its objectives in his article on page 4. Be sure to read it, and the *Operation IceBridge* blog at: blogs.nasa.gov/cm/blog/icebridge.blog/posts/index.html. ■

Earth Observing Missions Applications Workshop Summary

Rory Collins, Applied Sciences Program/Science Systems and Applications, Inc., rory.e.collins@nasa.gov

NASA's Earth Observing Missions Applications Workshop was held February 1-3, 2010 in Colorado Springs, Colorado. Attendees of the workshop included representatives from NASA Earth observing missions, the data user community, data centers, and academia.

The workshop focused on further developing application goals, objectives, and needs, as well as providing traceability to missions and required observations and measurements. The workshop was part of NASA's ongoing effort to better engage the applications communities early in the mission design and development processes.



John Musinsky [Conservation International], Nebeela Barbari [Department of Homeland Security—Remote Sensing], Jeanine Jones [California Department of Water Resources], and Bruce Davis [Department of Homeland Security—Geophysical Infrastructure] presented on the first day of the meeting.

Existing missions have demonstrated the value of NASA research measurements to operational users, while upcoming missions provide the opportunity to balance the science, applications, and response objectives of the missions. The workshop provided a forum to explore lessons learned from previous Earth observing missions and technical challenges to achieving the application goals. Workshop participants made recommendations that addressed strategic, organizational, and data aspects of improving end-user engagement in missions:

Strategic Recommendations

- Accelerate use of NASA data for applications and societal benefit;
- develop and maximize government, private and academic partnerships;
- organize around grand challenges in areas to be determined; and
- leverage existing activities.

Organizational Recommendations

- Integrate applications users into mission teams as early as possible;

- conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners; and
- train the next generation.

Data Recommendations

- Ensure data continuity;
- improve infrastructure to provide access to high level data products; and
- improve infrastructure to provide rapid access to data.

Participants recommended that organizing around grand challenges in areas to be determined would be a key avenue to develop better cooperation between academia, government, and business communities. They also discussed roles and responsibilities of users and other agencies, as well as their interfaces into the missions. This workshop was the first in a series of dialogues to maximize the return and minimize the cost of future missions for our national interest. ■

MODIS–VIIRS Science Team Meeting Summary

Holli Riebeek, NASA Goddard Space Flight Center, holli.a.riebeek@nasa.gov

A joint meeting of the Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imagery Radiometer Suite (VIIRS) science teams was held January 26–28, 2010, at the L'Enfant Plaza Hotel in Washington, DC. The science teams met in plenary meetings every day, as well as in discipline groups— atmosphere, land, and ocean—on January 26–27. The meeting also included poster sessions for both the MODIS and VIIRS science teams, on January 26 and 27, respectively, and a MODIS/VIIRS Calibration Workshop held at the Aerospace Building in Lanham, Maryland, on January 25. The complete meeting agenda and presentation slides for all sessions are available on the MODIS web site at: modis.gsfc.nasa.gov/sci_team/meetings/201001/.

January 26, 2010

Michael King [University of Colorado—*MODIS Science Team Leader*] opened the meeting by welcoming the science teams and providing an overview of the agenda and meeting logistics.

Paula Bontempi [NASA Headquarters—*MODIS Program Scientist*] offered a perspective from NASA Headquarters on the MODIS Science Team. She reviewed the current organization of the Science Mission Directorate and briefly discussed the status of the fiscal year 2010 budget and operating plan. For the MODIS Science Team, current and future research are focused on maintaining or refining existing data products, with an emphasis on core production; developing new data products to enable new science and applications; and using MODIS, and other Earth Observing System (EOS) data products to create new scientific understanding of Earth and new applications of knowledge for decision support. Bontempi discussed the process for reviewing new or alternate MODIS algorithms and highlighted three data products that are currently in review. Issues facing the MODIS Science Team include algorithm development and refinement, the need for tighter land, ocean, and atmosphere teams, and the role of the science community in developing a bridge to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP)¹. Upcoming funding opportunities include the EOS Recompete, known as *The Science of Terra and Aqua*, which is one element under Research Opportunities in Space and Earth Sciences (ROSES) 2009.

¹ As of February 1, 2010, the NOAA–NASA portion of NPOESS is now called the Joint Polar Satellite System (JPSS) but the name NPP is still being used for the “bridge” mission.

Jack Xiong [NASA Goddard Space Flight Center (GSFC)] gave a presentation on the status of the MODIS instruments. The MODIS instruments on both Aqua and Terra continue to work well, but constant calibration and characterization efforts are critical. All on-board calibrators continue to perform their designed functions. High quality data products continue to be developed. Preparation for *Collection 6* reprocessing is making good progress. MODIS Direct Broadcast continues to be important, with more than 150 stations worldwide. The number of science publications and applications based on MODIS data continues to grow, with 3000 journal publications on MODIS at the time of the meeting.

Claire Parkinson [GSFC—*Aqua Project Scientist*] provided an overview of the 2009 Aqua senior review. In 2009, 13 NASA Earth science missions, including Aqua and Terra, were reviewed to determine which warranted continued operation and how much funding each should receive for 2010–2013. Senior review proposals were submitted to NASA Headquarters on March 24, 2009, and Mike Freilich, [NASA Headquarters—*Director of the Earth Science Division*], notified the missions of the results on September 1, 2009. Aqua was funded at the requested optimal level.

Diane Wickland [NASA Headquarters—*Program Scientist for Terrestrial Ecology*] provided the NASA program science perspective on NPP and VIIRS. NPP is intended to continue the time-series climate data records from the Polar Operational Environmental Satellites and EOS and will be followed in the data record by NPOESS (now JPSS). NPP is also a risk reduction mission for NPOESS. The NPP Science Team's primary role is to evaluate NPP/NPOESS Environmental Data Records (EDRs) and to identify any needed improvements. NASA has developed disciplinary Earth science Product Evaluation and Analysis Tool Elements (PEATE) to support the science team's evaluation of EDRs.

Jim Gleason [GSFC—*NPP Project Scientist*] presented the status and expected science capability of NPP/VIIRS. The instruments on NPP are VIIRS, the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), the Ozone Mapping Profiler Suite (OMPS), and the Clouds and the Earth's Radiant Energy System (CERES). The VIIRS flight unit one (F1) testing program is complete, and the NASA team has completed an extensive analysis of VIIRS test data and reviewed all performance waivers. For most EDRs, the VIIRS instrument performance is expected to be good, and, with the exception of ocean

color and possibly aerosol optical depth, all EDRs will meet their operational performance requirements. NASA science requires algorithm continuity to ensure EOS data continuity. The NPP Science Team will quantify and remove all known mission-dependent biases to create a climate data record, a time series of measurements of sufficient consistency and continuity to determine climate variability and change. This will require reprocessing. The current launch data for NPP is September 2011.

Michael Freilich [NASA Headquarters—*Director of Earth Science Division*] provided an outlook from headquarters on the Earth Science Division. The President's fiscal year 2010 budget increases funding for the Earth Science Division through fiscal year 2015. Thirteen satellite missions were operating at the end of 2009. In the fall of 2009, NASA began the *Operation IceBridge* mission, which included 21 survey flights on a DC-8 over Antarctica². The first flight of NASA's *Global Hawk* was successful. Global Hawk is an unmanned aerial vehicle that will enable future flight missions over long distances. In addition eight more satellite missions are in formulation and implementation as of December 2009, including a reflight of the Orbiting Carbon Observatory (OCO-2); Glory; Aquarius; NPP; the second Ice, Clouds, and land Elevation Satellite (ICESat-2); Soil Moisture Active and Passive (SMAP); Global Precipitation Measurement (GPM); and Landsat Data Continuity Mission (LDCM).

The measurement teams met in breakout sessions on the afternoon of January 26. The **atmosphere team** discussed major *Collection 6* algorithm changes and efforts. The **land team** had a series of science presentations, and the **ocean team** had reports from the ocean biology processing group and the ocean science team.

January 27, 2010

The morning plenary session included the following talks:

Paula Bontempi provided an overview of ROSES 2009, the EOS Recompete, now titled *The Science of Terra and Aqua*. The overarching objectives are to use data and products from Terra and Aqua and to continue research—particularly research that integrates data across satellites—to answer NASA's Earth science research questions. The call specifically solicited five types of proposals: multiplatform and sensor data fusion, science data analysis, new data products, refinement of existing data products, and near or near-real-time data algorithms. Proposals were due March 25, 2010.

² *Operation IceBridge* is an ongoing mission designed to bridge the "data gap" between ICESat and ICESat-2. More flights are taking place this spring in Greenland, and others are planned for the future. For more information, see the article on page 4 of this issue.

Diane Wickland discussed the NPP science team re-competition, anticipated to be in ROSES 2010. The planned emphasis will be on long-time-series measurements for climate science and evaluation and improvement of Environmental Data Records (EDRs).

Bryan Franz [GSFC] gave a presentation titled *Advances in the Processing and Retrieval of Ocean Color from MODIS and SeaWiFS*. The ocean color team has improved agreement between satellite and *in situ* aerosol optical properties, revised the turbid-water atmospheric correction, updated Sea-viewing Wide Field-of-View Sensor (SeaWiFS) and MODIS calibrations, corrected issues with MODIS temporal drift in blue bands, improved the consistency of algorithms and calibrations between MODIS and SeaWiFS, and resolved long-standing mission-to-mission differences in oligotrophic chlorophyll.

Chris Justice [University of Maryland, College Park] discussed MODIS research and operations to VIIRS research and operations. Justice provided an overview of MODIS land products, processing, validation, and applications, and discussed the need for continuation with similar VIIRS data products. He recommended that a land science product suite from VIIRS be established and that agency partnerships on land product stewardship and long-term data records be explored.

Ping Yang [Texas A&M University] presented on *Progress in the radiative modeling of ice clouds and dust aerosols for MODIS-based remote sensing*. Yang discussed research with MODIS cloud properties, the use of MODIS cloud products to investigate tropical equatorial waves, improvements in deriving the single-scattering properties of aerosols and ice clouds, and the distribution and radiative forcing of tropical "thin" cirrus clouds.

William Balch [Bigelow Laboratory for Ocean Sciences] presented a science talk titled *Viewing the Ocean's Carbonate Cycle with MODIS* that provided a brief review of the carbonate cycle in the sea. Balch also talked about the MODIS particulate inorganic carbon (PIC) algorithm, looking at ocean PIC at different spatial scales, the global MODIS PIC record, and complex effects of ocean acidification and climate change.

The measurement teams met in breakout sessions on the afternoon of January 27. The **atmosphere team** had a series of science talks. The **land team** discussed data processing, new algorithms, and validation. The **ocean team** discussed data products, data record assessment, NPP data plans, and data characterization.

January 28, 2010

The final plenary session included two science talks and summary talks from each of the disciplines.

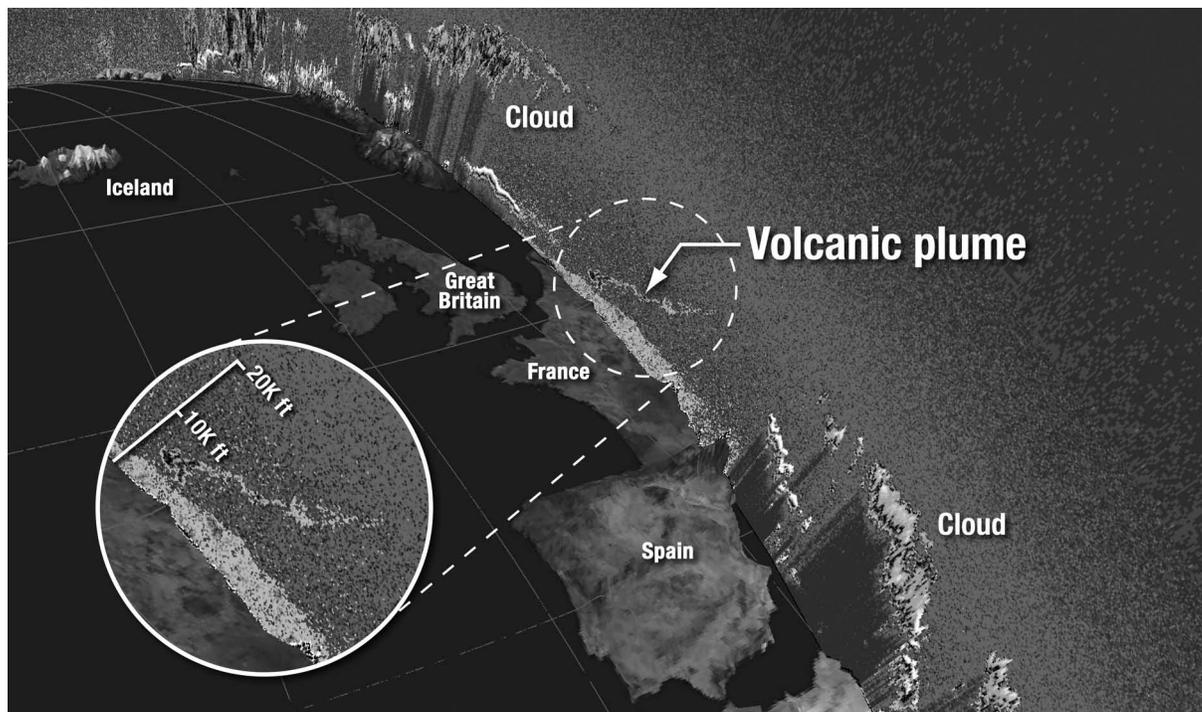
Steve Frolking [University of New Hampshire] talked about land use, disturbance, and the coupled carbon–climate system. Disturbance and land use contribute to increasing the airborne fraction of carbon dioxide. Disturbance has both anthropogenic and natural causes, can be temporary or permanent, and have a rapid or slow carbon flux. The last Intergovernmental Panel on Climate Change (IPCC) assessment report (the fourth assessment report) did not include carbon estimates from land use and disturbance, but the next assessment will include both land use history and future land use scenarios integrated into Earth System Models.

Kathleen Strabala [University of Wisconsin–Madison] presented the global impact of MODIS direct broadcast atmosphere products. Many different countries use Aqua and Terra direct broadcast products for

a wide variety of environmental applications. The free distribution of data, products, software, and visualization tools has promoted the creative use of the data.

Chuck McClain [GSFC], **Chris Justice**, and **Steve Platnick** [GSFC—*EOS Senior Project Scientist*] provided a summary of the ocean, land, and atmosphere breakout sessions, respectively.

Paula Bontempi concluded the meeting with parting thoughts. Proposals for two relevant ROSES competitions, *The Science of Terra and Aqua*, and *Remote Sensing Theory*, were due in March and April 2010. Two other calls are anticipated for 2010. Bontempi concluded with a list of noteworthy issues to be considered by the science team. ■



NASA's CALIPSO Satellite Observes Volcanic Plume

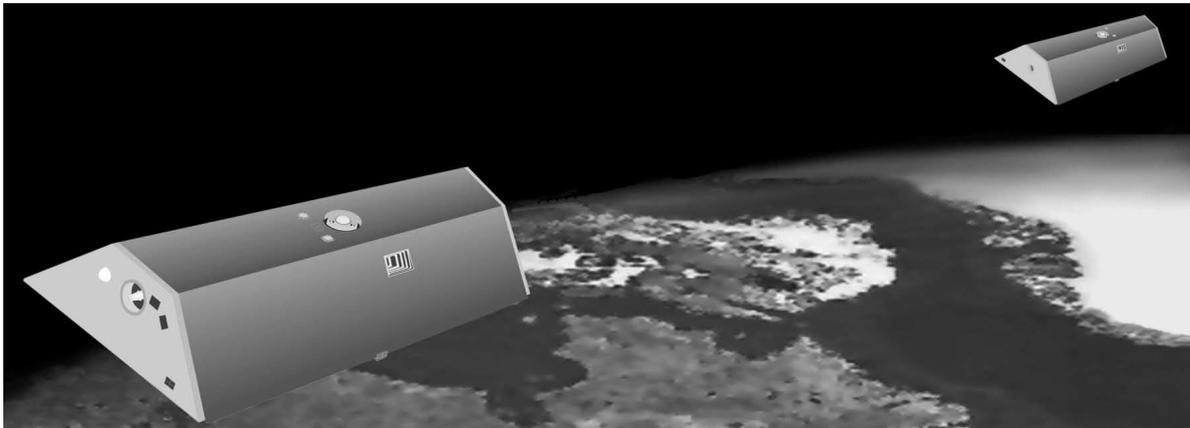
On Saturday, April 17, around 9:00 p.m. EDT, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite collected observations across Europe and captured this image of the Eyjafjallajökull ash cloud as it continued to drift over the continent. Unlike other satellites that provide a bird's-eye view of the ash cloud's horizontal spread, CALIPSO provides a unique vertical profile of a slice of the atmosphere. In this image, the ash cloud is seen as a thin, wispy layer of particles ranging in altitude from about 5,000–22,000 ft. To compare its altitude and breadth, see the clouds over Northern Europe, some of which are so thick that they block the penetration of light from CALIPSO's lidar to the surface. The layer near the surface over France is believed to be primarily air pollution.

For more information and to view this image in color, please visit: www.nasa.gov/topics/earth/features/iceland-volcano-plume-archive1.html. **Text Credit:** Patrick Lynch, NASA Langley Research Center, **Image Credit:** NASA/Kurt Severance and Tim Marvel

GRACE Science Team Meeting Summary

John C. Ries, The University of Texas at Austin, Center for Space Research, ries@csr.utexas.edu

The Gravity Recovery And Climate Experiment (GRACE), a joint NASA/German Deutsches Zentrum für Luft und Raumfahrt (DLR) Earth System Science Pathfinder (ESSP) mission, held its Science Team Meeting in Austin, TX on November 5-6, 2009. Due to commonality of goals and themes, the meeting was held the same week as a NASA Sea Level Workshop and the 2nd GRACE Hydrology Workshop in Austin. The meeting program included approximately fifty presentations and five posters, with over a hundred attendees. The meeting program and an electronic copy (pdf) of the proceedings are available at: www.csr.utexas.edu/grace/GSTM/2009/proceedings.html.



The GRACE mission consists of dual satellites with a high-accuracy inter-satellite ranging system, accelerometers, and Global Positioning System (GPS) receivers. The distance between the two satellites, nominally approximately 200 km, is measured with a precision of several microns. Microscopic variations in the distance between the two satellites can be used to infer slight changes in the gravity field of the surface below, and over the course of a month, a map of the Earth's gravity field can be created.

Byron Tapley [University of Texas Center for Space Research (UT/CSR)—*GRACE Principal Investigator (PI)*] opened the meeting on Thursday morning with welcoming remarks. Tapley addressed the mission status and the results from the 2009 NASA Earth Science Senior Review. At this review, the GRACE science was considered outstanding and the recommendation was to continue the mission until 2013.

Ab Davis [NASA/Jet Propulsion Laboratory—*GRACE Project Manager*] gave an update on the flight system status, indicating that the satellite resources are stable.

Presentations on the GRACE Science Data System (SDS) followed the opening remarks from Tapley and Davis. The Level-1 processing, which converts the raw engineering data into metric units, reported nominal processing. More than 99.9% of the raw data have been successfully retrieved, and so far, almost 3000 days of data have been distributed to the Level-2 centers. The on-board alignments were reported as stable and nominal. The Level-2 processing centers at the UT/CSR, NASA/Jet Propulsion Laboratory (JPL), and Germany's GeoForschungsZentrum (GFZ) reported on their progress in preparations for the next generation (*Release 05*) of the Level-2 gravity field products. Among the topics were improvements in the ocean tide and hydrological background modeling, alternative solution techniques (such as mascons, regularization, and windowing), Global Positioning System data processing, and the Level-1 data processing.

The remainder of the morning session focused on issues and developments related to a proposed GRACE follow-on mission. The measurements from GRACE have revolutionized our understanding of Earth's gravity field and had an impact on climate change studies, but in order to be able to confidently determine the secular mass changes associated with climate change we will have to establish a long time-series of GRACE-type gravity measurements. Two presentations examined alternative orbit scenarios, including multiple pairs of satellites in different orbits, in order to avoid the limitations associated with polar orbits. The session closed with a report on the Global Geodetic Observing System (GGOS) workshop, *Towards a Roadmap for Future Satellite Gravity Missions*, held in Graz, Austria, (For more information, please visit: www.igcp565.org/workshops/Graz/).

On Thursday afternoon, the talks focused on geodesy, and covered three main themes. Five of the presentations examined methods and modeling improvements for the extraction of the time variable gravity signal from the GRACE measurements. Two talks included comparison of the low degree gravity variations from GRACE with estimates from satellite laser ranging (SLR) or geophysical observations and models. The remaining four talks discussed the contributions of GRACE towards observing and understanding modern post-glacial rebound (PGR) or glacial isostatic adjustment (GIA).

The presentations on Friday focused on the themes of hydrology, oceanography, and the cryosphere. The morning session on hydrology opened with a summary of the 2nd *GRACE Hydrology Workshop*. At that meeting, it was recommended that standard higher-level (Level-3) products become a GRACE mission priority. The next few talks focused on using GRACE data as a tool to assist with water resources management, particularly ground water that is difficult to monitor on large spatial scales. Two talks focused on mass variations in high latitude regions, and several presentations discussed using GRACE to monitor water storage and droughts in the Amazon basin, the Southeast U.S., Australia, and Tibet.

Monitoring mass loss from the polar ice sheets and mountain glaciers has been an area of considerable interest, as it is a direct measure of the impact of climate change and provides a key measurement of the contribution of fresh water to global sea level rise. One presentation compared GRACE and Global Positioning System (GPS) measurements to relate mass loss with surface height changes in Greenland, and the results suggest that the mass loss along the ice sheet margin began spreading from the southern region up along the northwest coast 2–3 years ago. Three recent papers examined the mass balance of the Greenland and Antarctic ice sheets, and all reached similar conclusions:

1. The Greenland and Antarctic ice sheets appear to be losing mass on the order of 200 Gt/year or more;
2. there is clear evidence of acceleration and spreading of the mass loss in Greenland; and
3. there is evidence that East Antarctica may now also be losing mass and accelerating the mass loss in Antarctica.

The remaining presentation compared radar altimetry with GRACE to conclude that both show consistent patterns in trends and interannual variations, giving confidence in either result and opening new ways of synthesis.

Friday afternoon's presentations focused on oceanography, and began with a summary of the *NASA Sea Level Workshop*. At that workshop, it was noted that the loss of land ice will become increasingly important for sea level rise. Consequently, there was significant concern about the loss of mass change measurements with no GRACE follow-on mission¹ in the immediate future, as well as the gap between the ICESat and ICESat-2 missions². The next five presentations addressed GRACE applications for studying the Arctic ocean's circulation, tides, geoid, and ocean bottom pressure variations. The next few presentations discussed rapid (less than ~60 days) ocean bottom pressure variations, comparison of global ocean tide models to GRACE data, and ocean mass trends from GRACE. The final presentation presented a global evaluation of ocean bottom pressure from GRACE, the Ocean Model for Circulation and Tides (OMCT), and altimetry. It was shown that the GRACE data clearly agree better with ocean bottom pressure from steric-corrected altimetry than the model. ■

¹ **UPDATE:** The President's proposed FY'11 budget, sent to Congress in February, proposed allocating funds to begin work on a GRACE follow-on mission targeted for a 2016 launch.

² *Operation IceBridge* is seeking to bridge the "data gap" between ICESat and ICESat-2. For more details, see the feature article on page 4 of this issue.



Snapshots from the GRACE Science Team Meeting

[*Top Left*] **Byron Tapley** [UT/CSR—GRACE PI] and **John Labrecque** [NASA Headquarters—*Program Manager for Solid Earth & Natural Hazards*] converse during a break.

[*Top Center*] **Himanshu Save** [UT/CSR] describes his poster to **Shin-Chan Han** [Ohio State University]; **Gerard Kruizinga** [JPL] watches in the background.

[*Top Right*] **Nadege Pie** [UT/CSR] and **Jennifer Bonin** [UT/CSR] converse during the poster session.

[*Bottom*] The group poses for a photo.



NASA's GRACE Sees Rapid Spread in Greenland Ice Loss

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Isabella Velicogna, Jet Propulsion Laboratory, California Institute of Technology, Isabella@uci.edu

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To view full release, please visit: www.colorado.edu/news/r/f595fae00e6b451d4016ab9a43a049f8.html

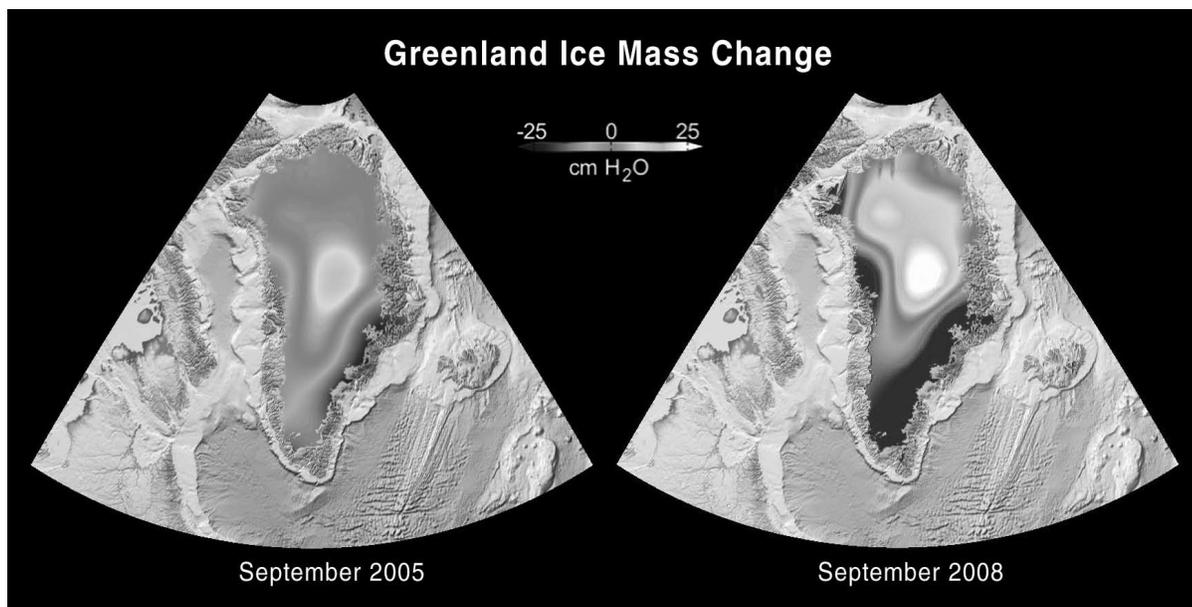
A new international study finds that ice losses from Greenland's ice sheet, which have been increasing over the past decade in its southern region, are now spreading rapidly up its northwest coast.

The researchers, including **Isabella Velicogna**, jointly of NASA's Jet Propulsion Laboratory, and the University of California, Irvine, compared data from the JPL-built and managed Gravity Recovery and Climate Experiment (GRACE) mission with continuous GPS measurements made from long-term sites on bedrock on the ice sheet's edges. The GRACE and Global Positioning System (GPS) data gave the researchers monthly averages of crustal uplift caused by ice mass loss. They found that the acceleration in ice loss began moving up the northwest coast of Greenland in late 2005. The authors speculate the dramatic ice mass losses on

Greenland's northwest coast are caused by some of the big glaciers in the region sliding downhill faster and dumping more ice into the sea.

"These changes on the Greenland ice sheet are happening fast, and we are definitely losing more mass than we had anticipated," says Velicogna. "We also are seeing this trend in Antarctica, a sign that warming temperatures really are having an effect on ice in Earth's cold regions."

The NASA/National Science Foundation-funded study was led by **Shfaqat Abbas Khan** of the Denmark Technical Institute's National Space Institute in Copenhagen. Other participating institutions included the University of Colorado at Boulder and the Ohio State University. ■



Changes in Greenland's ice mass as measured by NASA's Gravity Recovery and Climate Experiment (GRACE) mission between September 2005 [left] and September 2008 [right]. To view this image as a color animation, please visit: jpl.nasa.gov/news/news.cfm?release=2010-100.

Image credit: NASA/JPL

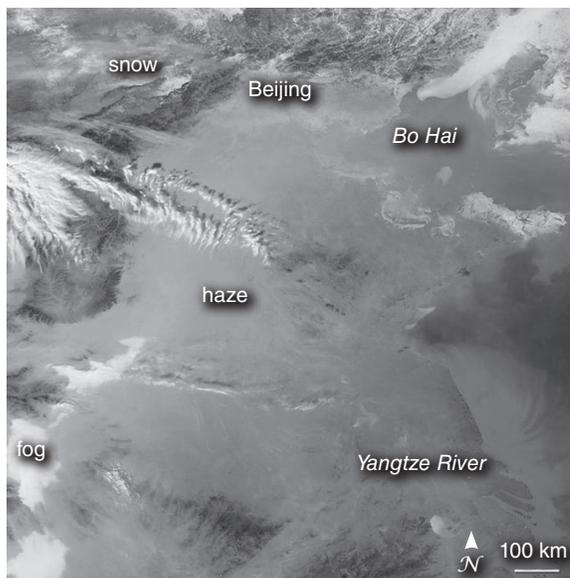
NASA Satellite Data Helps Everyone Breathe a Little Easier

Rory Collins, NASA Langley Research Center, rory.e.collins@nasa.gov

Feeling a little ill? Step outside for some fresh air.

But before you do, you may want to check the latest NASA data about what, exactly, is in the air we breathe.

NASA-funded scientists and medical researchers are working together to tackle the problems of public health associated with bad air quality. Bad air quality can contribute to and aggravate asthma, bronchitis, high blood pressure, and stroke—to name a few. Air quality-related health problems result in hospital visits that cost taxpayers millions of dollars annually.



Haze blanketed Beijing, China, on January 18, 2010, when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this image. **Credit:** NASA

RAND study: Air pollution costs \$193 million in hospital visits.

NASA is using data intended for weather and climate research to help pinpoint how environmental factors such as aerosol levels in the atmosphere impact cardiovascular health. Aerosols are solid and liquid particles suspended in the atmosphere, and can occur naturally or get emitted by human activities such as burning fossil fuels.

Scientists measure aerosols, also called particulate matter (PM), by their size. The smallest particles—less than 2.5 microns in diameter ($PM_{2.5}$)—are the worst for human health because they can make their way into the lungs or bloodstream and exacerbate cardiovascular problems, especially in very young and elderly populations.

The ability to detect these microscopic particles (often found in smoke and haze) is helping public health researchers better document the health risks for the general population and specifically at-risk populations.

Yang Liu, a researcher at Emory University, first realized that NASA satellite data could enhance public health tracking while attending a 2007 NASA workshop where scientists from the Center for Disease Control (CDC) presented an overview of a newly formed tracking network.

The National Environmental Public Health Tracking Network was created in 2002 as a cooperative program to find and document links between environmental hazards, such as aerosols, and diseases. The network uses ground-based air pollution data provided by the Environmental Protection Agency (EPA), and disease information from the CDC to monitor and distribute information about environmental hazards and disease trends, as well as develop a strategy to combat these trends.

Since the workshop, Liu has been working with NASA to integrate data from two instruments, the Multi-angle Imaging SpectroRadiometer (MISR) (onboard the NASA Terra satellite) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (onboard NASA's Terra and Aqua satellites) into the tracking network. Both MISR and MODIS are used to monitor tropospheric aerosols.

"NASA satellites allow faster observations with a wider view to increase our understanding of the connections between $PM_{2.5}$ and illnesses," said Liu. "We can essentially provide more timely estimates of harmful aerosol concentrations."

Until recently, ground-based air quality monitoring has been the only data source for estimating exposure to aerosols. However, even in the U.S., the networks are spread out and the coverage is limited by high operating costs. By incorporating NASA satellite information, federal, state, and local agencies will be better prepared to develop and evaluate effective public health actions.

Liu explains that "Satellites have both wide spatial coverage and long mission lives, so a satellite measuring the quantity of small aerosol particles over a larger area can supplement ground-based measurements and do so over a longer period of time."

NASA's contribution to public health does not stop there, however. NASA also has been working with researchers at the University of Alabama at Birmingham (UAB) to determine how atmospheric conditions contribute to cardiovascular disease in African Americans. Past research has shown that group to have a higher risk of contracting cardiovascular disease, hypertension, and other environmentally related diseases.

UAB has been working for six years on a public health study called Reasons for Geographic and Racial Differences in Stroke (REGARDS). Funded by the National Institutes of Health, REGARDS researchers recorded blood pressure, took blood samples, and asked detailed health questions of more than 30,000 people, particularly African Americans, from January 2003–October 2007. The study focused on the so-called *Stroke Belt*, the area in the southeastern U.S. where incidents of stroke are 1.5 times the national average.

The REGARDS program is now working with colleagues at NASA to integrate satellite data on temperature, humidity, particulate matter in the air, and other environmental elements, to understand the connections between the atmosphere and human health.

“We can merge the REGARDS data with our data from MODIS,” said **Mohammed Al-Hamden**, a co-lead on the project and a scientist at NASA's Marshall Space Flight Center. “We examine the statistical relationships

between these diseases and the air quality and climate where these people live. With the wide spatial coverage of satellite measurements, we can better help health officials with environmental alerts and health recommendations.”

Bill Crosson, the other NASA lead on the REGARDS project, says the value of integrating NASA data is “that the data comes quickly and more frequently—daily instead of weekly so we can provide it to the people who really need it.”

The regional study has been so successful that it has recently expanded to the entire nation, with the information that NASA provides being integrated into a CDC database of public health records, called the Wide-ranging Online Data for Epidemiological Research (WONDER). NASA and UAB researchers are expanding the subject of the study along with its geographic range. Researchers are now exploring the connection between harmful particulate matter and cognitive decline, including memory, attention span, as well as reading and listening comprehension.

With these two NASA-sponsored projects, public health officials are improving air quality forecasts, preparing hospitals for air quality-related health problems, and perhaps preventing health problems in the future by warning the public about the potentially harmful effects of aerosols. ■



On April 29, 2010, the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite captured a wide-view image of an oil slick just off the Louisiana coast. The oil appears as interlocking comma shapes, one opaque and the other nearly transparent. *Sun glint*—the mirror-like reflection of the sun off the water—enhances the oil slick's visibility. The northwestern tip of the oil slick almost touches the Mississippi Delta. The oil spill resulted from an explosion that occurred on April 20, 2010, on the *Deepwater Horizon* rig. *The New York Times* reported that two days after the explosion, the rig sank to the ocean floor and a pipe connected to the well on the sea floor broke, causing oil to leak from the pipe. For additional information on NASA's response to the Gulf oil spill, see page 3 of this issue. To view this image in color, please visit: earthobservatory.nasa.gov/IOTD/view.php?id=43846. **Credit:** NASA's Earth Observatory



EOS Scientists in the News

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

Ice Losses in Antarctica Move South, February 24; *Discovery News*. Data show ice shelves are now disappearing all along the Antarctic Peninsula, including the southern, colder part—a trend that **Eric Rignot** (NASA JPL) says is consistent with the changing air temperatures.

Arctic Arch Failure Leads to Sea-Ice Exodus, February 26; *New Scientist*. A team led by **Ronald Kwok** (NASA JPL) has studied satellite images of the Nares Strait—the narrow passage between Greenland and Ellesmere Island—and found that the curved barriers of ice spanning the strait are failing to form, which contributes to an exodus of sea ice from the Arctic Ocean.

Iceberg Breaks in Antarctica Not Where Expected, February 27; *Associated Press*. A big chunk of ice, slightly smaller than Oahu, broke off from the cooler eastern end of Antarctica; **Robert Bindshadler** (NASA GSFC) says while the event is probably nothing to worry about, it serves as reminder that it's not all about West Antarctica.

How Chile's Quake Could Have Shortened a Day, March 4; *BBC News*. Researcher **Richard Gross** (NASA JPL) and his colleagues calculated that the 8.8-magnitude quake in Chile could have cut 1.26 microseconds off the length of a day.

NASA Finds Shrimp Dinner Beneath Antarctica, March 15; *The Associated Press*. Scientists including **Robert Bindshadler** (NASA GSFC) found a shrimp-like creature and a jellyfish frolicking beneath a massive Antarctic ice sheet.

NASA Heads to Arctic to Measure Ice, March 22, *Discovery News*. **Lora Koenig** (NASA GSFC) and **Michael Studinger** (GEST/UMBC) are among a 35-member team of scientists, engineers, technicians and aircraft crew that arrived in Greenland in March for *Operation IceBridge*—a planned five-week field mission to collect information about polar ice. For more information on *Operation IceBridge* see the article on page 4 of this issue.

Seismologists at JPL and Wisconsin Update 20-Year-Old Model That Shows Where the Next 'Big One' Could Hit, March 24; *Pasadena Star-News*. **Donald Argus** (NASA JPL) and **Chuck DeMets** (University of Wisconsin-Madison) teamed up in 1990 to create a model of the Earth's 25 major tectonic plates, and they

have now teamed up again to update that model and show where the next "Big One" could hit.

More Africanized Bees Found in Southern Utah, March 24; *The Associated Press*. About 100 colonies of Africanized honey bees have been found in southern Utah in the year since the bees' arrival was announced, and the state is of interest to researchers including **Wayne Esaias** (NASA GSFC).

El Niño Ocean Warming May be Cooling Off, March 26; *Earthweek*. "Since June 2009, this El Niño has waxed and waned, impacting many global weather events," said oceanographer **Bill Patzert** (NASA JPL), and it may be weakening sometime soon, possibly followed by a La Niña.

Greenland Ice Loss Accelerating, March 27; *Softpedia*. New research by **Isabella Velicogna** (NASA JPL) and colleagues used satellite and *in-situ* GPS measurements to determine that Greenland is beginning to lose its ice sheets faster and also over more widespread regions than in the past decade. For more information on this topic see the article on page 25 of this issue.

Gulf Stream 'Is Not Slowing Down,' March 29; *BBC News*. The Gulf Stream does not appear to be slowing down, say U.S. scientists including **Josh Willis** (NASA JPL) who have used satellites to monitor tell-tale changes in the height of the sea.

Students Armed with Climate Facts, April 1; *La Ciénaga Valley Sun*. Scientists including **Michael Gunson** (NASA JPL) attended the Jet Propulsion Laboratory's second annual Climate Day event at the Pasadena Convention Center, attended by more than 1,400 children and 120 educators; Gunson manned the exhibit of JPL's Orbiting Carbon Observatory.

NASA Flies Over Arctic to Check Out Climate Change, April 2; *Central Florida News 13*. When it comes to monitoring the world's climate change, one thing NASA closely looks at is ice in the Arctic; News 13's Janelle Jordan talked with scientist **Tom Wagner** (NASA HQ) live from Maryland to find out what it all means.

Scientists' Use of Computer Models to Predict Climate Change is Under Attack, April 6; *Washington Post*. The computer models used to predict climate change are far more sophisticated than the ones that forecast the weather, elections, or sporting results; cli-

mate scientists including **Gavin Schmidt** (NASA GISS) say that while their models are imperfect, they still provide invaluable glimpses of change to come.

Climate Scientist Hansen Wins \$100,000 Prize, April 7; *Reuters*. U.S. climate scientist **James Hansen** (NASA GISS) recently won a \$100,000 environmental prize for decades of work trying to alert politicians to what he called an unsolved emergency of global warming. For more on this see the Kudos on page 10.

NASA Satellites Monitor Icelandic Volcano, April 8; *United Press International*. U.S. space agency scientists say they are closely monitoring the eruption of the Eyjafjallajökull volcano in Iceland that was first detected by satellites; if this eruption is preceding another larger eruption at the Katla (or Katia) volcano nearby, then NASA will be poised to provide imaging data of activity as the eruption evolves, according to **Ashley Davies** (NASA JPL).

Navy Submarine Runs Eternally on Thermal Power from Ocean Currents, April 8; *Popular Science*. Scientists have built an engine that uses the energy of the ocean to derive a practically limitless energy supply; **Yi Chao** (NASA JPL) said a fleet of thermal-engine-powered floats could provide oceanographers with constant data about ocean salinity, pH, and other variables, while bigger floats could even accommodate hydrophones or cameras that can venture deep into the ocean.

It's Back Down to Earth for NASA Scientists, April 9; *CBS, WJZ 13*. At NASA's Goddard Space Flight Center in Greenbelt, MD, Earth science is the focus and now it's the Obama administration's focus as well; **Peter Hildebrand** (NASA GSFC) explains how the focus on Earth science has changed morale and the work ahead.

NASA Begins Science Flights with Robotic Jet, April 14; *The Associated Press*. One of NASA's newest research jets soared high over the Pacific Ocean on April 13 during a 24-hour mission to study Earth's atmosphere, and **Paul Newman** (NASA GSFC) explains the science and goals of the mission.

NASA Drone Embarks on Science Flights, April 14; *BBC News*. An unmanned aircraft, operated by NASA, has successfully started flying scientific research missions over the Pacific Ocean, and **Ken Jucks** (NASA HQ) describes the advantages of using the aircraft for Earth science.

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. ■

Public Release of Aura-OMI Global Gridded (Level-3) Atmospheric NO₂ Product

The atmospheric nitrogen dioxide (NO₂) is an important trace gas in the Earth's atmosphere. It plays a major role in the destruction of ozone in the middle stratosphere and production of ozone in the lower troposphere. In the stratosphere, NO₂ is mainly produced by photo-dissociation of the NO₂ reservoir species. In the lower troposphere and near surface, the primary sources of NO₂ production are industrial and automobile combustion processes and biomass burning. These sources, together with emission from the soil, account for most of the NO₂ in the atmosphere.

The Aura Ozone Monitoring Instrument (OMI) daily global gridded *Level-3* NO₂ Product *OMNO2e* has been released and is now publicly available (disc.sci.gsfc.nasa.gov/Aural/data-holdings/OMI/omno2e_v003.shtml) from the NASA's GSFC Earth Sciences (GES) Data and Information Services Center (DISC).

The *OMNO2e* data product provides daily NO₂ data averaged at 0.25 x 0.25° global grids. Only those observations are averaged that are either cloud free or where cloud fraction is less than 30%. The product contains two column values of NO₂: total NO₂ column and tropospheric NO₂ column.

This Global Gridded NO₂ product joins a number of other OMI *Level-3* atmospheric products processed and already released by the U.S. OMI Science Investigator-led Processing System (OSIPS). Products include Total Column Ozone, Aerosol Optical Thickness, Aerosol Index, Aerosol Single Scattering Albedo, UV-B Surface Irradiance, and Erythral Daily Dose. These are available from the GES DISC OMI site at: disc.sci.gsfc.nasa.gov/Aural/data-holdings/OMI/.

For the full set of Aura data products available from the GES DISC, please see disc.sci.gsfc.nasa.gov/Aural/data-holdings/ or go directly to the data search and download system at mirador.gsfc.nasa.gov/. Online data analysis capabilities are available from the GES DISC Giovanni site at: giovanni.gsfc.nasa.gov/.

NASA Science Mission Directorate – Science Education Update

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New NASA Web Site Sheds Light on Science of a Warming World

Will 2010 be the warmest year on record? How do this year's recent "Snowmageddon" winter storms in the U.S. and record low temperatures in Europe fit into the bigger picture of long-term global warming? NASA has launched a new web page to help people better understand the causes and effects of Earth's changing climate.

The new *A Warming World* page hosts a series of new articles, videos, data visualizations, space-based imagery, and interactive visuals that provide unique NASA perspectives on this topic of global importance. The page includes feature articles that explore the recent Arctic winter weather that has gripped the United States, Europe, and Asia, and how El Niño and other longer-term ocean-atmosphere phenomena may affect global temperatures this year and in the future. A new video, *Piecing Together the Temperature Puzzle*, illustrates how NASA satellites monitor climate change and help scientists better understand how our complex planet works.

The new web page is available on NASA's Global Climate Change Web site at: climate.nasa.gov/warmingworld.

Eight My NASA Data Lesson Plans Passed NASA Product Review

Eight more of the exciting lessons in the *MY NASA DATA* lesson collection have passed the NASA Earth and space science education product review. To pass this review, a lesson must be approved by a panel of both scientists and educators, and be revised as necessary to meet their recommendations. The following lessons have passed:

- **Lesson 26**, "Using Vegetation, Precipitation, and Surface Temperature to Study Climate Zones," by Krista L. Gerhardt, Huber Heights, OH;
- **Lesson 28**, "Solar Cell Energy Availability From Around the Country," by Teri Rowland, Sheridan, WY;
- **Lesson 27**, "Correlation of Variables by Graphing," by Susan Batson, Pittsburgh, PA;
- **Lesson 34**, "Ocean Impacts of an El Niño Event," by Missy Holzer, Chatham, NJ;
- **Lesson 36**, "Identifying Ozone Variations Over Different Locations," by Eugene Cordero, San Jose State University, San Jose, CA;
- **Lesson 37**, "Variables Affecting Earth's Albedo," by Carl F. Katsu, Fairfield, PA;
- **Lesson 43**, "Differences Between Ground and Air Temperatures" by Tara Kisiel, Chicopee, MA; and
- **Lesson 52**, "Phytoplankton in the Gulf of Maine," by Margaret Morton, South Bristol, ME.

As you use the lessons, don't forget to submit your comments with the *Teacher Feedback* button located on each lesson's front page. If you have developed a lesson or activity incorporating *MY NASA DATA* microsets, please consider sharing it for possible posting on the site. Browse the *MY NASA DATA* lesson plans via: mynasadata.larc.nasa.gov/lessons.html. Learn more about the NASA education product review via: nasareviews.strategies.org/.

Piecing Together the Temperature Puzzle: NASA Earth Science Video

As NASA scientists improve their understanding and predictions about climate change, NASA satellites provide critical data about what's happening on our planet today—real-life observations scientists use to hone their predictions. And NASA gets a global view of three major pieces of the climate puzzle: how much of the sun's energy is hitting the Earth, how much of that energy is reflected back out into space, and how much is being trapped, heating the planet. Read the transcript, or view the video at: www.nasa.gov/multimedia/podcasting/temperature-puzzle.html.

Celebrate Spring With the Project BudBurst Field Campaign

The 2010 field campaign for *Project BudBurst* is officially underway. *Project BudBurst* is a national field campaign for students, families, and other volunteers. *Project BudBurst* is designed to engage the public in the collection of important climate change data based on the timing of leafing and flowering of trees and flowers. Over the past three years, thousands of people of all ages participated by taking careful observations of the phenological events, such as the first flower, first leaf, and seed or fruit dispersal of a diversity of tree and flower species, including weeds and ornamentals. Your help in making observations and sharing information about *Project BudBurst* will help in making this year's campaign even more successful. For more information, please visit: www.budburst.org. ■

EOS Science Calendar | Global Change Calendar

June 8–11, 2010

ASTER Science Team Meeting, Tokyo, Japan.

September 27–30, 2010

Aura Science Team Meeting, Boulder, CO.

November 11–12, 2010

GRACE Science Team Meeting, Potsdam, Germany.
URL: www.csr.utexas.edu/grace/GSTM/

June 8–12, 2010

International Polar Year Oslo Science Conference 2010, Oslo, Norway. URL: www.ipy-osc.no/

June 24–27, 2010

American Meteorological Society 38th Conference on Broadcast Meteorology, Miami, FL. URL: www.ametsoc.org/meet/fainst/201038broadcast.html

June 28–July 2, 2010

13th Conference on Cloud Physics/13th Conference on Atmospheric Radiation, Portland, OR. URL: www.ametsoc.org/MEET/fainst/201013atmosrad13cloudphysics.html

July 12–16, 2010

ESRI International User Conference, San Diego, CA.
URL: www.esri.com/events/user-conference/index.html

July 25–30, 2010

2010 IEEE International Geoscience and Remote Sensing Symposium, Honolulu, HI.
URL: www.igarss2010.org/

August 8–13, 2010

AGU Meeting of the Americas, Iguassu Falls, Brazil.
URL: www.agu.org/meetings/ja10/

October 2–7, 2010

35th Annual Meeting of the National Weather Association, Marriott University Park Hotel, Tucson, AZ.
URL: www.nwas.org/events.php

October 25–28, 2010

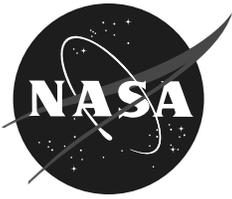
International Symposium on the A-Train Satellite Constellation 2010, Sheraton Hotel, New Orleans, LA.
URL: a-train-neworleans2010.larc.nasa.gov/

November 16–20, 2010

2010 National Association for Interpretation National Interpreters Workshop, Las Vegas, NV.
URL: interpnet.com/workshop/

January 27–28, 2011

International Year of Chemistry (IYC), Opening Ceremony: *Chemistry—Our life, Our future*, UNESCO HQ, Paris, France. URL: www.chemistry2011.org/



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