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Fieldwork

Studying the Link Between Arctic Methane Seeps and Degassing Methane Hydrates

By Carolyn Ruppel, John Pohlman, and Charles Worley

[revised October 26, 2009]

In spring and summer 2009, scientists with the U.S. Geological Survey (USGS) Gas Hydrates Project studied a methane seep in a lake near Alaska's Arctic coast, in part to determine whether the methane is coming from destabilization of gas hydrate—an ice-like crystalline solid formed from a mixture of water and natural gas, most commonly methane. Gas hydrates are stable at moderate pressures and low temperatures and are widespread in:

- continental-margin sediments at greater than 300-m water depth, and
- areas of continuous permafrost onshore and relict permafrost in the shallow offshore (less than 100-m water depth).

Globally, gas hydrate sequesters huge amounts of methane, which is known to be a far more potent greenhouse gas than CO_2. Climate perturbations could destabilize gas hydrate deposits and potentially release substantial amounts of methane to the atmosphere.

The USGS Gas Hydrates Project's climate-related research focuses on assessing the contribution of degassing methane hydrates to contemporary atmospheric methane concentrations and evaluating the vulnerability of gas-hydrate deposits to Holocene, present, and future climate perturbations. For at least the past 10,000 years, terrestrial and shallow offshore Arctic regions have undergone particularly rapid climate change. We are therefore targeting permafrost-associated gas hydrates to advance research on climate-hydrate interactions.

With sponsorship from the U.S. Department of Energy (DOE) National Methane Hydrates R&D Program and in collaboration with the University of Alaska, Fairbanks (UAF), our 2009 program has focused on Lake Qalluuraq, a thermokarst lake located in continuous permafrost approximately 60 mi south

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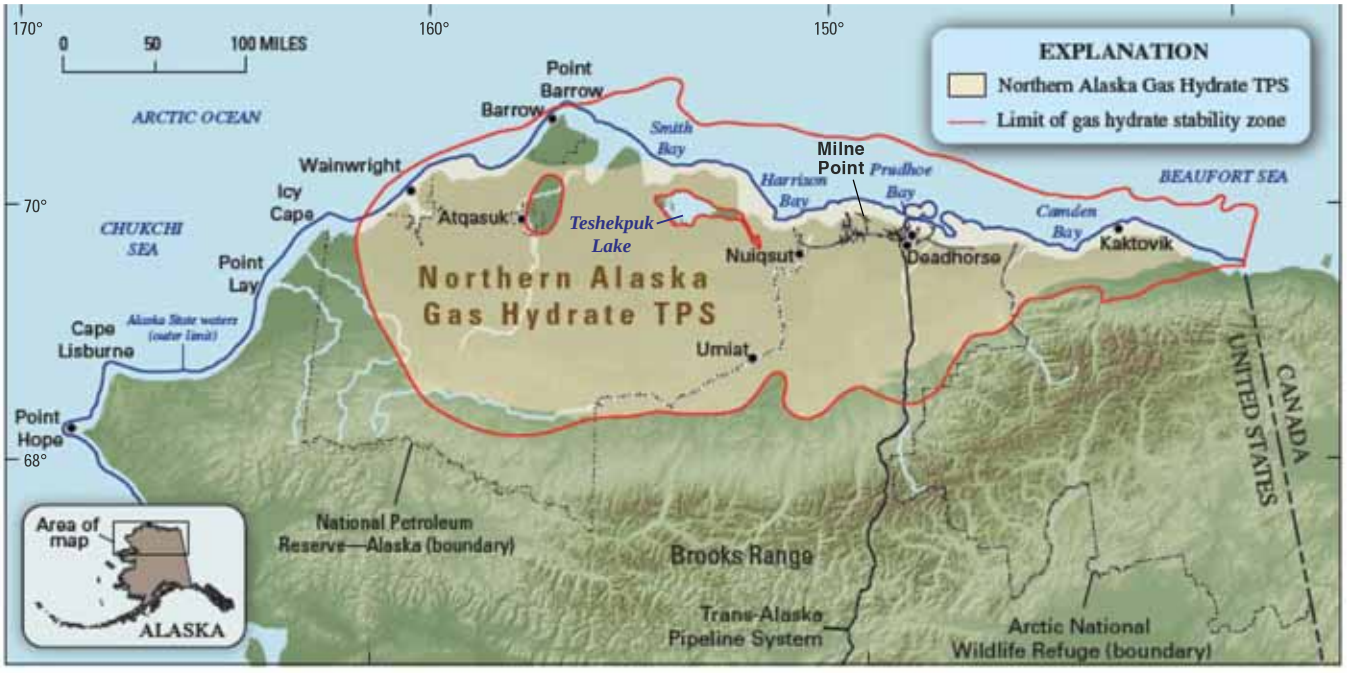
*Area in northern Alaska where subsurface temperature and pressure conditions are conducive to the occurrence of gas hydrates (red outline), compiled by **Timothy Collett** as part of USGS Fact Sheet 2008-3073 (**http://pubs.usgs.gov/fs/2008/3073/**). Note that gas hydrate could occur in sediments both onshore and at shallow water depths offshore. Lake Qalluuraq lies just south of Atqasuk in the western part of the Alaskan North Slope. TPS, Total Petroleum System.*



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Fieldwork, continued

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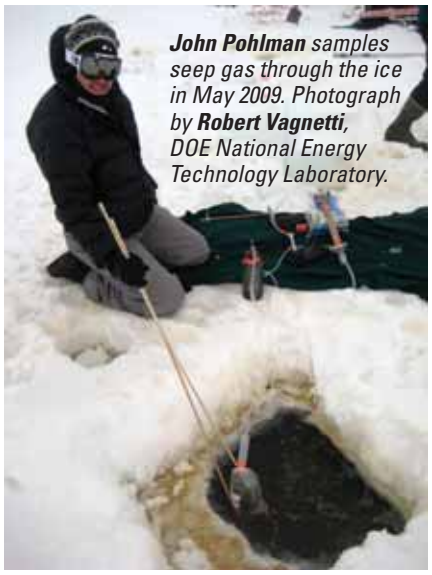
of Barrow, Alaska, near the Inupiat village of Atqasuk. Thermokarst lakes form in shallow depressions and are filled by meltwater from thawing permafrost. Lake Qalluuraq lies close to the thinnest part of the Alaskan North Slope gas-hydrate stability field, as inferred by USGS scientist **Timothy Collett** partly on the basis of deep borehole temperature data acquired by USGS geothermal investigator **Art Lachenbruch**. Ebullition (rapid release of gas) at a seep in Lake Qalluuraq is daily emitting nearly 140 m^3 of methane to the atmosphere, according to flux measurements completed by UAF researcher **K. Walter Anthony**. Seep methane sources in this area may include conventional deep-seated thermogenic gas (such as that associated with oil deposits), coalbed methane, dissociating gas hydrates near the top of the gas-hydrate stability zone, or microbial methane originating from decay of organic matter in the lake's thaw bulb (zone of thawed ground below the lake). As part of this DOE-sponsored project, we are working with **Andrew Hunt** (USGS, Denver, Colorado) to develop a chemical fingerprinting method that could distinguish hydrate-derived gases from other gas sources contributing to seeps.

A major component of the fieldwork was designed to document how geochemical and microbial cycles within the lake sediments and water column are influenced by profound seasonal changes in the lake's redox state: The lake is anoxic (lacking dissolved oxygen) in winter and fully saturated with oxygen in summer. In spring 2009, USGS geochemist **John Pohlman** and colleagues from UAF conducted operations from the lake's ice cover and retrieved short (less than 1 m long) percussion cores of lake-bottom sediments along a transect from the center of the seep to an area unaffected by seep activity. The sites were re-sampled during ice-free conditions in summer 2009. The USGS is responsible for conducting analyses of pore-water chemistry, gas composition, and sedimentary microbial biomarkers. The data will be used in conjunction with complementary analyses performed by UAF to delineate gas sources and the sedimentary biogeochemical cycles that influence contemporary and historical methane emissions from thermokarst lakes. Links between sedimentary cycles and the overlying water column are being addressed by **Monica Heintz** (University of California, Santa Barbara), who is measuring the rates at which microbes in the water column oxidize methane; microbial oxidation is the most critical sink for methane emitted into water bodies.



***John Pohlman** samples seep gas through the ice in May 2009. Photograph by **Robert Vagnetti**, DOE National Energy Technology Laboratory.*

During the summer 2009 fieldwork, the USGS also carried out extensive geophysical characterization of Lake Qalluuraq to constrain thaw-bulb thickness, the locations of lakebed pockmarks and other seep-related features, the distribution of gas-charged sediments, and the deeper structure of sediments beneath the ebullition site. The remoteness of Lake Qalluuraq and its shallow water depths (2 m maximum) posed challenges, but **Carolyn Ruppel** and **Charles Worley** successfully acquired Chirp seismic-reflection data with an Edgetech 424 fish towed at the lake's surface and operated at 4 to 24 kHz. They also rigged a Mala Geoscience 50-MHz ground-penetrating-radar remote-terrain antenna for water towing. The acoustic energy emitted by the Chirp system penetrates the lakebed and reflects off boundaries according to their acoustic properties, ultimately producing an image that captures sediment and gas distribution. (More information about Chirp and

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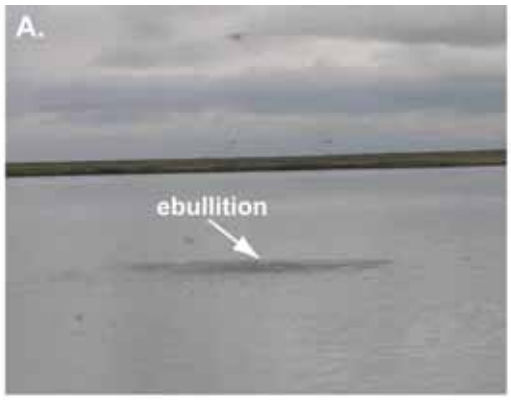
other seismic-reflection systems is available at **http://woodshole.er.usgs.gov/operations/sfmapping/seismic.htm**). Ground-penetrating radar (GPR) employs electromagnetic waves to image sediment boundaries below the lakebed on the basis of their dielectric properties. Seismic and GPR imagery can provide complementary information about sediment stratigraphy and about gas distribution and migration patterns.

Geophysical surveys also included continuous resistivity profiling, which detects vertical and horizontal variations in electrical conductivity. Frozen sediments generally have much higher resistivity than unfrozen sediments. Thus, resistivity profiles can be used to constrain the thickness of the thawed permafrost beneath the lake. Additional surveys used a simple fishfinder equipped with an 83-kHz transducer to locate water-column methane plumes and with a sidescan-sonar to image lake-bottom pockmarks.

Reconnaissance Chirp seismic-reflection data were also acquired at lakes in the nearby Teshekpuk Lake area of the North Slope to support research being conducted by geographer **Benjamin Jones** of the Alaska Science Center (see "Erosion Doubles Along Part of Alaska's Arctic Coast—Cultural and Historical Sites Lost," *Sound Waves*, May 2009, **http://soundwaves.usgs.gov/2009/05/research2.html**).



Methane seep in Arctic Lake Qalluuraq. A, *Surface bubbling of lake above methane seep.* B, *83-kHz seismic-reflection profile of lake-bottom depression at seep and methane bubbles (*m*) in water column. Horizontal black lines are depth markers, spaced at 2.5-ft intervals. Vertical scale is exaggerated in this profile. Depression is approximately 3 m across and 2.5 m deep, according to independent information provided by UAF colleagues.* C, *Sidescan-sonar image showing lakebed pockmark associated with seep.*

The next phase of the project involves October 2009 aerial photographic surveys to identify lake-based seeps between Teshekpuk Lake on the west and Milne Point on the east. Photographer **Dann Blackwood** will participate in these surveys, which are timed to capture imagery of just-frozen lake surfaces and as-yet unfrozen seeps within the lakes using an approach pioneered by **K. Walter Anthony**. The Milne Point area is of particular interest for this study, owing to the availability of data on the chemical composition of deep methane-hydrate samples recovered during 2007 drilling by DOE and British Petroleum, with significant involvement from the USGS Gas Hydrates Project. Starting in spring 2010, the coring scientists in our group will sample sediments from newly identified lake-based seeps in the Prudhoe Bay area. They also plan to revisit Lake Qalluuraq in order to document interannual variations in methane dynamics.

Additional details about the 2009 fieldwork are available in the article "Permafrost Gas Hydrates and Climate Change: Lake-Based Seep Studies on the Alaskan North Slope" in the summer 2009 issue of the National Methane Hydrates R&D Program newsletter, Fire in the Ice (**http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/newsletter/newsletter.htm**).

USGS Dive Team Assists Hydrologists with Contaminant Study in Ashumet Pond, Massachusetts

By Rick Rendigs

On July 21, 2009, **Dann Blackwood** and **Rick Rendigs** of the U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center's dive team successfully completed scientific diving operations at two long-term study sites in Ashumet Pond in Mashpee, Massachusetts. The dive work supports a continuing cooperative effort with team leader **Tim McCobb** of the USGS Water Resources Discipline (WRD)'s Massachusetts-Rhode Island Water Science Center.

WRD scientists are conducting an ongoing study to evaluate the spatial distribution, concentrations, and ultimate fate of various chemical pollutants that were discharged at the Massachusetts Military Reservation and have infiltrated into groundwater and local ponds in the upper Cape Cod area.

One part of this study reveals the impact of effluent from a decommissioned sewage-treatment plant that operated on the Massachusetts Military Reservation for almost 60 years, from 1936 to 1995. The effluent was dumped into infiltration beds, and the resultant sewage plume has been identified in groundwater samples approximately 6 km downgradient from the plant. (Groundwater

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Fieldwork, continued

(Ashumet Pond continued from page 3)

flows "downgradient," from areas where the water table is higher to areas where it is lower.) A segment of this sewage plume currently discharges as groundwater along the shoreline of Ashumet Pond, originating from the infiltration beds approximately 500 m upgradient from the study site.

One of the components of sewage effluent is phosphorus (P), which in sufficient concentrations causes eutrophication of freshwater lakes, changing their condition from low biologic productivity and clear water to high biologic productivity and water made turbid by the accelerated growth of algae. Decomposition of the abundant algae reduces dissolved oxygen in the water, which can cause other organisms, such as fish and shellfish, to die. An estimated 516 metric tons of phosphorus was disposed of in the infiltration beds during the operation of the plant.

*USGS diver **Dann Blackwood** displays a sample of algae removed from the bottom of Ashumet Pond at the shallow-water drill site 20 m from shore. Photograph by **Tim McCobb**.*

In order for scientists from WRD to determine the scope and concentrations of phosphorus entering the pond, USGS Woods Hole divers were enlisted over the years to implant various types of samplers (such as gel, diffusion, dialysis, and seepage meters) into the sediment of the pond to enable the collection of representative pore-water samples near the interface between the groundwater and the surface water. (For example, see related *Sound Waves* article at **http://soundwaves.usgs.gov/2004/07/fieldwork.html**.)

At the two long-term study sites in the area, multidepth drivepoint wells have been installed to more than 30 m below the pond's sediment surface. These wells make it possible to sample groundwater from a range of depths. USGS divers recently assisted with uncapping the wells and installed tubing in order for WRD scientists to pump the wells from the surface and sample the groundwater for phosphorus.

Voluminous amounts of algae were encountered along the bottom of the pond at the nearshore well site (20 m from shore), restricting visibility and making it a challenge to locate the nearshore wells. The deeper site, about 40 m from shore, was virtually free of algae along the bottom.

Most of the dissolved phosphorus in the sewage plume is in the form of inorganic orthophosphate (PO_4). In 2004, the installation of a permeable barrier of iron filings mixed with nearshore pond sediment was installed along the shoreline of the study area; the iron filings have a high affinity for and capacity to adsorb PO_4 and reduce its concentration in groundwater discharging to the pond. Initial results have been encouraging regarding the ability of the barrier to sequester PO_4; details and results from these studies may be found in the following publications:

- McCobb, T.D., LeBlanc, D.R., Walter, D.A., Hess, K.M., Kent, D.B., and Smith, R.L., 2003, Phosphorus in a ground-water contaminant plume discharging to Ashumet Pond, Cape Cod, Massachusetts, 1999: USGS Water-Resources Investigations Report 02-4306, 70 p. [**http://pubs.usgs.gov/wri/wri024306/***]*.
- McCobb, T.D., LeBlanc, D.R., and Massey, A.J., 2009, Monitoring the removal of phosphate from ground water discharging through a pond-bottom permeable reactive barrier: Ground Water Monitoring & Remediation, v. 29, no. 2, p. 43-55, doi:10.1111/j.1745-6592.2009.01235.x [**http://dx.doi.org/10.1111/j.1745-6592.2009.01235.x**].

Research

Remote-Sensing Technologies Provide Unique Maps and Datasets to Support Coastal Scientists, Managers, and Decision Makers

By Matthew Cimitile, Ann Tihansky, and Wayne Wright

The U.S. Geological Survey (USGS) Coastal and Marine Geology Program develops and uses specialized technology to build high-resolution topographic and habitat maps. These data products are critical to researchers, decision makers, resource managers, planners, and the public. A new Web site launched by the program, "Decision Support for Coastal Science and Management," provides data products and details about the capabilities of various USGS remote-sensing technologies. The information and tools provided by the Web site support research and decision making regarding important resources and vital habitat in coastal and marine environments.

"There are so many different applications of this technology that are relevant to the day-to-day life of the public," said **Amar Nayegandhi**, computer scientist and program manager of the decision-support Web site. A topobathymetric map of Tampa Bay is one example (**http://soundwaves.usgs.gov/2007/07/pubs.html**).

"Lidar [light detection and ranging] technology, along with other remote-sensing applications, was used to create a topographic map of Tampa Bay and the surrounding area that was extremely

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popular because it allowed people to identify the elevation of their property," said **Nayegandhi**. The value of detailed up-to-date topographic data to coastal managers and emergency planners in low-lying coastal areas is obvious; many regions at or near present sea level are vulnerable to flooding from hurricanes and other storms.

High-resolution maps of topography, bathymetry, and habitat describe important features affected by coastal-management decisions. The mapped information serves as a baseline for evaluating resources and tracking the effectiveness of resource- and conservation-management decisions. Datasets can be used to describe the topographic complexity of a barrier island or to monitor changes caused by extreme storms.

"Topography is so fundamental because it provides a dataset baseline—a context wherein you can understand all other resources—which is of prime importance to natural- and coastal-resource managers," said **John Brock**, oceanographer and principal investigator of the Decision Support Project.

Examples of recent lidar projects include surveying various characteristics of the benthic habitat (seafloor) of the Florida reef tract and Dry Tortugas National Park and mapping coastal changes in barrier islands on the U.S. Atlantic and Gulf of Mexico coasts, as well as along other coastal areas nationwide.

"On the coastal side, we've used this technology to try to understand how beaches and coastlines respond to hurricanes by accurately measuring the volume of sand and land that has been lost during a storm," said **Nayegandhi**.

The remote-sensing lidar tool known as EAARL (Experimental Advanced Airborne Research Lidar) uses laser technology to collect highly detailed elevation information that is processed by using a custom-built Airborne Lidar Processing System (ALPS). The EAARL system is unique in that it can simultaneously map elevations of both the land and the seafloor in clear shallow waters. The lidar data can also be processed to reveal the detailed structure of other features, such as buildings, trees, or coral reefs. In addition to mapping coastal changes and shallow-marine habitats, lidar has been used on land to map vegetation canopies, determine change in canopy structure, estimate volumes of vegetation available as wildfire fuel, and provide digital-elevation imagery for resource managers.

"It also gives us seabed topography, and that allows us to determine how healthy

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The modified eight-passenger Pilatus Porter model PC6T aircraft is designed to fly low and slow over the Earth's surface, sending laser pulses from its onboard sensor to the ground. It also is well suited for remote areas and unimproved landing strips, thanks to its STOL (short takeoff and landing) capability. The plane was tied down at Albert Whitted Airport in downtown St. Petersburg.

*Employees from the USGS Florida Integrated Science Center gather around the Pilatus Porter model PC6T aircraft during its June visit to St. Petersburg. Pilot **Wayne Wright** and computer scientist **Amar Nayegandhi** (second and third from right, below wing) show off the equipment and describe the capabilities and upcoming projects planned for the program.*

***Wayne Wright** shows off one of the 10 onboard computers that process data for constructing map products.*

Dashboard view of incoming data from the Experimental Advanced Airborne Research Lidar (EAARL)'s unique data-collection system, which can acquire detailed elevation information from both land and shallow seafloor.

(Decision Support continued from page 5)

coral reefs are by measuring the rugosity or topographic roughness," said **Nayegandhi**. Generally, the rugosity of a coral reef can be used to assess coral-reef health.

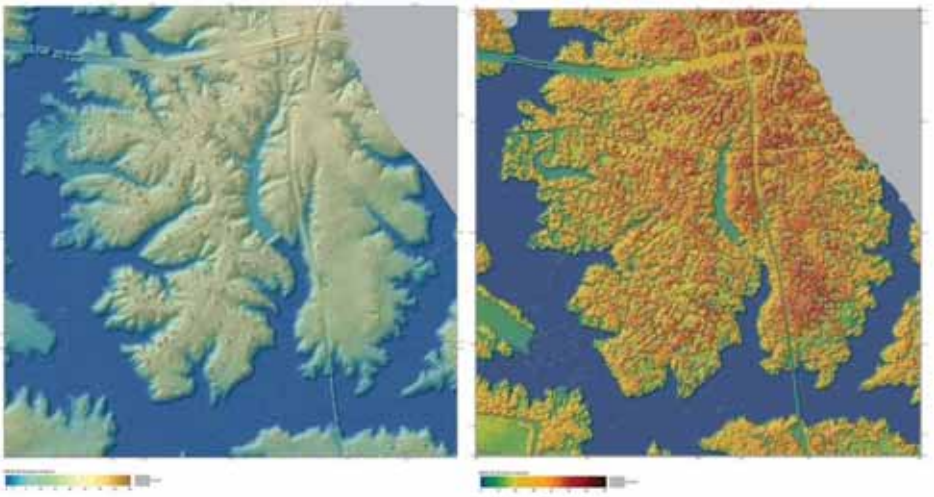
The USGS uses a specialized aircraft, the Pilatus Porter model PC6T, to collect these types of data. All but three seats have been removed from the normally eight-passenger aircraft, and a large, downward-looking port has been installed in the floor. Owned and operated by the USGS since 1975, the aircraft was transferred to the lidar project in 2008. The lidar is mounted above the port, giving it an unrestricted downward view of the Earth.

The crew consists of a pilot and a lidar operator who work together to operate and monitor the instrumentation onboard the aircraft. The pilot uses the navigation equipment to carefully guide the aircraft over the desired targets.

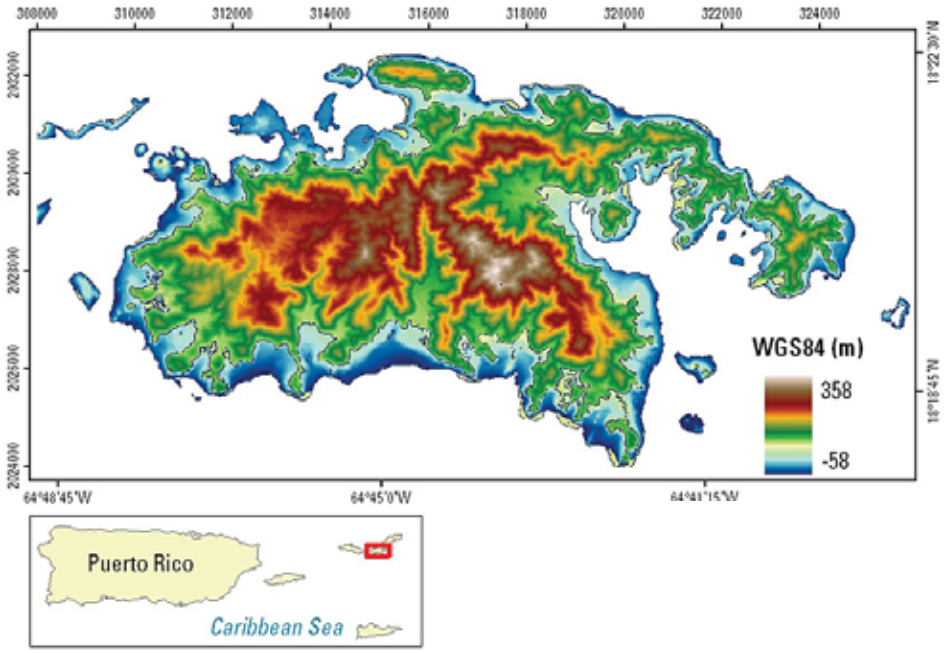
"The plane is uniquely designed to acquire very high resolution images by being able to fly low, around 300 m, and slow, between 60 and 90 knots, over areas of interest," said **Wayne Wright**, physical scientist at the USGS. "The plane is instrumented with 10 onboard networked computers that work together to capture the lidar, photography, navigation, and orientation data required to produce the high-accuracy remotely sensed datasets."

The laser repetitively emits a short (1.5 nanosecond) pulse of light that travels from the onboard sensor to the ground and is then reflected back up to the sensor. By timing how long it takes each pulse to reach the ground and return, scientists get a highly accurate measure of the distance between the sensor in the aircraft and the ground. The reflected light is then converted to digital values and passed to the onboard computer, where the information is stored.

Although the laser is used to precisely measure the distance from the airborne sensor to the ground, more information is required before maps can be made. Onboard survey-grade global-positioning-system (GPS) receivers record the precise position of the onboard sensor in three-dimensional space. Once this information is acquired, it can be combined with the distance measurement from the laser to compute the elevation of the surface and the location where the laser pulse contacted the Earth.



Two map images of the same area exemplify the various ways lidar data can be processed to create different views of the Earth's surface. The left image has been processed to show only the ground surface, known as "bare Earth." The right image, processed for "first-surface data," shows the tops of everything, including trees and buildings.



Another map produced from lidar data shows the topography and shallow bathymetry of St. John, U.S. Virgin Islands.

Lidar technology allows the USGS to create a whole suite of products ranging from topographic maps to digital-elevation models. Projects such as Decision Support for Coastal Science and Management are examples of how the USGS is uniquely suited to serve various partners and resource managers with new technologies that provide fundamental information to answer today's resource questions and challenges. Learn more about these technologies and their applications by visiting **http://ngom.usgs.gov/dsp/**.

About the author: Matthew Cimitile *is a journalist working with the USGS Florida Integrated Science Center office in St. Petersburg.*

Janine Powell Named New Director of the USGS National Wetlands Research Center

Janine E. Powell is the new director of the U.S. Geological Survey (USGS)'s National Wetlands Research Center, headquartered in Lafayette, Louisiana. **Powell** has previously led another USGS research center (the Northern Prairie Wildlife Research Center) and has years of research experience in Mississippi.

Powell said: "I am very pleased to be returning to the South, where I contributed earlier as a scientist. My new role in leading this prestigious National Wetlands Research Center is an incredible opportunity to influence research, development, and application in these critical systems, and I am deeply honored."

She replaces **Gregory J. Smith**, center director since December 2004. (See related *Sound Waves* article at **http://soundwaves.usgs.gov/2005/03/staff.html**.) **Smith** will now be director of the USGS Patuxent Wildlife Research Center in Laurel, Maryland.

Powell has 28 years of research experience with the U.S. Department of Agriculture (USDA) and the U.S. Department of the Interior. Most recently, she served as the assistant station director for Strategic Management and Accountability with the U.S. Forest Service's Rocky Mountain Research Station in Fort Collins, Colorado.

From 2007 to 2008, **Powell** was director of the USGS Northern Prairie Wildlife Research Center in Jamestown, North Dakota. There, center research included studies of waterfowl and other migratory birds west of the Mississippi River; the ecology of grasslands and wetlands of the northern and central plains; threatened and endangered species; and statistical and geospatial analyses, models, and monitoring.

Previously, **Powell** was affiliated with various USDA research. She was with the U.S. Forest Service's Rocky Mountain Research Station from 2002 to 2007, primarily as assistant director for research. She was responsible for overseeing research units in 12 States in the Interior West, where research focused on forest and rangeland issues. She also assisted in coordinating science needs in the aftermath of 2005 Hurricanes Katrina and Rita.

From 1998 to 2001, **Powell** was a lead scientist at the USDA Agricultural Research Service's Formosan Subterranean Termite Research Unit. The unit is based at the Southern Regional Research Center in New Orleans, Louisiana, but **Powell's** office was in Stoneville, Mississippi, at the Stoneville Research Quarantine Facility. She was responsible for developing biologically based control technology for management of the Formosan subterranean termite.

***Janine E. Powell**, new director of the USGS National Wetlands Research Center.*

Powell was project leader for the U.S. Forest Service's Southern Research Station Wood Products Insect Research Unit in Starkville, Mississippi, from 1995 to 1997. There, research led to new knowledge and methods for detecting, monitoring, and controlling wood-products pests. **Powell** was also a staff research forest entomologist and staff budget coordinator for the U.S. Forest Service's Forest Insect and Disease Research staff in Washington, D.C., from 1992 to 1995, where she assisted in planning, formulating, and tracking insect and disease research efforts nationally. She was research leader from 1991 to 1992 for the USDA Agricultural Research Service's Northern Grain Insects Research Laboratory in Brookings, South Dakota, where she guided research to develop integrated pest-management systems for insect pests of corn and small grains.

Powell was an entomologist at the USDA Agricultural Research Service's Southern Insect Management Laboratory in Stoneville, Mississippi, from 1981 to 1991. She managed the Stoneville Research Quarantine Facility and was a supervisory research entomologist at the Insect Rearing Research Unit in Starkville, Mississippi, and a researcher in Stoneville. During those 10 years, **Powell** developed new knowledge on the biology of field-crop insects to improve their control, especially by using natural enemies in cotton in the Mississippi Delta. She studied the use of imported and native natural enemies to manage insect pests. She worked with partners at many universities, including Louisiana State University, Baton Rouge.

Powell received a Ph.D. in entomology from Clemson University in South Carolina in 1981, a master's degree in biology from the State University of New York (SUNY) College at Plattsburgh in 1977, and a bachelor's degree in forest biology from the SUNY College of Environmental Science and Forestry in Syracuse in 1975.

Powell is from Ticonderoga, New York, located in the 6-million-acre Adirondack Park she calls "magnificent." She says that her pride and love for the part of the country where she grew up and became keenly interested in natural resources and science gave her a strong sense of place, but she is firmly attached to the South through a deep appreciation for its natural systems and people.

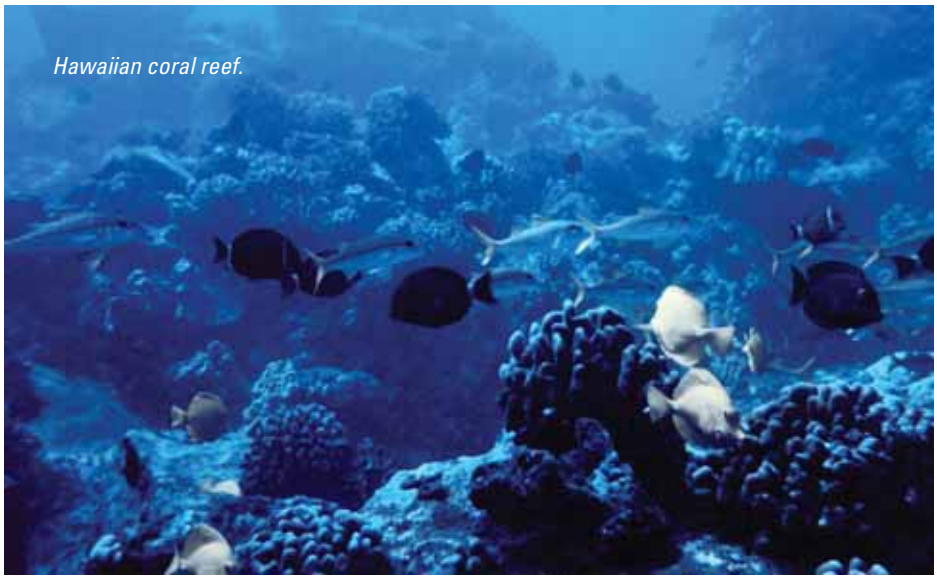
She and her husband, **Ron**, have two grown daughters and will reside in the Lafayette area.❁

New Fact Sheets Highlight Coastal and Ocean Science in the Western Region

By Durelle Smith

The science conducted by the U.S. Geological Survey (USGS) along our Nation's west coast and Pacific Islands ranges from documenting coastal erosion on Alaska's Arctic coast to analyzing the decline of tropical coral-reef ecosystems in Hawai'i.

Three new USGS Fact Sheets, the first in a new series highlighting the Western Region's coastal and ocean science, illustrate the spectrum of USGS research that provides information for resource managers and policy makers who must balance conservation mandates with increasing demands for resources that sustain the Nation's economy. These Fact Sheets include an overview of the entire region (Western Region), a more detailed look at a specific area (Alaska), and a narrower focus on one topic (seabirds). These cascading Fact Sheets are designed to nest into each other to provide a packaged overview of coastal and ocean science conducted by the USGS in Alaska, Hawai'i, the Pacific Islands, Washington, Oregon, and California.



Hawaiian coral reef.

A Look at the Western Region

USGS Western Region coastal and ocean science is interdisciplinary and collaborative, with projects that integrate expertise from science centers across the region. *USGS Western Region, Coastal and Ocean Science* (Fact Sheet 2009-3068) highlights many of these projects.

New modeling, monitoring, and mapping technologies are being developed to understand how changes in coastal watersheds affect nearshore coral reefs. This ridge-to-reef approach is a response to concerns about the health and decline of tropical coral-reef ecosystems in Hawai'i and the Pacific Islands.

The Santa Barbara Channel is of interest to numerous stakeholders, and the USGS conducts research to provide a range of scientific information to these partners. Projects include comprehensive seafloor mapping, studies of rockfish ecology in relation to oil and gas platforms, investigations of contaminants in fish, and studies of natural oil and gas seeps on the ocean floor.

Natural-gas hydrates are a potential energy resource and may play a role in global climate change. The USGS is compiling a global inventory of gas-hydrate occurrences and conducting scientific studies to provide information about this potential resource.

Massive amounts of sediment will be released when two dams are removed on the Elwha River in northwestern Washington in 2012. USGS scientists are conducting studies to better understand the likely impacts of dam removal on fluvial and coastal systems, including important salmon habitat, beaches, shellfish fisheries, and kelp beds.

Science Conducted in the Last Frontier

Alaska has more coastline than the rest of the United States combined. The range of science conducted in Alaska reflects the vastness of the largest State and the scientific information needed to manage its

(Fact Sheets continued on page 9)

Kasatochi Volcano in July 2008 (left) and October 2008 (right). The volcano erupted on August 7, 2008, blowing an ash cloud 45,000 ft into the air. The area of the island grew by 32 percent, owing to ash and lahar flows, and all signs of plant and wildlife were extinguished. (Photographs are at different scales.)

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resources. *USGS Western Region; Alaska, Coastal and Ocean Science* (Fact Sheet 2009-3069) highlights many of the key research efforts.

Research on species that depend on sea ice—such as the polar bear, listed as "threatened" under the Endangered Species Act, and the Pacific walrus, currently under status review—help define and constrain the consequences to these species of projected sea-ice loss. Satellite remote-sensing methods developed by the USGS allow researchers to detect sea-ice changes and determine the underlying mechanisms of change affecting the habitat of these Arctic species.

Erosion rates along the Arctic coast are among the highest in the world and have accelerated, possibly as a result of declining sea ice and increases in storm power on a coastline underpinned by warming permafrost. USGS research helps forecast future shoreline and potential ecological consequences.

In 2008, Kasatochi Volcano in the Aleutian Islands erupted, destroying much of the maritime ecosystem of the island and its seabird-nesting areas. The USGS and several partners are studying the ecological effects of the eruption to better understand the impact of volcanic events on ecosystems.

The USGS monitors many of Alaska's coastal glaciers and provides quantitative information on glacier mass balance—including a 50-year record of changes in glacier volume—allowing analyses of climate-change influences on water supplies and sea-level rise.

The extraordinary nonstop migration of a shorebird, the Bar-tailed Godwit, from Alaska to New Zealand and then back to

Double-crested Cormorant.

Alaska was documented by the USGS with satellite telemetry. This technology helps scientists track animals around the globe as part of a larger effort to understand the potential transmission of avian influenza viruses from Asia to North America.

Seabird Research Across the Region

Seabirds in the Pacific remain one of the great wildlife spectacles on the Earth. Yet seabirds face a number of threats, such as oil spills, introduction of predators, and conflicts with fisheries. Management agencies require increasingly sophisticated information on population dynamics, breeding biology, and feeding ecology to successfully manage seabird species and their ecosystems. *USGS Western Region; Seabirds, Coastal and Ocean Science* (Fact Sheet 2009-3067) highlights the research underway on many of these little-known species.

In Alaska, scientists are studying the status and ecology of the Kittlitz's Murrelet and the Marbled Murrelet. This information is essential to management agencies planning habitat conservation and discussing Endangered Species Act listing for each species.

In the Pacific Islands and Hawai'i, the USGS monitors seabird-population status and trends on the National Wildlife Refuges, providing standardized protocols for 13 species to meet seabird-management goals.

In San Francisco Bay, researchers are investigating contaminant concentrations and effects on several seabirds, including Forster's Terns, Caspian Terns, and Double-crested Cormorants. Several species show elevated mercury concentrations, linked to historical mining, that may be leading to eggs that fail to hatch and impaired chick growth and survival.

More Fact Sheets to Come!

These Fact Sheets are available as models that other centers, programs, and projects in the USGS Western Region can use to create their own, highlighting additional science activities at the regional, area, topical, or project level. You can download copies of the three Fact Sheets at the following links:

- *U.S. Geological Survey (USGS) Western Region, Coastal and Ocean Science*, **http://pubs.usgs.gov/fs/2009/3068/**
- *U.S. Geological Survey (USGS) Western Region; Alaska, Coastal and Ocean Science*, **http://pubs.usgs.gov/fs/2009/3069/**
- *U.S. Geological Survey (USGS) Western Region; Seabirds, Coastal and Ocean Science*, **http://pubs.usgs.gov/fs/2009/3067/** ❁

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