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NASA: Supporting Earth System Science 2005





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Applications of Earth System Science Data from the NASA Science Mission Directorate

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NASA Distributed Active Archive Centers
http://nasadaacs.eos.nasa.gov

Cover Images

Front

Clockwise from top left:

1. Students line up for school meals, made with locally produced foods, at Bar Sauri Primary School in the Millennium Village at Sauri, Kenya. (Image courtesy of Glenn Denning)

2. El Elegante Crater, part of the Pinacate Biosphere Reserve in northwestern Sonora, Mexico, is a maar crater about 1.6 kilometers (1 mile) in diameter and 244 meters (800 feet) deep. (Image courtesy of Jim Gutmann)

3. The Slender Loris (*Loris tardigradus*) from Sri Lanka is assessed as endangered and is on the World Conservation Union's 2004 Red List of Threatened Species. Habitat fragmentation over the years has seriously reduced the area available for this species. Between 1956 and 1993, Sri Lanka lost more than 50% of its forest cover to human activities, followed by a similar rate of decline in the remaining forest cover between 1994 and 2003. (Image copyright K.A.I. Nekaris)

4. The Qinghai-Xizang railroad, scheduled to be completed in 2007, will traverse some of the most desolate landscape on the Tibetan Plateau. (Image courtesy of Richard Armstrong)

5. An *Anopheles* mosquito takes blood from a human host. This mosquito is a vector for malaria, which kills more than a million people each year in over 100 countries and territories. (Image courtesy of James Gathany and the Centers for Disease Control and Prevention)

Back

The Multi-angle Imaging SpectroRadiometer (MISR) instrument captured this image of an actinoform cloud on November 16, 2001. The identification of this unusual cloud formation, which looks very much like a leaf, prompted a search for more examples of this cloud type in the MISR data. (Image courtesy of NASA/GSFC/LaRC/JPL, MISR Team)

Acknowledgements

We extend our gratitude to the Earth Science Data and Information System (ESDIS) project for its support of this publication; to the DAAC managers and User Services personnel for their direction and reviews; and to the DAAC scientists who alerted us to the research and investigations that made use of DAAC data in 2005. A special thanks goes to the investigators whose accomplishments we are pleased to highlight here.

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Supporting Earth System Science 2005 is also available online in PDF format at: http://nasadaacs.eos.nasa.gov/articles/index.html.

For additional print copies of this publication, please contact: nasadaacs@eos.nasa.gov.

Researchers working with NASA DAAC data are invited to contact the editor of this publication at daaceditor@nsidc.org to explore possibilities for developing a future article.

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The design featured at the end of the articles throughout this edition is one of many African symbols, called adinkra. The symbols are prevalent in the country of Ghana, located on the Atlantic coast of Africa between the Cote d'Ivoire and Togo. The adinkra symbols can be found in cloth, pottery, and on walls, and they reflect a system of human values that embrace family, integrity, tolerance, harmony, determination, and protection. The Denkyem (crocodile), the symbol featured in this edition, represents adaptability, based on the fact that the crocodile lives in the water, yet breathes the air, demonstrating an ability to adapt to changing circumstances.

Using newly-updated population data sets archived at the NASA DAACs, scientists are working to develop solutions to problems that threaten human populations in Africa, including hunger and poverty and the spread of malaria (see *Malaria by the Numbers*, page 6, and *War on Hunger*, page 31).

Symbol courtesy of:
West African Wisdom: Adinkra Symbols & Meanings
http://www.welltempered.net/adinkra/index.htm

Earth Science Data and Information Systems Project
National Aeronautics and Space Administration
Goddard Space Flight Center
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Dear Friends and Colleagues:

From space, we can view our Sun and Earth as a whole system, observe the results of complex interactions, and begin to understand how both natural and human-induced changes can impact life here on Earth.

NASA's Earth Observing System Data and Information System (EOSDIS) generates more than 2,400 Earth system science data products and provides associated services to researchers involved in interdisciplinary studies. EOSDIS manages and distributes these products through the Distributed Active Archive Centers (DAACs). These nine data centers process, archive, document, and distribute data from NASA's past and current Earth System Science research satellites and field programs. Each data center serves one or more specific Earth science disciplines and provides its science, government, industry, education, and policymaker communities with data information, data services, and tools unique to its particular science discipline.

This publication attempts to bring satellite science down to Earth. NASA: Supporting Earth System Science 2005 showcases recent research conducted using data from the NASA EOSDIS data centers. These unique articles incorporate data from multiple sensors and across data centers. We focus on what scientific results mean with a global perspective—now, and in the long term—for Earth and its inhabitants. With these stories, we hope to acquaint you with the wealth of resources available through the DAACs.

Jeanne Behnke
Earth Science Data and Information Systems Project
NASA Goddard Space Flight Center

NASA: Supporting Earth System Science 2005

The rushing waters of the 2004 tsunami approach the shore in Thailand. (Image courtesy of David Rydevik, Stockholm, Sweden)

Making Waves in Tsunami Research

Physical Oceanography DAAC

by Amanda Leigh Haag

It was pure coincidence that in the early morning light of December 26, 2004, within hours of the 9.0 earthquake that shook the floor of the Indian Ocean, two joint NASA/French Space Agency satellites watched from high overhead while tsunami waves silently raced across the Bay of Bengal. Half a world away, U.S. Geological Survey geophysicist Peter Cervelli came home from a Christmas dinner with friends to find seismometer readings heralding ominous news.

Sadly, scientists had no way to warn officials or the public about the deadly force that was minutes away from surging ashore. More than 220,000 lives were lost to the tsunami.

Today, scientists are gathering data from a variety of sensors in an effort to reconstruct the event and see what lessons they can learn from it. Serendipitously, as the tsunami waves were rolling toward the shore, the "Jason" and "TOPEX/Poseidon" satellites recorded the height changes of the waves as they formed—the first detailed measurements of their kind during a major tsunami.

While satellites cannot provide an early warning, their data hold great promise for helping scientists improve computer models of wave behavior during tsunamis. Scientists say that better models will be the first line of defense against the havoc tsunamis can cause on coastal areas. The data obtained from Jason and TOPEX/Poseidon—archived at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) in Pasadena, California—are enabling scientists to look at the mechanisms that produced the killer waves in the Indian Ocean.

"This kind of first-hand knowledge is helping researchers better understand how waves propagate in the ocean, so they can refine their ability to pinpoint where the wave is going to crash over beaches and with how much energy." - Lee-Lueng Fu

Jason and TOPEX/Poseidon are assembling a global, long-term record of sea surface height, which is helping scientists better understand ocean circulation and climate variability. Sea surface height reflects the storage of heat in the ocean: when the ocean warms, it expands, thus raising the sea level, explained Lee-Lueng Fu, chief scientist of the satellite missions from NASA's Jet Propulsion Laboratory in Pasadena.

But detection of the recent tsunami is a good example of their secondary benefits, said Fu. "This happened by chance, because the satellites were not designed to make observations of waves moving as fast as a tsunami, which attain the speed of a jet plane in the open ocean," said Fu. "At 500 miles per hour, the waves are moving very quickly and are very hard to detect."

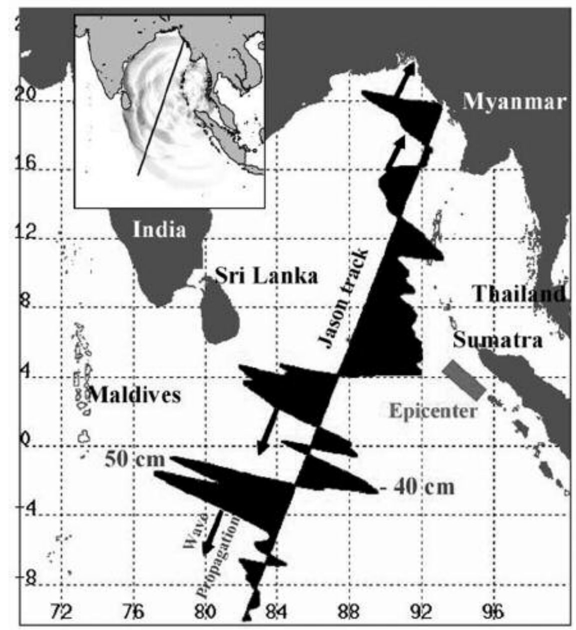
Since the satellites make 13 revolutions around Earth each day, the probability of catching a tsunami in the way that Jason and TOPEX/Poseidon did is about one chance in 50, said Fu. But their ability to detect minute changes in sea surface height enabled them to spot subtle changes in the wave behavior.

When the tsunami passed through the Bay of Bengal, the satellites picked up a sea height change of half a meter, which is a huge signal, according to Fu. "This kind of first-hand knowledge is helping researchers better understand how waves propagate in the ocean," he said, "so they can refine their ability to pinpoint where the wave is going to crash over beaches and with how much energy."

To make their measurements, Jason and TOPEX/Poseidon continually bounce radar pulses off the sea surface and record the time it takes for the signal to return. Each radar pulse gives a measure of the satellites' exact location and altitude above the sea surface. Using these measurements, scientists can also calculate the velocity at which ocean currents are moving.

Jason is the satellite credited with making such precise measurements of the recent tsunami event, according to Fu. Its observations included detailed ripples—on the order of 10 centimeters (about 4 inches) high—spread over a 200-kilometer (124-mile) area. Previously scientists believed tsunamis to be single, fast-moving elevations of the sea surface over a span of several hundred kilometers, according to Fu. Such movement would be akin to the simple rhythmic rise and fall of taking in a deep breath and expelling it. But scientists have learned from Jason's recent observations that tsunami waves in the open ocean are more complicated than that. "This kind of measurement is telling us that a tsunami has a much more complex structure than we used to think," said Fu.

Fu is quick to point out, however, that satellites will never be able to provide a warning system from space because the cost of deploy-



The black areas along the axis labeled "Jason track" represent sea surface height measured by the Jason satellite two hours after the initial magnitude 9 earthquake hit the region southeast of Sumatra (shown in red) on December 26, 2004. The data were taken by a radar altimeter onboard the satellite along a track traversing the Indian Ocean when the tsunami waves had just filled the entire Bay of Bengal. The maximum height of the leading wave crest was about 50 cm (1.6 ft), followed by a trough of sea surface depression of 40 cm (1.3 feet). The arrows indicate the directions of wave propagation along the satellite track. (Image courtesy of NASA/JPL/CNES/National Institute of Advanced Industrial Science)

A building destroyed during the Hilo, Hawai'i, tsunami on April 1,1946. Every house on the main street facing Hilo Bay was washed across the street and smashed against the buildings on the other side. (Image courtesy of NOAA and the U.S. Army Corps of Engineers)

ing enough satellites to be at any given point over the ocean within half an hour is prohibitive. "I don't want to give people the impression, 'oh, we caught this tsunami, therefore we should launch more satellites to catch tsunamis.' We just cannot afford to do that," said Fu. Moreover, since Jason and TOPEX/Poseidon data take a minimum of five hours to process, there is a low likelihood of using their data in time to warn coastal residents of an approaching tsunami. But in the rare case that the satellites do record the profile of a tsunami, they provide excellent hindsight because they have a continuous profile of the sea surface height change. "There's no other measurement that can produce such a record," said Fu. Ocean buoys, which are often separated by more than 500 kilometers (about 310 miles), don't record a continuous profile.

The key for early warning is to have more bottom-mounted pressure sensors in the ocean, according to Fu. But experts agree that even having such scientific instrumentation in place won't be sufficient if the communication and education components of a warning system are missing, as was the case on December 26. Cervelli, who's based at the Alaska Volcano Observatory in Anchorage, recalled the moment on Christmas night when the seismometer readings came in. "I remember thinking to myself, 'this is going to create a large tsunami that is going to kill a lot of people,'" he said. "Hundreds of people around the world—when they saw the information—knew that to be the truth, but there was nothing that we could do," he said.

Satellites carrying specialized radar instruments are making it possible for scientists, like Cervelli, to understand the geologic processes that could lead to undersea landslides and potentially devastating tsunamis in the future—perhaps in time to see them coming and to adequately prepare.

Cervelli, who has worked extensively on understanding the volcanic processes of Kilauea Volcano, noted that in Hawaii, the government has made a concerted effort to educate the public about what to do in case of a tsunami. Beginning in kindergarten, children are taught in school and through the newspaper about what to do if they hear a tsunami warning siren. "All of these things are now second nature to most Hawaiian residents, but Hawaii is a relatively small population in a first world country," said Cervelli. "The most challenging thing for establishing a warning system in the Indian Ocean is going to be the education and communication components."

Installing more buoys around the islands hit hard by the recent tsunami would not be too costly or difficult to do, Cervelli said. "But all of that is useless if there is no way to get that information to officials in the countries that will be affected, and it's also useless if you get the information to an official, but the officials are powerless to do anything about it. If people aren't educated about what to do when the tsunami horn goes off, if there even is a tsunami horn, then it doesn't really matter," said Cervelli.

Cervelli's research is one example of the way that scientists are using satellite data to understand tsunami-forming processes before they wreak havoc. The south flank of Kilauea Volcano on the island of Hawaii (the "Big Island") has been moving towards the sea at a rate of 6 centimeters (2.3 inches) per year for at least a decade. The fact that there's been so much motion has left some people to wonder whether the south flank is a candidate for "catastrophic flank failure," which would probably lead to a very large tsunami, Cervelli said. If it did occur, it would threaten the Hawaiian Islands, and under some models, the west coast of the United States, South America, and possibly Japan.

Some evidence suggests that very large tsunamis caused by massive undersea landslides have hit the Hawaiian Islands in the not-too-distant geologic past. Researchers have found anomalous corals and marine shells deposited hundreds of meters high above the shoreline of some islands. If it has happened before, some experts wonder whether giant tsunamis may plague the Hawaiian Islands from time to time.

So scientists like Cervelli are using a technique known as Synthetic Aperture Radar Interferometry (InSAR) to understand tectonic systems and, hopefully, identify high-risk areas. Satellites carrying InSAR instruments beam a radar signal down onto a given location of the Earth's surface at two different points in time. The second measurement reveals whether the ground has shifted either toward or away from the satellite, explained Cervelli.

While InSAR data can provide a glimpse into the geologic future, they are by no means a crystal ball. "I'm not suggesting that we can predict earthquakes. That, so far, has proven very difficult, if not impossible. But we can give you an idea that 'well, this fault is slipping or it's accumulating strain, so eventually it's going to result in an earthquake,'" said Cervelli. "The trick is telling you on what day and at what time it's going to happen."

So for now, scientists will take what they can get. Such fine resolution and detail from satellite data will help fortify the defense against tsunamis in the future. Computer modelers will be better equipped to compute the strength and pattern of the tsunami waves, explained Fu. "That's a critical link," he said. "Our data will aid researchers by improving their understanding of tsunami dynamics in order to make better models. So that's the benefit of quite a serendipitous measurement."

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Cervelli, Peter. 2004. The Threat of Silent Earthquakes. *Scientific American*.

Fu, L.-L., and A. Cazenave, editors, 2001. *Satellite Altimetry and Earth Sciences: A Handbook of Techniques and Applications*. San Diego, CA: Academic Press.

For more information, visit the following web sites:

Physical Oceanography (PO) DAAC
http://podaac.jpl.nasa.gov/

Ocean Surface Topography from Space
http://sealevel.jpl.nasa.gov/

USGS Earthquake Hazards Program
http://earthquake.usgs.gov/eqinthenews/2004/usslav/

USGS Hawaiian Volcano Observatory
http://hvo.wr.usgs.gov/

Pacific Tsunami Museum
http://www.tsunami.org/

Peter Cervelli is a U.S. Geological Survey research geophysicist at the Alaska Volcano Observatory in Anchorage, and an adjunct professor in the Department of Geology and Geophysics at the University of Alaska, Fairbanks. His research focuses on deformation processes at Kilauea Volcano on the "Big Island" of Hawaii. Cervelli is credited with discovering the first "silent earthquake" to occur at a volcano after he and colleagues observed that Kilauea's south flank had imperceptibly shifted 10 centimeters over a course of 36 hours in November 2000. He holds a PhD in geophysics from Stanford University.

Lee-Lueng Fu is a senior research scientist at the Jet Propulsion Laboratory (JPL) at the California Institute of Technology, and a NASA project scientist for the joint U.S./French TOPEX/Poseidon and Jason missions. He is also head of the Ocean Science Research Element of the Division of Earth and Space Sciences at JPL. Since 1988, Fu has led an international team of oceanographers and geophysicists in the development of precision measurements of ocean surface topography from TOPEX/Poseidon and its follow-on instrument, Jason. He holds a PhD in oceanography from Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.

Malaria by the Numbers

An *Anopheles* mosquito takes blood from a human host. This mosquito is a vector for malaria, which kills more than a million people each year in over 100 countries and territories. (Image courtesy of James Gathany and the Centers for Disease Control and Prevention)

Socioeconomic Data and Applications Center (SEDAC)

by Kelly Kennedy

When Bob Snow of the Kenya Medical Research Institute/Wellcome Trust Collaborative Programme in Nairobi travels through Africa, he sees firsthand the effects of malaria. Children suffer from fevers, chills, seizures, and anemia, and then often lapse into comas and die. Sometimes the victims get the medicine they need, but more often, parents who can't afford food or school fees must go without the drugs that could save their children.

The World Health Organization (WHO) estimates that more than a million people in Africa die from malaria every year, including 3,000 children each day. "It's a huge problem," said Snow, who is also a professor of tropical public health at the University of Oxford. "*The New York Times* reported 150,000 deaths from the recent tsunamis in Indonesia, but that number is only the margin of error for malaria deaths in Africa." Despite 20 years of research in Africa on ways to combat the burden posed by malaria, Snow said he hasn't seen much progress in the fight against the disease.

Malaria is caused by a parasite carried by the female mosquito *Anopheles*. Mosquitoes transmit the parasite to humans through their bite, and they also contract it by biting already-infected humans. The parasite travels first to the liver, where it reproduces, then proceeds to the bloodstream, where it reproduces again and destroys the red blood cells. In Africa, a particularly dangerous strain of malaria, known as *Plasmodium falciparum*, resists most drugs and often kills its victims.

Problems in Africa are compounded by the fact that malaria helps create a "circle of poverty." Because of high infant mortality, women tend to have more children to ensure that some survive. With many children to care for, mothers can't leave the home to help provide for their families. So, malaria burdens individual households, as well as local health services.

In the 1980s, scientists found that using bed nets significantly decreased the chance of getting malaria, yet fewer than 5 percent of African children sleep under them, according to Snow. In addition, limited funding leads to the use of cheaper drugs to which the malaria parasite has developed resistance, which makes them ineffective. "Malaria victims are being treated for a life-threatening disease with drugs that don't work," he said.

Targeting bed nets and effective drugs to specific populations could cut the spread of malaria in half, Snow said, but researchers must have accurate population data to determine exactly where they should concentrate their efforts. For example, Snow said the United Kingdom gave a non-governmental organization (NGO) $20 million to market bed nets. The NGO marketed the nets in a city where people were less likely to contract malaria and, therefore, the project failed. “It’s a complete mess on the international level,” he said. “There’s a lot of rhetoric and a lot of hand-holding and a lot of meetings, but that doesn’t translate to solutions.”

Andrew Tatem, a zoology researcher at the University of Oxford, said that before scientists can make headway in fighting malaria, they must first understand how the disease affects different populations. “There is so much we don’t currently know about malaria,” he said. “The basic numbers must be understood.” The WHO, along with the United Nations Development Program and the World Bank, plans to “Roll Back Malaria” by half by 2010. But Tatem said no one knows exactly what “half” is. If malaria researchers had accurate numbers for specific locations, they might be able to attack the problem in a proactive way. Data, Snow said, could provide solutions.

Deborah Balk, lead project scientist for the Socioeconomic Data and Applications Center (SEDAC) at Columbia University, and her colleagues recently released a grid that shows population densities for specific regions not only in Africa, but in the rest of the world as well. The Gridded Population of the World (GPW) data set, version 3, converts census information from more than 375,000 administrative subdivisions, such as countries and provinces, into a series of longitude/latitude grids that provide estimates of where those populations live. The data set allows researchers to easily analyze population data with other geographically referenced data, such as land-use patterns, geophysical hazards, and climate information.

Version 3 of the data set includes more input units (individual sets of data for the administrative units) than the first two versions of GPW, allowing Balk to create smaller grids for many countries. “We did a massive update when the year 2000 census updates came out,” Balk said. “In addition, we collected a different stream of census data—population estimates of human settlement and urban areas—and matched it with night-time-lights satellite data.”

The third version of GPW spawned two new projects: the Global Rural Urban Mapping Project (GRUMP) and the Gridded Population of the World, Future Estimates 2015. GRUMP adds a new dimension to the gridded population data by consistently defining how many people live in urban versus rural areas. “This has never been done before,” said Balk. “It allows us to ask, ‘What geophysical and environmental features define city location?’ and ‘Why are coastal areas disproportionately urban?’”

“We now have maps of malaria risk with accuracy to within 1 kilometer. Once you have the numbers, you can come up with a plan and goals to work out how you’re going to attack the problem.”
- Andrew Tatem

Balk, who works at the Center for International Earth Science Information Network (CIESIN) at Columbia University, where SEDAC is based, said that she and her colleagues have already begun using these new data to investigate where people live relative to ecosystems and urban areas. For example, they found that while coastal ecosystems in Africa are densely populated and disproportionately urban, close to 45 percent of Africans live in cultivated zones, with only about 40 percent of those residents being urban dwellers. With these data, scientists can look at where malaria-

	GPW v1	GPW v2	GPW v3	GPW 2015	GRUMP v1
Publication year	1995	2000	2004	2004	2004
Years of estimation	1994	1990, 1995	1990, 1995, 2000	2015	1990, 1995, 2000
Number of input units	19,000	127,000	376,500	376,500	c. 1,000,000

The Gridded Population of the World (GPW) data set has undergone a substantial improvement in the number of input units and in the target years of estimation. This table describes these improvements, and also refers to the new Global Rural-Urban Mapping Project (GRUMP) data collection, which shows how many people live in urban versus rural areas. (Information courtesy of Socioeconomic Data and Applications Center)

More than 3,000 children in Africa die from malaria every day. (Image courtesy of Pedro Sanchez, Earth Institute at Columbia University)

ridden mosquitoes live in relation to people, and learn about the effects of population growth on the environment.

Although field research shows that malaria is more prevalent in rural areas, the combined GPW, GRUMP, and satellite data allow scientists to better estimate malaria risk and burden. "You're less likely to be bitten by a malarious mosquito in an urban area," Tatem said. So, the new data give scientists a better idea of where to send bed nets and medicine.

Tatem works with Simon Hay, also of the University of Oxford and principal scientist for the malaria project, to combine the GRUMP population data with maps of areas considered to be at-risk from malaria. Using the data to determine disease distribution, they study the effects of climatic conditions on malaria. "We now have maps of malaria risk with accuracy to within 1 kilometer," Tatem said. "Once you have the numbers, you can come up with a plan and work out how you're going to attack the problem."

While the new population data promise to aid researchers in cutting malaria risk, compiling the data sets is not without obstacles. Although most nations have been open with their data, Balk said it's not always easy to get information. And for many countries, data may not be redistributable. Such was the case with the Indonesian census. Aid workers immediately called Balk after the tsunami hit in December 2004 to see if she could share her high-resolution input data for Aceh Province. Unfortunately, because of perceived security risks, Balk said the Indonesian government required her to sign a contract agreeing not to release the information to other parties. "We made the gridded data and estimates of exposed population available to the aid agencies as soon as possible, but we could not release the underlying data," Balk said. "That was a real shame."

In addition to financial and political hindrances, some governments simply don't have the information. War-torn countries, such as the former Yugoslav republics and Afghanistan, don't collect census data regularly or have had their regular census-taking interrupted. Other nations, such as Rwanda and Uganda, have seen their populations move to other countries to seek safety.

There is enough census data in Africa, however, to try to sort out the malaria problem. Doctors and scientists have solved the malaria problem before, according to Tatem. "Malaria used to be a problem in the central United States and in Northern Europe, but global efforts pushed it back to the tropics," he said.

The WHO sprayed DDT from the 1940s until 1969, when environmental concerns forced them to stop. And, as Europeans improved their housing with windowpanes, screens, and doors, they lessened malaria risks there. Growing cities and changing land use also removed many mosquito breeding grounds, but these precautions were often not taken in Africa. "Once the African countries gained independence, funding for controlling malaria dried up," Tatem said.

Snow said solving the malaria problem boils down to understanding where people live in relation to the malaria risk, and that's why the GPW, GRUMP, and population prediction data are so important. Analysis using GPW and UN projected population growth suggests 400 million births will occur within the malaria-infested areas of the world in the next five years, according to Tatem, but even that isn't a clear indicator of future malaria numbers. For example, the population boom will possibly cause those areas to become more urban, thus reducing mosquito habitat.

At the turn of the 20th century, about 77 percent of the world's population was at risk of contracting malaria. By 1994, that number had fallen to 46 percent. But in 2002, it went back up to 48 percent because of population growth in at-risk areas. This underscores the need for accurate population data, and for a thorough understanding of how population distribution affects the spread of infectious diseases.

Despite his frustrations, Snow continues to conduct research in Kenya and work with African governments to control the problem. "African governments can't fight this alone—it takes money," he said. "And we need to get the numbers first."

"That is why I keep going. It's a lifetime of work."

Reference:

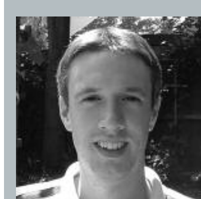
Malaria is alive and well and killing more than 3000 African children every day. World Health Organization. Accessed January 10, 2005. http://www.who.int/mediacentre/news/releases/2003/pr33/en/

For more information, visit the following web sites:

Center for International Earth Science Network (CIESIN)
http://ciesin.columbia.edu
Socioeconomic Data and Applications Data Center (SEDAC)
http://sedac.ciesin.columbia.edu/
Gridded Population of the World
http://beta.sedac.ciesin.columbia.edu/gpw/
World Health Organization "Roll Back Malaria"
http://www.rbm.who.int/cgi-bin/rbm/rbmportal/custom/rbm/home.do

Deborah Balk is an associate research scientist at Columbia University's Center for International Earth Science Information Network (CIESIN), one of the Earth Institute's centers, and the lead project scientist for NASA's Socioeconomic Data and Applications Center (SEDAC). She also heads CIESIN's spatial demography efforts, where she led development efforts on the Gridded Population of the World data set and spearheaded the Global Urban-Rural Mapping Project. Currently, Balk also co-leads efforts at CIESIN to map and conduct spatial analysis in support of the United Nations Millennium Project. She received a PhD in demography from the University of California, Berkeley.

Robert Snow is a professor of tropical public health in the Centre for Tropical Medicine at the University of Oxford, and head of the Public Health Group at the KEMRI/Wellcome Trust Programme in Nairobi, Kenya. In 1997, Snow was named an honorary fellow at the Liverpool School of Tropical Medicine, and in 1999, he earned the Chalmers Medal for Tropical Medicine from the Royal Society of Tropical Medicine and became a senior research associate at the Wellcome Unit for History of Medicine at the University of Medicine. Snow earned a PhD in epidemiology from the London School of Hygiene and Tropical Medicine.



Andrew Tatem is a research officer on a Wellcome Trust-funded project aimed at using satellite imagery to map settlements and populations across Africa. His most recent research focuses on applying satellite data-based solutions to public health problems, particularly the spread of malaria. He earned a PhD in electronics and computer science from the University of Southampton, UK.

Kachemak Bay, located off the shores of Homer, Alaska, is home to a variety of fish and bird species. (Image courtesy of John Maurer)

Bloom or Bust:
The Bond Between Fish and Phytoplankton

GSFC Earth Sciences Data and Information Services Center DAAC

by Laurie J. Schmidt

When you're a juvenile salmon trying to survive into adulthood, timing is everything. If you're lucky enough to be born in a year when there's an ample supply of zooplankton, then this food source helps keep your predators at bay. If, however, you're born during a lean plankton season, there's a good chance you might become a snack for fish like pollock and herring.

Oceanographers have long known that food web dynamics influence fish and bird populations in marine coastal areas. But new evidence has led some researchers to suspect that Mother Nature may have a unique way of sustaining populations by bringing young fish, like salmon, into the world when food sources are at their maximum.

The marine food chain starts with microscopic plants called phytoplankton, which typically float close to the surface where there is sunlight for photosynthesis. Phytoplankton are eaten by slightly larger, more mobile, herbivores called zooplankton, which range in size from single-celled organisms to jellyfish. In turn, zooplankton provide food for krill and some small fish.

Sudden explosive increases in phytoplankton, called "blooms," occur in the ocean when nutrient and sunlight conditions are just right. The timing of these blooms plays a large role in maintaining marine ecosystems, and is crucial to the survival of certain fish and bird species. "In theory, you have to have high levels of phytoplankton to support a high abundance of zooplankton, which then supports an abundance of small feeder fish," said oceanographer Scott Pegau.

"All fish are tied back to phytoplankton somewhere along the line. So, most of the coastal fisheries could benefit from understanding bloom patterns and being able to make inferences to survival rates."
- W. Scott Pegau

Pegau, a researcher at the Kachemak Bay Research Reserve in Homer, Alaska, has been using satellite data to look at the possible link between phytoplankton blooms and fisheries and bird health. By analyzing imagery from ocean color sensors, like the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS), Pegau and his colleagues can get a good look at both the timing and location of phytoplankton blooms and, hopefully, identify significant patterns that might lead to better fisheries management. "All fish are tied back to phytoplankton somewhere along the line," said Pegau. "So, most of the coastal fisheries could benefit from understanding bloom patterns and being able to make inferences to survival rates."

Kachemak Bay is located off the shores of Homer, Alaska, on the southwest side of the Kenai Peninsula, a region dependent on recreational and commercial fishing for its livelihood. "Fisheries are extremely important to coastal Alaska," said Pegau. "Many of the communities are strictly fishing communities—it's the sole dimension to their economy."

But during the past 10 years, several fisheries have collapsed in the Kachemak Bay area, including king crab, tanner crab, Dungeness crab, and shrimp. According to Pegau, these collapses are due partly to ocean circulation changes, but they also can be traced to a poor understanding of the variables that can influence fish populations in a given year. "We're still getting millions of pounds of salmon from this area, but better fishery management techniques could help ensure that the industry as a whole survives," said Pegau.

Understanding phytoplankton bloom patterns and their effects on fish populations could spawn new management practices that help safeguard the future of the Alaska fishing industry. But without satellite data, Pegau and his team wouldn't be able to see an area large enough to detect any clear trends. "Kachemak Bay has 320 miles of coastline, and it's just a small dot on the Alaska map," said Pegau. "There is no way we can monitor what's happening in coastal Alaska without ocean color sensor data—SeaWiFS gives us the opportunity to see the big picture."

In the world's oceans, color varies according to the concentration of chlorophyll and other plant pigments in the water. Satellite sensors that detect these subtle changes in ocean color are critical tools for scientists studying ocean productivity. By analyzing data from SeaWiFS and MODIS, Pegau and his team discovered two patterns in the Gulf of Alaska: high chlorophyll concentrations show up in April/May, and then again in September/October. But the satellite data also show a third bloom that occurs in late June or early July.

The bloom timing is significant to both fish and birds because it determines when food sources are available. "If you're a fish getting ready for winter, then a fall bloom will provide a food source that will allow you to fatten up enough to get through the winter," Pegau said. "Conversely, if you're a bird, you want the bloom to happen just before your eggs hatch in the spring. If the bloom happens in late July, then it may be too late to be of any value to you."

But exactly what causes the blooms to occur when they do is still a mystery to oceanographers. One theory, Pegau explained, is that the timing may be related to the strength of winter storms. Like all plants, phytoplankton need light, and getting light in the ocean means

Homer is one of many communities in coastal Alaska that are dependent on recreational and commercial fishing for their livelihood. (Image courtesy of John Maurer) being able to stay near the surface. If an area is plagued by continual storms, then the phytoplankton keep getting mixed down into deeper water—away from the light. But at the same time, they need the storms to bring nutrients up from the deep and fertilize the ocean surface. "It's a tricky balance," said Pegau. "You need enough storms to bring the nutrients up, but then you also need the storms to cease early enough to allow things to grow."

The team is also using the ocean color data to look at the spatial patterns of blooms, which are believed to have a significant effect on bird populations. "If the area that has a lot of phytoplankton is located far offshore, then the parent birds have to fly farther out to get it and, therefore, have less energy to provide for their offspring when they return," he said. "They eat up more of their food flying than they would if conditions kept the blooms closer to shore."

Having phytoplankton blooms occur far from shore poses risks not only to birds, but to salmon as well. "If food sources are located farther offshore, the juvenile salmon are forced to move away from shore to a place where they're more vulnerable to predators," said Pegau. "The farther out they have to swim to find food, the more likely they are to be taken by predators."

Each spring and summer, more than 16,000 birds migrate to Gull Island in Kachemak Bay. (Image courtesy of John Maurer)

While many fish spend their entire lives in the ocean, other fish—such as salmon—spend a portion of their lives at sea and then return to rivers to spawn. "The ocean provides a much larger food source than the rivers and lakes where these fish are born," said Pegau. "By going out into the ocean to feed, they can grow more rapidly and reach the size and maturity that allows them to spawn. And the faster a fish can grow, the sooner it stops being prey."

Ted Cooney, Professor Emeritus in the Institute of Marine Sciences at the University of Alaska, Fairbanks, believes predators play a significant role in the relationship between salmon and plankton. He and his colleagues have been looking at survival rates of juvenile salmon in Prince William Sound, a large region of protected waters located on the east side of the Kenai Peninsula. "About 800 million juvenile salmon enter Prince William Sound from streams and hatcheries in April and May each year," said Cooney. "These small fish immediately encounter a host of predators, including walleye pollock, Pacific herring, cod, and various seabirds and marine mammals."

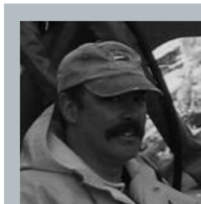
The record in the Prince William Sound area suggests that when zooplankton stocks are high in the spring, pollock and herring derive most of their energy from that source, Cooney said. But when zooplankton stocks are low, they're forced to derive more of their energy by feeding on small fishes—like juvenile salmon.

Pegau's team has taken an important first step by identifying the fall and spring bloom patterns, but more work needs to be done before long-term trends can be reported with certainty, he said. "Our hunch is that we're eventually going to find a connection between juvenile salmon and bird survival rates and the phytoplankton bloom patterns," he said.

"The big thing is being able to manage the fisheries more effectively—knowing which years you can expect a big return to come in, and which years aren't going to produce much. You don't want to end up over-harvesting if the ocean isn't supporting the fish that year."

For more information, visit the following web sites:

GSFC Earth Sciences Data and Information Services Center DAAC
http://daac.gsfc.nasa.gov/
Ocean Color Data Support
http://daac.gsfc.nasa.gov/oceancolor/
SeaWiFS Project
http://oceancolor.gsfc.nasa.gov/SeaWiFS/
What Are Phytoplankton?
http://earthobservatory.nasa.gov/Library/Phytoplankton/



W. Scott Pegau is an oceanographer at the Kachemak Bay Research Reserve in Homer, Alaska, where he established a research program to address ocean circulation and production issues in Kachemak Bay, Lower Cook Inlet, and the surrounding Gulf of Alaska waters. He holds a PhD in oceanography from Oregon State University.

Cloudy with a Chance of Drizzle

Each year, Southern Californians experience a long cycle of dreary, overcast days known as May Gray and June Gloom. Scientists are learning that regions where these systems occur are good hunting grounds for actinoform cloud formations. (Image from Photos.com)

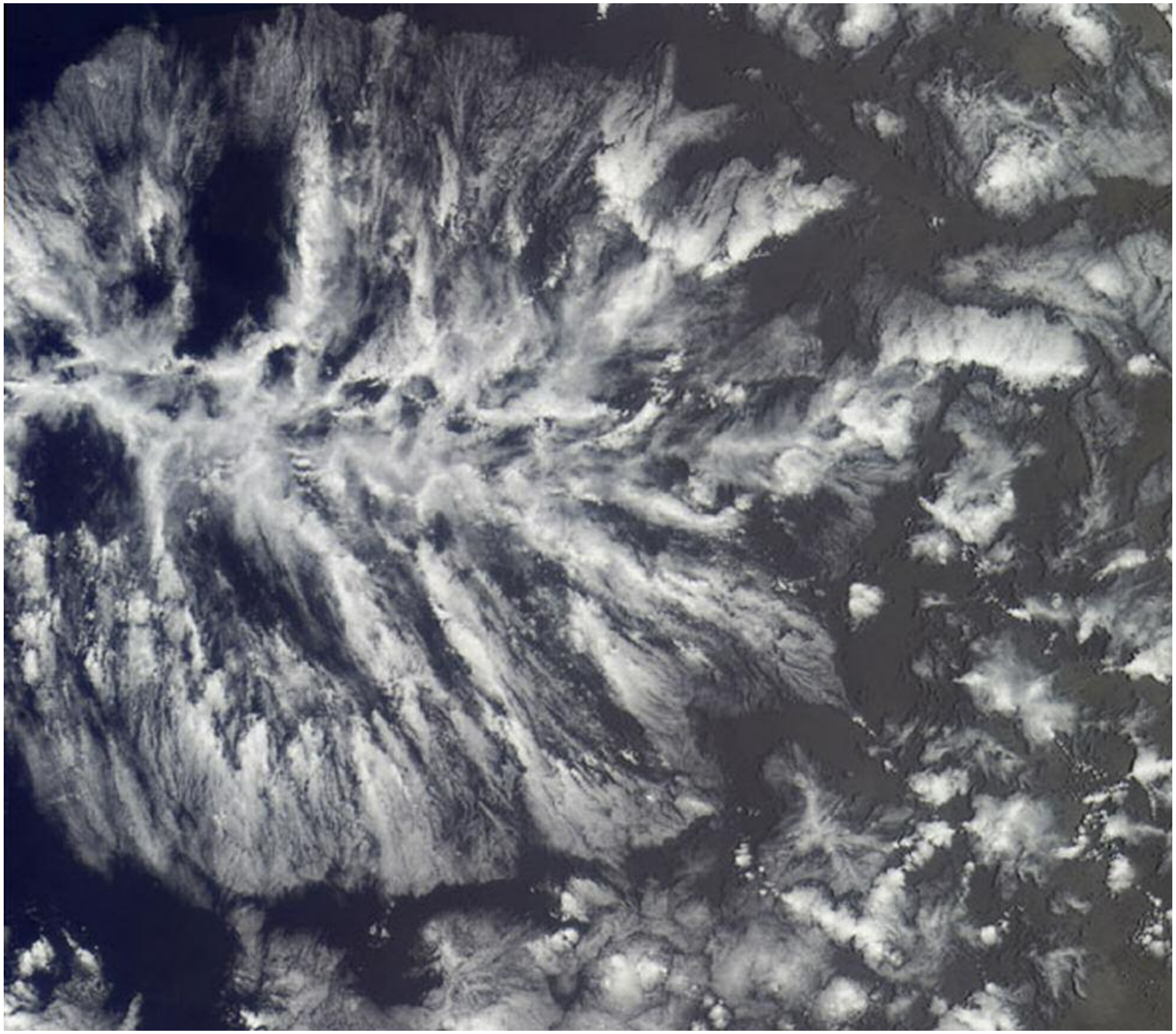
NASA Langley Atmospheric Sciences Data Center DAAC

by Amanda Leigh Haag

Ask just about anyone who's lived along the Southern California coast what it's like to plan a picnic or a day at the beach during the months of May and June. Chances are they'll warn you about the seemingly endless chain of dreary, overcast days known locally as "May Gray" and "June Gloom." The heavy cloud banks rolling in off the ocean do little more than spoil an otherwise perfect sunny day and drop a harmless drizzle from time to time. To someone hoping to spend a day basking in the sun and surf, these clouds are just gray, gloomy, and boring.

But scientists who study cloud behavior are learning that these dismal clouds hold a lot more interest than meets the eye. Researchers are finding that the western coasts of continents where May Gray and June Gloom-type cloud systems occur are bountiful hunting grounds for unique formations called actinoform clouds. Named after the Greek word for "ray" due to their radial structure, these previously overlooked clouds are only now coming into focus as scientists use satellite data to better understand their complexity.

Children around the world learn that clouds take on unique shapes in the sky and that cloud patterns often foretell the oncoming weather. Yet scientists still know very little about what determines the shape of individual clouds. Michael Garay, a graduate student at



The MISR instrument captured this image of an actinoform cloud on November 16, 2001. The identification of this cloud, which looks very much like a leaf, prompted a search for more examples of this cloud type in the MISR data. (Image courtesy of NASA/GSFC/LaRC/JPL, MISR Team)

the University of California, Los Angeles (UCLA), is one of a handful of experts who are trying to discover what gives actinoform clouds their complex shape and what role they play in climate and weather systems. “In a general sense, we understand that stratus clouds are formed by one type of process and one type of atmospheric conditions, while cumulus—the puffy clouds—are formed by another process,” said Garay. “But when it gets down to the details of ‘why this cloud looks like a bunny and this cloud look like a horse,’ that’s really hard to understand.”

But the actinoform clouds that Garay and his colleagues are studying are not the kind that you can see while gazing at the sky. They are actually cloud fields—collections of clouds that can be up to 300 kilometers (186 miles) across, an area roughly the size of the state of South Carolina and a field of view too large to see with the naked eye. In addition, they can form “trains” that are up to six times the length of the original cloud field, yet they maintain their own, distinct identity. Using satellite data from the Multi-angle Imaging SpectroRadiometer (MISR)—one of five instruments onboard NASA’s Terra spacecraft—scientists are finding these clouds to be much more prevalent and complex than they originally thought.

When viewed in a satellite image, actinoform clouds look like distinct leaf-like or spokes-on-a-wheel patterns that stand out from the rest of the low-lying cloud field. Bjorn Stevens, a meteorology professor at UCLA, describes them as being similar to a “leaf floating in a pond.” Embedded within the low-lying clouds that give rise to what Southern Californians call May Gray and June Gloom, actinoform clouds have a distinct pattern that doesn’t fade away towards infinity, he said. “Imagine your grandmother’s quilt where one of the squares really stands out as being something different,” said Stevens. Like the square in the quilt, the cloud will hold its shape and stand out from the rest, he explained. “It will move with the wind, but it doesn’t grow or contract very much—it just has its own life,” he said.

Actinoform clouds are not a recent discovery; they appeared in meteorological literature as far back as the early 1960s, when the first weather satellites began sending back images. But until the late 1990s, scientists had dismissed them as merely a transitional form between other more familiar types of clouds, and they were all but forgotten. In fact, the term "actinoform" isn't included in the 2000 edition of the Glossary of Meteorology, which is considered to be the comprehensive reference manual for meteorologists. "There's also a recent review of all the research that's been done in the past 20 years on low-level clouds and they don't even mention actinoform clouds," said Garay. "People just kind of forgot they were there."

The NASA Langley Atmospheric Sciences Data Center (LaRC) played an important role in the rediscovery of actinoform clouds. Garay recalled that his advisor, Roger Davies, now at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., was looking through imagery from the MISR instrument, which is archived and distributed by the LaRC Distributed Active Archive Center (DAAC).

MISR collects data on the sunlit side of the Earth, using cameras that look in nine different directions simultaneously. The change in reflection at different viewing angles enables researchers to distinguish different types of atmospheric particles (aerosols), cloud forms, and land surface covers. Davies noticed a giant, leaf-shaped cloud that took up almost the entire width of one image, recalled Garay. "This sent me on a very interesting chase through the meteorological literature looking for pictures of these clouds, because as good as these database searches are—and they get better all the time—it's hard to put in a search term like 'cloud that looks like a leaf' and get the right information, much less come up with the right picture," said Garay.

Garay eventually tracked down satellite images of actinoform clouds taken by early weather satellites in the 1960s. But what he uncovered about the clouds themselves was quite unexpected. Actinoform clouds had been thought to be a relatively uncommon transitional form. However, by sifting through MISR images of the western coast of Peru, Garay found that actinoform-like clouds showed up roughly a quarter of the time as distinct formations within the more common stratocumulus clouds in that region. Closer examination showed that actinoform clouds occur worldwide in nearly every region where marine stratus or stratocumulus clouds are common, particularly off the western coasts of continents—especially Peru, Namibia in Africa, Western Australia, and Southern California. Such cloud systems are persistent year-round off the coast, yet in certain seasons they blow ashore and create the gloomy "May Gray" effect on land.

And to Garay's astonishment, the closer he looked at the clouds, the more complex he found their patterns of organization to be. "This is something you wouldn't expect," said Garay. "We don't have a good understanding of why they have this radial structure to them and why it's fairly common."

So what might these elaborate features mean to weather systems and climate patterns? Unfortunately, there's no simple answer, according to Garay. "Clouds trace atmospheric motion, so they're responding to the atmosphere in a complicated way," said Garay. Clouds are complex: they change in response to small-scale effects, like the presence of a hill or the local wind, but they also respond to large-scale weather systems, such as cold fronts and the presence of the jet stream, said Garay.

"A recent review of the research on low-level clouds doesn't even mention actinoform clouds. People just kind of forgot they were there." - Michael Garay

Stevens, who studies a closely related cloud form dubbed "pockets of open cells," or POCs, has a theory that may begin to explain the complex interactions between clouds and the climate system. Both POCs and actinoform clouds have a compact and distinct shape embedded within low-level marine stratus clouds. But the taxonomy to determine the exact relationship between actinoform clouds and POCs hasn't yet been worked out. "How similar they are is an open question," said Stevens.

The open cells that Stevens studies are one of two well-known types of stratocumulus cloud formations: open and closed cells. Open cells resemble a honeycomb, with clouds around the edges and clear, open space in the middle. Closed cells are cloudy in the center and clear on the edges, similar to a filled honeycomb. Like actinoform clouds, the 'cells' in this case do not refer to a single cloud but to the system of associated clouds. Previously, researchers believed that actinoform clouds represented a transitional form between open and closed cells, but the recent findings on actinoform clouds show that they are clouds in their own right.

Stevens' observations from field studies in the Pacific seem to indicate that when marine stratus clouds exist alone, in the absence of these open cells, the cloud formations are associated with little, or no, drizzle. Yet when the open cells are present—and likewise actinoform clouds—there seems to be a corresponding increase in drizzle. Thus, his data suggest that the presence of POCs and actinoform clouds is related to the onset of precipitation. "The shape of the cloud field reorganizes itself when the clouds begin to rain," said Stevens. In fact, Stevens has been able to mirror this reorganization using a computer model of a drizzling cloud field.

Stevens' findings suggest that clouds play an important role in regulating climate. Clouds reflect incoming sunlight, and they also act as a blanket that slows the upward movement of heat from Earth's surface back into space. This is why cloudy days are generally cooler than sunny days, but cloudy nights are generally warmer than clear nights. Thus, cloud cover is instrumental in setting Earth's energy balance and controlling its internal "body" temperature. "It makes the observation of these peculiar cloud forms, which seem to be linked to the development of precipitation, more interesting than they would've otherwise been," said Stevens.

So for those of us who spent some of our childhood days lying with our backs in the grass and gazing at the sky, the prevalence of unexpected cloud features in the sky might not come as a particular surprise. But for scientists, it raises the question of whether looking for patterns in the clouds might help unveil some of the deeper mysteries of the climate system. Either way, it appears that these clouds will continue to puzzle children and scientists alike. "It's really kind of fascinating," said Garay. "You'd expect these clouds to be sort of round or flat. But looking like a wheel with spokes coming out of them is just kind of surprising."

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Stevens, B., G. Vali, K. Comstock, M.C. van Zanten, P.H. Austin, C.S. Bretherton, and D.H. Lenschow. 2005. Pockets of open cells and drizzle in marine stratocumulus. *Bulletin of the American Meteorological Society* 86(1): 51-57.

For more information, visit the following web sites:

MISR (Multi-angle Imaging SpectroRadiometer)
http://www-misr.jpl.nasa.gov/

NASA Langley Atmospheric Sciences Data Center DAAC
http://www-misr.jpl.nasa.gov/

Clouds are Cooler Than Smoke
http://earthobservatory.nasa.gov/Study/SmokeClouds/

Tracking Clouds
http://earthobservatory.nasa.gov/Study/tracking/

Clouds in the Balance
http://earthobservatory.nasa.gov/Study/CloudsInBalance/

Clouds from a Different Angle
http://nasadaacs.eos.nasa.gov/articles/2004_clouds.html

Michael Garay is a graduate student at the University of California, Los Angeles, where he earned a MS degree in atmospheric sciences and is currently working on developing a proposal for a PhD in atmospheric sciences. He also works in the Multi-angle Imaging Spectroradiometer (MISR) group at the Jet Propulsion Laboratory (JPL), California Institute of Technology. Garay's work includes developing cloud masks and assessing the performance of existing cloud masks for the MISR instrument.

Bjorn Stevens is an associate professor of dynamic meteorology at the University of California, Los Angeles. His research focuses on cloud climate interactions, particularly those associated with shallow maritime convection.

Riding the Permafrost Express

The Qinghai-Xizang railroad will traverse some of the most desolate landscape on the Tibetan Plateau. This photo was taken south of the village of TuotuoHeyan near Tangulla Pass at an elevation of 6,070 meters.(Image courtesy of Richard Armstrong)

National Snow and Ice Data Center
DAAC

by Evelyne Yohe and Laurie J. Schmidt

Behind the Himalaya Mountains lies a cold, isolated landscape, where the average elevation is higher than most of the Rocky Mountains in North America. Often referred to as “The Roof of the World,” the Tibetan Plateau is the largest and highest plateau on Earth. Treeless, except for a few river valleys, the Plateau is an expansive alpine zone, with more than 17,000 glaciers covering its surface.

Historically, paths and roads built for trade connected the Tibetan people to neighboring regions, but journeys into or out of Tibet were long and difficult. Travel between Lhasa and towns within China’s Qinghai or Sichuan provinces could take six months to a year. Even in the early 1950s, lack of adequate roads and railways forced China to use camels to transport cargo to Tibet. On average, 12 camels died for every kilometer the caravan traveled across the Tibetan Plateau and over high mountain passes.

Beginning in 2007, the Qinghai-Xizang railroad will connect Lhasa to the rest of China, providing a major access route into Tibet. Its pressurized cars will protect passengers from the extreme altitude along the route, much of which lies at least 4,000 meters (about 13,000 feet) above sea level.

But building a railroad across the highest plateau in the world is laden with construction hazards. Due to the thin air, unacclimated workers risk nosebleeds, blackouts, and even death. So, they carry oxygen bags, undergo daily medical monitoring, and work no more than six hours a day. In addition, workers rotate off the Plateau every few weeks to avoid prolonged exposure to the extreme climate conditions.

In addition to the risks associated with construction at high altitude, engineers face the challenge of building a railroad across an unstable landscape. Half of the Qinghai-Xizang railroad’s 1,118 kilometers (695 miles) of track will lie across permafrost areas, and builders must take extraordinary measures to protect each mile of track from permafrost thawing.

“The Qinghai-Xizang railroad is the most ambitious construction project in a permafrost region since the Trans-Alaska Pipeline,” said Tingjun Zhang, a scientist at the National Snow and Ice Data Center in Boulder, Colo. Zhang studies the effects of climate change on permafrost areas around the world. “Permafrost is thawing in many regions, and this is significantly influencing landscapes and engineered structures,” he said.

Permafrost refers to perennially (year-round) frozen ground that occurs where temperatures remain below 0 degrees Celsius for two years or longer, regardless of the rock and soil particles in the ground. Permafrost regions occupy about 20 to 25 percent of the world’s land surface, and in parts of northern Siberia, permafrost can be up to a mile (1,600 meters) thick.

Scientists and engineers charged with monitoring permafrost along the Qinghai-Xizang railroad’s route are primarily concerned with the layer that lies directly above permafrost, known as the active layer, which freezes and thaws seasonally. Longer periods of seasonal thaw cause the active layer to become even deeper, which can result in increased thaw settlement during the summer and more frost heaving (distortion of the surface) during the winter.

When buildings, roads, and railroads are built on permafrost with a deep active layer, seasonal changes in the soil can wreak havoc on the structures above. As the ground thaws and freezes, it contracts and expands, putting stress on foundations and twisting rail lines. In arctic areas where structures have been built over permafrost, insufficient insulation has led to the collapse of buildings and twisting of rail beds, due to the movement of thawing permafrost. For example, in south-central Alaska, thawing permafrost caused the railroad bed of the Copper River and Northwestern Railway to settle unevenly, resulting in a "roller coaster" buckling effect. Although maintenance and use of the railroad were abandoned in 1938, lateral displacement continues today.

To prevent structural damage from thawing permafrost, engineers have developed various methods for maintaining stable temperatures below buildings and roads, including painting roads to increase surface reflectance, elevating buildings on pilings above the ground, and using thermo siphons—metal tubes placed along roads or around buildings that help remove heat from the ground. Thermo siphons helped alleviate permafrost problems along the Alaska pipeline route, but they are costly to install and maintain, and they must be placed along the entire length of a road or railway.

On the Tibetan Plateau, railroad engineers have even more cause for concern than in the past. When the Qinghai-Xizang railroad was first designed, researchers predicted that the region's air temperatures would increase by only 1 degree Celsius over the next 50 years. Now, scientists believe that the Plateau's temperature may rise by 2.2 to 2.6 degrees Celsius in that time period, making the rail bed even more susceptible to deformation from frost heaving and thaw settlement. Recent studies show that the average annual temperature on the Tibetan Plateau has risen 0.2 to 0.4 degrees Celsius since the 1970s, and according to the Chinese Academy of Sciences, some permafrost areas on the Tibetan Plateau are 5 to 7 meters (16 to 23 feet) thinner now than they were just 20 years ago.

"The Qinghai-Xizang railroad is the most ambitious construction project in a permafrost region since the Trans-Alaska Pipeline." - Tingjun Zhang

About half the permafrost under the rail bed is "high-temperature" permafrost, which means that the frozen soil is only 1 or 2 degrees Celsius below freezing, according to Zhang. "This high-temperature permafrost is very susceptible to thawing," he said. "And that's a problem, because not only is the climate in that region slowly warming, but the construction and operation of the railroad itself also creates heat."

But researchers hope to spare the Qinghai-Xizang railroad from the fate of Alaska's Copper River Railway. Construction engineers are using several techniques to stabilize the permafrost below the roadbed and protect the rail line from freeze/thaw hazards. These include re-routing some sections to avoid unstable areas, erecting overpasses across sensitive terrain, and building an insulation layer under the rail bed to maintain permafrost stability.

Researchers from the Chinese Academy of Sciences found that a layer of crushed rock can be used to insulate the railbed and keep the foundation stable. "Like thermal siphons, the crushed rock can both insulate and cool the permafrost," said Zhang. Although installation of crushed rock is labor-intensive, its maintenance costs are extremely low.

Through a series of experiments, engineers found that a 1-meter layer of loose rocks minimizes the transfer of heat to the soil under railroad embankments during warmer months.

The abandoned Copper River and Northwestern Railway near Strelna in south-central Alaska illustrates how building a railroad on permafrost thaw can cause the railroad bed to settle unevenly. Although maintenance and use of the railroad was halted in 1938, lateral displacement continues today. (Image courtesy of U.S. Geological Survey)

The Qinghai-Xizang railroad will traverse some of the most desolate landscape on the Tibetan Plateau. This photo was taken south of the village of TuotuoHeyan near Tangulla Pass at an elevation of 6,070 meters. (Image courtesy of Richard Armstrong)

The Cold and Arid Regions Environmental and Engineering Institute in Lanzhou, China, tested a crushed rock layer in a section of railroad embankment that overlaid permafrost. After one year, the section was significantly colder than before the installation of the rock layer. “The rock layer is so effective that it actually helped create a cooling effect over time,” said Zhang. Crushed rock insulation was first investigated as early as the 1960s, but this is the first time a large-scale project is using the technique as one of its primary solutions, according to Zhang.

Despite the cooling effects of the crushed rock, the fragile permafrost along the Qinghai-Xizang railroad must be routinely inspected to detect any frost heaving or thaw settlement below the tracks. But the sheer size and inaccessibility of the Tibetan Plateau make large-scale monitoring a difficult task.

Over the past 10 years, improved satellite instrumentation has enabled researchers to monitor the freeze/thaw cycles that threaten structures and railroads. “The advantage of satellite data is that it enables us to see the entire plateau,” said Zhang. So, instead of just looking at changes that are occurring in a small, isolated area, which may or may not apply to the whole plateau region, Zhang and his colleagues can now create weekly maps that show the timing and extent of near-surface soil freezing and thawing over the entire Tibetan Plateau.

Passive microwave instruments, including the Special Sensor Microwave Imager (SSM/I) and the Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E), can detect surface soil freeze or thaw based on brightness temperatures—a measure of the radiation emitted by an object. The large contrast between the brightness temperatures of water and those of ice makes it possible for scientists to distinguish between freezing and thawing conditions.

“Knowing when the freeze cycle starts in autumn and when thawing begins in spring helps us see whether the thaw season is getting shorter or longer, which can help us predict changes in the active layer thickness,” said Zhang. Data from both sensors are archived and distributed by the National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC).

“If current observations are indicative of long-term trends, we can anticipate major changes in permafrost conditions during the next century,” said Zhang.

“Changing trends in the freeze/thaw cycle indicate a warming climate,” said Richard Armstrong, a research scientist and one of Zhang’s colleagues at the National Snow and Ice Data Center. “And if there’s a warming climate, then that means more days of thaw—which is a concern for the railroad.”

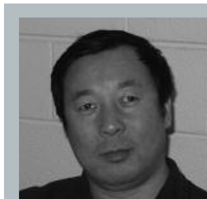
But as three diesel engines pull each train across the “Roof of the World,” a combination of innovative construction techniques and remote-sensing monitoring will ensure a smooth ride when the Qinghai-Xizang railroad opens in 2007.

Reference:

Zhang, T., R.G. Barry, and R.L. Armstrong. 2004. Applications of satellite remote sensing techniques to frozen ground studies. *Polar Geography* 3: 163-196.

For more information, visit the following web site:

National Snow and Ice Data Center DAAC
http://nsidc.org/



Tingjun Zhang is a research scientist at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado. His research interests include land surface processes in cold regions/cold seasons; snow, ice, permafrost, and seasonally frozen ground; and the application of satellite remote sensing data to snow, near-surface soil freeze/thaw status, and northern phenomena. Zhang leads the Frozen Ground Data Center at the NSIDC in efforts to rescue, archive, and distribute frozen ground-related data products worldwide. He is also a lead author for the next IPCC Assessment Report, due in 2007. Zhang earned a PhD from the Geophysical Institute at the University of Fairbanks, Alaska.

Silent Signals

Alaska Satellite Facility DAAC

by Kelly Kennedy

Lascar volcano in Chile is the most active volcano in the central Andes, with several eruptions occurring during the 1990s. Pritchard and Simons found no evidence of deformation at Lascar during their survey of 900 volcanoes in the region. (Image courtesy of Mark Simons)

In the Andes Mountains of South America, people as far back as the Incas learned to accept devastating volcanoes and earthquakes as simply part of life's lot. Local lore speaks of the anger of ancient gods, which, it was believed, often resulted in violent eruptions and ground shaking.

A recent incarnation of Mama Pacha, the Earth Goddess of Incan mythology, killed 2,000 people in Chile after a magnitude 9.5 earthquake lurched through the region in 1960. But geologist Matthew Pritchard sees the swaying and swelling of the Earth as pure science, and he believes that science can potentially save hundreds of thousands of people.

"Our long-term research goal is to minimize the number of surprises we get from planet Earth," said Pritchard, assistant professor of earth and atmospheric sciences at Cornell University. He and his colleagues hope to reach a point where they can determine whether a volcano or earthquake poses an immediate threat—even if they can't predict them.

For now, Pritchard said he's motivated by two key findings he uncovered while working on his PhD dissertation at the California Institute of Technology (Caltech). First, about 40 fewer volcanoes in the Andes show activity than was previously believed. As a result, scientists on the ground can spend valuable time and resources evaluating just a few volcanoes in the Andes for dangerous activity, rather than dozens.

Second, some earthquakes make slow and steady progress over a period of months, rather than causing one abrupt shake—what Pritchard refers to as "silent earthquakes." This means that some faults may never actually trigger violent temblors. Other earthquakes Pritchard observed in satellite imagery did not send out jarring seismic signals, but slipped silently down without discernable movement from the ground above. "Why do these occur?" he asked. "Why do we get some earthquakes that are devastating and others that are not?"

Pritchard said his fascination with geology began when he was about 10 years old. "I had a rock collection, and I started reading about earth science," he said. Though he grew up on a "flat and featureless" farm in Illinois, Pritchard said his parents took him to the Grand Canyon and Yellowstone National Parks, where he got a first-hand look at the landforms he had read about. "I started reading more about rocks and wondering why they were different," he said.

As Pritchard studied his rocks, he began to wonder about other worlds, which led him to study planetary science. "I became very interested in why the Earth behaves as it does and why we have certain activities here, like earthquakes and volcanoes, and not on some other planets," he said. But the movements of his own planet pulled him back down to Earth. "These events have a big impact on humans, and it's important to understand the way hazards affect society," he said.

Pritchard's graduate advisor at Caltech, Mark Simons, suggested that he look at some Synthetic Aperture Radar (SAR) data, some of which are archived at NASA's Alaska Satellite Facility Distributed Active Archive Center, that covered a small area in the Andes. Through a process known as SAR interferometry (InSAR), radar satellite instruments shoot beams of radar waves towards the Earth and record them after they bounce back off the Earth's surface. If the backscattered signal differs between two images of the same object, taken at two different times, then the object has moved or changed. Scientists can also tell what material the radar wave hits by how much of it is reflected back. For example, water reflects the wave back differently than rock does.

"With a large earthquake, it's no mystery that a fault slip occurred. But exactly which area slipped and where another slip might occur in the future aren't as apparent."
- Matthew Pritchard

Think about standing on the edge of a ravine. If you toss a string with a rock tied to the bottom over the side of the ravine, you can mark the string at the top, pull it back up, and then measure the distance from the mark to the rock to see how deep the ravine is. And if you toss the rock from the same spot a week later and the measurement decreases by a foot, what does that mean? Either your measurements are inaccurate, or the ground moved.

In the Andes, InSAR technology works particularly well because much of the region is arid and sparsely populated. "We needed a study area where the ground properties weren't changing," Pritchard said. "There's no one plowing the fields, and there's little vegetation there. That helps ensure that we get accurate measurements." Pritchard and Simons began their study by looking at volcanoes in a small area of the Andes, but they quickly realized how difficult it would be to survey the area from the ground, given its immense size. "Global Positioning System (GPS) surveys could do the job, but that's a very labor-intensive process," Pritchard said. "With 900 volcanoes, it could take years to do what we did in a couple of weeks using satellite data."

Even if they had the time and resources to survey the Andes from the ground, it would involve great risk. "Fieldwork there is dangerous, because of the volcanoes themselves and also because of the need to cross political borders," said Pritchard.

So, the researchers used satellite imagery to fill in the gaps from areas that could not be measured from the ground. They found that analysis of the InSAR data could reveal up to a 2-centimeter deformation (ground movement) at the volcanoes. They also found that far fewer volcanoes showed activity than they had expected.

This image shows a tsunami warning sign in the city of Antofagasta in northern Chile, which was shaken by a magnitude 8.0 earthquake on July 30, 1995. (Image courtesy of Mark Simons)

"Out of about 900 volcanoes, only four showed signs of deformation or magma movement that we didn't already know about," Pritchard said. "I think it's safe to say that we were expecting more than four volcanoes—maybe 50 had been considered potentially active. So we realized that the life cycles of these volcanoes are a little more complicated than we thought." Now, rather than monitoring all 900 volcanoes in the Andes, Pritchard and his colleagues know which ones they need to watch closely.

Still, Pritchard said, it's important to remember that volcanic eruptions and earthquakes can't be predicted. "Volcanoes have very different personalities," he said. "Sometimes they do things we expect, but sometimes they surprise us. Sometimes magma moves underneath the volcano, but it doesn't necessarily lead to an eruption."

Knowing precisely which volcanoes to monitor can help researchers concentrate their ground studies in the areas at most risk. An example of how effective monitoring can save lives came in June 1991 when seismic data revealed that earthquakes were occurring at Mount Pinatubo

Considerable damage to quality, wood-frame houses in Valdivia, Chile occurred during the 1960 earthquake that shook southern Chile. Valdivia suffered catastrophic damage because of its proximity to the epicenter of the massive quake. (Image courtesy of NOAA, Pierre St. Armand, photographer)

in the Philippines. The Philippine Air Force's Air Base command notified local towns that the volcano might erupt, and 60,000 people were evacuated. Officials estimate that 20,000 people would have died if the eruption alert had not been issued.

For the past year, Pritchard has applied InSAR data to earthquakes with the same striking results he observed with the volcanoes. "With a large earthquake—a magnitude 7 or 8—it's no mystery that a fault slip occurred," he said. "But exactly which area slipped and where another slip might occur in the future aren't as apparent." And sometimes, the earth slips slowly with no quake at all, triggering Pritchard's newest questions: "Can a silent earthquake accelerate into a violent earthquake?"

In the Pacific Northwest, GPS recordings show that a silent earthquake occurs beneath Washington State and British Columbia about once every 14 months, but no one on the ground even notices it happening. Pritchard is looking for the same phenomena in the Andes where, unfortunately, there are few continuously operating GPS stations.

Since silent earthquakes may take days, weeks, or even months to occur, they don't send out seismic waves, Pritchard said. So, he watches them to try to learn how to assess potential hazards. "There appear to be some faults that never produce large earthquakes," he said. "And maybe there are also a few silent earthquakes that never evolve into a major event."

Pritchard and his colleagues sometimes joke about things seen in satellite images that don't actually appear on ground, like "the lost city of Atlantis." Some have suggested that the continent disappeared into Lake Titicaca in Bolivia, based on descriptions by Plato. But for Pritchard, the movements of the Earth hold plenty of fascination without lost cities.

"Some people claim to see evidence of Atlantis in satellite data," said Pritchard. "But if they saw the same area from the ground, they'd realize it's not Atlantis." But he does agree that observations from space often lead to discoveries that could take years to find from the ground alone, and he believes it's important to use both ground and remote sensing techniques.

"In satellite imagery, we get a bird's-eye view of where the deformation is happening," he said. "We spend most of our time looking at those images and using models to interpret the data, but we still like to get out in the field to see what's happening from the ground."

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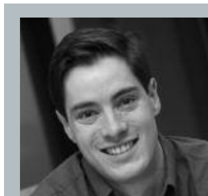
For more information, visit the following web sites:

Alaska Satellite Facility DAAC
http://www.asf.alaska.edu/

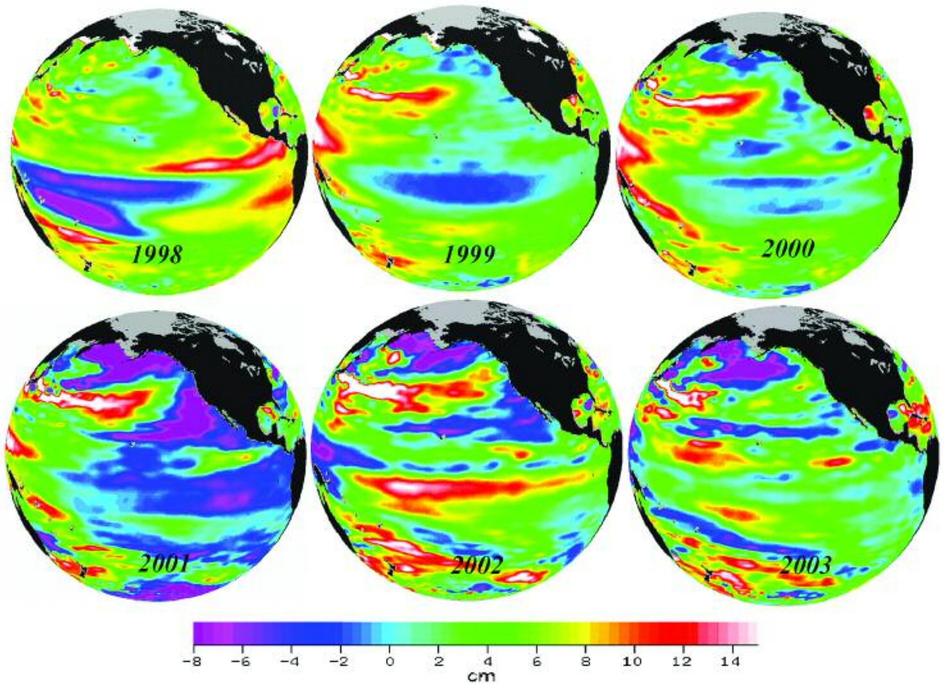
U.S. Geological Survey Earthquake Hazards Program
http://earthquake.usgs.gov/

U.S. Geological Survey Volcano Hazards Program
http://volcanoes.usgs.gov/



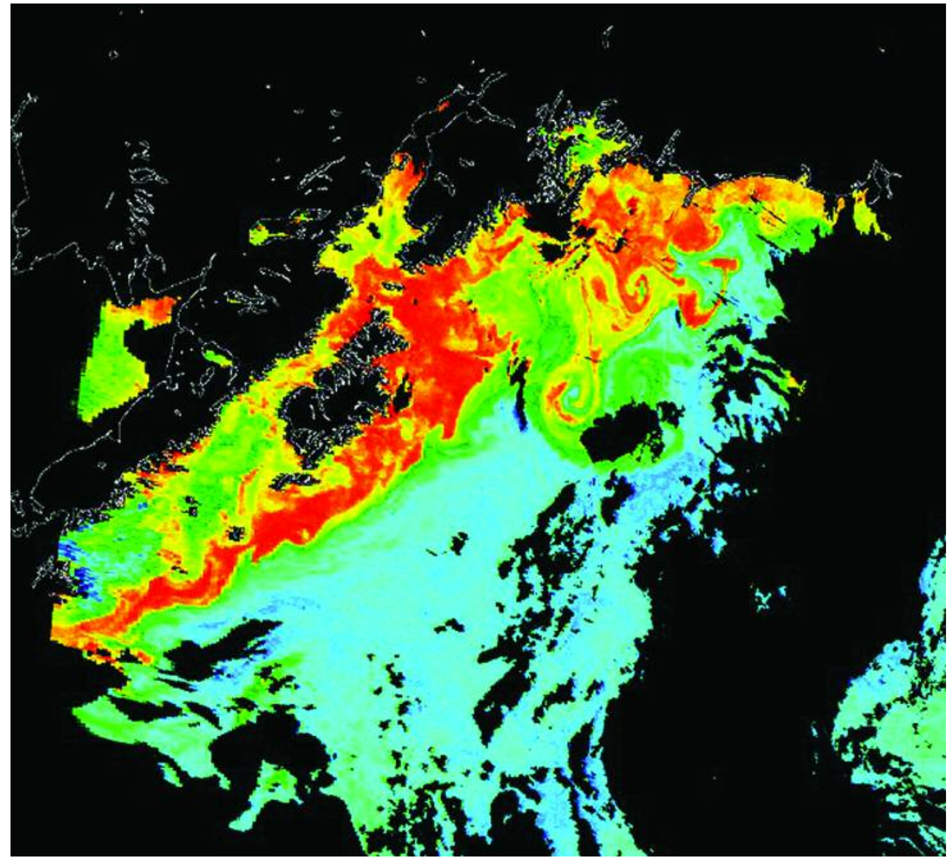
Matthew Pritchard is an assistant professor of earth and atmospheric sciences at Cornell University. He earned his PhD in geophysics from California Institute of Technology (CalTech) in 2003, where he worked as an assistant scientist at the Caltech Seismological Laboratory. His research interests include earthquakes, volcanoes, crustal deformation, subduction zones, and terrestrial planets. Pritchard completed internships at the Lunar and Planetary Institute in Houston, and at the NASA Planetary Geology and Geophysics Undergraduate Research Program.

Supplemental Data Image Section



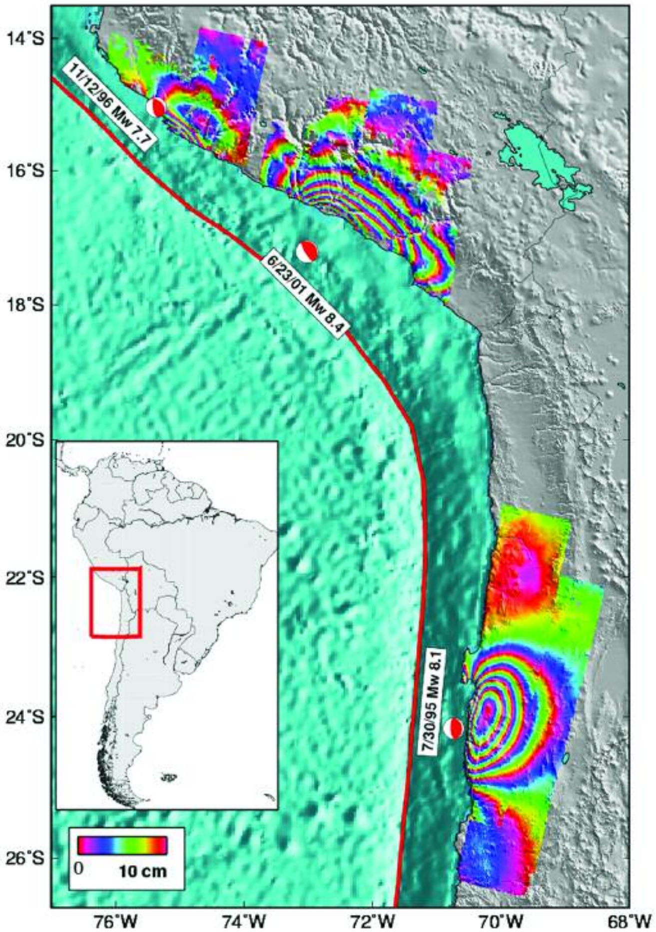
Above, left: These six images, acquired by the TOPEX/Poseidon satellite, show sea surface height anomalies for six different years. Each image represents a 365-day average of that year's data, with a "Normal Year" defined as the average from 1992 to 2002 removed from the individual years. The year-to-year differences in these six images are called anomalies, or residuals. When oceanographers and climatologists view these anomalies, they can identify unusual patterns and estimate how heat is being stored in the ocean during a particular year relative to previous and future years (i.e., how the ocean climate is slowly evolving to influence the next year's planetary climate events). These year-to-year, and even decade-to-decade, changes in the ocean indicate climate events such as the El Niño, La Niña, and Pacific Decadal Oscillation. For oceanographers and climatologists, these sea-surface height images are one of the most modern and powerful tools for taking the "pulse" of the global oceans. (Image courtesy of Lee-Lueng Fu)

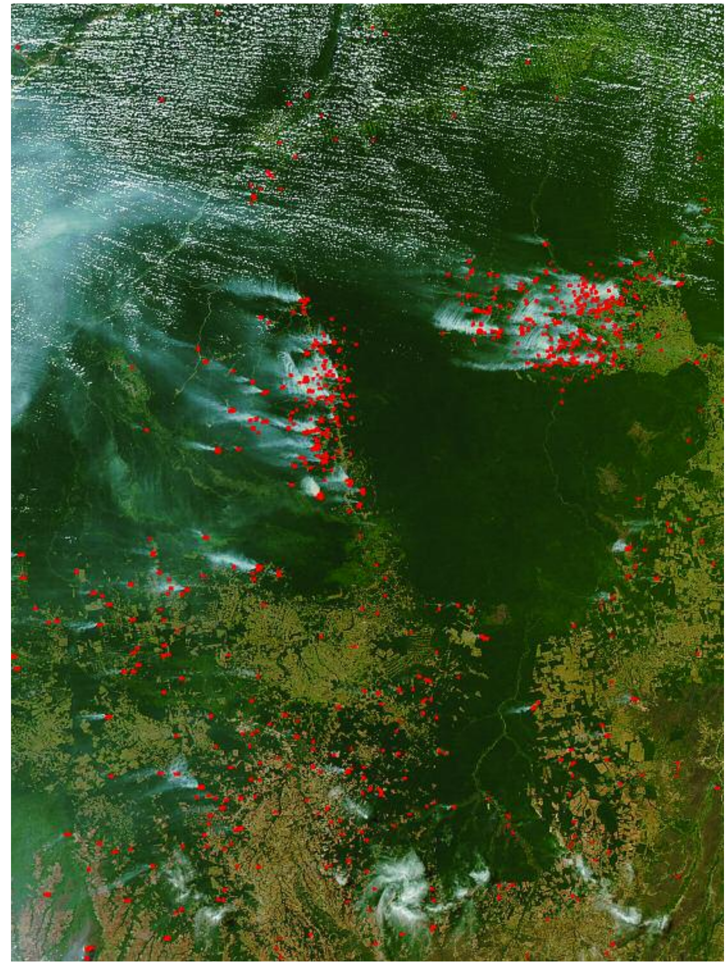
(See *Making Waves in Tsunami Research*, page 2)



Above, right: This SeaWiFS image shows a spring phytoplankton (chlorophyll) bloom over the Gulf of Alaska. Red represents high chlorophyll levels and blue represents low concentrations. The timing and location of these blooms are crucial to fish and bird populations. (Image courtesy of Scott Pegau, Kachemak Bay Research Reserve)

(See *Bloom or Bust: The Bond Between Fish and Phytoplankton*, page 10)



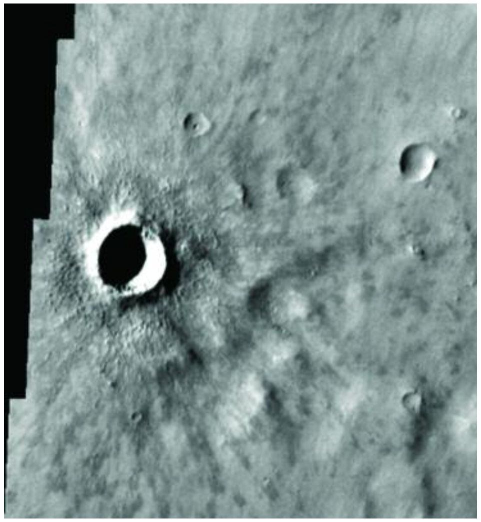


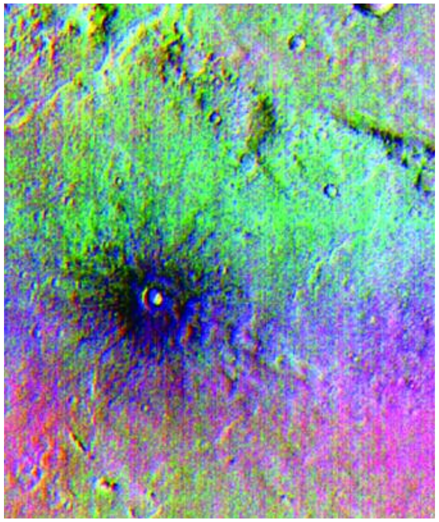
Above, left: This composite SAR interferometry (InSAR) image shows color contours of ground deformation draped over shaded relief from three shallow thrust subduction zone earthquakes along the coast of Chile (dates and magnitudes of the earthquakes are labeled). Each contour represents 10 centimeters of deformation. Because the European Resource Satellite-1 (ERS-1) satellites primarily measure vertical deformation, the gross features can be interpreted as portions of the ground that were uplifted or subsided. For the 1995 earthquake, only part of the dry land was uplifted (the southwest corner of the Mejillones Peninsula), and the closed contours in the interferogram are mostly caused by the on-land subsidence. For the 1996 earthquake, the slip was closer to land, so more uplift was recorded on-shore, but the closed contours represent subsidence. Most of the fault slip from the 2001 earthquake was off-shore, so only subsidence is measured on land. The reference map in the lower left places the region in context on the continent of South America. (Image courtesy of Matthew Pritchard)

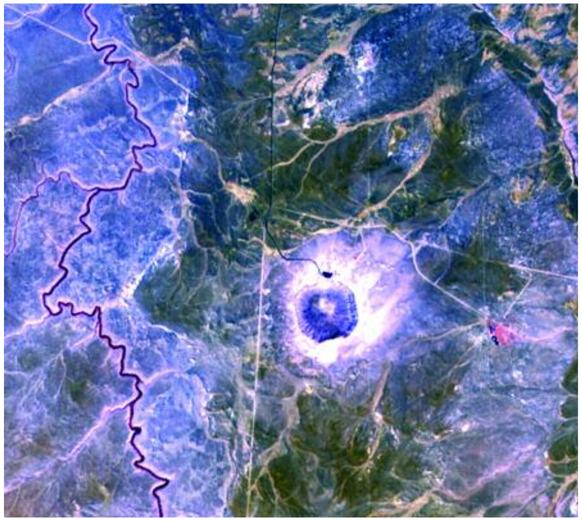
(See *Silent Signals*, page 20)

Above, right: This satellite image, acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on July 29, 2004, shows smoke from hundreds of small fires drifting across the rainforest in Mato Grosso, Brazil. Colonists use fire to clear forest for farming and cattle pastures. However, several years of intensive agriculture depletes the soil of nutrients. Instead of reinvesting in the depleted land, farmers will often just clear a new piece of land, creating a cycle of land use destructive to the rainforest. (Image courtesy of MODIS Rapid Response Project at NASA/GSFC)

(See *A Rainforest Divided*, page 27)





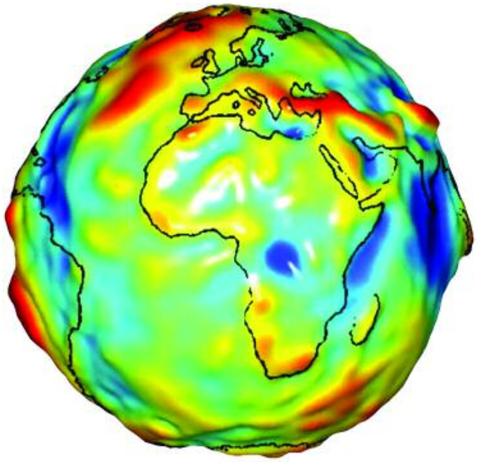


Above, left and center images: These images, acquired by the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey spacecraft, show two representations of the same small crater on the surface of Mars. The crater, located in the Syrtis Major region, is slightly larger than Meteor Crater in Arizona and has been provisionally named Winslow Crater (after the small town in Arizona near Meteor Crater). On the left side is a grayscale image taken in the visible wavelengths (18 meters per pixel) that shows ejected blocks, the outer crater rim, inner crater wall, and ejecta blanket. On the right side is a false-color composite made from three individual THEMIS thermal infrared (TIR) bands (100 meters per pixel). The false-color image was colorized using a technique called decorrelation stretch (DCS), which emphasizes the spectral differences between the bands to highlight compositional variations in the surface materials. The left image is at a scale of 31 kilometers (19.2 miles), and the right image is at a scale of 7.5 kilometers (0.75 miles) in diameter.

Above, right: This image was acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) in June, 2004, and shows Meteor Crater in north-central Arizona. It is a color composite of the visible near-infrared (VNIR) bands (15 meters per pixel) that highlights the flat-lying sedimentary rock units surrounding the crater in shades of gray and green. The ejecta, reworked by wind and blown to the northeast, appears as brighter white areas.

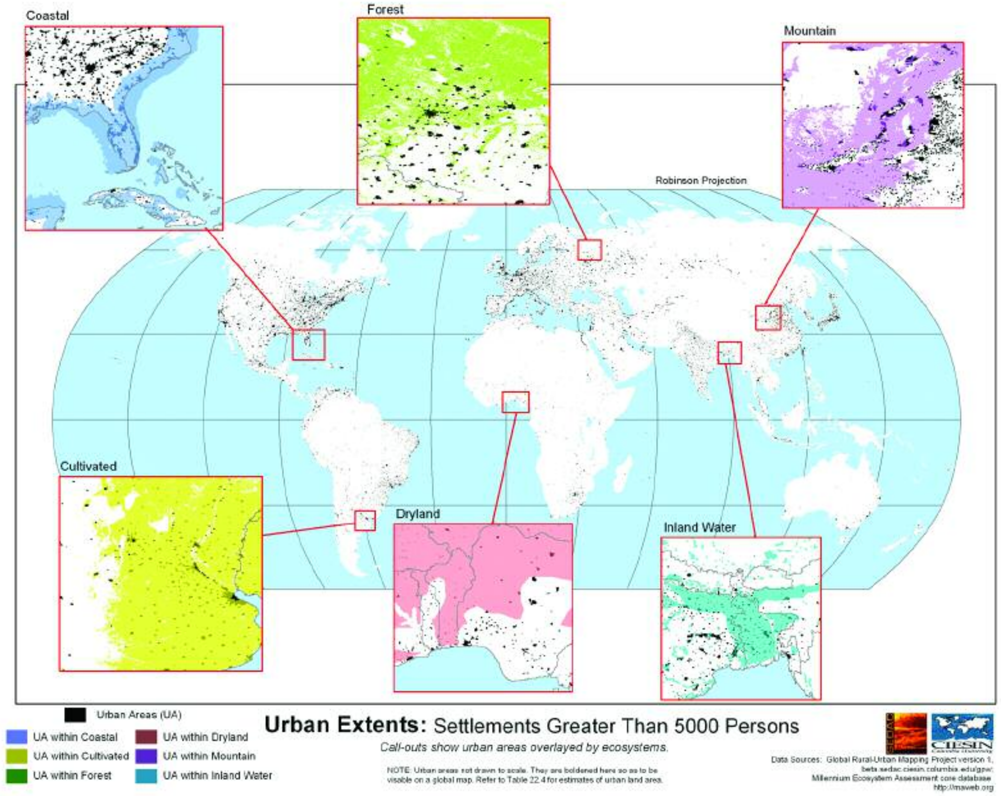
Both the ASTER and THEMIS instruments have very similar spatial and spectral resolutions in the VNIR and TIR. Therefore, data from ASTER can be used as an ideal analog for THEMIS data in studies of certain surface features, such as craters. (THEMIS images courtesy of NASA/JPL/Arizona State University; ASTER image courtesy of NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team).

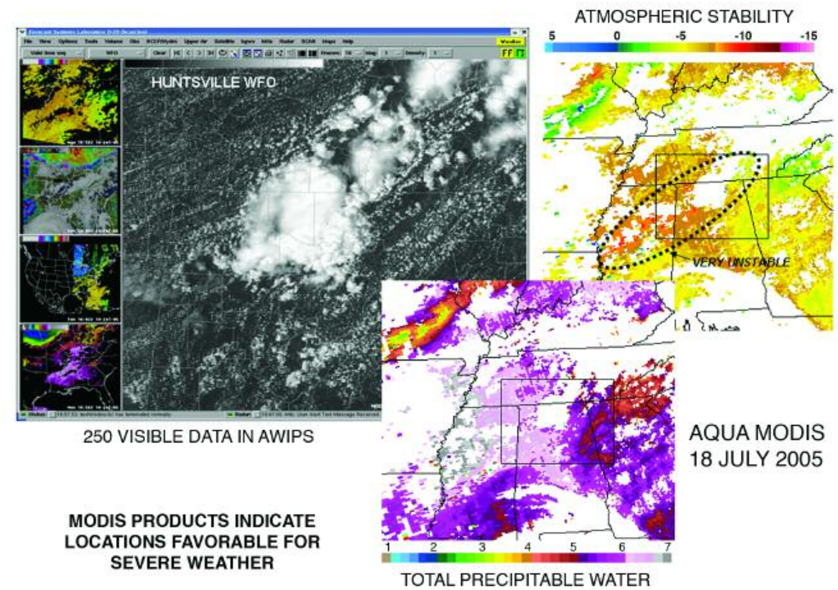
(See *In Search of Martian Craters*, page 39)



Right: This map, created using data from the Gravity Recovery and Climate Experiment (GRACE) mission, reveals variations in the Earth's gravity field. Dark blue areas show areas with lower than normal gravity, such as the Indian Ocean (far right of image) and the Congo river basin in Africa. Dark red areas indicate areas with higher than normal gravity. The long red bump protruding from the lower left side of the image indicates the Andes Mountains in South America, while the red bump on the upper right side of the image indicates the Himalayan mountains in Asia. (Image prepared by The University of Texas Center for Space Research as part of a collaborative data analysis effort with the NASA Jet Propulsion Laboratory and the GeoForschungsZentrum in Potsdam, Germany)

(See *Matter in Motion: Earth's Changing Gravity*, page 35)





Above, left: This map indicates urban areas on a global scale. The call-outs indicate the overlay of urban areas with various ecosystems. Note that ecosystem boundaries may often distinctly omit core parts of urban areas, for example, the cultivated ecosystem call-out. The core part of the urban area of Buenos Aires, for example, is black, indicating that it is not part of the cultivated ecosystem, but the peri-urban and surrounding smaller settlements (in gray) are contained within that ecosystem. In contrast, the inland water system does not exclude urban areas.

Though drylands are the predominant ecosystem, and coastal zones the smallest, coastal areas are disproportionately urban, with about 65% of the population residing in urban areas and occupying about 10% of the coast land area (compared to 47 and 3%, respectively, for global averages). Further, even in rural regions of both coastal and cultivated areas, population is disproportionately dense. Understanding how population varies by ecosystem in both rural and urban areas is an important step in providing services to populations in a sustainable manner. (Image courtesy of Socioeconomic Data and Applications Center [SEDAC])

(See *Checking Earth's Vital Signs*, page 44)

Above, right: NASA's Short-term Prediction Research and Transition (SPoRT) Center collaborates with the National Weather Service to provide data from NASA's Earth Observing System satellites. This example is from the MODIS instrument on Aqua, collected on July 18, 2005 over Alabama and Tennessee. The large upper left image reveals an intense thunderstorm over Huntsville, Alabama, and shows how MODIS data are displayed through the National Weather Service's Advanced Weather Information Processing System (AWIPS). The smaller color insert pictures show MODIS data products that indicate regions favorable for thunderstorm development and possible severe storms (indicated by the dotted oval area in the upper right image). In a mere 30 minutes, this storm produced more than 6.35 centimeters (2.5 inches) of rain over a portion of Huntsville. (Image courtesy of Gary Jedlovec)

(See *SPoRTscast*, page 48)

A Rainforest Divided

Oak Ridge National Laboratory DAAC

by Laura Naranjo

If a tree falls in the Amazon rainforest, biologist William Laurance just might hear it. And as human activity encroaches on the forests, Laurance is finding that a lot of trees are falling.

As people penetrate the Amazon interior, they build roads and clear large expanses of land. Over time, this process of deforestation creates forest fragments, islands of trees surrounded by a sea of pastures, farmland, and other degraded habitats. Laurance and his colleagues at the Smithsonian Tropical Research Institute are studying what happens to the forests when trees lose ground to agriculture, logging, and roads. By tracking the results of forest fragmentation, the researchers hope to assess the impacts of land-use change on forest dynamics and study how ecosystems respond.

To support Amazon rainforest research, the Brazilian government launched an international effort in 1993, called the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). LBA project investigators study a wide range of Amazon ecosystem dynamics, such as the movements of nutrients through the ecosystem, the chemistry of the atmosphere among and above the canopy, and changes in the sources and sinks of carbon. Laurance is an investigator for a component of the LBA Project, called LBA-ECO, which focuses on the effects of land use changes in the Amazon.

In fragmented forests, old-growth trees (shown in image) are replaced by less dense, faster-growing trees, which tend to store less carbon. (Image from Photos.com)

In the Amazon rainforest near Manaus, Brazil, Laurance's team monitored both fragmented and pristine portions of a 1,000-square-kilometer area that was sectioned into plots. Field technicians collected data for each plot at least five times over a 20-year period, counting, classifying, and measuring the diameters of all living and dead trees each time. Laurance's colleagues at the Biological Dynamics of Forest Fragments Project inventoried animal, bird, and insect populations before and after fragmentation.

Their long-term study was unusual in that they carefully surveyed most of the plants and animals in each of the fragments before clear-cutting isolated the fragments from the continuous forest. "That was the big advantage of our study. We built up a very good picture of what species existed before the habitat was fragmented," said Laurance. This picture provided a basis against which to assess changes in the forest ecosystem in its fragmented state.

Laurance admits that his study represents a best-case scenario, since a presidential decree protects the study area from the damaging activities that most other fragmented rainforests endure: logging, hunting, and fire-based agriculture. "These four processes together can be pretty devastating for some species, and certainly for the forest ecosystem as a whole," he said.

But even in the protected study area, the team found that forest dynamics in fragments were changing dramatically. Trees were dying along the forest edges, and the biggest trees—with trunks greater than 60 centimeters (24 inches) in diameter—were dying the fastest. As the larger trees died off around the edges of fragments, the remaining trees were more exposed to temperature changes and dry, hot winds that left them vulnerable to drought. These "edge effects" impacted not just the forest edges, but penetrated as far as 300 meters (nearly 1,000 feet) into the forest.

Aside from providing habitat for rainforest flora and fauna, the Amazon plays an important role in storing and removing carbon dioxide from the atmosphere. Carbon dioxide is a gas that contributes to the Earth's greenhouse effect, in which atmospheric gases trap thermal energy and cause surface and air temperature to rise. Adding more carbon dioxide to the atmosphere magnifies this greenhouse effect.

The Amazon rainforest covers an area more than seven times the size of Texas, populated with nearly half a billion hectares (1.2 billion acres) of trees and vegetation that are critical to the Earth's carbon cycle. However, high rates of deforestation in the Amazon (reaching 2.4 million hectares, or nearly 6 million acres, per year in 2002 and 2003) are diminishing the rainforest's ability to store carbon.

Each hectare of destroyed forest releases around 200 tons of carbon into the atmosphere—worsening, rather than slowing, the greenhouse effect, Laurance explained. The extreme mortality of trees in forest fragments means that the fragments are losing considerable amounts of carbon, perhaps as much as 150 million tons per year in the world's tropical regions.

Birds and other animals are often specially adapted to living in the cool, dark habitat below the thick rainforest canopy. (Image courtesy of William Laurance)

In the fragments Laurance studied, less dense, faster-growing trees replaced old-growth trees, and lianas (woody vines) proliferated around forest edges. Both lianas and faster-growing trees store less carbon than large, dense trees. "The denser the wood, the more carbon a tree can store. A lot of the new trees coming in tend to be lighter wooded pioneer species that store less carbon," said Laurance. "So fragmentation is reducing the amount of stored carbon in two ways. There are fewer trees and smaller trees, and the composition of the forest is changing."

Besides impacting tree populations, fragmentation alters habitat vital to rainforest animals, particularly in the forest understory—the small trees and vines between the forest floor and the upper canopy. Protected from wind and rain, the shaded understory provides a dark, cool, humid environment for a variety of specialized mammals, birds, frogs, and insects. "A lot of the understory birds are sensitive to fragmentation. They're adapted to deep, dark forest conditions, and they won't come out anywhere near a road or clearing," said Laurance.

Because the rainforest ecosystem supports complex webs of interactions, when extinction claims one animal, plant, or insect, other creatures suffer as well. For instance, explained Laurance, a number of frog species use the little wallow ponds made by peccaries (wild pigs). The peccaries need large areas for foraging, so when fragmentation reduces their range and drives them out of the ecosystem, frogs in the area start disappearing.

Fragmented forests also isolate animal populations, which can be a driving force behind extinction. Animals such as jaguars and pumas require large areas, and fragmentation can limit their ability to hunt or force them deeper into the forest. In addition, fragmentation increases human access to the forests, attracting hunters who kill jaguars, monkeys, deer, and agoutis (giant rodents), Laurance said.

This image shows the rainforest canopy north of Manaus, Brazil. (Image courtesy of NASA LBA-ECO Project)

Laurance cited road building as one of the main culprits behind forest loss and fragmentation. The Brazilian government currently plans to pave about 7,500 kilometers (about 4,600 miles) of new highways that will provide more access to the Amazon interior, and Laurance's research indicates that this will increase fragmentation of the rainforest.

Fragmentation begins when a paved highway penetrates undisturbed forest. Loggers and colonists then build numerous roads branching off of the highway, creating a pattern of land use that fragments long strips of forest. "Once you get a major highway providing year-round access, then all kinds of things happen—colonization, logging, and a lot more road development," Laurance said. And once the colonists reach their pristine destination, fire-based agriculture then poses a problem for the Amazon's remaining forests. Colonists hoping to tame a piece of the rainforest often clear the land for agriculture with slash-and-burn techniques.

Laurance also blames "surface fires," annual fires that farmers light in their pastures to destroy weeds and produce fresh grass. These fires burn not only the pastures, but often spread into the surrounding forest as well.

"Because fire is foreign to the rainforest ecosystem, the plants there are just not adapted to it. Even a little fire that's only 10 or 20 centimeters (4 to 8 inches) high will slowly burn through the forest understory, killing 20 to 50 percent of the trees and all of the vines," said Laurance. Dead trees and vines then accumulate on the forest floor, becoming tinder that fuels the following year's fire.

"Every time there's a new fire, it creates more flammable material. So at the end of the cycle there is just a scorched landscape of completely destroyed forest," Laurance said. "You can literally see the fragments imploding over time." The problem worsens when El Niño years bring drought to the region, making the forests even more vulnerable to fire.

"We're advocating a system in which there are more incentives for farmers to invest in their land and develop more sustainable kinds of agricultural strategies."
- William Laurance

Data from Laurance's study, along with a variety of other data sets generated by the LBA project, will be archived and available from the LBA web site in Brazil and the Oak Ridge National Laboratory Distributed Active Archive Center. As scientists gather more data, they will gain a clearer understanding of how land use change affects the Amazon and its ability to store carbon.

Laurance hopes that his research will ultimately promote policy change. The Brazilian government is trying to develop sustainable economic strategies for the rainforest, but land in the rainforest is so cheap that once a farmer's soil is depleted, he can simply purchase another patch of forest to clear and burn. "Rather than relying on very destructive fire-based agriculture," Laurance said, "we're advocating a system in which there are more incentives for farmers to invest in their land and develop more sustainable kinds of agricultural strategies." By making currently cleared land more productive, he suggests, farmers could work closer to existing markets, and the government could then set aside larger tracts of pristine rainforest, preserving the rich flora and fauna of the Amazon.

Deforestation in the Amazon rainforest threatens many species of tree frogs, which are extremely sensitive to environmental changes. (Image from Photos.com)

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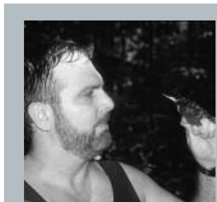


William F. Laurance is a staff scientist at the Smithsonian Tropical Research Institute and president of the Association for Tropical Biology and Conservation. His research interests include assessing the impacts of land-use changes (such as habitat fragmentation, logging, and fires) on tropical forests, and global-change phenomena. He works in the Amazon, central Africa, and Australasia, and holds a PhD in integrative biology from the University of California, Berkeley.

For more information, visit the following web sites:

Large Scale Biosphere-Atmosphere Experiment in Amazonia
http://lba.inpa.gov.br/lba/

Large Scale Biosphere-Atmosphere Experiment in Amazonia ECO
http://www.lbaeco.org/lbaeco/

An Introduction to the Large Scale Biosphere-Atmosphere Experiment in Amazonia
http://earthobservatory.nasa.gov/Study/LBA/

Smithsonian Tropical Research Institute
http://www.stri.org/index.php

Oak Ridge National Laboratory Distributed Active Archive Center
http://www.daac.ornl.gov/

Stealing Rain from the Rainforest
http://earthobservatory.nasa.gov/Study/AmazonDrought/

From Forest to Field
http://earthobservatory.nasa.gov/Study/AmazonFire/

The Road to Recovery
http://earthobservatory.nasa.gov/Study/recovery/

War on Hunger

Socioeconomic Data and Applications Center (SEDAC)

by Amanda Leigh Haag

In December 2004, the eyes of the world turned toward the tsunami-ravaged coasts of Asia and Eastern Africa. Donations, foreign aid, and emergency health care from all nations poured in to help deal with the loss of more than 200,000 victims and the many homeless and destitute people that the Indian Ocean tsunami left behind.

But each month, 200,000 Africans die from what Pedro Sanchez calls “a silent tsunami,” the tide of chronic hunger and malnutrition that sweeps across the African continent. No one is immune: it reaches coastal fishing towns, rural villages, and urban centers alike.

Sanchez, co-chair of the United Nations (UN) Millennium Project’s Hunger Task Force, is working to change the way that most people think of world hunger. Once the public begins to realize that the vast majority of hungry people around the world are not starving, but are instead chronically hungry, the course of intervention will change, Sanchez believes.

Students line up for school meals, made with locally produced foods, at Bar Sauri Primary School in the Millennium Village at Sauri, Kenya. (Image courtesy of Pedro Sanchez, Earth Institute at Columbia University)

Acute hunger resulting from famines, wars, and natural disasters represents only a small fraction of the hungry but receives most of the media attention and coverage, according to Sanchez, who received the 2002 World Food Prize. “The stereotypical image we have of an Ethiopian child with flies in his eyes dying in some sort of refugee camp is not representative of the situation faced by over 90 percent of hungry people,” he said. “Starvation only accounts for about 8 percent of the hungry people in the world; the other 92 percent suffer from hunger silently, and they die in droves because of malnutrition-related diseases.”

In the summer of 2002, UN Secretary General Kofi Annan asked the director of the Earth Institute at Columbia University, Jeffrey Sachs, to lead the “UN Millennium Project.” Its purpose was to develop a set of practical strategies to achieve the “Millennium Development

Goals" (MDGs), targets set by the world community in the year 2000 for reducing poverty and promoting sustainable development. The project's 10 task forces dealt with the roots of poverty and hunger, including health, water and sanitation, gender, education, and environment. The Hunger Task Force became the team specifically assigned the goal of halving world hunger by 2015 and, eventually, eliminating it.

"The stereotypical image we have of an Ethiopian child with flies in his eyes dying in some sort of refugee camp is not representative of the situation faced by over 90 percent of hungry people." - Pedro Sanchez

Through the Hunger Task Force, Sanchez and other experts identified hunger "hot spots" to get a better sense of where poor and hungry people are in the world. Scientists at Columbia University's Center for International Earth Science Information Network (CIESIN) undertook a geospatial analysis that stitched together national census data from maternal and child health surveys at the sub-national level. The task force found 313 provinces or districts in sub-Saharan Africa where more than 20 percent of children under five years old are underweight. Their analysis showed that 80 percent of hungry people in the area they studied live in the hot spot regions.

Next, the team set out to determine the different causes of hunger in various regions and to pinpoint the geographical distribution of malnutrition. Using data from the Socioeconomic Data and Applications Center (SEDAC), such as the "Gridded Population of the World" (GPW) data set, they found that factors such as climatic conditions, geographic remoteness, and elevation were statistically related to the distribution of child malnutrition and infant mortality.

"You're more likely to be poor if you're located far away from the coast or from a road," said Marc Levy, one of SEDAC's project scientists and an associate director with CIESIN. "You're also more likely to be poor if you live in a region that has little rainfall or a short growing season, if you're far from an urban center, or if you live at a high elevation," said Levy. All of these variables assist in diagnosing the causes of poverty, he said.

The precise combination of interventions to address poverty depends greatly on the geographical and physical factors at play in a given area. In sub-Saharan Africa, for example, a growing body of evidence shows that lack of access to transportation networks creates hunger "traps," according to Levy. If someone is far from a main highway, it takes more effort to get out of a poverty trap, so investing in better transportation infrastructure would be a key strategy, he said.

For populations that live in higher-elevation regions, other factors such as soil or growing conditions might need to be addressed first. Yet, at the same time, these populations have the benefit of reduced exposure to diseases like malaria. But the net effect of all these factors can only be understood when you have the relevant data at your disposal, said Levy.

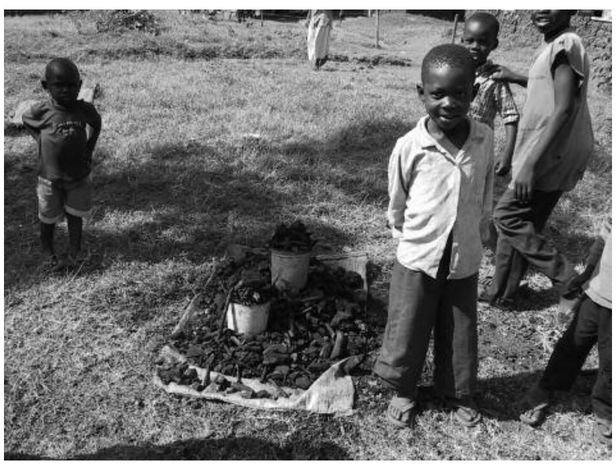
Levy noted an emerging trend: countries that create detailed poverty maps are doing a better job of charting intelligent interventions, since they are able to identify their own hot spots and set priorities where the greatest attention is needed. "This is sort of 'brave new world' territory," said Levy. "It's the first time in human history that people have started talking about global poverty as seriously as they're currently talking about it."

But another darker trend is also emerging: even when there is a plan in place to reduce poverty, many countries do not have the financial resources to meet their goals. And foreign aid to fill that gap is lagging far behind; in some cases, financial commitments from wealthy, developed countries are disproportionately low. In other cases, even where sizeable commitments have been made, the money has not been coming in quickly enough, said Glenn Denning, director of the MDG Center based in Nairobi, Kenya. "So the money hasn't been

A protected spring provides a clean water supply to residents in Sauri, Kenya. (Image courtesy of Glenn Denning) flowing at the speed it should be, and certainly not at the speed that is needed to achieve the goals of the Millennium Project," said Denning.

In 2004, the Millennium team set up the MDG Center in Nairobi to work specifically with individual countries and to translate the Millennium Project recommendations into financing plans at the country level. Their approach is to work intensively with country leaders, analyze the programs each nation has in place and the means that it has to achieve its objectives, and assess whether those objectives line up with the goals of the Millennium Project. Next, they set up "MDG-based poverty reduction strategies," which serve as a blueprint for how each country can address poverty and hunger.

So far, in every country the team has studied, including Kenya, Ethiopia, Tanzania, Ghana, Senegal, and others, progress is not happening at the pace needed to reduce hunger or cut it



Local children sell charcoal in Kisumu, Kenya.(Image courtesy of Pedro Sanchez, Earth Institute at Columbia University)

in half by 2015, said Denning. "Our assessment is that they're lagging behind in terms of progress and level of investment that they're putting into cutting hunger," said Denning. "It's simply not enough. The developed countries need to fill that gap by increasing their aid contributions to the countries that have plans in place but do not have the resources to actually implement them."

Average aid contribution from developed countries is about 0.25 percent of gross national product. The United States falls far below the average, at 0.16 percent, although it has committed itself to giving much more, said Denning. Australia, Japan, and Italy also fall far below average in contributions. "A number of developed countries have expressed in principle that they're committed to delivering on their long-held promise of reaching 0.7 percent," said Denning, "but their actual contributions remain appallingly small."

One major issue with foreign aid is that some countries do not have a sufficient plan in place to ensure that international aid is used effectively. And potential donor countries "remain concerned about corruption and inefficiency in using aid," said Denning. "The developed countries might even say, 'yes, we know there's a need -- but show us an accountability system whereby most of the money really gets to the people who need it,'" said Denning.

Typically, it takes about 18 months from the time that a needs assessment is done to the time that a country has a full-blown poverty reduction strategy in place. But in the meantime, the MDG Center has designed "quick

Pedro Sanchez and Awash Teklehaimanot, an Earth Institute malaria expert, learn soil science in the Nyando District of Western Kenya. (Image courtesy of Pedro Sanchez, Earth Institute at Columbia University)

wins"—swift interventions that have immediate or short-term payoffs. For example, one quick win strategy is to dispense anti-malarial mosquito nets. Since malaria is the number one killer among African children, mosquito nets begin cutting down on infirmities and mortality from malaria immediately.

The MDG Center also advocates programs that enable primary school children to have a nutritious noontime meal every day, using locally produced foods instead of food aid. This has multiple benefits, including increased attendance and improved quality of learning. But central to this strategy is that the food be procured locally, "not imported from Iowa, Europe, or Australia," said Denning. Using local foods creates a demand in the community for farmers to produce more.

Many experts in the Millennium Project consider agriculture to be the "engine of growth" and are promoting the central message that foreign aid organizations should facilitate local food production, rather than encourage a dependency on imported food. "It goes back to the old Chinese proverb that if you give people fish, they will eat for a day, but if you teach them how to fish, they'll eat for a lifetime," said Sanchez. "Imported food aid creates dependencies and sometimes really stunts local markets."

Experts in the Millennium Project agree that the solutions to world hunger are not far out of reach. "So much of what is needed in the poorest parts of the world, especially in Africa, lies in information that already exists," said Denning. "The cost of ending poverty is very small compared to what people in the developed world spend on their Starbucks coffees."

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For more information, visit the following web sites:

UN Millennium Development Goals
http://www.un.org/millenniumgoals/

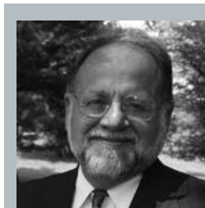
UN Millennium Project
http://www.unmillenniumproject.org/

The Earth Institute at Columbia University
http://www.earthinstitute.columbia.edu/

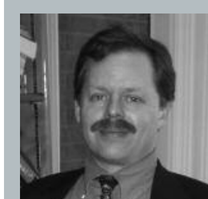
Center for International Earth Science Information Network (CIESIN)
http://www.ciesin.columbia.edu/

Socioeconomic Data and Applications Center (SEDAC)
http://sedac.ciesin.columbia.edu/index.html

In Africa, dairy cows provide income and a way out of poverty for many rural villagers. (Image courtesy of Glenn Denning)



Pedro Sanchez is Director of Tropical Agriculture and Senior Research Scholar at the Earth Institute at Columbia University. He received the World Food Prize in 2002, a MacArthur Fellowship in 2004, and serves as co-chair of the Hunger Task Force of the United Nations Millennium Project. Sanchez is author of *Properties and Management of Soils of the Tropics*, rated among the top 10 best-selling books on soil science worldwide. A native of Cuba, Sanchez received his PhD from Cornell University. He has dedicated his professional career to improving tropical soils management through integrated natural resource management approaches in an effort to achieve food security and reduce rural poverty while protecting and enhancing the environment.



Marc Levy heads the Science Applications group at the Center for International Earth Science Information Network (CIESIN), part of the Earth Institute at Columbia University. He also leads CIESIN's work on the Environmental Sustainability Index, Poverty Mapping, and the Human Footprint; serves as a project scientist for the Socioeconomic Data and Applications Center; coordinates CIESIN's involvement with the Millennium Development Project, and directs work on conflict early warning. Levy is a Convening Lead Author for the Millennium Ecosystem Assessment.

Glenn Denning joined the Earth Institute at Columbia University in July 2004 and serves as associate director of the Tropical Agriculture Program. He has played a lead role in establishing The Millennium Development Goals (MDG) Centre in Nairobi, where he now serves as director. The Centre works with governments, United Nations agencies, and the Millennium Project to strengthen policies, plans, and investments aimed at achieving the MDGs.

Matter in Motion:
Earth's Changing Gravity

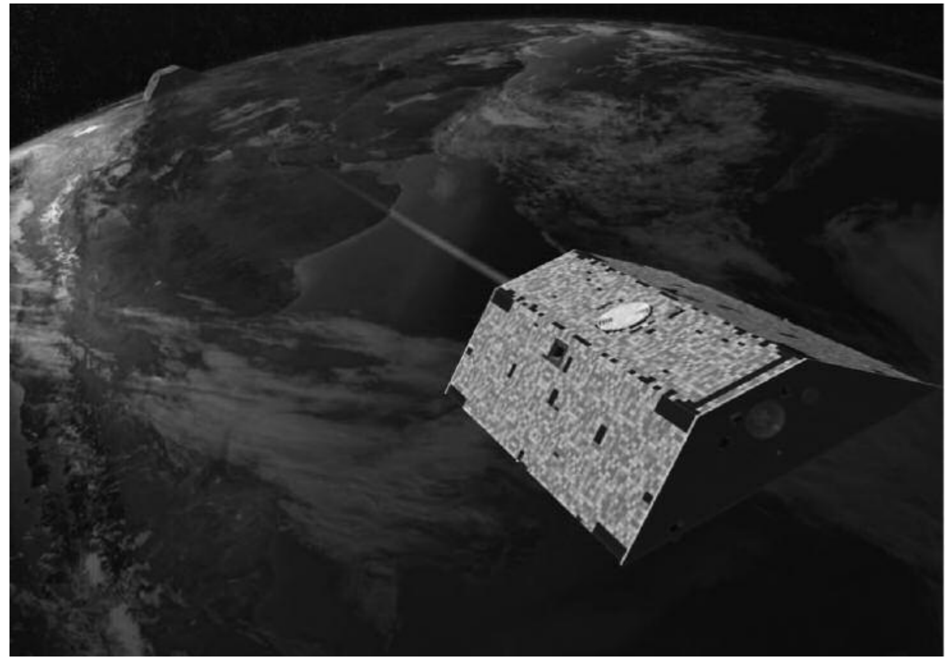
Physical Oceanography DAAC

by Laura Naranjo

According to legend, Isaac Newton discovered gravity after watching an apple fall from a tree. Using the word "gravitas" (Latin for "weight"), he described the fundamental force that keeps objects anchored to the Earth. Since then, scientists have used maps of the Earth's gravity to design drainage systems, lay out road networks, and survey land surfaces. But Newton probably didn't imagine that gravity could reveal new information about the global hydrology cycle.

Traditionally, scientists constructed gravity maps using a combination of land measurements, ship records, and more recently, remote sensing. However, those measurements weren't accurate enough to capture the slight changes in water movement that cause gravity to vary over time. With the help of a new satellite mission, scientists can now weigh water as it circulates around the globe and relate these measurements to changes in sea level, soil moisture, and ice sheets.

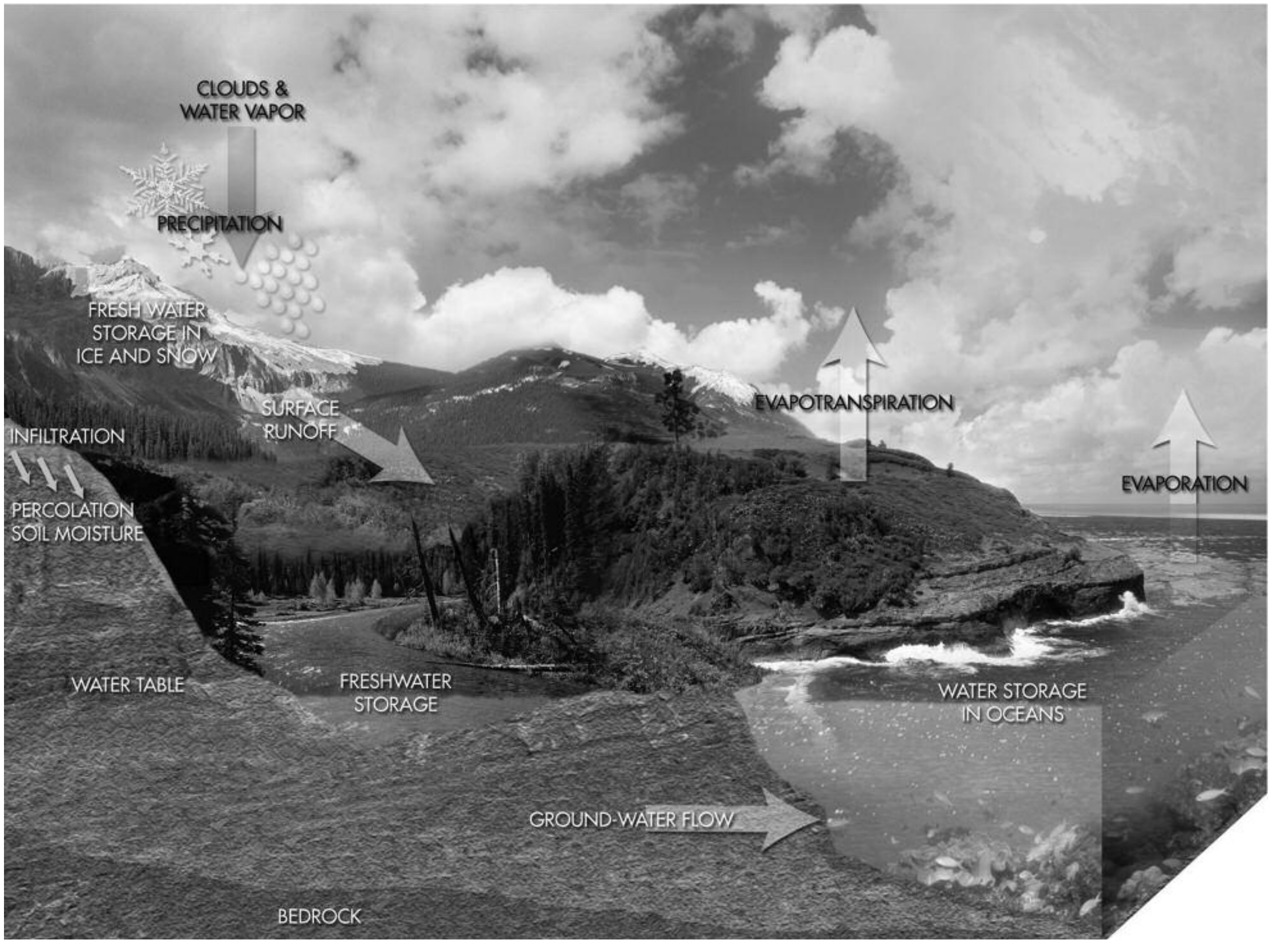
To better assess these gravity variations, an international team of engineers and scientists developed the Gravity Recovery and Climate Experiment (GRACE) mission. Launched in March 2002 as a joint venture between NASA and the Deutsches Zentrum für Luft und Raumfahrt (German Aerospace Center), the mission was implemented through collaboration between the University of Texas Center for Space Research, the GeoforschungZentrum (Germany's National Research Centre for Geosciences), and the NASA Jet Propulsion Laboratory (JPL).



By measuring changes in the distance between the GRACE mission's lead satellite and trailing satellite, scientists can determine changes in the Earth's gravity. (Image courtesy of NASA Jet Propulsion Laboratory)

GRACE relies on two identical satellites, each about the size of a small car. As the satellites fly approximately 220 kilometers (137 miles) apart, one following the other, a microwave ranging system monitors the distance between them to within a micron—smaller than a red blood cell. Scientists can map gravity anywhere on the Earth's surface by measuring tiny changes in distance between the two satellites as each of them speeds up and slows down in response to gravitational force.

Archived at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) in Pasadena, California, and the GeoForschung-Zentrum Information System and Data Center (GFZ/ISDC), GRACE data are changing the way scientists and modelers view gravity. GRACE



This diagram illustrates the hydrologic cycle and shows how water circulates over, under, and above the Earth's surface. GRACE data may lead to the identification of new fresh water sources in arid regions on the Earth. (Image courtesy of NASA Goddard Space Flight Center)

provides monthly maps that are at least 100 times more accurate than previous maps at detailing changes in the Earth's gravity field. "The classic idea of gravity being something that you measure once is no longer accepted. Gravity is an element that scientists must continue to monitor," said Byron Tapley, director of the Center for Space Research and principal investigator for the GRACE mission.

Because scientists can't see, feel, or directly observe gravitational forces, they map the Earth's gravity using a mathematical model that describes an imaginary spherical surface called the geoid. The geoid represents oceans as smooth, continuous surfaces unaffected by tides, winds, or currents. It creates a locally horizontal surface against which scientists can measure the downward pull of gravity.

Gravity is determined by how much mass a given material has, so the more mass an object has, the stronger its gravitational pull. For example, granite is a very dense material with a high level of mass, so it will exert a greater pull than the same volume of a less dense material, such as water. Earth's mass is distributed between various landforms and features—such as mountain ranges, oceans, and deep sea trenches—that all have different mass, which creates an uneven gravity field.

Consequently, the geoid doesn't form a perfect sphere, and in maps based on the geoid, the Earth's gravity field exhibits bulges and depressions. "Because the distribution of materials deep inside the Earth varies, its gravity field has hills and valleys. The ocean tries to lay along that hilly surface," said Michael Watkins, GRACE project scientist at JPL. For instance, the ocean surface off the tip of India is about 200 meters (650 feet) closer to the Earth's core than the ocean surface near Borneo. Without tides, currents, and wind, the ocean surface would follow the hills and valleys of the geoid, reflecting the variations in the strength of Earth's gravitational force.

"The Earth's gravity field changes from one month to the next mostly due to the mass of water moving around on the surface," said Watkins. "Because water in all its forms has mass and weight, we can actually weigh the ocean moving around. We can weigh rainfall, and we can weigh changes in the polar ice caps."

GRACE observes the Earth's hydrologic cycle and allows scientists to track water as it evaporates into the atmosphere, falls on land in the form of rainfall or snow, or runs off into the ocean. “The biggest freshwater hydrologic events that GRACE detects are the rainfall runoff in the larger river basins, like the Amazon, and the monsoon cycle in India,” said Tapley.

Detecting how much water is entering the oceans is key to learning about sea level changes. Other remote sensing instruments can observe sea level change, but they can’t discriminate between thermal expansion (when warmer water expands) and additional mass in the form of water being added to the ocean. “GRACE is sensitive only to the portion of sea level change that is due to water mass being added,” said Don Chambers, research scientist at the Center for Space Research. “Most models assume that the total mass of the ocean is constant—that there is no water being added to it or taken away. With GRACE measurements, modelers will need to account for fluctuations in mass.”

Developing a more accurate account of sea level change is important for low-lying countries such as Tuvalu. Situated in the Pacific Ocean between Hawaii and Australia, the country is a combination of nine islands and atolls (ring-like coral islands that enclose a lagoon). But because the islands reach a mere 5 meters (16 feet) above sea level at their highest point, they are vulnerable to rising oceans. GRACE data can reveal long-term climate trends that may affect sea level changes.

“The classic idea of gravity being something that you measure once is no longer accepted. Gravity is an element that scientists must continue to monitor.” - Byron Tapley

In addition to gauging changes in water mass on the Earth’s surface, GRACE can detect large-scale moisture changes underground. For instance, during record heat waves in Russia in 2002 and Europe in 2003, GRACE data enabled scientists to measure the amount of moisture that evaporated from the soil during those very dry periods. This ability will also alert hydrologists to changes in aquifers and underground water supplies. “It’s very hard to measure how much water is deep in the ground and how much it changes from one year to the next. GRACE is one of the few tools we have to do that,” said Watkins. “It can help us understand local hydrology, evapotranspiration, precipitation,

Like many atolls in the Pacific Ocean, Aitutaki in the Cook Islands rises only a few meters above sea level. Several island nations, such as Tuvalu in the Pacific Ocean and the Maldives in the Indian Ocean, are composed entirely of low-lying islands and atolls, making them especially vulnerable to rising sea levels. (Image courtesy of Laurie J. Schmidt)

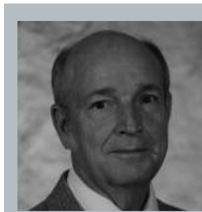
and river runoff, and it can give us an idea of how much water is available deep in the Earth for irrigation and agriculture,” said Watkins.

Scientists are also using GRACE data to survey frozen water in the form of ice sheets and large glaciers. Isabella Velicogna, a research scientist at the University of Colorado, studies mass changes in the Greenland ice sheet. “Some components of the seasonal cycle in Greenland are not very well understood, like ice discharge and subglacial hydrology. GRACE sees some of these components that are difficult to measure,” she said. Other instruments, such as altimeters, can determine elevation changes in the ice sheet, but GRACE sees the total mass, alerting scientists to how much ice and water are draining off the ice sheet. “GRACE provides information that you can’t get from any other satellite instrument,” said Velicogna.

After analyzing two years of data, Velicogna reported a longer-term trend: the ice sheet is losing mass. Although other Greenland research supports this finding, she added that scientists need a longer time series of data to understand what is happening to the ice sheet. Greenland holds about 2,600,000 cubic kilometers (624,000 cubic miles) of ice, which, if melted, would result in a sea level rise of about 6.5 meters (22 feet). Since the late nineteenth century, melting ice sheets and glaciers have increased global sea level by about 1 to 2 centimeters (0.3 to 0.7 inches) per decade.

Even glaciers that melted long ago affect sea level today. For instance, a large mass of ice covered the Hudson Bay area during the last Ice Age, which ended around 15,000 years ago. Now, without the weight of glaciers, the land beneath that area is slowly rebounding at a rate of about 1 centimeter (0.3 inch) per year. Over time, this postglacial rebound affects regional coastlines, complicating tide gauge readings and making it harder to monitor changes in global sea level. GRACE data will allow scientists to measure the change that can be attributed to postglacial rebound, making it easier to determine how much other factors—such as global warming—contribute to rising sea levels.

Investigators designed GRACE as a five-year mission, but scientists hope to gather data for up to 10 years. Continuing the mission life will allow them to explore new applications for GRACE data. "We're combining gravity measurements with other data, like those from ice sheet altimetry or radar altimetry. But we're still trying to understand what all these data tell us," said Watkins. "It's a very impressive engineering accomplishment that allows us to make such detailed measurements. GRACE gives us high-resolution gravity mapping—it's a pioneering remote sensing tool."



Byron Tapley is principal investigator for the GRACE mission. His research interests focus on determining crustal motion, the Earth's geopotential, and ocean and atmosphere circulation. He has served as Chairman of the Geodesy Section for the American Geophysical Union (AGU), is a member of the National Academy of Engineering, and is a Fellow of AGU, the American Institute of Aeronautics and Astronautics, and the American Association for the Advancement of Science. Tapley holds a Phd in engineering mechanics from the University of Texas at Austin.

Don Chambers, a research scientist at the Center for Space Research, is responsible for analyzing and verifying satellite altimetry data used to study changes in ocean heat storage, such as those caused by El Niño. His research includes determining accurate marine geoids. Chambers earned a PhD in aerospace engineering from the University of Texas at Austin.

As project scientist and science data system manager for the GRACE mission, Michael Watkins provides an interface between spacecraft system engineering and science requirements, and ensures the development of all required science analysis algorithms and software. He earned a PhD in aerospace engineering from the University of Texas at Austin.

Isabella Velicogna is a research associate at the University of Colorado in Boulder, where she examines the use of gravity observations from the GRACE mission to monitor geophysical processes, including hydrology, oceanography, meteorology, glaciology, and solid earth physics. She received a PhD in applied physics from the University of Trieste, Italy.

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For more information, visit the following web sites:

Physical Oceanography DAAC
http://podaac.jpl.nasa.gov/grace/

GRACE web site
http://www.csr.utexas.edu/grace/

GRACE Fact Sheet
http://earthobservatory.nasa.gov/Library/GRACE_Revised/

GRACE Space Twins Set to Team up to Track Earth's Water and Gravity
http://earthobservatory.nasa.gov/Newsroom/NasaNews/2002/200203077838.html

In Search of Martian Craters

Land Processes DAAC

by Laurie J. Schmidt

At first glance, Mars and Earth are two very different planets. The desert-like landscape on Mars is stark, without vegetation, and seemingly lifeless. Its surface area is a mere one quarter that of Earth, yet its largest volcano, Olympus Mons, is three times the height of Mount Everest. And the average temperature on Mars is a frigid -63 degrees Celsius (-81 degrees Fahrenheit), while Earth's average temperature hovers around 15 degrees Celsius (59 degrees Fahrenheit).

But when it comes to geologic processes, the two worlds are surprisingly alike. And it's this similarity that is helping planetary scientists learn how to interpret high-resolution remote sensing data of the Martian surface. "Mars is a very similar planet to Earth," said Michael Ramsey, assistant professor in the Department of Geology and Planetary Science at the University of Pittsburgh. "We see wind streaks, volcanoes, water channels—pretty much the same geologic features that we see on Earth."

Ramsey is part of a research team developing techniques to accurately identify and analyze small features on the Martian surface in satellite images. "In the past, we've focused on the

El Elegante Crater, part of the Pinacate Biosphere Reserve in northwestern Sonora, Mexico, is a maar crater about 1.6 kilometers (1 mile) in diameter and 244 meters (800 feet) deep. (Image courtesy of Jim Gutmann) large volcanoes, the giant impact basins, and the big channels," said Ramsey, "but we've never really been able to look at the small things on Mars."

"Trying to understand the history of other planets helps us compare them to the Earth and learn about patterns and geologic evolution on a planetary scale." – David Crown

The "small things" that Ramsey and his team hope to shed light on are craters—bowl-shaped depressions on a planetary surface that are typically caused by one of two processes. Impact craters form when a meteoroid, asteroid, or comet collides with a planet. Volcanic craters delineate vent areas at the summit of a volcano. "When you get down to small sizes, it's hard to tell the difference between a volcanic crater and an impact crater," said David Crown, senior scientist at the Planetary Science Institute in Tucson, Ariz., and a co-investigator on the project.

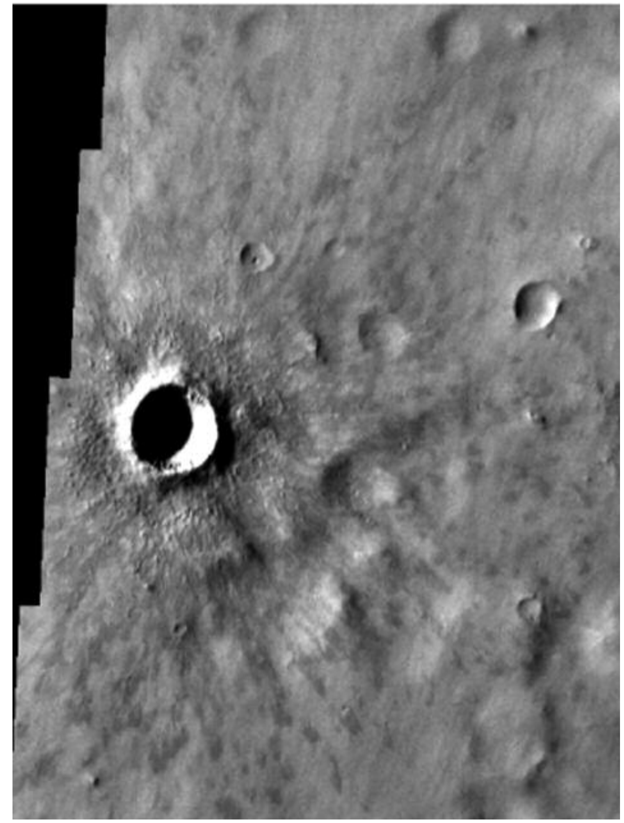
Ramsey and Crown are particularly interested in a type of volcanic crater known as a maar crater, which is created by a violent explosion that occurs as magma moves up toward the surface and hits groundwater or a body of surface water. Typically, magma that contains enough gas to erupt explosively forms a cinder cone, as debris accumulates around the volcano's vent. But if abundant water exists in the region of the volcano, the magma interacts with the water, causing highly explosive eruptions that build a maar rather than a cinder cone. "Maar craters are volcanic, but they're not volcanoes as you tend to think of them," said Ramsey. "It's basically a steam vent, and they look just like impact craters—a big hole in the ground with a lot of rocks around the outside."

The researchers hope to come up with criteria that will enable them to distinguish between impact craters and maar craters solely by looking at satellite data. "The goal is to look at small craters on Earth, both impact and volcanic, and study the differences so that as we get high-resolution images of Mars, we can make useful interpretations," said Crown.

On Earth, maar craters may fill with water to form a lake or pond. Because the presence of maar craters is a strong indication of water beneath the surface, the ability to identify them on Mars has important implications for understanding the planet's geologic history. "We're interested in craters that are potentially water-driven features, because that means there could be liquid water beneath the surface, which is a big deal for Mars exploration," said Ramsey.

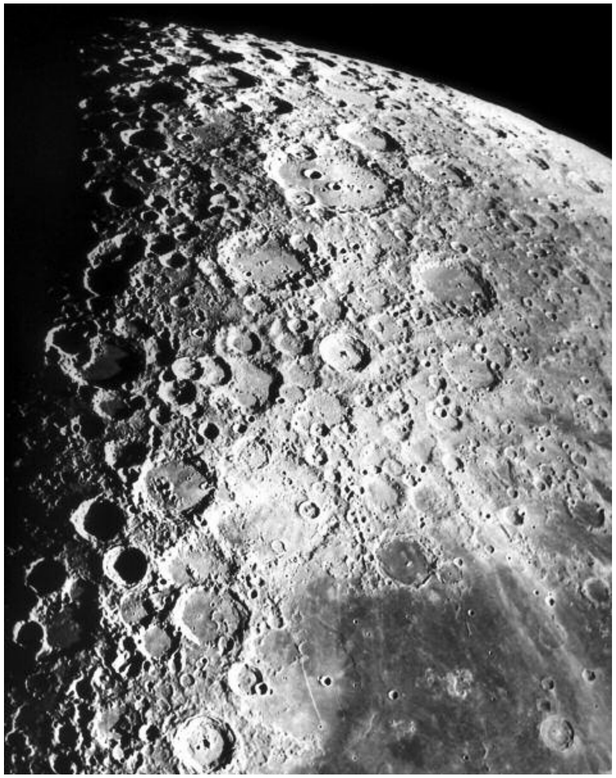
In the past, most scientists believed that Mars' volcanic activity was most intense in its ancient past. "The belief has been that Mars was really active in its early time (its first billion years), and that the last three billion years have been relatively quiet," Ramsey said. But the ability to now see smaller things on the Martian surface may change existing beliefs about the planet's geologic history.

One of the first things scientists do to estimate the age of a planetary surface is count the number of impact craters. "An old surface will have a lot more impact craters on it than a young surface," said Ramsey. "So if we find an area on Mars that only has one impact crater on it, that means it's a very young area."



This image, acquired by the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey spacecraft, shows a small crater on the surface of Mars. The crater, located in the Syrtis Major region, is slightly larger than Meteor Crater in northern Arizona and has been provisionally named Winslow Crater (after the small town in Arizona near Meteor Crater). The grayscale image was taking in the visible wavelengths (18 meters per pixel) and shows ejected blocks, the outer crater rim, inner crater wall, and ejecta blanket. (Image courtesy of NASA/JPL/Arizona State University)

Although craters provide important clues into a planet's past, Crown said the research community didn't pay much attention to small craters until fairly recently, as new high-resolu-



The surface of Earth's moon is covered with impact craters. They represent an early period in the Moon's history when intense meteorite bombardment occurred. (Image from Photos.com)

tion images of the Martian surface were acquired. "The whole idea of volcanic versus impact craters dates back to the early days of looking at the moon," he said. "Initially, scientists thought that the craters on the moon were due to gas bubbles coming out and blasting through the surface—that was actually in the scientific literature." Then in the 1960s, results of studies done at sites such as Meteor Crater in northern Arizona showed that the moon's craters were due to impacts, Crown said.

Although remote sensing on Mars is still in its infancy stage, using satellite data to identify surface land features on Earth is nothing new. Data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), archived at NASA's Land Processes Distributed Active Archive Center, have been used to study landforms on the surface of the Earth. Because of its high spatial resolution, it enables researchers to see features that are relatively small. Ramsey, a member of the ASTER Science Team, has used ASTER data to study volcanic domes, fire scars, and urban growth. But on Earth, scientists can compare satellite imagery with ground data to verify their interpretations, in a process known as validation—something they can't do on Mars.

The Thermal Emission Imaging System (THEMIS), one of three instruments launched onboard the Mars Odyssey in April 2001, generates high-resolution data very similar to that of ASTER. Images from THEMIS helped NASA mission scientists choose landing sites for the Mars Exploration Rovers in 2003. One of the instrument's major mission goals is to study small-scale geologic processes on the Martian surface. But before scientists can begin to interpret the data from THEMIS, they have to be certain that what they think they're seeing is what's actually there.

So Ramsey, Crown, and their colleagues came up with a plan: If they could develop some techniques to accurately identify and examine impact and maar craters on Earth using ASTER data, then these same techniques could help them distinguish between the two crater types in satellite imagery of Mars and assess their geologic implications.

Because ASTER and THEMIS generate data that are so similar in wavelength and pixel size, they offer an ideal comparison opportunity. "It's almost a perfect analog—like launching an instrument on Earth and an identical one on Mars, and then studying the results," said Ramsey.

The researchers chose two different crater sites on Earth—an impact crater and a maar crater—and set out to look for differences between the two, using both ASTER data and ground fieldwork.

Meteor Crater (also known as Barringer Crater), located in north-central Arizona, served as the impact crater study site. Known as one of the best-preserved impact craters on Earth, it is 180 meters (590 feet) deep and 1.2 kilometers (0.75 miles) in diameter. Arid climate and a lack of vegetation in the vicinity of Meteor Crater make it an excellent comparison site for similar-sized impact craters on Mars, Ramsey said.

Relatively close to Meteor Crater, just across the Mexican border from southern Arizona, lies the Pinacate Biosphere Reserve—home to a volcanic field and rare collection of maar craters. Measuring 1,400 meters (4,593 feet) wide, El Elegante Crater is the largest of these and was chosen as the maar crater study site. "The maar craters in Pinacate are almost the same age as Meteor Crater," said Ramsey, "so you basically have the same size craters in the same weathering environment."

The idea was to make comparisons between the ejecta (material thrown out of a crater dur-

Meteor Crater, located in north-central Arizona, is one of the most recent and well-preserved impact crater sites on Earth. The region's arid climate and lack of vegetation make Meteor Crater an excellent analog for similar-sized impact sites on Mars. (Image courtesy of Michael Ramsey)

ing an explosion) they found at the rims of the two craters. "Since the walls of a crater are pretty vertical and don't show up in a satellite imagery, you have to concentrate on looking at the stuff that was thrown out," said Ramsey. "Then you can make inferences based on mapping the ejecta and rocks around the edge and in the general vicinity of the crater."

During two field campaigns in 2004 at both crater sites, the team, led by Ramsey and his graduate student Veronica Peet, created a dataset that included details about crater rim topography, block sizes and composition, and vegetation types and percentages—information that may reveal some definitive differences between the two crater types.

Although Ramsey is quick to point out that the study is still a work in progress, he said they already have some initial results. "Right now, we can't tell you that X, Y, and Z tells an impact and maar crater apart," he said. "We could end up with a null result that says they're just too similar to tell them apart using remote sensing data. But I don't think that's the case—we've already found some tantalizing differences."

One difference the team found relates to block size and location. "It appears that blocks at El Elegante Crater are bigger, on average, and are located closer to the crater rim than the blocks at Meteor Crater," said Ramsey. If the fieldwork results show this to be a consistent finding, it could serve as an important yardstick in telling the two crater types apart—on Earth and on Mars, the researchers said.

But the results are preliminary, and further comparisons need to be done. "You need to constantly calibrate what you see on the ground with what you see from space," said Crown. "It's a learning process—some things we see on the surface are expected, and others are a big surprise." Crown cited the example of the Martian "blueberries" photographed by the Mars rover Opportunity in December 2004. Blueberries are marble-sized pebbles that contain hematite, a mineral that supports the idea that water existed in Mars' past. "Nobody knew what that was going to look like," he said, "and every bit of new information can change things dramatically."

Understanding how to use satellite data to map subtle differences around a crater on Earth will give scientists a better handle on how to do it on Mars. But finding impact craters to study on Earth is like a complicated treasure hunt. Erosional processes and plate tectonics effectively erase impact craters from view. "If you look at the Earth's surface, your first impression would be that there are no impact craters on Earth. In reality, there are lots of older impact craters here, but they've been weathered away," said Ramsey.

While only about 120 impact craters have been identified on the Earth, scientists estimate that on the surface of Mars, there are more than 43,000 impact craters with diameters greater than 5 kilometers (3 miles), and probably over a quarter of a million impact craters that are similar in size to Meteor Crater. Scientists believe that most craters on Mars were formed by meteorite impact early in Mars' history, but some may be from more recent impacts.

"Things on Mars stay around a lot longer than on Earth. You don't have plate tectonics erasing things as they go down a subduction zone," said Ramsey. "So our intent is to do the best we can making comparisons with these two craters, come up with some classifications, and then go to work on the THEMIS data from Mars."

Learning about small-scale processes on Mars can also provide valuable clues into the planet's climate history. "I don't think there's any question that there's water and ice near the Martian surface," said Crown. "The question is, 'what does this say about the climate history of the planet?' Does the existence of water on Mars in its earlier history mean that there was an atmosphere and a warmer planet? Or does it mean that there is just water locked up in the surface that sometimes gets released from the interior?" Answers to questions such as these could reveal information about Earth's future climate.

"It's all part of the big question: Why study the planets?" said Crown. "Trying to understand the history of other planets helps us compare them to the Earth and learn about patterns and geologic evolution on a planetary scale."

For now, the researchers continue to focus on one very small piece of the planetary geology puzzle: learning how to recognize different types of craters using satellite data. "We can't walk around to every crater on Mars and examine the material around the rims," said Ramsey. "Right now, we have to look at these features from space."

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For more information, visit the following web sites:

Land Processes (LP) Distributed Active Archive Center
http://lpdaac.usgs.gov/main.asp

Image Visualization and Infrared Spectroscopy (IVIS) Laboratory
http://ivis.eps.pitt.edu/

NASA's Mars Exploration Program
http://mars.jpl.nasa.gov/

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
http://asterweb.jpl.nasa.gov/

Thermal Emission Imaging System (THEMIS)
http://themis.asu.edu/

Michael Ramsey is an assistant professor in the Department of Geology and Planetary Science at the University of Pittsburgh, where he formed and supervises the Image Visualization and Infrared Spectroscopy (IVIS) Laboratory. He is also a science team member for NASA's Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) instrument, with a focus on using ASTER's unique thermal infrared capability for emergency hazard response. His varied research interests include remote sensing of active volcanoes, planetary surface processes using Earth analogs, and the science of natural hazard reduction. He holds a PhD in geology from Arizona State University.

David A. Crown is a senior scientist at the Planetary Science Institute (PSI) in Tucson, Arizona, with research interests in planetary geology, physical volcanology, and remote sensing. His current research focuses on the geologic history of Mars and integrating analyses of spacecraft imaging with field and remote sensing studies of terrestrial analogs. Prior to joining PSI in 2001, Crown was an assistant professor in the Department of Geology and Planetary Science at the University of Pittsburgh and a National Research Council Research Associate at NASA's Jet Propulsion Laboratory. He received a PhD in geology from Arizona State University.

Checking Earth's Vital Signs

Socioeconomic Data and Applications Center (SEDAC)

by Amanda Leigh Haag

Mention to someone that a little known species such as the "Alerce"—a large tree native to Chile and Argentina—is endangered, and they're likely to not bat an eyelash. But then drop the name of a more relatable endangered species such as, say, the Slender Loris from Sri Lanka—a fuzzy little primate with brown eyes that would give any teddy bear a run for its money—and it's likely to elicit more compassion.

Both are endangered, due in large part to habitat fragmentation from logging and other human activities. And both are evidence of the Earth's dwindling natural resources, according to the Millennium Ecosystem Assessment (MA), the first-ever global effort to take stock of the planet's ecosystem health. And the vital

The Madagascan Tomato Frog, found only on the northeastern coast of Madagascar, has suffered severe habitat loss due to encroachment by humans and deforestation. (Image from Photos.com) signs aren't looking good. Of the 24 categories of ecosystem health that were evaluated, 15 are being seriously degraded at a rate that cannot be sustained, said Walt Reid, director of the MA, an international, multimillion-dollar undertaking. "If we think of the planet's ecosystem services as a bank account that could last indefinitely if managed wisely, we are instead spending the principal. That does provide short-term benefits, but the long-term costs will be significant," said Reid. By altering the planet, be it through deforestation, overfishing, or degradation of land and climate change, "we're depleting a capital asset," he said.

The assessment represents scientists' first global-scale attempt at putting a price tag on the benefits that humans get from natural systems, a concept dubbed 'ecosystem services.' Some of the services studied include things that can be traded in markets, such as food and fibers. Others have less tangible, yet equally important, values, such as the flood control and prevention of erosion that forests provide. The summary of the MA findings, released on March 30, 2005, was the result of four years of work by 1,300 scientists from 95 countries.

"We looked at ecosystems through this lens of the services they provide to people," said Reid. "For example, we weren't looking at tropical forests as just a nice thing society ought to protect. Instead, the researchers examined the economic and health benefits that people obtain from the forest." And what they found is cause for grave concern. "In these utilitarian terms, the degradation of ecosystem services represents a substantial cost," said Reid. "We're losing in economic terms, and we're losing in terms of human health." The study showed that not only have ecosystems been dramatically altered, but they've been changed more in the last 50 years than in any comparable time period in human history.

By analyzing data from the NASA Socioeconomic Data and Applications Center (SEDAC) at Columbia University, scientists determined that in dryland ecosystems, such as sub-Saharan Africa and Central Asia, land degradation through agricultural use and climate change is closely linked to growing poverty. Drylands cover 41 percent of the Earth's land surface and are home to more than 2 billion people—a third of the human population. Desertification, or the expansion of dry lands unsuitable for crop production, is one of the greatest threats to human well-being, according to the report. "Drylands, which are among the most fragile ecosystems, are now the areas with the highest rate of population growth," said Reid. "Many dryland regions have become poverty traps, where a spiral of growing poverty and environmental degradation feed on one another."

People living in drylands depend primarily on the productivity of their land for their livelihoods. Crop and dairy production, livestock, and growth of fuel and construction materials all depend upon plant productivity, which is inextricably linked to water availability. Overgrazing and intensive cultivation in areas that do not have adequate levels of nutrients and water supply can lead to greater soil loss through erosion, reduced water quality, and ultimately, less vegetation to sustain life.

People living in dryland regions depend heavily on crop production and livestock for their livelihoods. Overgrazing and intensive cultivation in areas that do not have adequate levels of nutrients and water supply can lead to greater soil loss through erosion, reduced water quality, and less vegetation to sustain life. (Image from Photos.com)

In addition, climate change has led to more extreme drought cycles, according to the MA report. At least 90 percent of dryland populations live in the developing world, making them far less technologically able to adapt to these vulnerabilities. As a result of the MA findings, the link between environmental degradation and poverty is becoming the focus of considerable attention in high-level international circles, said Reid.

Other "costs" to human well-being, according to the MA study, include soil degradation and loss of pollinating insects, loss of water purification services, and decreased flood control, to name a few. In addition, scientists were able to put a specific number—2 degrees Celsius (3.6 degrees Fahrenheit)—on the amount of warming that the planet can sustain before ecosystems begin to deteriorate. While some northern latitude countries might actually benefit from a warmer climate, due to longer growing seasons, "once you get beyond 2 degrees Celsius, there's really no region of the world where the benefits outweigh the costs," said Reid.

"Directly relating ecosystem well-being to human well-being can make a difference, because it gives people a better sense of what's at stake." - Marc Levy

The study also determined that degradation of fisheries resources warrants immediate action. In most cases, both marine and freshwater fisheries have either peaked or are being seriously over-harvested, according to the report. The concept of over-fishing is certainly not a new one. But by studying population data from SEDAC, scientists participating in the MA were able to determine where fisheries-dependent populations live and estimate the potential cost to their livelihoods.

"A handful of earlier reports awakened people to the threats of biodiversity loss and habitat loss, but for the most part, they have not generated a groundswell of concern or action," said Marc Levy, who co-authored one of the chapters of the assessment and coordinated the use of SEDAC data in the MA study. "But directly relating the ecosystem well-being to human well-being can make a difference, because it gives people a better sense of what's at stake."

Before the MA study, scientists had to "engage in fairly idle guesswork" in order to determine where people live with respect to vulnerable ecosystems, said Levy. "You can look through the literature and find these numbers that people just pulled out of thin air." So researchers applied the highest-quality population data set available—known as the "Gridded Population of the World" (GPW)—and superimposed it on the countries that the MA was studying, yielding much more precise estimates.

One challenge faced by the MA in trying to reconcile ecosystem services with their value to human welfare was the potential for conflict of interest, according to Levy. "The conservation folks suspect that the poverty reduction people want to go in and build roads to connect markets and subsidize fertilizers to help farmers grow higher yields," said Levy. "At the same time, the poverty reduction people think the conservationists just don't care about people. But the MA brought together a lot of people who overcame those tensions in order to work together in a framework that was equally fair to both sides."

Loss of pollinating insects is among the many "costs" associated with deteriorating ecosystem health, according to the Millennium Ecosystem Assessment. (Image from Photos.com)

The Slender Loris (*Loris tardigradus*) from Sri Lanka is assessed as endangered and is on the World Conservation Union's 2004 Red List of Threatened Species. Habitat fragmentation over the years has seriously reduced the area available for this species. Between 1956 and 1993, Sri Lanka lost more than 50% of its forest cover to human activities, followed by a similar rate of decline in the remaining forest cover between 1994 and 2003. (Image copyright K.A.I. Nekaris)

Another challenge that scientists faced over the course of the study is that until now, almost all environmental monitoring has taken place at the national level. There is simply no method in place to survey environmental variables on a global scale, said Anthony Janetos, a coordinating lead author of the study from The H. John Heinz III Center for Science, Economics and the Environment. In some cases, countries don't have the financial resources to do large-scale surveys; in other cases, it is difficult to measure resources that no one country owns, such as fish in the ocean, said Janetos. "It's not like weather data, where every nation understands that in order to do a good job understanding weather and climate, you really need a global observation system," said Janetos. "That's still a new concept for looking at ecosystems."

But the scientists stress that the upside of the MA findings is that many of the trends that are occurring can be reversed. The findings weren't the "traditional doom and gloom, 'we're destroying the world and there's nothing we can do about it,'" said Reid. "Three of the four scenarios that we developed in this assessment actually showed that in the next 50 years, it is possible to turn this situation around and protect many of the ecosystem services."

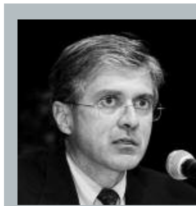
Reid noted that one exception to this is the loss of biodiversity. The MA concluded that due to habitat loss from human activities, a 10-15 percent extinction rate of species is expected by the year 2050. "We've got to feed another 3 billion people on the planet, so there's going to be more loss of habitat," said Reid. "The end result is you still end up with a substantial amount of species committed to extinction. It would be very hard to end the crisis of species extinction over the next 50 years."

For more information, visit the following web sites:

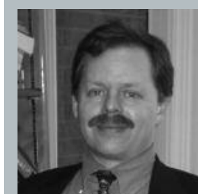
Socioeconomic Data and Applications Center (SEDAC)
http://sedac.ciesin.columbia.edu/

Center for International Earth Science Information Network
http://www.ciesin.columbia.edu/

Millennium Ecosystem Assessment
http://www.millenniumassessment.org/en/index.aspx



Anthony C. Janetos is vice president of The Heinz Center, where he directs the Center's Global Change Program. He has also served as vice president for Science and Research at the World Resources Institute, senior scientist for the Land-Cover and Land-Use Change Program in NASA's Office of Earth Science, and program scientist for NASA's Landsat 7 mission. Janetos has written and spoken widely to policy, business, and scientific audiences on the need to understand the scientific, environmental, economic, and policy linkages among the major global environmental issues, and on the importance of considering basic human needs in environmental policymaking. He holds a PhD in biology from Princeton University.



Marc Levy heads the Science Applications group at the Center for International Earth Science Information Network (CIESIN), part of the Earth Institute at Columbia University. He also leads CIESIN's work on the Environmental Sustainability Index, Poverty Mapping, and the Human Footprint; serves as a project scientist for the Socioeconomic Data and Applications Center; coordinates CIESIN's involvement with the Millennium Development Project, and directs work on conflict early warning. Levy is a convening lead author for the Millennium Ecosystem Assessment.

Walter Reid directed the Millennium Ecosystem Assessment (MA) from 1998 until the release of the project's findings in March 2005. He continues to work with the MA secretariat to disseminate the findings and support ongoing activities linked to the Assessment. Reid has also served as coordinator of the Puget Sound Salmon Collaboration, and as vice president of the World Resources Institute (WRI) in Washington D.C., where he was responsible for the oversight of WRI's strategic focus and research programs. He earned his PhD in zoology (ecology and evolutionary biology) from the University of Washington.

SPoRTscast

Fog obscures the landscape around Interstate 40 in the Smoky Mountains west of Asheville, North Carolina. NASA's Short-term Prediction Research and Transition (SPoRT) Center developed a fog product using MODIS data that helps forecasters identify regions of developing fog at night and early in the morning. (Image courtesy of NOAA Photo Library; Ralph F. Kresge, Photographer)

Global Hydrology Resource Center

by Laura Naranjo

Weather has always been difficult to predict. For centuries, people relied on myths and folklore to reckon the weather. Some sayings, like the rhyme "Ring around the moon, rain by noon. Ring around the sun, rain before night is done," actually contain some truth. Because ice crystals in clouds can cause haloes around the sun or moon, these rings are a genuine indication that wet weather is on the way. But other folklore legends, such as interpreting a groundhog's shadow to mean six more weeks of winter, are pure fiction.

Weather forecasters can now forego the folkloric guesswork and instead rely on a variety of ground and space-based instruments to make predictions. But accurate forecasts require a steady stream of satellite data, and modern meteorologists must combine traditional forecasting methods with the latest remote sensing techniques.

To help forecasters better incorporate satellite data into their decision-making process, NASA partnered with the National Weather Service (NWS) to form the Short-term Prediction Research and Transition Center (SPoRT), based at the Global Hydrology and Climate Center in Huntsville, Ala. SPoRT provides a central location where NASA and scientists can interact with weather service meteorologists and supply them with data products specifically suited to their needs.

SPoRT atmospheric scientist Gary Jedlovec and his colleagues rely on feedback from forecasters to create specialized data products. "We asked them, 'what are your forecast issues and problems?' We didn't just send data to them to see what they thought," said Jedlovec. "We wanted to match up a product or a data set with a particular problem."

What forecasters wanted was data in near-real time, meaning they need access to the data very soon after it is received from the satellite. "If it takes six hours for forecasters to receive the data, particularly in the case of clouds or thunderstorms that change on a short time scale, the information is not going to be of much value to them," said Jedlovec. Forecasters also requested higher-resolution imagery that would help them estimate cloud cover and height, fog, sea and land surface temperatures, and precipitation.

Although the weather service had already been receiving imagery from the Geostationary Operational Environmental Satellite (GOES) mission, some of the products had low resolution. In particular, resolution for the atmospheric water vapor product was about 50 kilometers (31 miles), which is slightly larger than the north-to-south width of Oklahoma's panhandle. Jedlovec was familiar with NASA's Earth Observing System (EOS) satellites and knew they could be used to provide products with the improved resolution that forecasters needed.

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, for instance, provides measurements with 250 to 1,000 meter resolution, resulting in imagery with much finer detail. By detecting a broader range of energy reflected or emitted by the Earth, MODIS can observe weather variables and physical characteristics of land and ocean surfaces that can't be detected by GOES.

"If it takes six hours for forecasters to receive the data, particularly in the case of clouds or thunderstorms that change on a short time scale, the information is not going to be of much value." - Gary Jedlovec

MODIS gives forecasters improved data for cloud thickness and land and sea surface temperatures—all of which contribute to evolving weather. For instance, harmless, fluffy cumulus clouds can rapidly evolve into towering cumulonimbus clouds that often result in powerful storms. And land and ocean surface temperatures affect wind direction along the coasts. "If forecasters have timely, accurate, high-resolution sea and land surface temperature information, they can better understand and predict land and sea breeze circulations, which affect cloud cover and also influence where thunderstorms will occur," said Jedlovec.

For instance, on July 18, 2005, SPoRT provided forecasters with MODIS imagery that showed severe weather conditions developing over Huntsville. The imagery indicated atmospheric conditions that were likely to produce storms, and indeed, a severe storm formed over the city, dropping more than 2.5 inches of rain in 30 minutes. During stormy weather, high-resolution MODIS data help forecasters more accurately pinpoint and follow storm development.

The SPoRT team also produced a nighttime fog product. Fog develops when air near the surface cools, condensing atmospheric moisture into small water droplets suspended near the ground. Due to reduced visibility, fog can create hazardous travel conditions. Because MODIS can observe subtle changes in temperature and cloud cover, the SPoRT fog product helps forecasters identify regions of developing fog at night and early in the morning.

Meteorologists also need accurate information about rainfall, so in May 2005, SPoRT began supplying several NWS Forecast Offices data from NASA's Advanced Microwave Scanning Radiometer-EOS (AMSR-E), which measures water vapor, precipitation, and other hydrologic factors in the Earth's environment. By monitoring marine weather phenomena before they reach land, forecasters can better anticipate the impact of storm systems too far off shore to be detected by land-based radars. "Forecasters are now using real-time precipitation data from AMSR-E to monitor offshore rain systems approaching coastal Florida," said Jedlovec. AMSR-E data are archived at NASA's Global Hydrology Resource Center (GHRC) in Huntsville, which handles data management and distribution for the SPoRT project.

Because fluffy, fair weather cumulus clouds (top) grow vertically, they can quickly develop into the powerful, threatening-looking cumulonimbus clouds (bottom) that often precede severe thunderstorms. The tops of fair weather cumulus clouds usually range from about 5,000 to 8,000 meters (3,000 to 5,000 feet) high, while the tops of towering cumulonimbus clouds can extend over 12,000 meters (39,000 feet) into the air. (Image courtesy of NOAA Photo Library; Ralph F. Kresge, Photographer)

In addition to MODIS and AMSR-E imagery, the SPoRT team also plans to include data from NASA's Atmospheric Infrared Sounder (AIRS) in its products by the fall of 2005.

Unlike the MODIS and AMSR-E products, which are provided directly to forecasters, AIRS data will be incorporated into weather service models used to predict regional weather. "We believe that AIRS data will improve model predictions of temperature, moisture, clouds, and precipitation in the 0 to 24-hour time range," said Jedlovec. In addition, using MODIS sea surface temperatures in models is expected to improve the prediction of wind and temperature along major U.S. coastlines.

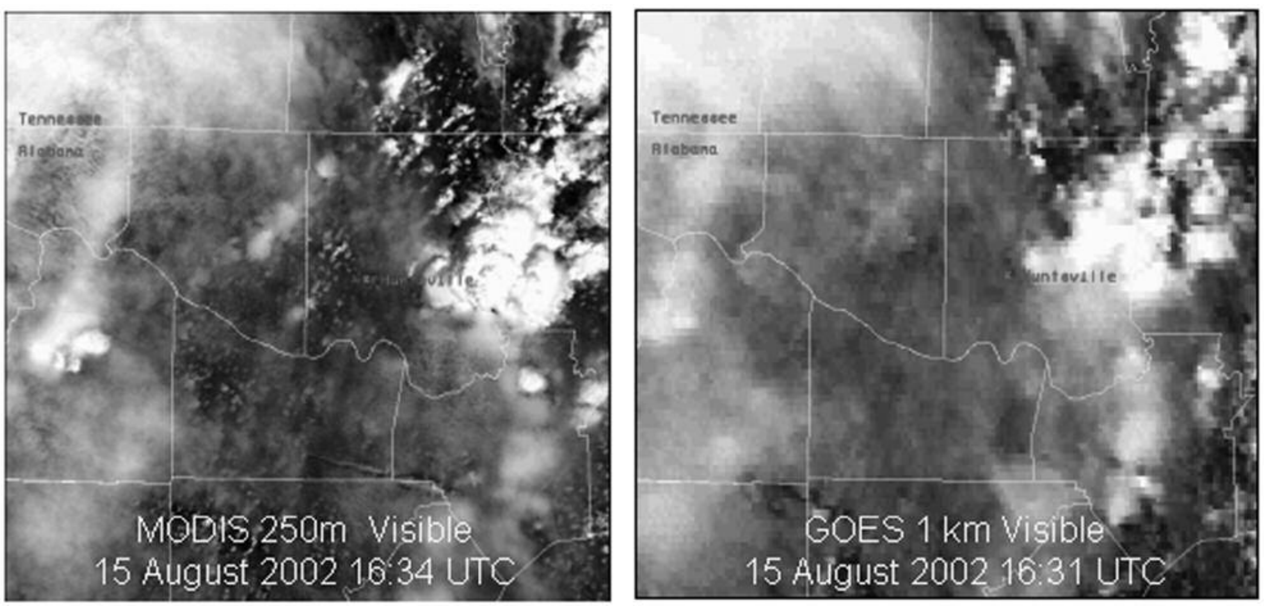
But simply sending data to forecasters isn't enough. So a key part of SPoRT's mission is training forecasters how to use the data. "We show them how to access and interpret the data," said Jedlovec. SPoRT also holds bi-weekly meetings with the Huntsville NWS Forecast Office, providing a forum for NASA scientists and NWS forecasters to share ideas for additional uses of the data.

When severe weather strikes, forecasters don't have time to visit satellite web sites, download data, and hope that it's relevant to the weather situation at hand. By working closely with forecasters, SPoRT designed data imagery that works specifically within existing weather service computer and display systems. "Forecasters can overlay all their other data right on top of the imagery, which enables them to make direct comparisons and detect changes," said Jedlovec.

Although SPoRT interacts primarily with southeastern weather service offices, where precipitation and coastal circulations are important weather factors, it also provides unique products to the NWS office in Great Falls, Montana. "Once word got out that we were providing real-time MODIS data products to some NWS Forecast Offices, the science operations officer in Great Falls contacted us to see how they could get the data," Jedlovec said. In response, SPoRT generated a MODIS snow product that helped forecasters in Montana understand the distribution of snow cover, how it recedes as it melts, and how it contributes to regional flooding. "They can now view daily snow cover changes, as well as detect possible ice and log jams that could exacerbate flood conditions caused by snowmelt," said Jedlovec.

Incorporating MODIS and AMSR-E data into forecasts is also preparing meteorologists to work with products generated by future satellites. The Geostationary Operational Environmental Satellite R series (GOES-R), scheduled to launch in 2012 as a joint development effort between NASA and the National Oceanic and Atmospheric Administration (NOAA), will provide more accurate data and improve forecasters' detection of meteorological phenomena. Another collaborative venture between NASA, NOAA, and the Department of Defense will result in a suite of National Polar Operational Environmental Satellite System (NPOESS) satellites, which will collect atmospheric, land, and ocean weather data.

"As soon as the data, products, and imagery are made available from NPOESS and GOES-R, offices with experience using MODIS data will instantly know how to use data from these new satellites," Jedlovec said. "And the weather service will be able to get the data every 15



The MODIS image on the left shows greater cloud and surface detail than the GOES image on the right. MODIS resolution is fine enough to show developing cloud lines (small white spots near the center of the left image) and provides crisper observations of the cloud cover. (Image courtesy of SPoRT) minutes, instead of only four times a day like they do with MODIS and AMSR-E data."

While supplying MODIS and AMSR-E data to NWS Forecast Offices nationwide is outside the SPoRT mandate, Jedlovec and his colleagues are working with the weather service and NOAA to begin sending EOS satellite data to additional offices. "We've established a model and documented a procedure so that this approach can be more easily implemented in other locations," he said.

SPoRT not only generated specialized products and offered training, but streamlined the data delivery process. Rather than sending data to individual offices, SPoRT delivers data to a regional weather service hub, where it can be downloaded by many offices. "We only have to send data to one place to serve 25 different weather service offices in the southeastern U.S.," said Jedlovec.

Interacting directly with forecasters has allowed the SPoRT team to develop high-resolution satellite data products that smoothly integrate into existing weather service forecasting processes in an efficient and timely way. "By giving the data directly to forecasters within the NWS decision support system, it really saves a lot of time. It's right there instantly for them in a format they are familiar with," Jedlovec said.

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For more information, visit the following web sites:

Short-term Prediction Research and Transition Center
http://weather.msfc.nasa.gov/sport/

Global Hydrology and Climate Center
http://weather.msfc.nasa.gov/

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

Gary Jedlovec is an atmospheric scientist at NASA's Global Hydrology and Climate Center. He is involved with NASA's Short-term Prediction Research and Transition Center (SPoRT), a project designed to transition the use of unique NASA EOS satellite data into the Huntsville National Weather Service Forecast Office to improve aviation and public weather forecasts. Jedlovec received his PhD in meteorology from the University of Wisconsin-Madison.

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Web: http://daac.gsfc.nasa.gov

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Email: larc@eos.nasa.gov
Web: http://eosweb.larc.nasa.gov

Land Processes
Land Processes DAAC (LP DAAC)
LP DAAC User Services
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Center for Earth Resources Observation and Science
Sioux Falls, South Dakota
Voice: +1 605-594-6116
Fax: +1 605-594-6963
Email: LPDAAC@eos.nasa.gov
Web: http://LPDAAC.usgs.gov

Snow and Ice, Cryosphere and Climate
National Snow and Ice Data Center DAAC (NSIDC DAAC)
NSIDC DAAC User Services
University of Colorado
Boulder, Colorado
Voice: +1 303-492-6199
Fax: +1 303-492-2468
Email: nsidc@eos.nasa.gov, nsidc@nsidc.org
Web: http://nsidc.org

Biogeochemical Dynamics, Ecological Data, and Environmental Processes
Oak Ridge National Laboratory DAAC (ORNL DAAC)
ORNL DAAC User Services
Oak Ridge National Laboratory
Oak Ridge, Tennessee
Voice: +1 865-241-3952
Fax: +1 865-574-4665
Email: ornl@eos.nasa.gov
Web: http://www.daac.ornl.gov

Oceanic Processes and Air-Sea Interactions
Physical Oceanography DAAC (PO.DAAC)
PO.DAAC User Services
NASA Jet Propulsion Laboratory
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Fax: +1 626-744-5506
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podaac@podaac.jpl.nasa.gov
Web: http://podaac.jpl.nasa.gov

Population, Sustainability, Geospatial Data, and Multilateral Environmental Agreements
Socioeconomic Data and Applications Center (SEDAC)
SEDAC User Services
CIESIN, Earth Institute at Columbia University
Palisades, New York
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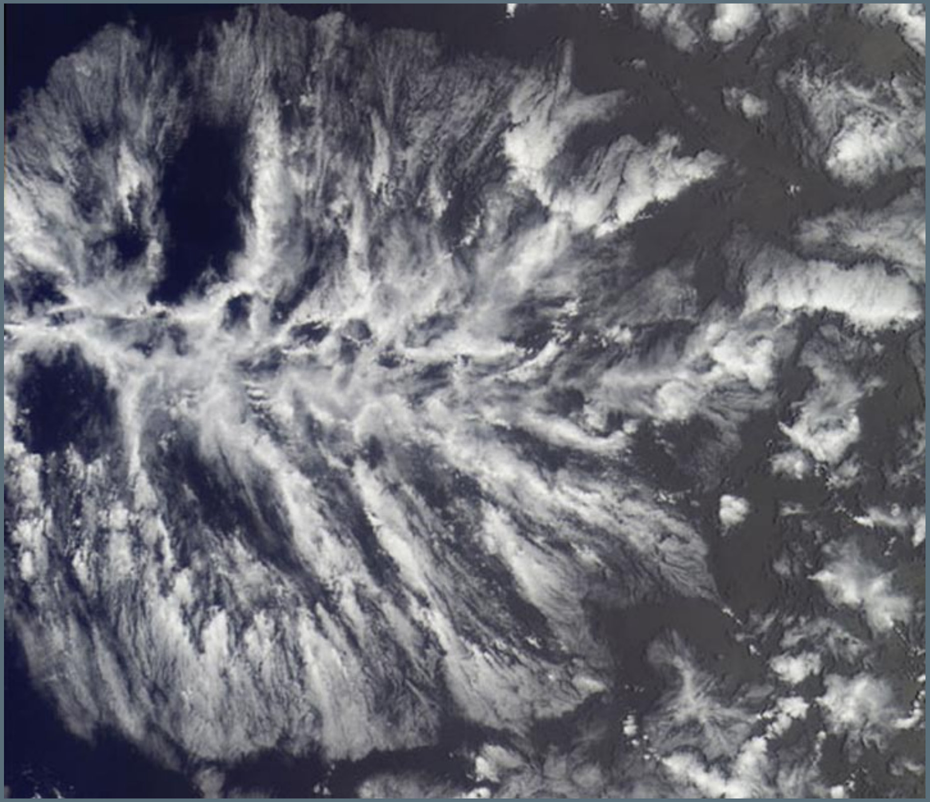
Fax: +1 845-365-8922
Email: sedac@eos.nasa.gov
Web: http://sedac.ciesin.columbia.edu

Applications of Earth System Science data from the NASA Science Mission Directorate



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http://nasadaacs.eos.nasa.gov