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Fieldwork

Degradation of Subsea Permafrost and Associated Gas Hydrates Offshore of Alaska in Response to Climate Change

By Carolyn Ruppel, Patrick Hart, and Charles Worley

Much of the shallow Arctic seafloor just off Alaska's North Slope was formerly subaerial tundra that was flooded during rapid sea-level rise beginning 15,000 years ago. In August 2010, U.S. Geological Survey (USGS) scientists collected data from part of this area—Harrison Bay in the U.S. Beaufort Sea—to study the degradation of subsea permafrost and associated gas hydrate in response to climate change. The survey was the first by the U.S. Department of the Interior since 1980 to target shallow-water areas of the U.S. Beaufort Sea and also the first systematic USGS survey of Alaskan subsea permafrost.

Gas hydrate—an icelike combination of water and certain gases, but most commonly methane—represents a highly concentrated form of gas and is stable only within a specific range of temperatures and pressures beneath the seafloor and in and beneath permafrost. Globally, gas hydrate sequesters large volumes of methane and thus may have potential as a future energy resource. On the other hand, methane is 20 times more potent than CO_2 as a greenhouse gas, and a large release of methane from dissociating gas hydrates could exacerbate global warming.

On the central Alaskan North Slope and in the nearshore environment, gas hydrate could occur in some strata within a zone ranging from 400 to more than 1,000 meters in thickness, starting at depths as shallow as 200 to 250 m.. An estimated $3x10^{13}$ m^3 of methane (measured at standard pressure and temperature) may be sequestered within gas hydrates in sands in permafrost areas. The deep conventional gas reservoirs that supply some of the source gas for gas hydrates currently sequestered in

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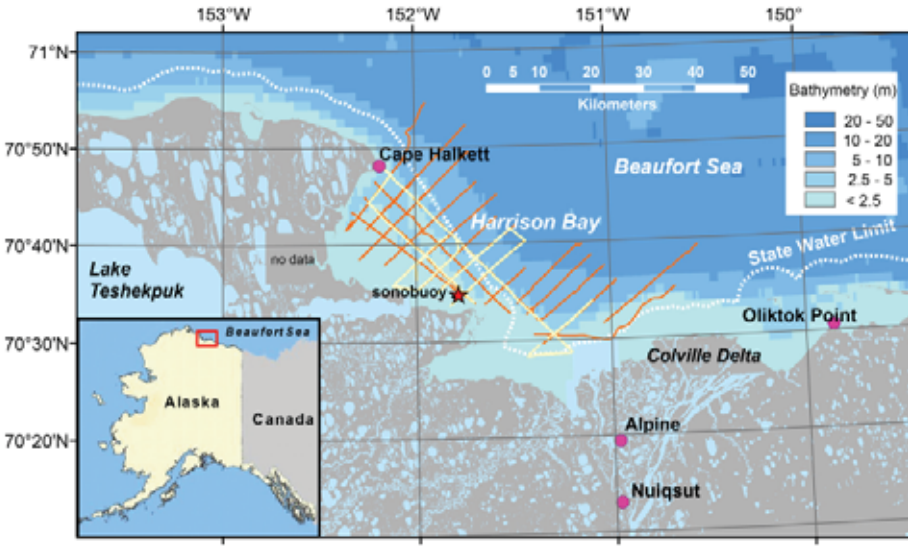
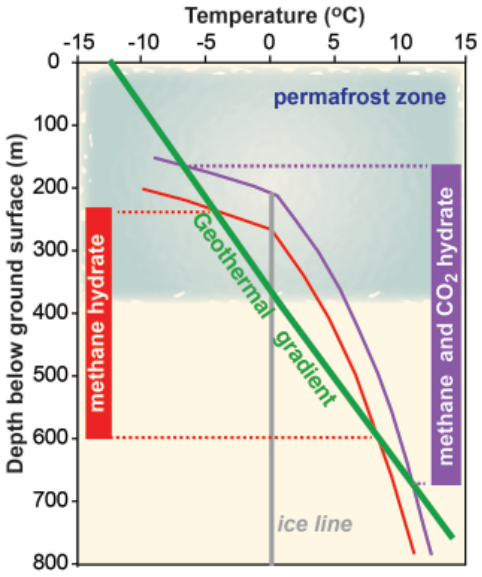


Location map (inset) and Harrison Bay study area on the U.S. Beaufort Sea inner continental shelf. Orange lines denote legacy seismic surveys from the late 1970s; yellow lines indicate combined mini-sparker, Chirp, and sonar surveys conducted in August 2010. Many of the new survey lines coincide with legacy lines. Star marks location of sonobuoy deployment.



*Relationships among an example Alaskan North Slope geothermal gradient (rate of change in temperature with depth), the thickness of the permafrost zone, and potential gas-hydrate occurrences. Gas hydrate is stable to the left and below the red curve for pure methane hydrate, and to the left and below the purple curve for a mixture of methane and CO_2 that is similar to gas in the shallow part of an onshore well near Harrison Bay, according to data compiled by **T. Lorenson**. The situation illustrated here might prevail onshore and at offshore water depths of a few meters.*

Sound Waves

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Fieldwork, continued

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sedimentary deposits on the Alaskan North Slope and in shallow offshore regions also contain significant CO_2. This CO_2 could be reintroduced to the atmosphere through climate-induced gas-hydrate dissociation.

The August 2010 study focused on the Harrison Bay area of the U.S. Beaufort Sea inner shelf (the part of the continental shelf closest to shore) and was conducted from the research vessel (R/V) *1273* of the Bureau of Ocean Energy, Management, Regulation and Enforcement (formerly the Minerals Management Service). The scientists collected approximately 185 km of high-resolution geophysical imagery of the water column, the seafloor, and the upper 100 m or more of the sediments beneath the seafloor. This research is one component of a multiyear effort by the USGS Gas Hydrates Project to study the impact of late Pleistocene to contemporary climate change on circum-Arctic gas-hydrate deposits, both offshore and onshore. (See related article in *Sound Waves*, October 2009, at **http://soundwaves.usgs.gov/2009/10/**.)

Arctic regions are undergoing rapid contemporary warming, but the overall warming trend in the Arctic began at the end of the Last Glacial Maximum (approx 19,000 years ago), and sea level began rising sharply about 15,000 years ago, with the onset of major melting in the southern Hemisphere. Much of the shallow Arctic shelf at water depths between approximately 10 and 100 m was formerly subaerial tundra that was flooded during rapid sea-level rise before 3,000 years ago. At water depths less than 10 m, such as those in most of the Harrison Bay survey area, the inundation may be more recent. The thick permafrost underlying the flooded tundra experiences thawing because the temperature of the overlying water is higher than the average surface temperature when the tundra was subaerial. Such thawing processes have been recognized in other parts of the circum-Arctic but have never been studied on a regional basis in the U.S. Arctic Ocean. The thawing of subsea permafrost leads to enhanced methane emissions due to microbial degradation of newly released organic carbon that had previously been trapped in permafrost, and possibly due to methane hydrate degassing. (For more information, see recent studies by **Natalia Shakhova** and others in the *Journal of Geophysical Research*, **http://dx.doi.org/10.1029/2009JC005602**, and *Science*, **http://dx.doi.org/10.1126/science.1182221**.)

Before the August 2010 cruise, the USGS Gas Hydrates Project re-evaluated seismic-refraction data acquired on the shallow (less than 25-m water depth) Beaufort Sea shelf by Western Geophysical in the late 1970s (see map, previous page). The "pre-stack" unprocessed field data are available to the USGS through a licensing agreement; the "post-stack" processed data can be freely accessed through the National Archive of Marine Seismic Surveys (**http://walrus.wr.usgs.gov/NAMSS/**). Harrison Bay was chosen as the initial focus area for the re-analysis because an older study by the U.S. Army

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(Left) R/V 1273*, a 33-ft-long aluminum-hulled research vessel managed by the Bureau of Ocean Energy, Management, Regulation and Enforcement, departs West Dock, Prudhoe Bay. (Right)* ***Patrick Hart*** *(foreground) and* ***Chuck Worley*** *deploy the mini-sparker.*

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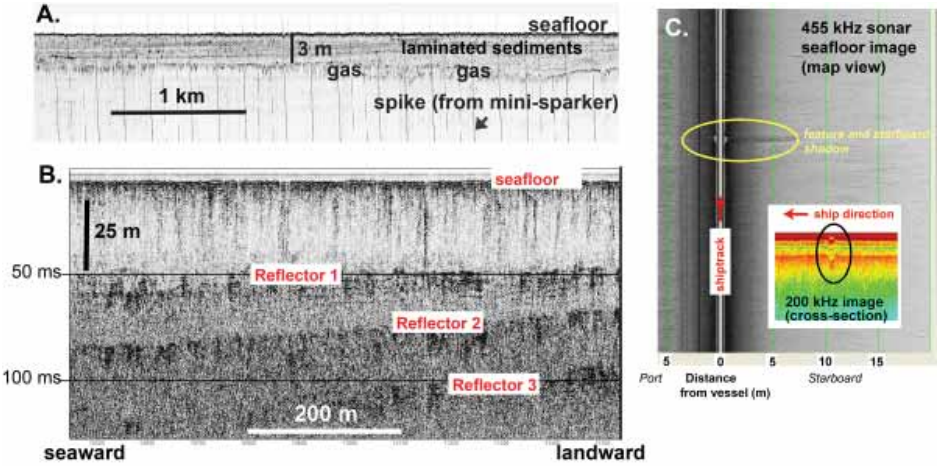
Cold Regions Research and Engineering Laboratory (CRREL Report 82-24) had used the same data to map subsea permafrost there. The new analysis challenges the older interpretation of permafrost distribution in western Harrison Bay and reveals deepening of the top of permafrost to more than 300 m beneath the seafloor in the eastern part of Harrison Bay. Because permafrost onshore near Harrison Bay may reach thicknesses of 400 m, we infer that much of the permafrost now in the bay has probably thawed within less than 10 km offshore. The data pattern interpreted as permafrost on seismic-refraction records abruptly disappears within central Harrison Bay at a location mapped as the apparent seaward extent of the subsea permafrost. Numerical models predict gas-hydrate dissociation at this location.

The August 2010 cruise used low-energy sound sources (such as the Edgetech 424 Chirp and mini-sparker) and fishfinder sonar to (a) track the top of subsea permafrost from the shallowest nearshore waters of Harrison Bay to several kilometers offshore, (b) map the distribution of gas in the shallow subseafloor, and (c) image seafloor features associated with ice scouring and possible methane emissions. The 200-kHz fishfinder mode was used to target possible methane plumes in the water column, and data obtained during a single sonobuoy deployment will provide constraints on sound velocities in subseafloor layers, required for interpretation of the seismic data. The low-energy seismic sources chosen for the 2010 cruise were intended to provide data of overlapping vertical resolution and depth of penetration, not to reproduce the results of the earlier Western Geophysical surveys. Important criteria in choosing instrumentation for the 2010 cruise were portability, compact size, low power demand, and manageable regulatory and permitting requirements, particularly with respect to the Marine Mammal Protection Act and the Endangered Species Act.

Shown on this page are sample data obtained in August 2010. Sound energy from the mini-sparker source penetrated more than 100 m below the seafloor in some places, and the data reveal the presence of



Examples of new data collected in three different parts of Harrison Bay in August 2010. Two examples on left are cross-sectional views of sub-seafloor sediment layers in (A) Edgetech 424 (Chirp) data and (B) mini-sparker data. Map view and cross-section (C) of multifrequency sonar (fishfinder) data reveal a feature (circled in yellow) whose origin is unknown and will require further analysis.

three prominent seaward-dipping reflectors in the example shown here (labeled "B"). The Chirp data vary in quality depending on the lithology and sea state; the section reproduced here (labeled "A") shows thinly laminated sediments draping gas-charged sediments approximately 3 m below the seafloor. This gas may originate through microbial degradation of organic matter in sediments that formerly hosted permafrost, with the possible addition of some methane that has migrated from deeper in the sedimentary section. Further processing will be required to generate images of the seafloor from the fishfinder sonar; the map view labeled "C" shows one example of a seafloor feature of unknown origin.

To date, an estimated 5 percent of the Western Geophysical seismic data for the U.S. Beaufort Sea has been re-analyzed. Weather and time limitations permitted us to reoccupy only about 50 percent of the legacy seismic lines in Harrison Bay during the summer 2010 cruise. In October, National Research Council/Department of Energy Methane Hydrates postdoctoral fellow **Laura Brothers** joined the USGS in Woods Hole, Massachusetts, to commence re-analysis of the most promising of the remaining legacy refraction data. In summer 2011, reconnaissance surveys will likely target degradation of subsea permafrost and associated gas hydrate both westward and eastward (toward Prudhoe Bay) from Harrison Bay. During that research, we will also be able to continuously measure methane concentrations in seawater to map methane hotspots. Eventually, the USGS Gas Hydrates project intends to extend climate-hydrate studies farther offshore to the Beaufort Sea continental slope, where the upper edge of the deepwater gas-hydrate system could be dissociating and possibly exacerbating slope failures as Arctic Ocean temperatures and sea-ice conditions change in response to global warming.

Partial support for this research was provided by interagency agreements DE-FE0002911 and DE-AI26-05NT42496 between the USGS and the U.S. Department of Energy's National Methane Hydrates R&D Program. We thank the Bureau of Ocean Energy, Management, Regulation and Enforcement and **C. Coon** for arranging our use of the R/V *1273*; **G. Lawley** from Kinnetics Laboratories, Inc., for serving as captain for the cruise; and the National Marine Fisheries Service and the U.S. Fish and Wildlife Service for assistance with permitting and compliance. This research was made possible through the advice and support of the Native Village of Nuiqsut, native observer **E. Nugapigak**, and several North Slope Borough officials, particularly **T. Hepa** and **W. Williams**. **T. Collett** (USGS, Denver, Colorado) and **B. Jones** (USGS, Anchorage, Alaska) were generous in sharing knowledge and advice that contributed to the project's success.

Coral Calcification Rates in South Florida During Times of Changing Ocean Conditions

By Matthew Cimitile and Ilsa Kuffner

This is the second in a series of articles about CREST research in Dry Tortugas National Park. The first article was published in the August/September issue of Sound Waves, *at* ***http://soundwaves.usgs.gov/2010/08/research.html***

A curious reef squid hovers over a calcification-monitoring station at Fowey Rocks Light reef in Biscayne National Park.

At several reef sites in South Florida, among the colorful corals and rich marine life, lie concrete cinder blocks. Each of these blocks is firmly attached to the reef and holds a transplanted coral on top. The transplanted coral is fixed onto a disc with a bolt that can easily slide into a hole at the top of the block and just as easily be removed to weigh the coral. This device, designed by U.S. Geological Survey (USGS) scientists with the Coral Reef Ecosystem Studies Project (CREST), is used to measure baseline calcification rates for one of the most abundant reef-building corals in South Florida, the massive starlet coral *Siderastrea siderea*. The goal of the study is to monitor coral growth as ocean conditions change.

With ever-increasing amounts of carbon dioxide (CO_2) entering the atmosphere, oceans are absorbing more and more CO_2. Part of this CO_2 becomes carbonic acid when it dissolves in oceans, lowering pH levels. Recent research shows that many marine organisms may be at risk in conditions of declining pH.

This phenomenon of lowered pH in the oceans, known as "ocean acidification," is predicted to directly affect calcifying organisms such as corals, algae, and phytoplankton, as well as the multitudes of marine life that depend on them for food and habitat. Experimental work has demonstrated decreases in calcification rates of corals and other calcifying organisms related to changes in ocean chemistry. (For example, see "Coral Reef Builders Vulnerable to Ocean Acidification," *Sound Waves*, March 2008, **http://soundwaves.usgs.gov/2008/03/research.html**.) The changes are expected to occur during the present century. CREST scientists are studying and establishing baseline rates for coral and algal growth in Florida by conducting in-situ field measurements of calcification rates.

"We are making measurements to establish these baseline rates for calcification now because it has not yet been done in a systematic, direct manner," said USGS marine scientist **Ilsa Kuffner**. "To do this, we have four calcification-monitoring sites at reefs offshore from Miami, Key Largo, Marathon, and in the Dry Tortugas."

The corals are periodically removed from the monitoring stations and weighed using the buoyant-weight technique. The method involves suspending the coral in a cooler of seawater while the coral hangs from a balance overhead. The difference in buoyant weight between each weighing is used to calculate the mass of calcium carbonate gained per unit time.

While the corals wait in specially modified buckets to be weighed, they are stained with a dye, alizarin red, that becomes incorporated into the outermost skeletal layer of the coral. The stain provides a reference mark because corals, like trees, grow by accreting annual layers. "Knowing the date of the staining and later measuring coral growth above the stain line give us the linear extension rate of newly calcified material," said **Kuffner**.

(Calcification Rates continued on page 5)

CREST researchers (left to right) ***Adam Brame***, ***Don Hickey***, ***Kristen Hart***, *and* ***Keith Ludwig*** *assist with coral alizarin red staining off East Key, Dry Tortugas National Park.*

(Calcification Rates continued from page 4)

The stain line also helps with another aspect of CREST research. The modern-day calcification study contributes directly to a CREST study to reconstruct paleoclimate by using coral cores collected from the Dry Tortugas. Historical coral-core records are valuable tools for comparing calcification rates of the past with those of the present or future. The stain line on each coral confirms the time period when material above it was deposited. When coral skeletal composition and instrumental data are calibrated properly, cores can provide temperature and environmental records predating the instrumental records, revealing coral responses to past ocean conditions. Density, thickness, and elemental composition of the growth bands are influenced by such factors as temperature, rainfall, nutrient variability, and water clarity. Studying these skeletal characteristics as they have changed through time can help scientists predict how future coral growth will respond to decreasing ocean pH and warming temperatures.

"We are hypothesizing that corals on the Florida reef tract will slow their calcification rates noticeably between now and 20 or so years from now," said **Kuffner**. "Depending on the trajectory that CO_2 emissions end up taking, experimental research indicates we could see a 30-percent decline in calcification by 2050 or 2100."

This is year 2 of the CREST 5-year plan for studying processes that affect the status of shallow coral-reef resources in three Federally protected areas: the Florida Keys National Marine Sanctuary, Biscayne National Park in Florida, and Virgin Islands National Park on St. John. CREST scientists hope to contribute scientific knowledge that can inform reef managers on best-management strategies for coral reefs and associated ecosystems.

Additional information about this topic is available in the following technical papers:

Kuffner, I.B., Andersson, A.J., Jokiel, P.L., Rodgers, K.S., and Mackenzie, F.T., 2008, Decreased abundance of crustose coralline algae due to ocean acidification: Nature Geoscience, v. 1, p. 114-117 [**http://dx.doi.org/10.1038/ngeo100**].

Jokiel, P.L., Rodgers, K.S., Kuffner, I.B., Andersson, A.J., Cox, E.F., and Mackenzie, F.T., 2008, Ocean acidification and calcifying reef organisms—a mesocosm investigation: Coral Reefs, v. 27, p. 473-483 [**http://dx.doi.org/10.1007/s00338-008-0380-9**].

Coral Paparazzi—Looking for a Quick Way to Spot Evidence of Coral Disease

By Christina A. Kellogg and David G. Zawada

Lights, camera, action! That's surely what it felt like to be a diseased coral in the Florida Keys during the first two weeks of August 2010. Using both an underwater, diver-operated spectrometer and an imaging spectrometer, U.S. Geological Survey (USGS) scientists collected data to determine whether certain light wavelengths or spectral signatures can be used as diagnostic indicators of coral disease. The spectrometer measures the distribution of light energy over a range of wavelengths—in this case, just visible light reflected off the coral. The imaging spectrometer collects a series of images that correspond to specific wavelengths across the electromagnetic spectrum—spanning visible to near-infrared light in this study—and combines them in an "image data cube," which can be thought of as a deck of cards in which each card has a unique color.

Mitigation of impacts from coral diseases and syndromes requires better diagnostic techniques to detect the onset of disease; and, ideally, these techniques would be rapid and non-destructive. The ultimate goal is to develop an imaging system that could remotely sense disease-

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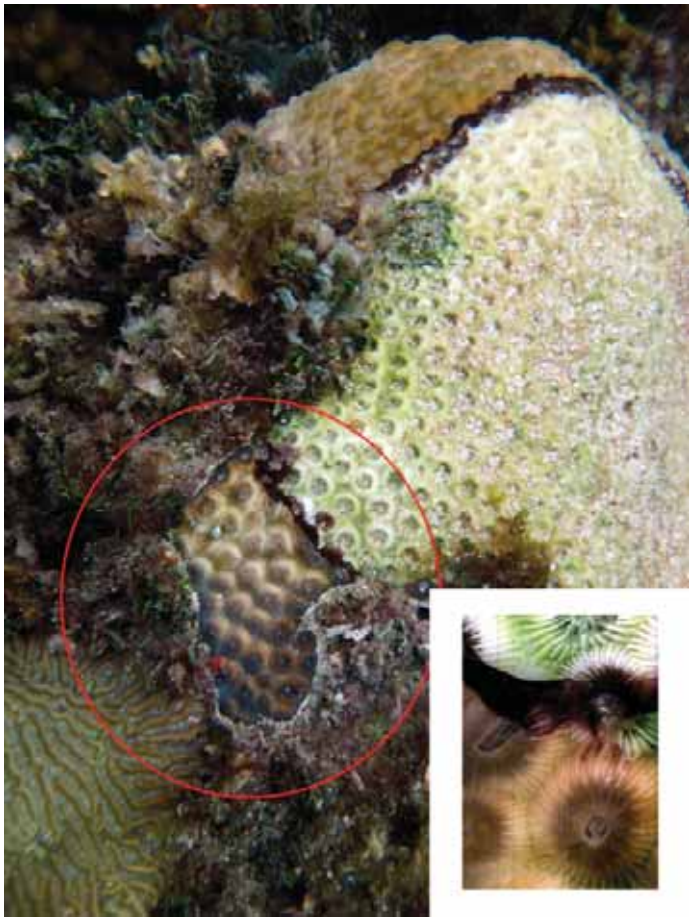


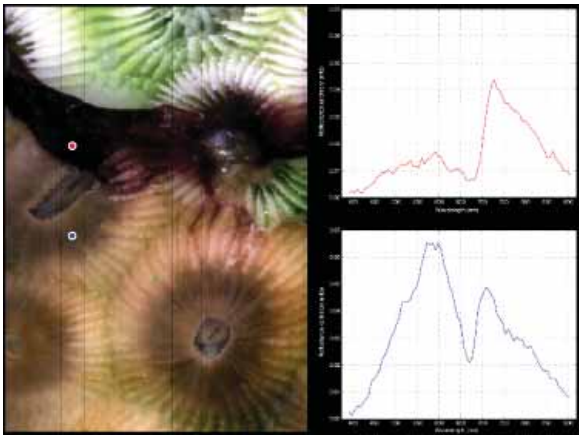
*Great star coral (*Montastraea cavernosa*) affected by black-band disease. Coral tissue is light brown, black line is disease lesion, and white area is dead coral skeleton. Area circled in red is the part of the coral collected for imaging spectroscopy, histology, and microbiology sampling. Inset shows the detail of the disease interface captured by the imaging spectrometer.*

(Coral Paparazzi continued from page 5)

induced stress on the coral reef while being towed behind a boat, allowing much greater coverage in a day than current diver surveys. To this end, **Chris Kellogg** and **Dave Zawada** of the USGS St. Petersburg Coastal and Marine Science Center in St. Petersburg, Florida, collected diseased corals and small healthy corals (as controls) to scan with these various instruments. To ground-truth any optical signatures that might be discovered, they also sampled disease lesions for laboratory studies of cell and tissue anatomy (histology) and examination of microbes living on the coral. Analyses of this unique dataset will be carried out over the next year. This research was conducted under National Marine Sanctuary Permit FKNMS-2010-084.

For additional information, visit the Coral Reef Ecology Study (CREST) Web site at **http://coastal.er.usgs.gov/crest/research-themes/coral-disease.html** (includes image galleries of bleached and diseased corals observed during this fieldwork) and read USGS Fact Sheet 2009-3133, "Applying New Methods to Diagnose Coral Diseases" (**http://pubs.usgs.gov/fs/2009/3113/**).

*Small, healthy colony of great star coral (*Montastraea cavernosa*). Inset shows detail of several polyps captured by the imaging spectrometer. Black squares on the ruler are 1 cm wide; black bars are 1 mm wide.*



The imaging spectrometer captures a series of 640 images, each one corresponding to a different wavelength. The stacked images form an "image data cube," much like a deck of cards in which each card has a unique color. As a result, every pixel in the image has its own spectrum. The example spectra on the right correspond to the points marked by colored dots in the image. In each spectrum, the horizontal axis is light wavelength, and the vertical axis is reflectance. Note that the spectrum for a point in the diseased, "black band" region (red dot) differs from the spectrum for a point in healthy coral tissue (blue dot). Observing spectral changes while moving from healthy to diseased to dead areas of the coral is a key aspect of this study.

Whale Falls

By Jeremy Geist
USGS Volunteer for Science

When a whale dies, it drifts to the seafloor. Its carcass, known as a "whale fall," provides massive amounts of nutrients to the normally food-deprived inhabitants of the deep sea, resulting in a wholly unique ecosystem. In addition to some of the more common scavengers, such as hagfish and crabs, microscopic organisms known as foraminifera (commonly abbreviated as "forams") live at whale falls, providing valuable fossil records for the future.

One whale fall in particular, located in Monterey Bay on the central California

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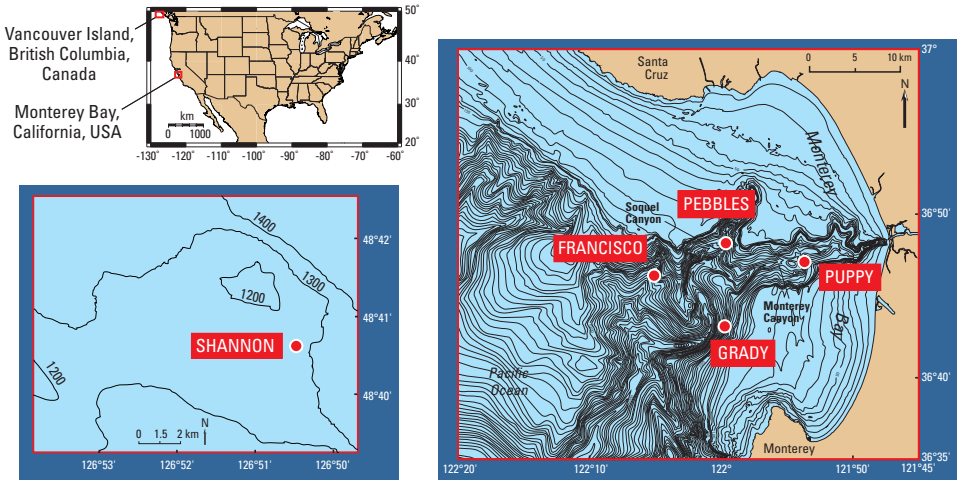

*Five whale falls (one in British Columbia, Canada, and four in Monterey Bay, California) where USGS scientist **Mary McGann** has studied foraminiferal distributions.*

(Whale Falls continued from page 6)

coast, has undergone a massive increase in the population of a certain species of foram, providing fascinating insights to these environments. To **Mary McGann** of the U.S. Geological Survey (USGS) and her colleagues at the Monterey Bay Aquarium Research Institute, this carcass is known as "Puppy."

"Puppy wasn't found on the seafloor but was towed out to sea and dropped after it had washed up onto the beach," said **McGann**. Unfortunately, the whale fall was accidentally placed in a strong current, leading to rapid scatter of the bones. Some interesting results could still be gained, however, from studying the earlier phases of carcass decomposition, most notably the dramatic increase in the abundance of a specific foram species.

Puppy is one of five whale-fall sites off California and Canada where **McGann** has studied foraminiferal distributions. Forams are present in many marine environments, in many different varieties. Their shells are commonly left behind as fossils, providing a biological record for scientists to use to determine what conditions were like in the ocean millions of years ago. In addition, foram assemblages can be used as indicators of environmental degradation and repair.

"In Santa Monica Bay near Los Angeles, various sewage outfalls have been in use since the 1920s. In the 1960s, they added a very large one that polluted the area because they were dumping untreated sewage offshore. When the distribution of forams was studied, two species of one genus had been very negatively impacted. They both used to be in great abundance in Santa Monica Bay, but their numbers declined dramatically after the new outfall came on line. Both of these species have not returned to their former abundance, even though new remediation techniques have been employed that, supposedly, stopped the pollution. Instead, a third species is more abundant than it used to be before the 1960s," said **McGann**.

Like human-caused pollution, whale falls introduce new components—such as unusually large amounts of nutrients—to the seafloor environment. Scientists investigating whale falls are particularly interested in how this new input affects seafloor ecosystems. To study Puppy's effect on foraminifera, samples of the sediment underneath the whale fall were taken with push cores, plastic tubes inserted into the sediment by a remotely operated vehicle (ROV) from the Monterey Bay Aquarium Research Institute. The sediment was then analyzed centimeter by centimeter for the presence of forams. This analysis uncovered a spike in the abundance of one foram species, *Epistominella pacifica*, at the top of the core.

This population explosion contributes to a current theory concerning whale falls: that foraminifera, which reproduce both sexually and asexually, multiply in large numbers when there is a ready supply of nutrition. Unlike some other organisms,

(Whale Falls continued on page 8)

Carcass of a gray whale, "Puppy," sunk in 381 m of water in Monterey Bay. Puppy is in the first stage of decomposition (the mobile-scavenger stage), with eel-shaped hagfish and small white amphipods feeding on the carcass. Photograph courtesy of Monterey Bay Aquarium Research Institute.

In a later photograph, little flesh remains on Puppy's bones, which have been jumbled by currents. Photograph courtesy of Monterey Bay Aquarium Research Institute.

Gray whale "Pebbles," sunk to 632 m in Monterey Bay. Photograph courtesy of Monterey Bay Aquarium Research Institute.

Remotely operated vehicle (ROV) from the Monterey Bay Aquarium Research Institute inserts a push core into sediment near Pebbles. Photograph courtesy of Monterey Bay Aquarium Research Institute.

(Whale Falls continued from page 7)

such as worms and clams, no forams are endemic to whale falls, and the foram species that drastically multiplies during decomposition depends on the water depth at which the whale lands.

Although Puppy is a particularly short-lived site to study forams, the evidence gathered there will contribute to further research into the prevalence of certain foram species over others and the factors that contribute to this phenomenon.

About the author: *USGS volunteer* ***Jeremy Geist*** *is a freshman at Santa Clara University, with a double major in English and Theater.*

◄ Whale fall "Grady" (species unknown), recently found at 586-m depth in Monterey Bay. Photograph courtesy of Monterey Bay Aquarium Research Institute.

▼ Skeleton of a fin or blue whale, "Shannon," observed off Vancouver Island, British Columbia, Canada, at 1,288-m depth. Photograph courtesy of Monterey Bay Aquarium Research Institute.

A New Understanding of 31 Years of Chesapeake Bay Nutrient Trends

By Robert Hirsch and Kara Capelli

Reducing the delivery of nutrients to the Chesapeake Bay is one of the most important components of restoration efforts to achieve a healthy bay ecosystem. The U.S. Geological Survey (USGS) has developed a new method for tracking the progress toward reducing nitrogen and phosphorus delivery from the watershed to the bay.

"The public and public officials care deeply about progress toward clean water goals for the Chesapeake Bay and other impaired waters of the Nation," said **Robert Hirsch**, the USGS Research Hydrologist who led the development of this new method. "We developed the new technique and applied it by using more than 13,000 measurements of nitrogen and phosphorus and 100,000 daily streamflow values for nine major rivers flowing into the Chesapeake Bay, in order to provide clearer answers about the changes taking place as part of these long-term restoration efforts."

A description of the new technique and the results of its application to nine Chesapeake Bay tributaries were reported in the October issue of the *Journal of the American Water Resources Association* (v. 46, no. 5, p. 857-880, **http://dx.doi.org/10.1111/j.1752-1688.2010.00482.x**).

"The new USGS method will allow the Chesapeake Bay partners to better assess progress toward reducing the delivery of nutrients and sediment to the bay," said **Rich Batiuk**, Associate Director for Science, U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program. "This method, based on monitoring data, will improve accountability regarding the nutrient reductions needed to meet our restoration goals for the bay."

Chesapeake Bay watershed, outlined in white. Modified from USGS poster "The Chesapeake Bay Watershed," ***http://chesapeake.usgs.gov/poster.html****.*

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(Chesapeake Bay continued from page 8)

When evaluating the quality of the water entering the bay, this new method takes into consideration seasonality, variations in river flow, and long-term trends driven by the wide range of human activities in the watershed, such as wastewater treatment and changing land-management practices.

"When we analyze long-term nutrient trends for the Chesapeake Bay or other major water systems, it's important that we consider flow variations, because water quality can change greatly from year to year as a result of random variations in streamflow," said **Hirsch**. "This new method enables us to remove this source of variation from the data and get a much clearer picture of the effect of human activities, including nutrient-management actions, on nutrient delivery from these watersheds to the bay."

The analysis reveals both good and bad news about the progress being made regarding the reduction of nutrient inputs over the past 31 years, as well as the past decade. The study looked at dissolved nitrate plus nitrite and total phosphorus. Nitrogen and phosphorus are the primary nutrients responsible for the creation of algal blooms, which decrease light penetration in the bay and result in oxygen depletion when the algae die.

Looking at the four largest rivers in this study, the results show that since the year 2000, nitrogen has been decreasing in the Susquehanna and Potomac Rivers and has remained nearly unchanged in the James and Rappahannock. During the same period, phosphorus changed minimally in the Susquehanna; however, moderate decreases have occurred in the Potomac, and measurable increases have occurred in the James and the Rappahannock.

Methods that do not consider variations in stream flow can paint a much different picture of long-term nutrient trends in the bay. For example, the years 1999-2002 were very dry years throughout the Chesapeake Bay watershed, and as a consequence, nutrient delivery to the bay was relatively low, and conditions in the bay appeared to be much improved in those years. They were followed by extremely high flow conditions in 2003, and then a series of progressively drier years from 2004 through 2008. The 2003 data show very poor conditions, but the subsequent years' data suggest progressive improvements from one year to the next.

"These apparent changes were largely due to differences in flow," said **Hirsch**. "This new method helps us to see past these random year-to-year changes and get at the underlying long-term changes taking place."

Additional key findings include the following:

- Substantial improvement in the Patuxent River basin, between Baltimore, Maryland, and Washington, D.C.: Total phosphorus from this watershed declined by 75 percent from 1978 through 2000 and was essentially unchanged from 2000 through 2008. Nitrogen decreased by about 26 percent from 1978 through 2000 and an additional 15 percent from 2000 to 2008. These results are likely due to large investments in advanced water-treatment plants.
- Increase in nitrogen in the Choptank watershed on the Eastern Shore of the Chesapeake Bay: Nitrogen from the Choptank watershed increased 36 percent from 1978 to 2000 and a total of 53 percent for the whole period from 1978 to 2008. The new method shows that much of this increase took place on those days when flow was made up almost entirely of groundwater flowing into the river, an important consideration for watershed managers.
- Over the whole 31-year period, most of the changes in rivers across the Chesapeake Bay watershed are relatively gradual: Only two of the nine watersheds had average rates of change for total phosphorus flux that were more than 2 percent per year. None of the nine watersheds had changes in nitrogen of greater than 2 percent per year.

The USGS, in partnership with the EPA Chesapeake Bay Program and agencies in six states throughout the Chesapeake Bay watershed, collects data from the Chesapeake Bay Program Nontidal Water-Quality Monitoring Network. The USGS provides critical science to the Chesapeake Bay Program partners and is expanding its efforts to meet the new commitments in the President's Executive Order to restore the Chesapeake Bay. Visit the Web site "USGS Chesapeake Bay Activities" (**http://chesapeake.usgs.gov/**) for more information.

*Patuxent River near Bowie, Maryland. Photograph courtesy of the USGS (**http://va.water.usgs.gov/chesbay/RIMP/rimp_gallery.html**).*

The data used in the recent study are available from the USGS National Water Information System (**http://waterdata.usgs.gov/nwis**). The nine rivers that were studied are the Susquehanna, Potomac, James, Rappahannock, Appomattox, Pamunkey, Mattaponi, Patuxent, and Choptank. The USGS is engaged in expanding the application of this method to other data sets related to the Chesapeake Bay and other parts of the Nation where nutrients are an important issue.

For information on this new method and the results of this specific study, contact **Robert Hirsch** at **rhirsch@usgs.gov** or (703) 648-5888.

For information about the involvement of the USGS in Chesapeake Bay studies, contact **Scott Phillips** at **swphilli@usgs.gov** or (443) 498-5552.

Manatee Subspecies Genetically Confirmed, But Diversity Challenge Looms

Two Belize Populations Offer Opportunity in a Desert of Genetic Diversity

By Margaret Hunter and Rachel Pawlitz

The first genetic study to compare nuclear DNA of endangered Antillean manatees in Belize with Florida manatees confirmed their designation as separate subspecies. Belize's manatees, however, were found to have extremely low genetic diversity, raising questions about their long-term genetic viability.

The Central American country of Belize hosts the largest known breeding population of Antillean manatees and is touted by biologists for its potential to repopulate other parts of Central America where manatees are severely reduced, rare, or absent.

"It turns out that the genetic diversity of Belize's manatees is lower than some of the classic examples of critically low diversity," said U.S. Geological Survey (USGS) conservation geneticist **Margaret Hunter**, who led a molecular DNA study of genetic diversity in the Antillean subspecies in Belize.

Belize's Antillean populations scored lower in genetic diversity than textbook examples of "bottlenecked" endangered species, such as the Wanglang giant panda, the East African cheetah, and an island koala population founded by only three koalas.

Endangered species need genetic diversity to weather threats to their survival, including random or rare shocks, such as disease, hurricanes, or habitat destruction. When a population drops to low numbers, the diversity of its gene pool also shrinks. Even after it rebounds to greater numbers, that population decline leaves a legacy of reduced genetic diversity known as a bottleneck, making the population more vulnerable to future shocks, explained **Hunter**.

The low genetic diversity in Antillean manatees is attributed, in part, to centuries of hunting that was curtailed only early in the 20th century. Once found throughout the coastal regions of Central and South America, Antillean manatees are now rare or absent in parts of Central America where they used to be considered abundant. Today, even Belize hosts only about 1,000 individuals—a number well below the threshold recommended for long-term sustainability, said **Hunter**.

*Belize manatee and health-assessment capture crew. Photograph by **Robert Bonde**, USGS.*

***Margaret Hunter** assisting with health assessment of a Florida manatee named Ariel. Photograph by **Cathy Beck**, USGS.*

Distinct Populations Offer Opportunity

Although the study found low overall genetic diversity in Belize, notable differences were found in manatees that live near Belize City in comparison with manatees living in lagoons, rivers, and cayes farther south. These differences, said **Hunter**, equate to genetic variation, which is valuable for sustaining a diverse gene pool.

"When it comes to the sustainability of a species, this is the type of genetic diversity you want to preserve for the future," explained **Hunter**.

To sustain the diverse gene pool these populations offer, managers will need to consider methods of enabling natural migration and mixing to take place between the two populations.

"These results show the importance of corridors of suitable habitat and low human impact that allow manatees to travel between key sites," said coauthor **Nicole Auil Gomez**, a Belizean biologist who does consulting for the Florida-based conservation organization Sea to Shore Alliance.

(Manatee Subspecies continued on page 11)

(Manatee Subspecies continued from page 10)

"Leaving pockets of habitat is no longer enough," she added.

Confirmation of the Subspecies

The genetic evidence that Florida manatees (*Trichechus manatus latirostris*) are not regularly mixing with populations of Antillean manatees (*Trichechus manatus manatus*) in Belize means they don't naturally affect each other's population size or genetic diversity, **Hunter** said.

The question of whether these two seemingly distant populations were interbreeding had been raised in light of radiotracking evidence that manatees are capable of migrating long distances. Florida manatees have turned up in places as far away as Rhode Island, the Bahamas, and Cuba.

The only prior genetic data comparing the subspecies came from mitochondrial DNA, which is useful for understanding historical relationships on an evolutionary time scale (think millennia, not decades). By including nuclear DNA, this study provided a modern-day assessment of whether the two populations are migrating and interbreeding.

Tuque, a rehabilitated Antillean manatee in Puerto Rico, trailing a radiotracking device (upper right) connected to a belt around his tail. Photograph by ***Antonio Mignucci-Giannoni****, Inter American University of Puerto Rico; used with permission.*

"We are continuing to piece together the genetic relationships of manatees throughout the Caribbean, and it's giving us insights into how to maintain healthy and stable populations," said USGS biologist and co-author **Bob Bonde**.

The study, "Low Genetic Variation and Evidence of Limited Dispersal in the Regionally Important Belize Manatee," was recently published in the journal *Animal Conservation* (published online July 23, 2010, **http://dx.doi.org/10.1111/j.1469-1795.2010.00383.x**).

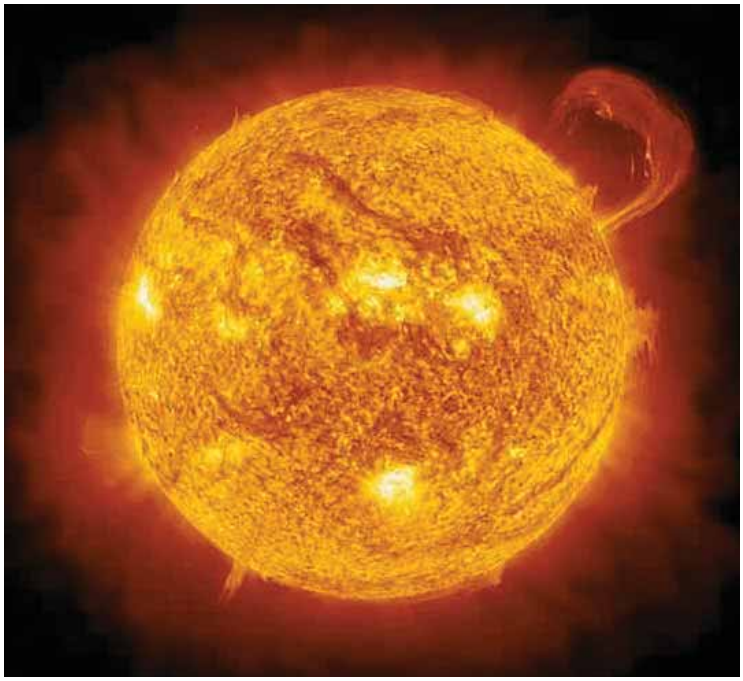
For more information about USGS research on manatee genetics, visit the USGS Sirenia Project Web site at **http://fl.biology.usgs.gov/Manatees/manatees.html**.

By and For Teachers: Earth-Science Multimedia Educational Products

By Matthew Cimitile

During summer 2010, a graduate-level Physical and Earth Science Education class at the University of South Florida-St. Petersburg (USFSP) set out to produce several indepth science multimedia presentations that could be shared with other class members and the teaching community at large. The project came out of a partnership between the U.S. Geological Survey (USGS) Science Communications Team at the St. Petersburg Coastal and Marine Science Center (St. Petersburg, Florida) and USFSP Science Education Professor **Malcolm Butler**. The partners sought to empower the education students to develop skills by using multimedia as they prepare science-topic resources for educators. The students of the class are local teachers working to boost their expertise in teaching math and science

(By and For Teachers continued on page 12)



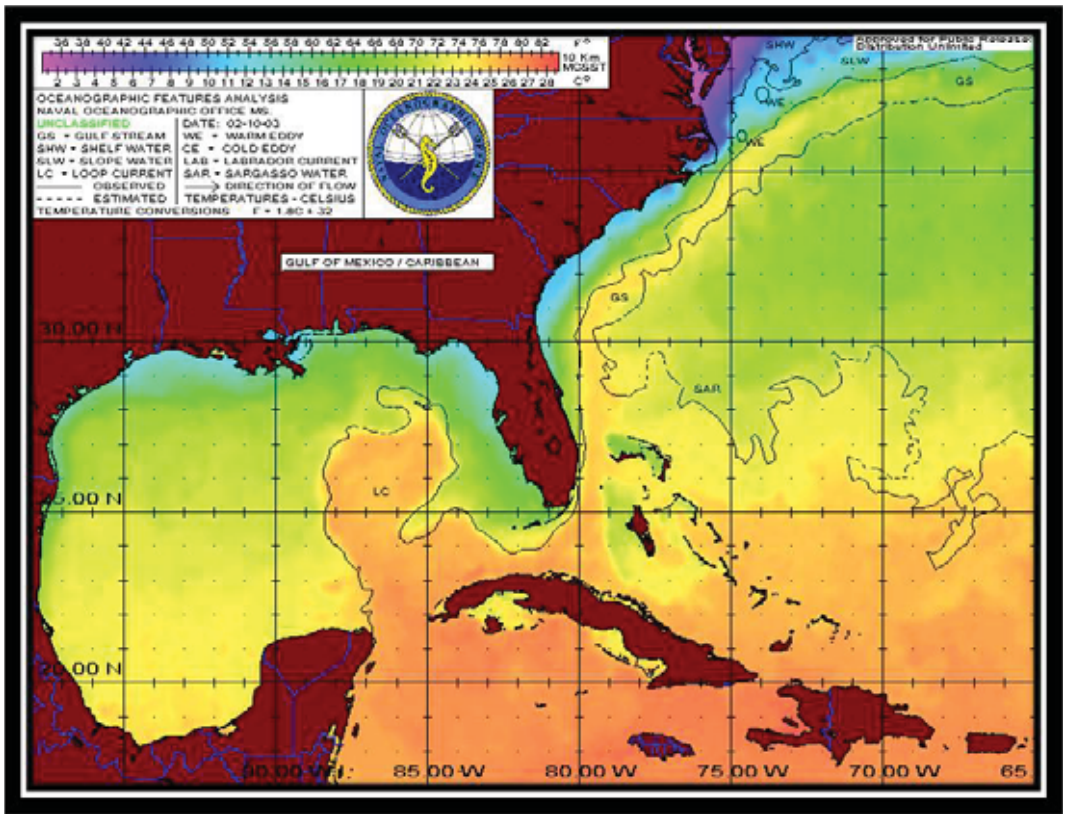
Use of imagery and multimedia applications can enrich a teacher's ability to illustrate complex and intangible scientific concepts, such as the size and makeup of the solar system. (Image of huge solar prominence taken September 14, 1999, by NASA's SOHO Extreme ultraviolet Imaging Telescope [EIT], ***http://sohowww.nascom.nasa.gov/gallery/images/superprom.html****.)*

(By and For Teachers continued from page 11)

at the elementary-school level. The result was a collection of well-crafted, unique multimedia science-education products that teachers share with each other and use when teaching their own students.

"Presented to the teachers was the idea of a typical elementary-school scenario, in which one teacher catches a colleague in the hallway seeking advice on how to approach a particular science topic," said **Butler**. "The colleague has only a few minutes to share some key ideas with the teacher. What should he or she say and share? These multimedia presentations are the outcomes of the teachers' response to this scenario."

Topics for these multimedia products ranged from astronomy (Sun as a Star) to marine science (Red Tide) and are tied to current events (Gulf Oil Spill). Teachers acquired new knowledge about a range of scientific concepts, located key resources to use when teaching students, and developed skills in multimedia applications. These included shooting and editing video, PowerPoint animation, and use of graphics.



This map, used in a teacher's presentation on the Gulf oil spill, embodies information from the Naval Oceanographic Office to show the location of the Loop Current (in orange) and its flow from the Gulf of Mexico through the Straits of Florida and into the Atlantic Ocean. Teachers learned where to locate credible resources such as this to use in their classrooms.

"Graphics and media are powerful educational tools. At the USGS, we constantly hear that teachers want more high-quality, reliably researched, multimedia educational products that put science and math topics into an exciting context. During this class, this is exactly what the teachers researched and created for themselves," said **Ann Tihansky**, Information Specialist with the USGS. "Lots of new relevant science isn't in textbooks yet, but there are many good sources on the Web and many exciting ways to link science to society and current events. The partnership with USFSP is a great way to reach teachers and help them locate reliable scientific sources and develop multimedia resources. Connecting with teachers also helps the USGS share new scientific findings with a wider audience."

The presentations involved a combination of showing the relevance of science in everyday life, illustrating hands-on approaches to teaching Earth science, and explaining more difficult, intangible scientific concepts, such as the solar system, through the use of multimedia. The success of the partnership venture was evident in watching teachers share their enthusiasm as they created their science presentations and as they collaborated in devising creative ways to communicate these concepts with their students.

"The teachers were very much engaged in the process of this project. Their interest was raised even further when the class attended a public forum on the recent oil spill in the Gulf of Mexico," said **Butler**. "The teachers were amazed and quite moved by the public's concern and participation in discussions regarding their community. They were even more motivated after attending this event, and their projects substantiated their commitment to ensuring that other teachers are well informed."

The introduction of multimedia into the classroom is a great way to boost scientific literacy and trains educators in gathering information through good, reliable sources from scientific institutions and organizations. In general, these products are valuable to teachers by:

- Being an information source,
- Serving as a "how to" guide for teachers,
- Providing hands-on examples of teaching complex scientific concepts,
- Covering current events to bring scientific findings into everyday life,
- Expanding and enriching the educator's toolkit.

We hope to share these products to further extend the reach of science educational resources for all teachers. Currently, these resources are posted online at **http://cdnportfolio.net/usgs/**.

USGS Woods Hole Center Contributes to Unique Summer Intern Program

By Ben Gutierrez

The Woods Hole Partnership Education Program (PEP) completed its second year on August 13 with a research presentation by each student and a concluding celebration. This program is a multi-institution collaboration that brings 16 summer interns to Woods Hole, Massachusetts, for a 4-week course and a 6-week independent-research internship. The program's goal is to increase diversity within the Earth and ocean science workforce, which lags behind other disciplines. Open to students from all backgrounds, the program attracts college and university students from around the country. PEP is supported by the six institutions that make up the Woods Hole Diversity Initiative: the U.S. Geological Survey (USGS) Woods Hole Science Center, the Woods Hole Oceanographic Institution (WHOI), Sea Education Association (SEA), the Marine Biological Laboratory, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service, and the Woods Hole Research Center. The program is also run in partnership with the University of Maryland Eastern Shore, which provides academic credit for PEP students. Members of the Woods Hole Diversity Advisory committee designed the program over the past few years and are able to implement it with the help of volunteers from each institution.

PEP students after the closing ceremony and completion of their final presentations, which were held in the USGS Woods Hole Science Center conference room. Left to right: ***Emily Motz*** *(State University of New York [SUNY] Maritime College),* ***Chris Cepero*** *(Bridgewater State University),* ***Melika Uter*** *(University of Massachusetts [UMass] Boston),* ***Anna-Mai Christmas*** *(University of the Virgin Islands),* ***Alex DeLeon*** *(Morehouse College),* ***Rachel Rochon*** *(University of New Haven),* ***Victoria Morgan*** *(Cornell University),* ***Brian Redding*** *(Virginia Commonwealth University),* ***Zachary Williams*** *(South Carolina State University),* ***Dolores Toledo*** *(University of California, Berkeley),* ***Lucy Flores*** *(Nova Southeastern University),* ***Diara Townes*** *(Hampton University),* ***Delawrence Sykes*** *(Morehouse College),* ***Laney Boyer*** *(University of Arkansas),* ***Angela Anorve*** *(University of California, San Diego), and* ***Nam Siu*** *(University of Tampa). Photograph by* ***Chris Polloni****.*

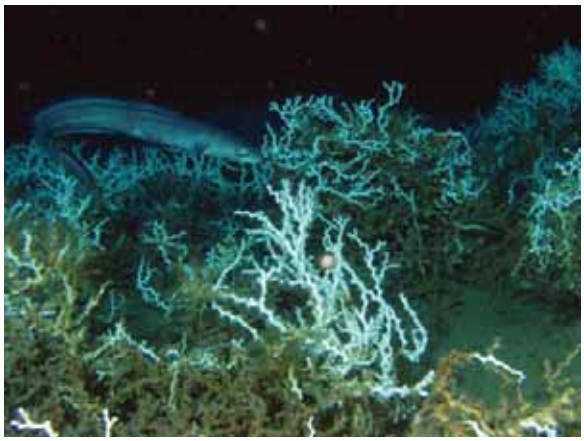
PEP begins with a course in Global Climate Change that is accredited through the University of Maryland Eastern Shore. The course consists of five modules, each providing 3-day intensive studies of specific topics in global climate change organized according to the four oceanographic disciplines (physical, chemical, geological, and biological oceanography) and marine-ecosystem management. In addition, course instructors introduce students to common research methods, such as basic statistics and time-series methods. This year, the course was taught by a team of eight instructors, including **John Bratton** of the USGS Woods Hole Science Center. Other members of the USGS center also contributed: **Matt Arsenault** participated as an invited speaker. **Ben Gutierrez** served as the course director and implemented public-speaking workshops and panel discussions for students. **Claudia Flores** led students in thought exercises, encouraging them to reflect upon what they had learned over the summer and how this compares with what is reported in the media. **Neil Ganju** and **Bill Waite** served as panelists for discussions regarding careers in science and approaching graduate school. **Kathy Scanlon** advised one of the PEP students, **Lane Boyer** (University of Arkansas), during his research internship after the Global Climate Change course. **Boyer's** research focused on assembling data for defining regions where cold-water corals could thrive in Glacier Bay, Alaska. Together with **Ken Foote** (WHOI), **Marinna Martini** (USGS) advised PEP students **Chris Cepero** (Bridgewater State University) and **Dolores Toledo** (University of California, Berkeley). **Cepero** and **Toledo** worked toward developing an effective calibration for the AQUAscat acoustic sensor.

For the PEP to succeed in diversifying the Earth and ocean sciences, PEP students must remain engaged in these sciences. Several students from PEP's inaugural summer (2009) have done just that, returning to Woods Hole to take part in other student programs or to pursue other summer research opportunities. PEP's early success and a dramatic increase in the number of applicants are due largely to the dedicated effort of its many volunteers, particularly **Ambrose Jearld**, **George Liles**, and this year's PEP coordinator, **Joniqua Howard** (all from NOAA Fisheries). The Woods Hole Diversity Advisory Committee remains committed to sustaining this productive program.

International Workshop on Cold-Water Corals Held in Norway

By Christina Kellogg

If someone asked you to name a country with a lot of corals, you'd expect tropical answers like "Australia" or "Belize" because of their well-known barrier reefs. Norway, crossed by the frigid Arctic Circle, would probably not even make the top 10 guesses. In fact, Norwegian waters are home to large numbers and varieties of cold-water corals. These corals, including both stony corals and seafan-like soft corals, do not host photosynthetic algae and so can survive in dark, deep waters. For that reason, they are also known as deep-sea corals. However, they may be found as shallow as 40 m in Norwegian fjords and as deep as thousands of meters on seamounts and on the continental shelf. As in the Gulf of Mexico, the areas of hard bottom where these corals are found are commonly areas of interest for oil and gas exploration and drilling.



Cold-water-coral habitat featuring the stony coral, Lophelia pertusa. *This image is from the USGS DISCOVRE project in the Gulf of Mexico, but the same coral is even more common in Norwegian waters. Photograph courtesy of USGS DISCOVRE (**http://fl.biology.usgs.gov/DISCOVRE/**).*

***Christina Kellogg** (center, coral shirt) participates in a lively discussion after one of the presentations at the cold-water-coral workshop. Photograph courtesy of IRIS.*

The first Norwegian-hosted workshop on cold-water corals was sponsored by the Norwegian Oil and Gas Association (OLF) and hosted by the International Research Institute of Stavanger (IRIS) on May 31-June 1, 2010. This workshop was designed to bring together researchers, government and nongovernmental organizations, and representatives from the oil and gas industry who are actively involved in cold-water-coral research and management. (See workshop Web site at **http://www.iris.no/coralworkshop2010**.) **Christina Kellogg** of the U.S. Geological Survey (USGS) St. Petersburg Coastal and Marine Science Center in St. Petersburg, Florida, was the only invited speaker and attendee from the United States. **Kellogg** was invited to speak specifically because of her knowledge of coral-associated microbial communities and how they can be used as diagnostics of coral stress (see related article, "Coral Paparazzi," this issue). Other scientific experts attended from Australia, Brazil, Canada, Germany, the Netherlands, Norway, Sweden, and the United Kingdom, with the goal of sharing results and expertise from national and international research projects. The workshop focused on establishing the current state of knowledge about the sensitivity of cold-water corals to oil and gas activities and on promoting discussions about management measures needed to protect cold-water-coral habitats.

*IRIS is in Mekjarvik, Norway, 13 km north of Stavanger. The view from the institute includes a fjord and an oil rig in port for repairs. Photograph by **Christina Kellogg**, USGS.*

IRIS
International Research Institute of Stavanger

*The workshop was organized and hosted by the International Research Institute of Stavanger (IRIS; **http://www.iris.no/**), some of whose researchers are studying the possible impacts of oil and gas activities on deep-sea corals.*

USGS Gas Hydrates Scientists Lead and Participate in the Inaugural Gordon Research Conference on Natural Gas Hydrates

By William Waite

From June 6 to 11, 2010, 86 researchers from academia, industry, and federal institutions worldwide met for the inaugural Gordon Research Conference on Natural Gas Hydrates, held at Colby College in Waterville, Maine. Gordon Research Conferences (**http://www.grc.org/**) is an 80-year-old nonprofit organization that manages and supports nearly 200 intense, retreat-like scientific meetings each year. The inaugural Gordon Research Conference on Natural Gas Hydrates was initiated through a competitive proposal process led by conference chair **Carolyn Ruppel** of the U.S. Geological Survey (USGS) and vice-chair **Peter Flemings** of the University of Texas at Austin. For this first biannual meeting, the Natural Gas Hydrates conference focused on the physical, chemical, and biological interactions among gas hydrate, sediment grains, free gas, pore fluids, and microbes at various spatial scales. The Gordon Research Conference format schedules five talks and one 2-hour poster session between 9 a.m. and 9:30 p.m., with the remaining time available for informal discussions in unstructured settings. The meeting was hailed by many attendees for conveying state-of-the-art science while fostering a spirit of collegiality that led to many new research collaborations.

Seven current USGS gas hydrates scientists, two former USGS postdoctoral researchers, and an incoming USGS Mendenhall postdoctoral researcher were vital participants in the conference. Additional attendees included postdoctoral researchers and senior professors from the United States, Japan, the United Kingdom, and Europe. An estimated 40 percent of the attendees were graduate students or recent Ph.D. recipients. A generous grant from the National Science Foundation's Division of Ocean Sciences and contributions from private-sector firms made it possible for many participants to receive substantial support for registration fees. If approved by the Gordon Research Conferences Board of Trustees, the 2012 meeting will focus on the theme "Energy and Climate," with **Peter Flemings** as chair and **Michael Whiticar** (University of Victoria) as vice-chair.

For additional information about the recent conference, visit **http://www.grc.org/programs.aspx?year=2010&program=naturalgas**.

William Winters *(left; USGS) and* ***Ann Cook*** *(Lamont-Doherty Earth Observatory) discuss recent results at the Natural Gas Hydrates Gordon Research Conference held on the Colby College campus in Waterville, Maine. Photograph by* ***Peter Flemings*** *(University of Texas at Austin).*

USGS Scientist Emeritus Jeff Williams Receives NPS Director's Career Achievement Award

On September 8, 2010, U.S. Geological Survey (USGS) Scientist Emeritus **S. Jeffress Williams** was one of five recipients of the National Park Service (NPS) Director's Awards for "Service in Natural Resources Stewardship and Science," awarded by NPS Director **Jon Jarvis** at an awards ceremony during an all-hands meeting in Denver, Colorado. **Williams'** award, which was one of two for scientific research, consisted of a framed certificate and a handsome limited-edition bronze bison sculpture by artist **Chris Schiller**.

"These men and women have dedicated themselves to the restoration and maintenance of this Nation's natural heritage," said NPS Director **Jarvis**, "and while the awards recognize individual achievement, it is the teamwork, professionalism, and shared sense of purpose with their colleagues that matter most to the recipients."

In a statement released by NPS, **Williams** was recognized for his career as a "Research Geologist, U.S. Geological Survey (USGS), Woods Hole Science Center, MA, and Program Coordinator of USGS Coastal and Marine Geology Program: **Williams** has focused his research career

(NPS Awards continued on page 16)

National Park Service Director ***Jon Jarvis*** *(left) presents a Director's Award for Service in Natural Resources Stewardship and Science to USGS Scientist Emeritus* ***S. Jeffress Williams****.*

(NPS Awards continued from page 15)

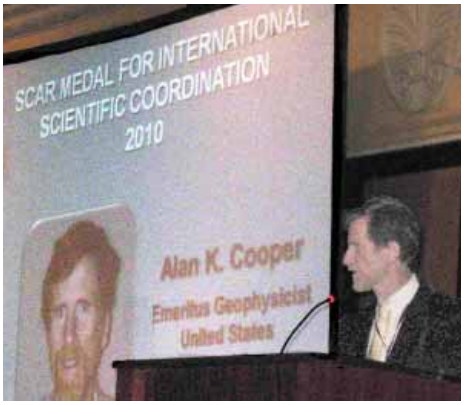
on the geologic history and processes of coastal, estuarine, wetland, and inner continental shelf regions and has developed a vulnerability index for U.S. coasts. He has assessed the vulnerability of coastal national parks to sea-level rise. His work has led to a better understanding of potential future impacts of sea-level rise on coastal systems and has provided GIS [geographic information system] maps and information needed to better manage coastal regions for the future."

In addition to his work on assessing the potential effects of sea-level rise on NPS national seashores, **Williams'** research along the Long Island coast and offshore shelf region has provided important information on coastal processes to aid in managing barrier islands and wetlands. More recently, he served as an expert witness giving testimony on coastal geology and nearshore sediment processes for the U.S. Justice Department, which was defending the NPS in a legal action. The suit against NPS, if successful, could have had a major impact on the management of federally operated beaches and could have limited public access to them. Ultimately, the judge ruled in favor of the Department of Justice.❁

SCAR Medal for International Scientific Coordination Awarded to USGS Emeritus Scientist Alan Cooper

Alan Cooper, a scientist emeritus with the Coastal and Marine Geology Program of the U.S. Geological Survey (USGS), was awarded the Scientific Committee on Antarctic Research (SCAR) Medal for International Scientific Coordination, 2010. **Cooper** was recognized for his work over the past 25 years in initiating and overseeing the Antarctic Seismic Data Library System (SDLS) for Cooperative Research, and in helping with the coordination, compilation, and analysis of seismic data collected along the margins of Antarctica. The SDLS is the only geoscience agency directly linked to the Antarctic Treaty, via ATCM Recommendation XVI-12. **Cooper** was further recognized for his work in editing and publishing the proceedings of SCAR's 10th International Symposium on Antarctic Earth Sciences in 2007, with more than 100 peer-reviewed reports and 200 extended abstracts, all published online in advance of the conference and in book format less than a year later (**http://pubs.usgs.gov/of/2007/1047/** and **http://www.nap.edu/catalog.php?record_id=12168**). **Cooper** received the award in Buenos Aires, Argentina, at the SCAR Open Science Conference in August 2010 (**http://www.scar.org/awards/**).

Congratulations, **Alan**!❁



***Alan Cooper**, winner of the Scientific Committee on Antarctic Research (SCAR) Medal for International Scientific Coordination, gives acceptance remarks at the SCAR Open Science Conference.*

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