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Fieldwork

Earthquake, Landslide, and Tsunami Hazards in the Northeastern Caribbean—Insights from a 2013 E/V *Nautilus* Expedition

By Uri ten Brink, Dwight F. Coleman (Ocean Exploration Trust), Jason Chaytor, Amanda W.J. Demopoulos, Roy Armstrong (University of Puerto Rico), Graciela Garcia-Moliner (National Oceanic and Atmospheric Administration Caribbean Fisheries Management Council), Nicole A. Raineault (Ocean Exploration Trust), Brian Andrews, Roger Chastain (Scripps Institution of Oceanography), Katherine Rodrigue (University of Rhode Island), and Mathieu Mercier-Gingras (Université de Montreal)

[Based on an article in the journal *Oceanography*, <**http://dx.doi.org/10.5670/oceanog.2014.supplement.01**>]

USGS team on the exploration vessel (E/V) Nautilus *(left to right): chief scientist* ***Uri ten Brink*** *(research geophysicist, Woods Hole Coastal and Marine Science Center [WHCMSC]),* ***Jason Chaytor*** *(research geologist, WHCMSC),* ***Amanda Demopoulos*** *(research ecologist, Southeast Ecological Research Center),* ***Brian Andrews*** *(geographer, WHCMSC), and expedition leader* ***Dwight Coleman*** *(previously with USGS, now at University of Rhode Island).*

The first systematic deep-sea exploration of the northeastern Caribbean has changed scientists' understanding of geologic hazards around Puerto Rico and the Virgin Islands, and it has provided a glimpse into the region's hitherto unknown deep-sea ecology.

The multidisciplinary expedition was conducted by the Ocean Exploration Trust (<**http://www.oceanexplorationtrust.org**/>) from October 4–18, 2013, aboard the exploration vessel (E/V) *Nautilus*. Expedition members used the remotely operated vehicles (ROVs) *Hercules* and *Argus* to view features that U.S. Geological Survey (USGS) chief scientist **Uri ten Brink** and his colleagues had studied on their seafloor maps and subseafloor records but had never before had the opportunity to see. The primary goal was to investigate faults and landslides that might have triggered earthquakes and tsunamis in the region. The impact of earthquake and tsunami hazards on Puerto Rico and the Virgin Islands is potentially very significant, because more than 4 million people inhabit the islands, numerous tourists visit them each year, and many civilian and military installations are spread along their coastlines.

Earthquakes and submarine landslides are common around Puerto Rico and the Virgin Islands, which lie near the boundary between two tectonic plates—the North American plate and the Caribbean plate. These vast blocks of the Earth's outermost rigid layer are grinding past each other and, in the process, causing earthquakes and lifting or pulling down the Earth's surface. Among the peculiarities of this plate boundary is the Puerto Rico Trench, an unusually deep trench north of Puerto Rico (the deepest place in the Atlantic Ocean) where the North American plate is sliding beneath the Caribbean plate at a highly oblique angle (see map, next page).

Some of the features explored during the expedition are submarine fault systems thought to have generated damaging earthquakes in Hispaniola (1842), the Virgin Islands (1867), and western Puerto Rico (1918). The researchers also examined landslide scarps (scars in slopes where material has broken away) left by the Mona landslide—a submarine slide thought to have triggered a devastating tsunami during the 1918 earthquake. Additionally, they viewed the Noroît Seamount east of the Virgin Islands, a feature suspected to be a submarine volcano. What they saw changed some of

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Sound Waves

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Publications: When new publications or products are released, please notify the editor with a full reference and a bulleted summary or description.
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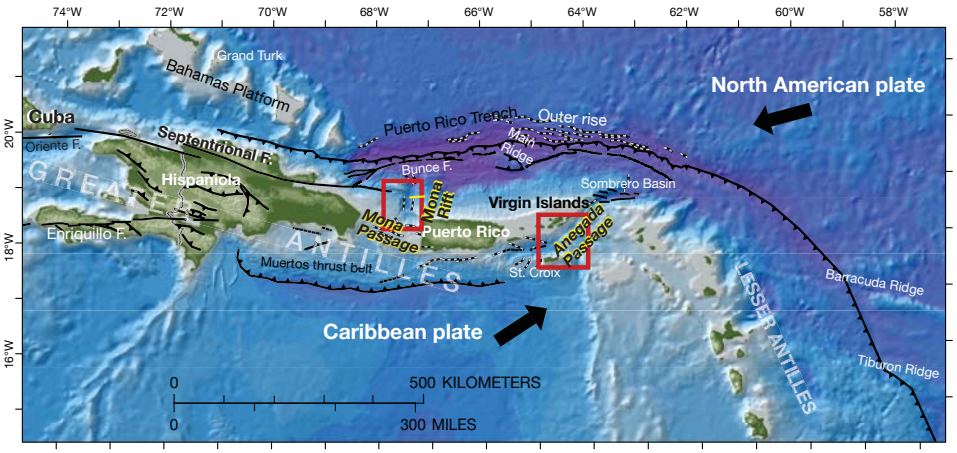
Fieldwork, continued

(Nautilus *Expedition continued from page 1)*



Regional map showing major tectonic features and direction of convergence (black arrows) between the North American and Caribbean tectonic plates. Red boxes outline the two expedition diving areas (see enlarged maps, next page). Barbed lines indicate mapped thrust faults. Continuous lines indicate strike-slip faults. Black-and-white-dashed lines indicate normal or mixed normal and strike-slip faults. Modified from figure 1 in "Historical perspective on seismic hazard to Hispaniola and the northeast Caribbean region" by ten Brink and others, 2011, Journal of Geophysical Research, *<**http://dx.doi.org/10.1029/2011JB008497**>*

their earlier interpretations and confirmed others.

ROV transects of the Mona landslide scarps, for example, showed the walls to be covered by slow-growing iron-manganese deposits called "varnish," an indicator that the slide occurred long before 1918. A steep vertical cliff several hundred meters high and approximately 20 kilometers (12 miles) north of the Mona landslide appeared to be a fresh scarp, probably caused by a large landslide or a series of smaller incremental slides. Further analysis will shed light on whether the younger landslide might have triggered the 1918 tsunami.

The expedition also explored the Septentrional fault, a major strike-slip fault that is similar to California's San Andreas fault and stretches from Cuba to the Mona Rift (see map). Exploration dives revealed no surficial evidence for the fault's eastward continuation beyond the Mona Rift. This finding suggests that the fault is shorter and thus less of an earthquake hazard to Puerto Rico than previously thought.

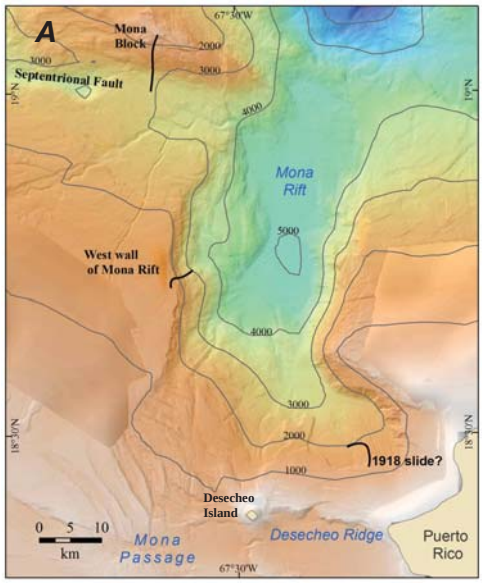
Likewise, the researchers found no evidence of a fresh fault surface running from Desecheo Island into western Puerto Rico. On the other hand, the previously proposed fault trace of the 1867 Virgin Islands earthquake was found to be associated with a 30-meter (100 foot)-high linear and somewhat fresh rock wall—a good candidate for a fault. An additional possible fault, cut in places by landslide scars, was mapped by the ship's multibeam echosounder closer to St. Thomas and could be associated with past earthquakes in the area.

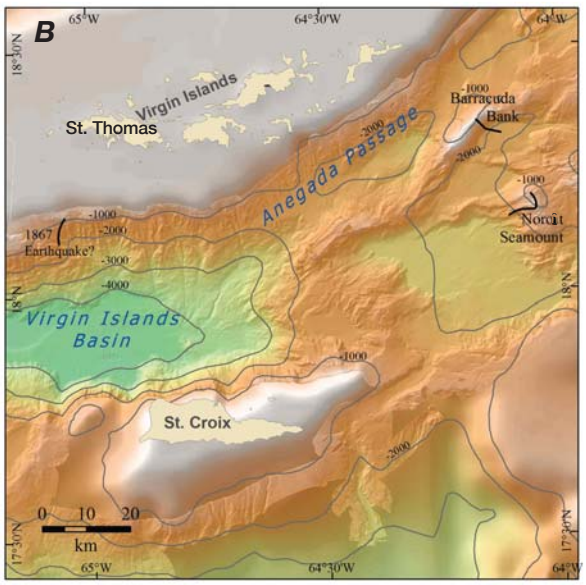
The Noroît Seamount was mapped in detail and verified as a fairly young but inactive volcano. If this seamount is part of the Lesser Antilles volcanic chain, then the Lesser Antilles chain extends almost to Barracuda Bank in the middle of Anegada Passage. Barracuda Bank is a sliver of seafloor a few hundred meters wide that lies just below the sea surface and is surrounded by steep walls that descend almost 2,000 meters (6,500 feet) deep. Some of the walls are subvertical, probably formed by a steep landslide or a fault trace.

The exploration dives were carried out with the ROV *Hercules*, equipped with high-definition video cameras, a manipulating arm for collecting rock and biological samples, push cores for collecting sediment samples, and equipment for sampling water. Throughout the dives, *Hercules* was illuminated by its companion ROV, *Argus*, hovering a few hundred feet above *Hercules*. The ROVs spent a total of 4.5 days of sea-bottom time at seven dive sites in Mona and Anegada Passages and reached a maximum depth of 3,000 meters (nearly

(Nautilus *Expedition continued on page 3)*

(Nautilus *Expedition continued from page 2)*





Areas explored with remotely operated vehicles (ROVs) during the 2013 expedition on E/V Nautilus*:* ***A****, Mona Rift area northwest of Puerto Rico and* ***B****, Anegada Passage area south of the Virgin Islands. Bathymetric data were collected by* Nautilus*'s multibeam sonar system and integrated with bathymetry collected previously by the USGS and the National Oceanic and Atmospheric Administration (NOAA). Black lines denote sites of ROV dives.*

10,000 feet). The only previous diving expeditions in the Greater Antilles were several dives by the manned submersible *Alvin* and a series of dives by the Navy submarine NR-1 expedition in Mona Passage in the 1970s, all of which covered a much shallower depth range.

In addition to new geologic information, the 2013 ROV dives yielded new insights into the region's deep seafloor (benthic) organisms, including corals, sponges, other invertebrates, and fishes. For example, deep-sea corals (living deeper than 200 meters [650 feet]) appeared to be much less abundant in the Greater Antilles region than in canyons along the northeast U.S. Atlantic margin and the Bahamas—although their patchy distribution in the areas viewed by the ROVs may not be representative of their abundance in the broader region. No clear distinction was evident between the benthic communities northwest of Puerto Rico (Atlantic Ocean) and the Virgin Islands (transition to the Caribbean Sea).

Noroît Seamount stood out in its complex and diverse communities of benthic organisms. Large gastropods (sea snails) and the largest primnoid octocorals (corals) were encountered only here. The numbers of fish observed during the dives were generally low except near Noroît Seamount, where the ROVs recorded species not seen during the other dives. Also at Noroît Seamount, the ROV encountered a Bluntnose Sixgill Shark (*Hexanchus griseus*) longer than the 11-foot-long ROV, lurking at a depth of 1,800 meters (6,000 feet). (See the shark on a video clip at <**http://www.youtube.com/watch?v=27x_prad9RE**>.)

Seafloor mapping by the ship's Kongsberg EM302 multibeam echosounder was used to plan the dive transects and to improve the resolution and coverage of current USGS bathymetry of the region. A total of 2,028 line-kilometers of multibeam bathymetry were collected and processed onboard.

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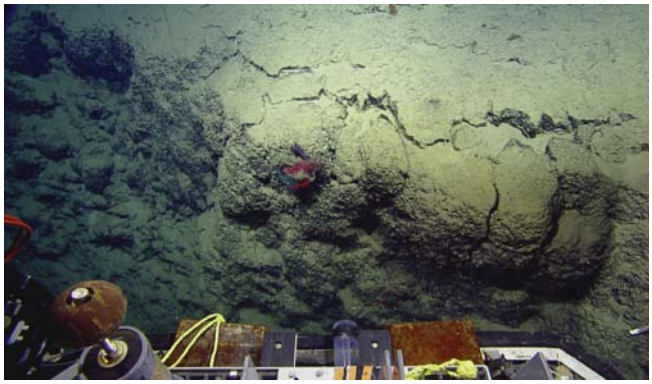
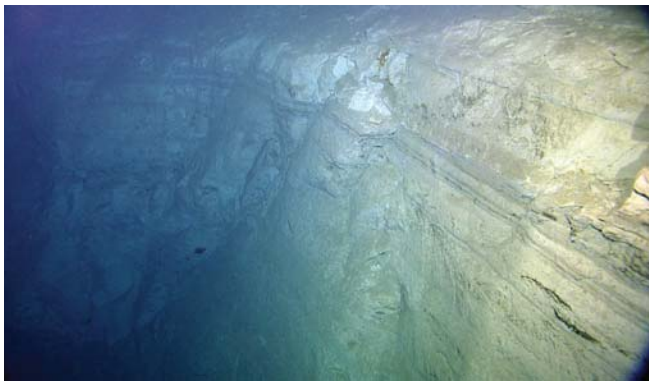


Iron-manganese coating on wall of Mona slide. This slow-growing "varnish" is evidence that the slide was not the source of the 1918 tsunami, as previously thought. The front of the ROV, about 1.5 meters (5 feet) wide, is visible at bottom of photograph. View of wall is about 2 to 3 meters (6 to 10 feet) wide. Water depth is 1,270 meters (4,170 feet).

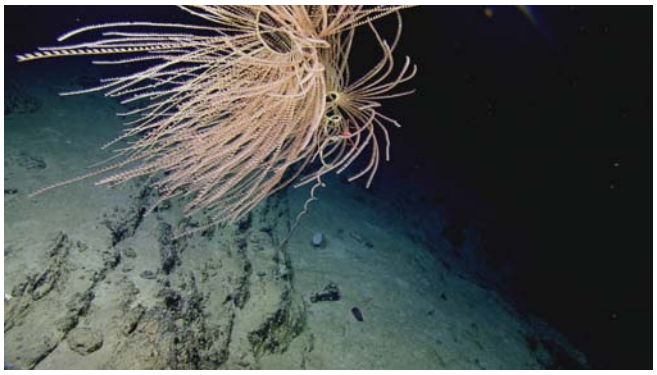


A fresh escarpment at the top of Mona Rift. The wall in this view is probably about 10 to 20 meters (60 to 100 feet) wide. Water depth is 1,700 meters (5,600 feet).

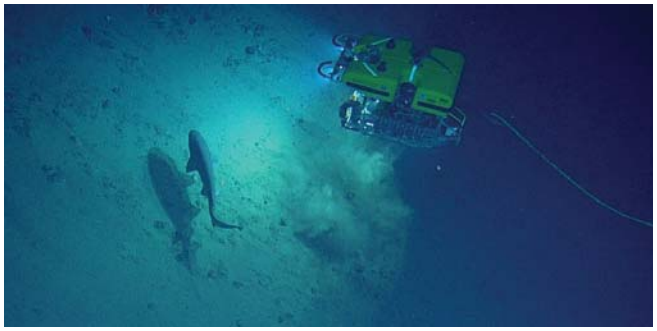
(Nautilus *Expedition continued from page 3)*

The entire expedition was broadcast live to numerous schools, youth clubs, and science museums around the United States. Public interest in the expedition surpassed that in all previous *Nautilus* expeditions, with 195,276 website visits, 91,733 unique visitors, and 790,649 page views. Interest was particularly intense in Puerto Rico and the Virgin Islands, due in part to a focused publicity effort with local Puerto Rico news outlets. The expedition was also filmed by National Geographic for a film titled "Caribbean's Deadly Underworld" (<**http://channel.nationalgeographic.com/wild/episodes/caribbeans-deadly-underworld/**>).

Expedition information and imagery are archived on the Nautilus Live website. View an interview with chief scientist **Uri ten Brink** at <**http://www.nautiluslive.org/video/2013/10/03/behind-science-ocean-geology-puerto-rico-trench**>. Explore dive photographs and video footage at <**http://www.nautiluslive.org/albums**> and <**http://www.nautiluslive.org/videos**> (cataloged by dive date).



Iridigorgia *sp. (a type of Chrysogorgidae octocoral), with a typical coiled shape at the base of Noroît Seamount. The organism is about half a meter to a meter (2 to 3 feet) across. Water depth is approximately 1,800 meters (5,900 feet).*



*Bluntnose Sixgill Shark (*Hexanchus griseus*) near Noroît Seamount, photographed by the ROV* Argus *in 2013. The 11-foot-long ROV* Hercules *is in the upper right. A video clip of the shark, shot from the* Hercules, *is posted at* ***<http://www.youtube.com/watch?v=27x_prad9RE>****.*

To learn more about results of the expedition, see "2013 Field Season Summary—Earthquake, Landslide, and Tsunami Hazards and Benthic Biology in the Greater Antilles" in *Oceanography*, v. 27, no. 1, supplement, <**http://dx.doi.org/10.5670/oceanog.2014.supplement.01**>.

Through the Eyes of a Polar Bear—First "Point of View" Video

By Anthony Pagano, George Durner, and Todd Atwood

The first "point of view" video (<**https://www.youtube.com/watch?v=xXuh_0u4leY**>) from a polar bear on Arctic sea ice was posted online June 6, 2014, by the U.S. Geological Survey (USGS). Scientists applied video-camera collars to four female polar bears on the sea ice north of Prudhoe Bay, Alaska, in April 2014 and are releasing the first clips of footage that provide unique insight into the daily lives of the bears.

"We deployed two video cameras in 2013, but did not get any footage because the batteries weren't able to handle the Arctic temperatures," said **Todd Atwood**, research leader for the USGS Polar Bear Research Program (<**http://alaska.usgs.gov/science/biology/polar_bears/**>). "We used different cameras this year, and we are thrilled to see that the new cameras worked."

The video collars were deployed as part of a new study to understand how polar bears are responding to sea-ice loss from climate warming. The study, led by USGS research biologist and University of California Santa Cruz Ph.D. student **Anthony Pagano**, is taking a close look at polar bear behaviors and energetics.

Scientists with the USGS have been studying polar bear movement and habitat use for decades using radio and satellite telemetry (for example, see <**http://alaska.usgs.gov/science/biology/polar_bears/tracking.html**>), mostly used to determine a polar bear's location. New video collars allow scientists to link the location data from the collar with the actual behavior recorded by the cameras.

Although these collars were only on the bears for about 8–10 days, scientists can start to understand the activity patterns of polar bears—for example, how often they eat, hunt, rest, walk, and swim—and how these behaviors may be affected by sea-ice conditions and other variables. "Ultimately, this information will help scientists examine the energetic rates and nutritional demands of these animals and the potential effects of declining sea-ice conditions," said Pagano.

This ongoing research is part of the USGS Changing Arctic Ecosystems initiative (<**http://alaska.usgs.gov/science/interdisciplinary_science/cae/**>). The research is also relevant to the U.S. Fish and Wildlife Service Polar Bear Recovery Team (<**https://www.facebook.com/pages/USFWS-Polar-Bear-Recovery-Team/1396012640676864**>), of which the USGS is a member. The team is drafting the Polar Bear Conservation Management Plan, which will meet requirements of both the Endangered Species Act (<**http://www.fws.gov/endangered/laws-policies/esa.html**>) and the Marine Mammal Protection Act (<**http://www.mmc.gov/legislation/mmpa.shtml**>). The required

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(Polar Bear continued from page 4)

plan, when finalized, will guide activities for polar bear conservation in response to the 2008 determination that the polar bear is a threatened species due to the ongoing loss of sea-ice habitat from global climate-change.

Two weeks after posting, the "Polar Bear – POV Cams (Spring 2014)" video had more than 300,000 views on YouTube. Watch it yourself at <**https://www.youtube.com/watch?v=xXuh_0u4leY**>.

*Screenshots from video released June 6, 2014, at <**https://www.youtube.com/watch?v=xXuh_0u4leY**>. Left, near a hole in the ice. Below left and right, a potential mate.*

Spotlight on Sandy

Updates on USGS Research to Support Restoration and Recovery from Hurricane Sandy

Hurricane Sandy Impacts Did Not Contribute to Subsequent Storm Flooding—Study looks at Great South Bay and Barnegat Bay

By Alfredo Aretxabaleta, Bradford Butman, and Neil Ganju

Flooding in coastal areas bordering Great South Bay, New York, and Barnegat Bay, New Jersey, caused by winter storms that occurred after Hurricane Sandy was not influenced by changes Sandy made to barrier islands or other bay features, according to a new U.S. Geological Survey (USGS) study.

USGS scientists studying Barnegat Bay and Great South Bay looked at data from November 2012 to October 2013, when winter storms brought water levels in these bays to among the 20 highest storm water levels reached from October 2007 to October 2013.

"The frequent and extreme high-water levels caused by storms in these two bays in the months after Hurricane Sandy led to perceptions that the mainland was more vulnerable to flooding," said USGS oceanographer and coauthor of the study **Neil Ganju**. "This study shows that changes to bay features caused by Hurricane Sandy did not influence these post-Sandy storm water levels."

Hurricane Sandy caused extreme floods along portions of the northeast coast of the United States and cut new inlets across barrier islands in New Jersey and New

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York. Scientists investigated whether Hurricane Sandy had in some way reduced the protection provided by the barrier islands and the bays, leaving the mainland more vulnerable to flooding.

The study compared water-level measurements made at stations within Great South Bay and Barnegat Bay to ocean water levels before and after Hurricane Sandy. Both are back-barrier bays—bodies of water behind barrier islands and connected to the ocean through one or more inlets.

"Changes in water levels in the back-barrier bays are primarily caused by ocean water levels driving water into or out of the bays through inlets," said USGS oceanographer and lead author of the study **Alfredo Aretxabaleta**. "The study showed that most of the ocean water-level fluctuations caused by storms make their way into the bays, while only a fraction of tidal fluctuations do."

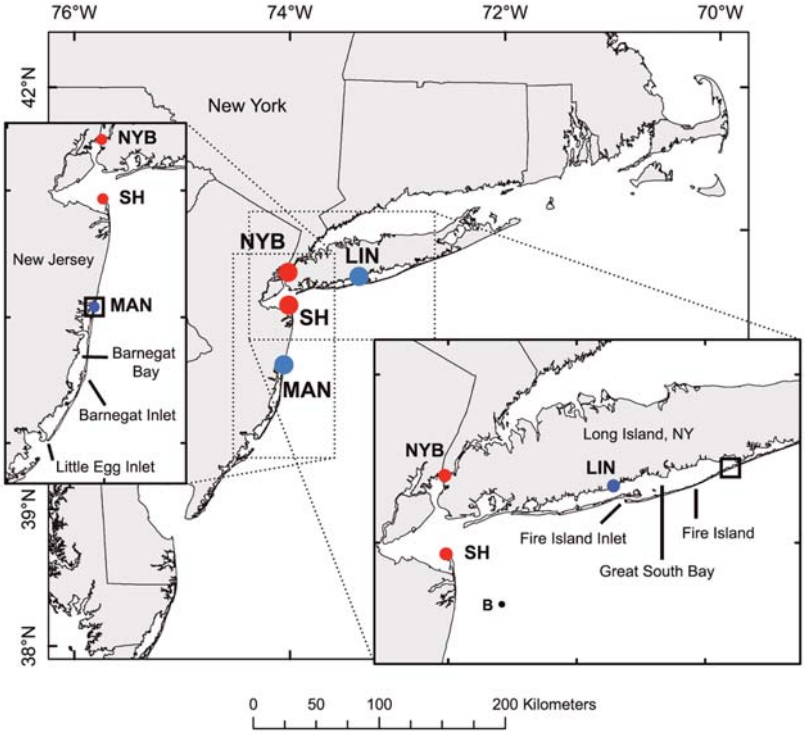
The results showed that alterations to the barrier, inlet, and bay systems caused by Hurricane Sandy did not influence the high water levels caused by storms from November 2012 to October 2013. None of these post-Sandy storms opened new inlets or caused overtopping of the protective dunes and barrier beach systems. Both before and after Sandy, about 80 percent of storm surge—a temporary rise in water level caused by an offshore storm's winds or low pressure—made its way into the back-barrier bays, whereas only about 20 percent of the tidal fluctuations do. This suggests that whether the same storm occurred before or after Hurricane Sandy, the water level in the bays would be the same.

"While the existing barrier-island and inlet system shields the mainland to a great extent from the daily tides, most of the storm surge, and all long-term changes in water level, such as those resulting from sea-level rise, reach the mainland" said USGS oceanographer and coauthor **Bradford Butman**. "These results will inform coastal communities and planners how water levels in back-barrier bays respond to ocean fluctuations."

Several studies related to Hurricane Sandy recovery, restoration, and rebuilding efforts, many of which are funded by

(Storm Flooding continued on page 7)

*Oblique aerial photographs of Pelican Island (arrow points to a fishing shack on the island) and Fire Island, New York, looking northwest toward Great South Bay. This location is within Fire Island National Seashore near Old Inlet—a narrow part of the island that has been breached in previous large storms. The island breached during Hurricane Sandy, creating a new inlet. The new study shows that such shoreline changes did not affect flooding caused by post-Sandy storms. USGS photo pair from <**http://coastal.er.usgs.gov/hurricanes/sandy/photo-comparisons/**>.*



Map of Middle Atlantic Bight showing locations of water-level stations at Mantoloking, New Jersey (MAN), and Lindenhurst, New York (LIN), in blue (in estuaries behind barrier islands) and at Sandy Hook, New Jersey (SH), in red (used as proxy for offshore water level). The Battery in New York (NYB) is also shown in red. Inset maps show (left) Barnegat Bay and (right) Great South Bay, and open squares show the location of breaches at Mantoloking, New Jersey, and Old Inlet, New York, that occurred during Hurricane Sandy. The letter B marks the location of pressure measurements on the inner shelf (1999–2000). (Figure 1 from "Water level response in back-barrier bays unchanged following Hurricane Sandy," Geophysical Research Letters, *<**http://dx.doi.org/10.1002/2014GL059957**>.)*

(Storm Flooding continued from page 6)

Disaster Relief Appropriations Act 2013, are currently underway.

"The USGS is committed to providing the science foundation for Federal, State, and local authorities to build more resilient communities," said **John Haines**, coordinator of the USGS Coastal and Marine Geology Program. "This is one of many studies the USGS is doing to understand the effects of Hurricane Sandy and to evaluate the vulnerability of the coast and its communities to future storms."

Results of the study have been published in a paper in the journal *Geophysical Research Letters*, posted online at <**http://dx.doi.org/10.1002/2014GL059957**>..

The full citation for the new paper is:

Aretxabaleta, Alfredo L., Butman, Bradford, and Ganju, Neil K., 2014, Water level response in back-barrier bays unchanged following Hurricane Sandy: Geophysical Research Letters, v. 41, no. 9, p. 3163–3171, doi:10.1002/2014GL059957 [**http://dx.doi.org/10.1002/2014GL059957**]. ☸

*Water-level station (tide gage) at Mantoloking, New Jersey <**http://waterdata.usgs.gov/usa/nwis/uv?01408168**>.*

New Personnel Contribute to USGS Studies of How Estuaries Respond to Storms

By Neil Ganju

Several people have recently begun contributing to the U.S. Geological Survey (USGS) "Estuarine Physical Response to Storms" project, which is measuring and modeling sediment responses to Hurricane Sandy and future storms in three Atlantic estuaries: Barnegat Bay along the New Jersey coast, Chincoteague Bay between Assateague Island and mainland Maryland and Virginia, and Jamaica Bay, adjacent to the southeast shore of Brooklyn, New York. The four scientists are working closely with project chief **Neil Ganju** at the USGS Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts.

*(Left to right) **Alexis Beudin**, **Steve Suttles**, **Zafer Defne**, and **Will Oestreich** huddle around a map and numerical model grid of Chincoteague Bay, off Maryland and Virginia, to plan field and modeling studies.*

Coastal scientist **Zafer Defne** began working in January 2012 on a collaboration between the USGS and the New Jersey Department of Environmental Protection to map Barnegat Bay and study its water quality (learn more about this project at <**http://soundwaves.usgs.gov/2013/02**/>). He is now contributing to the Estuarine Physical Response to Storms project by simulating Barnegat Bay's geomorphic (related to the shape of the bay) and hydrodynamic (related to how water moves in the bay) response to Hurricane Sandy. Defne received his Ph.D. from the Georgia Institute of Technology in 2010 and enjoys soccer in his spare time.

Alexis Beudin, who started in May 2014, is mirroring Defne's Barnegat Bay efforts by developing a hydrodynamic model of Chincoteague Bay to investigate how storms and vegetation affect estuarine function—that is, the estuary's ability to provide habitat for aquatic flora and fauna, protection from storm surges, flushing of land-derived nutrients, and other benefits. Beudin did his doctoral research at the University of Western Brittany, France, investigating the role of invasive gastropods (snails) on estuarine hydrodynamics. Beudin enjoys surfing and sailing when he is not doing numerical modeling.

Adding to the USGS surfing team is **Steve Suttles**, a professional engineer leading field observations in Barnegat and Chincoteague Bays. Suttles has more than 20 years of experience leading field studies, developing new instrumentation, and analyzing sediment-transport data. Before his current assignment, he worked at the University of Maryland's Horn Point Laboratory.

Last but not least is **Will Oestreich**, a Woods Hole Oceanographic Institution Summer Student Fellow, who is investigating the effect of dissolved organic matter on light attenuation (reduction in the intensity of a light beam due to absorption or scattering). Oestreich is an undergraduate at Northwestern University and is examining the relationship between fluorescence, absorbance, and isotopic signature of organic material in U.S. Atlantic coast estuaries.

(Read about two others who recently joined the estuary project in a *Sound Waves* article at <**http://soundwaves.usgs.gov/2014/04/spotlight3.html**>.)☸

Summer Hires Assist Studies of Coastal Sediment Transport

By John C. Warner, Jeffrey H. List, and William C. Schwab

Robert Forney and **Elizama Pons-Montalvo** are undergraduate students working this summer at the U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts, helping to investigate the impacts of Hurricane Sandy. The two students are analyzing data collected along the coast of Fire Island, New York, as part of an effort to measure coastal wave and current processes that mobilize and move sediment. The data-collection program was described in a previous Spotlight on Sandy article in *Sound Waves* (<**http://soundwaves.usgs.gov/2014/02/spotlight3.html**>).

Elizama Pons-Montalvo *(left) and* ***Robert Forney****, undergraduates working this summer at the USGS Woods Hole Coastal and Marine Science Center. USGS photograph by* ***Sandy Baldwin****.*

Robert Forney is a student at the Institute of Marine and Coastal Sciences at Rutgers University in New Brunswick, New Jersey. He is a physics major studying ocean processes and wants to attend graduate school to further his knowledge of oceanography. His previous research has focused on evaluating surface ocean currents using radar. This summer Forney is analyzing how wave heights, periods, and directions vary along the coast during storms. This analysis will increase our understanding of how variations in the strength of alongshore wave-driven flows can create regions of erosion and deposition along the coastline.

Elizama Pons-Montalvo is a student at the City College of New York in Manhattan. She is majoring in geology and is interested in the physical aspects of the ocean. She has previous experience in bioinformatics (an interdisciplinary field that develops methods and software for organizing and analyzing biological data) and more recently has conducted experiments on the effects of antibiotics in groundwater systems. This summer she is studying how ocean currents vary along the coast and investigating how these currents transport sediment during major storm events. Although surface currents tend to move in the direction of the wind, near-bottom currents are more complex and more important for moving sediment along the coast.

Both Forney and Pons-Montalvo are also participating in other activities, including collecting data on day cruises, helping to process data, and interacting with scientists at the Woods Hole Oceanographic Institution. We welcome their involvement in the project and anticipate that they will have a rewarding summer experience.

Research

Tracking Oil—USGS Tools and Analysis Inform Response to *Deepwater Horizon* and Future Oil Spills

By P. Soupy Dalyander, Joseph W. Long, Nathaniel G. Plant, and Theresa Burress

U.S. Geological Survey (USGS) scientists have developed a new computer model to track the movement of residual oil that persists along the northern Gulf of Mexico coast 4 years after the *Deepwater Horizon* disaster released several million barrels of gas and oil into the gulf. This new model is being used to help guide ongoing cleanup efforts and can be used to aid the response to future oil spills.

In the weeks and months after the *Deepwater Horizon* oil spill, oil

(Tracking Oil continued on page 9)

Surface residual ball (SRB) made of a mix of oil and sand on Gulf of Mexico beach. Photograph taken May 8, 2011, by the U.S. Coast Guard.

(Tracking Oil continued from page 8)

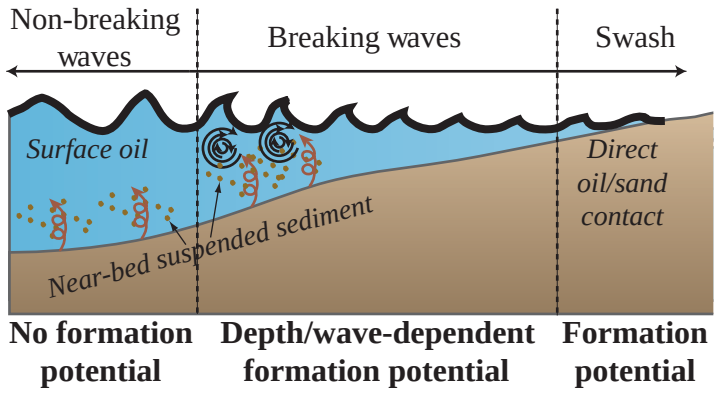
mousse—a frothy blend of oil and seawater—was transported by waves and currents toward northern Gulf of Mexico beaches, where it mixed with sand in the shallow surf zone to form rounded clumps or mats of material, sometimes as much as 10s of meters long and several centimeters thick. In some cases, smaller clumps, called surface residual balls (SRBs), formed in the surf zone or broke free from the larger mats and caused a re-oiling of the beach. During the response to the spill, the U.S. Coast Guard attempted to locate and, where possible, remove mats and SRBs. Response was hampered, however, by the difficulty in determining the depth range over which mats and SRBs may have formed within the surf zone, and by not knowing when and where SRBs would be transported.

As part of the Operational Science Advisory Team (OSAT3)—one of several multiagency working groups formed to provide scientific information to assist the government response to the *Deepwater Horizon* oil spill—researchers at the USGS St. Petersburg Coastal and Marine Science Center in St. Petersburg, Florida, developed a methodology for determining at what depths waves could suspend enough sediment to the water's surface to mix with floating oil and form agglomerates. The analysis indicated that formation of oil/sand mats was likely in the swash zone and possible within the surf zone under plunging breaking waves (see diagram, upper right). The results of this analysis are included in the OSAT3 report (<**http://www.restorethegulf.gov/release/2014/01/15/operational-science-advisory-team-report-iii**>).

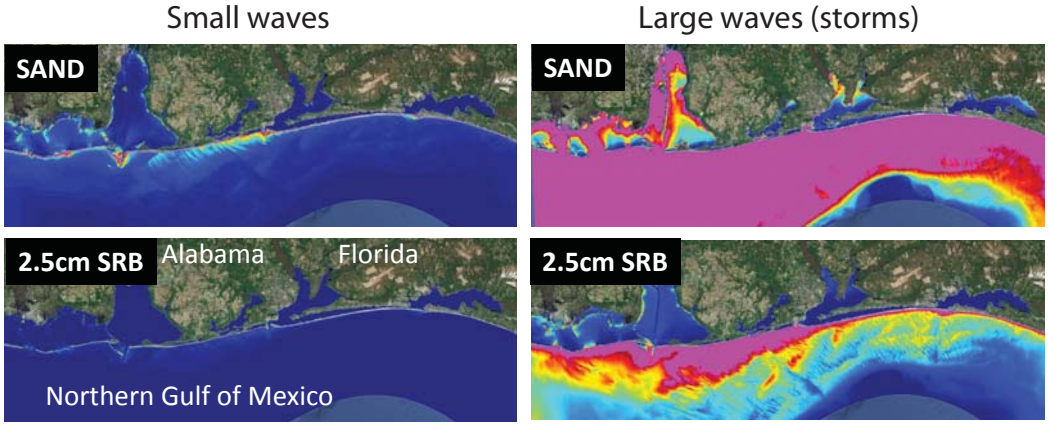
A numerical modeling approach (<**http://pubs.usgs.gov/of/2012/1234/**>) was also developed to analyze the seafloor interaction and alongshore movement of SRBs. This work determined that centimeter-size SRBs are not mobilized during the low-energy wave conditions typically observed in the northern Gulf of Mexico, but that during storm events SRBs as much as 10 centimeters in diameter could be transported. Because sand is more mobile than the larger SRBs, burial by sand and subsequent exhumation are key processes of SRB dynamics, and larger SRBs may be found by response teams under lower energy wave conditions if the sand covering them is swept away. The analysis also found that inlets will trap SRBs, inhibiting their alongshore transport. Comparison with field data collected by the Coast Guard supported the key findings of the study (<**http://dx.doi.org/10.1016/j.marpolbul.2014.01.004**>).

Recent research aims to provide additional observational data to quantify the accuracy of the results of the numerical-modeling analysis. In December 2013, pseudo-SRBs constructed out of paraffin wax and sand were deployed in the shallow surf zone near St. Petersburg, Florida. Wave conditions were quantified with a pressure gauge, and the movement of the pseudo-SRBs was tracked with the USGS Along-Track Reef Imaging System (ATRIS, <**http://pubs.usgs.gov/fs/2006/3051/**>) and commercial video camera systems. In March 2014, the pseudo-SRBs were tested in an oscillatory flow tank at the Sediment Dynamics Laboratory of the Naval Research Laboratory at Stennis Space Center, Mississippi, to further observe and quantify, under more controlled conditions, their thresholds of incipient motion and interaction with the seafloor. (View video footage of one of the oscillatory-flow tank experi-

(Tracking Oil continued on page 10)



Formation of sand/oil agglomerates requires the interaction of sediment and floating oil. Analysis of sediment suspension indicates that such interaction is likely in the shallow swash zone, but at deeper depths can only occur in the surf zone under plunging breaking waves.

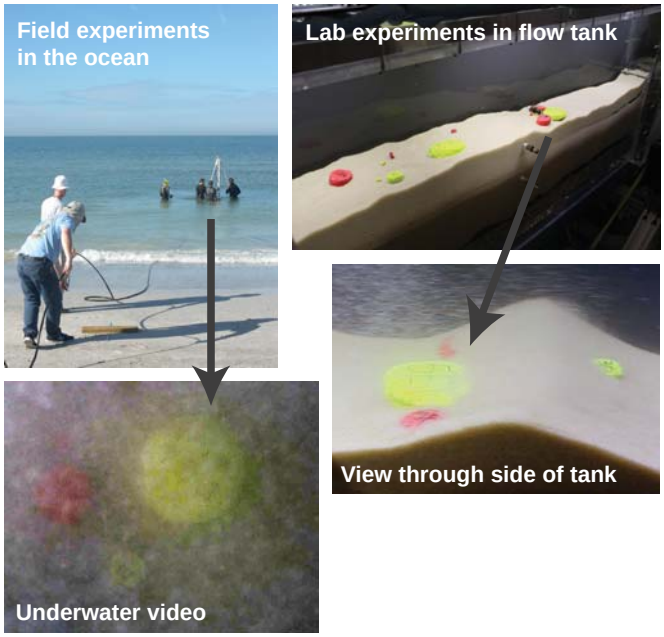


Numerical-model results showing mobility of sand and surface residual balls (SRBs—clumps of oil and sand) in small waves (left) and large (storm) waves (right). Warmer colors indicate greater mobility, with magenta indicating the greatest mobility. Model results demonstrate that sand (top panels) is more mobile than SRBs (bottom panels), making burial and exhumation of SRBs likely. (2.5 centimeters [cm] is approximately 1 inch.)

(Tracking Oil continued from page 9)

ments at <**http://soundwaves.usgs.gov/2014/06/research.html**>.) Ongoing analysis of the field and laboratory data supports the previous findings of the importance of seafloor interaction and burial and exhumation, and may provide the basis for more refined estimates of SRB movement.

The methodologies developed here informed the Coast Guard response to the *Deepwater Horizon* oil spill, and they can be applied to future disasters to help inform response and cleanup.



*Pseudo-SRBs (surface residual balls) made of paraffin wax and sand were deployed in the shallow surf zone (left panels) and tested in an oscillatory-flow tank (right panels). Initial findings support the numerical-modeling conclusion that centimeter-size SRBs are not mobilized under low-energy conditions, and that burial and exhumation are important processes. For example, see lower right panel, where a sand ripple, moving from right to left, has uncovered an SRB to its right and is beginning to migrate over several SRBs to its left. View video footage of one of the oscillatory-flow tank experiments at <**http://soundwaves.usgs.gov/2014/06/research.html**>.*

"iCoast—Did the Coast Change?" Help Identify Coastal Hazards with USGS Aerial Photographs

By Sophia B. Liu and Barbara Poore

The U.S. Geological Survey (USGS) has launched a new crowdsourcing application called "iCoast—Did the Coast Change?" that allows citizen scientists to identify changes to the coast by comparing aerial photographs taken before and after storms.

iCoast (<**http://coastal.er.usgs.gov/icoast/**>) invites visitors to explore and classify aerial photographs that are part of an extensive collection taken by USGS researchers since 1995. The first project in iCoast focuses on aerial images taken before and after Hurricane Sandy. Viewers can witness the real-world impacts of the hurricane, they can examine places they know and places they have never been, and, perhaps most important, they can help USGS scientists identify and map coastal change after extreme storms by tagging aerial imagery with pre-defined keywords. In doing so, they will help the USGS improve predictive models of coastal change to inform evacuation, preparedness, and mitigation efforts.

*Four days after Hurricane Irene made landfall on North Carolina's Outer Banks on August 27, 2011, USGS geologist **Karen L.M. Morgan** was taking aerial photographs of the affected coast. Since 1995, the USGS has acquired more than 140,000 high-resolution oblique aerial photographs of the Atlantic and Gulf coasts after 24 extreme storms (<**http://coastal.er.usgs.gov/hurricanes/oblique.php**>)*

Why Coastal Change Matters

Coastal areas are essential to the economic, cultural, and environmental health of our nation. More than half of the U.S. population lives within 50 miles of the coast. Current trends point to increasing numbers of hurricanes making landfall and an increasing number of people moving into coastal areas that are vulnerable to storms.

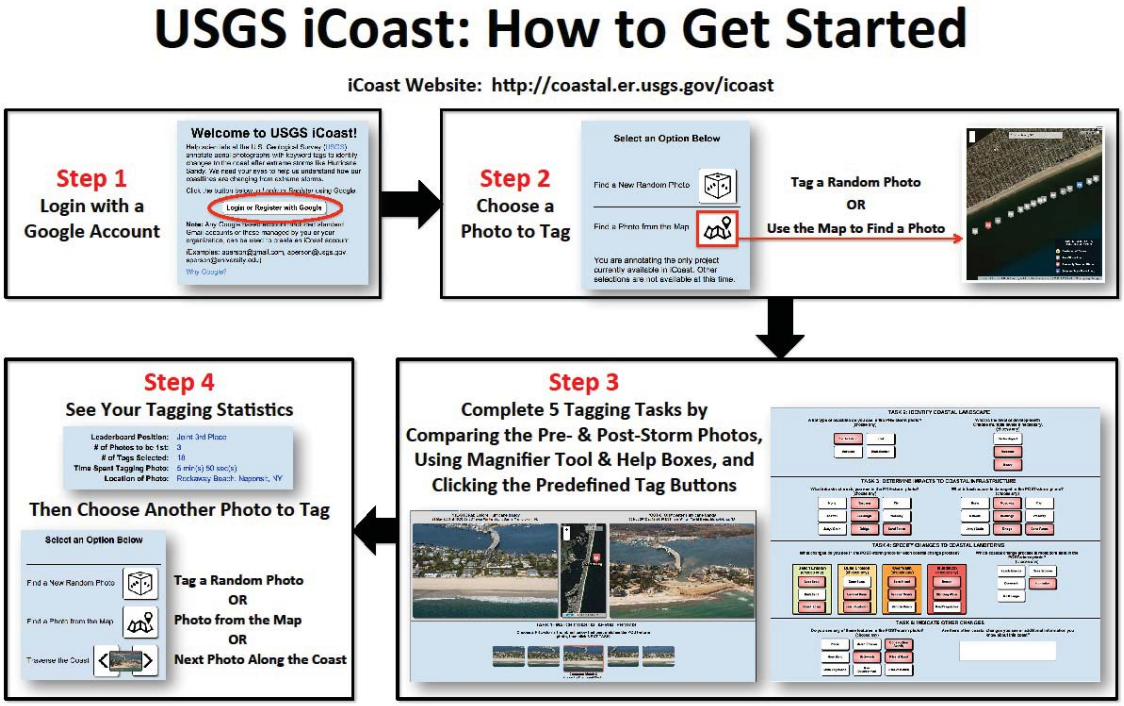
Our shorelines are constantly changing, and a storm can cause dramatic coastal changes in a matter of hours. As coastal population and development escalate, so will the potential for loss of life, property damage, and economic disruption caused along the coast by extreme storms. Barrier islands and coastal wetlands are the first line of defense for numerous coastal communities, but many of these natural protections are themselves overly urbanized, with beaches and dunes rapidly eroding and thus heightening coastal vulnerability. As a nation, we must face difficult decisions regarding coastal planning, development, and management practices to strengthen our resilience to coastal hazards.

The USGS hurricane research and response activities for the National Assessment of Coastal Change Hazards (<**http://marine.usgs.gov/coastalchangehazards/**>) include collecting storm-surge water levels, taking pre- and post-storm aerial photographs, and

(iCoast continued on page 11)

(iCoast continued from page 10)

conducting laser altimetry (a.k.a., lidar, for "light detecting and ranging") surveys of pre- and post-storm beach topography to understand the underlying physical processes of coastal-change hazards. These ephemeral data are critical for developing and improving hazard assessments and situational awareness in the immediate aftermath of a storm.



How to use iCoast.

Aerial Imagery of the Coast Before and After Storms

Since 1995, the USGS has acquired more than 140,000 high-resolution oblique aerial photographs of the Atlantic and Gulf coasts after 24 extreme storms (<**http://coastal.er.usgs.gov/hurricanes/oblique.php**>). For Hurricane Sandy alone, more than 9,000 aerial photographs were taken a week after the storm. These aerial photographs were taken at a low altitude (approximately 500 feet above the ground at a distance 1,000 feet offshore) to get a detailed look at a small area of the coast.

While the imagery contains valuable information, the USGS does not have the personnel or capacity to analyze all the photographs taken after every storm to ground-truth and validate prediction models. Also, computers cannot yet automatically identify damages and geomorphic changes to the coast from the oblique aerial photographs. Human intelligence is still needed. The USGS decided to launch a citizen-science project to address this need.

The Power of Crowds for Improving Coastal-Hazard Science

"iCoast—Did the Coast Change?" is an interdisciplinary research project that seeks to engage the whole community in coastal-hazard science. The iCoast team (<**http://coastal.er.usgs.gov/icoast/about.php**>; scroll down) is targeting many crowds with coastal expertise, including coastal scientists, residents, managers and planners, teachers and students, and people who use the coast or nearshore waters for recreational or commercial purposes.

iCoast asks volunteers to identify changes to the coast by comparing aerial photographs taken before and after a storm, and then selecting simple one-to-three-word tags (for example, "seawall," "sand on road," and "dune scarp"). When users hover the cursor over a pre-defined

(iCoast continued on page 12)

The USGS iCoast application organized the pre-defined keywords to help volunteers tag evidence of coastal change on post-storm photos, as well as to allow USGS researchers to test their coastal-change prediction models.

(iCoast continued from page 11)

tag, a pop-up box appears to provide text and pictorial explanations to assist the volunteers' selection of appropriate tags.

Analyzing aerial photographs to identify storm damage helps USGS coastal scientists evaluate and refine their predictive models of coastal erosion and damage caused by extreme storms—steps that are vital to improving the resolution and timeliness of these models. Currently, these mathematical prediction models are derived from dune elevations and predicted wave action during storms (for example, see <**http://coastal.er.usgs.gov/hurricanes/sandy/coastal-change/**>). Adding human observations, especially observations of impacts to human systems such as buildings, roads, and other infrastructure, will allow USGS scientists to ground truth their vulnerability assessments and provide better predictions of damage before storms occur.

Hovering the cursor over a pre-defined iCoast tag opens a popup window with text and pictorial explanations of the tag.

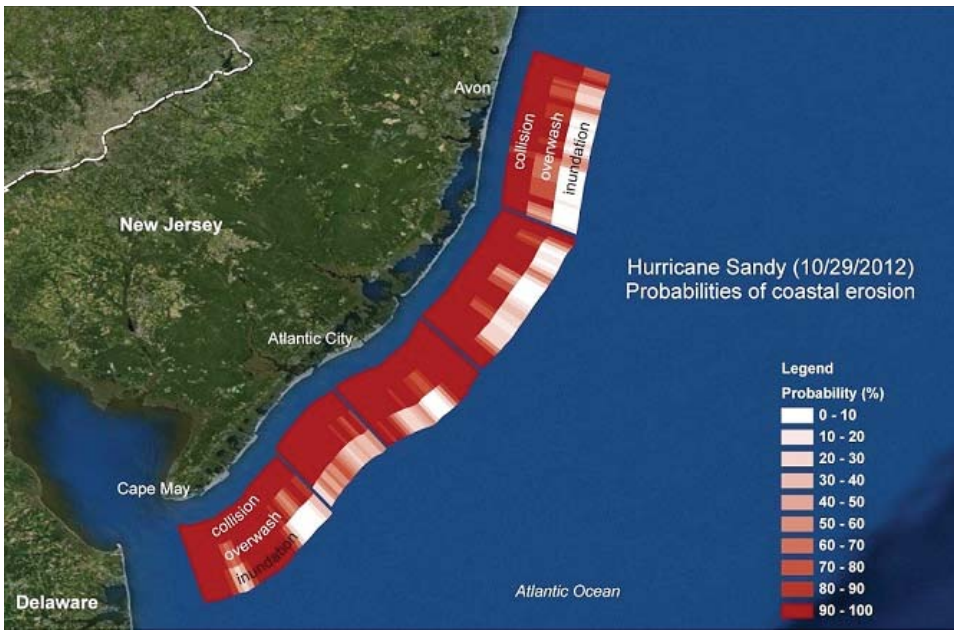
Ground Truthing Prediction Models with Crowdsourced Data

The USGS has been a scientific leader in developing models with robust predictive capability by providing geospatial probability estimates of coastal hazards on a regional to national scale. Hurricane-induced water levels from waves and storm surge are compared to the coastal topography or elevation of beaches and dunes to determine the probabilities of four types of coastal change:

- Beach erosion (<**http://coastal.er.usgs.gov/hurricanes/impact-scale/swash.php**>) occurs when wave runup (<**http://coastal.er.usgs.gov/hurricanes/impact-scale/water-level.php#runup**>) is confined to the beach.
- Dune erosion (<**http://coastal.er.usgs.gov/hurricanes/impact-scale/collision.php**>) occurs when the base or toe of the dune is eroded by waves and storm surge.
- Overwash (<**http://coastal.er.usgs.gov/hurricanes/impact-scale/overwash.php**>) occurs when sand is transported and deposited inland by waves and storm surge.
- Inundation (<**http://coastal.er.usgs.gov/hurricanes/impact-scale/inundation.php**>) occurs when the beaches and dunes are submerged by storm surge and wave runup.

Immediately before a hurricane makes landfall, USGS scientists rapidly generate coastal-hazard maps showing the likelihood of storm-induced coastal changes in particular regions along the Atlantic and Gulf coasts. (For example, see "USGS Scientists Predict, Measure Sandy's Impacts on the Coastal Landscape," *Sound Waves*, November/December 2012, <**http://soundwaves.usgs.gov/2012/12/**>.)

(iCoast continued on page 13)



*Probabilities of dune erosion ("collision"), overwash, and inundation for Hurricane Sandy. The USGS posted this map on October 29, 2012, at 11:00 a.m. Eastern Daylight Time, just hours before the storm made landfall on the U.S. east coast (<**http://coastal.er.usgs.gov/hurricanes/sandy/coastal-change/**>). The USGS determines the probabilities of hurricane-induced coastal change for the nation's Atlantic and Gulf coasts to better inform evacuation, response, preparedness, and mitigation efforts.*

(iCoast continued from page 12)

These probabilistic assessments are immediately shared to help coastal residents and decision makers understand, prepare for, and respond to coastal hazards in their region. They can help people predict where barrier islands and evacuation routes will likely be washed over in an approaching hurricane and so facilitate better communication among groups preparing for and responding to the storm.

Benefits of iCoast

Citizen-science projects like iCoast serve the cause of open government (<**http://www.whitehouse.gov/open**>) and open data (<**https://www.data.gov/open-gov/**>) by actively sharing USGS aerial imagery with the wider public. iCoast also supports the broad objectives of the USGS Natural Hazards Science Strategy (<**http://www.usgs.gov/natural_hazards/**>) to improve communication of hazard-data collection and research knowledge. The crowd-sourced data produced through iCoast will help the USGS improve the accuracy of coastal-erosion prediction models and vulnerability assessments that can inform pre-storm evacuation planning as well as post-storm rescue and recovery efforts.

The iCoast project is also a way to engage the public's interest in coastal hazards and boost awareness and risk-wise behavior. It is an interactive source for basic coastal-hazard education that can be used during crises as well as non-emergency times to assist the nation in preparing for extreme storms. iCoast allows users to remotely witness the conditions of bridges, roads, and properties along the coast just days after extreme storms. iCoast can also be a great tool for teachers to facilitate science, technology, engineering, and math (STEM) education.

The iCoast application was designed to be reusable for past and future storms. Its initial development was based on aerial imagery taken before and after Hurricane Sandy. The iCoast team anticipates a stronger public interest in volunteering for iCoast immediately after storms.

Now that hurricane season is underway (it started June 1), consider volunteering for iCoast (<**http://coastal.er.usgs.gov/icoast/**>)!

For additional ways to help the USGS as a citizen scientist, please visit <**http://txpub.usgs.gov/myscience/**>.

Coral Reefs Provide Critical Coastal Protection
New study shows that coral reefs provide risk-reduction benefits to hundreds of millions of coastal inhabitants around the world

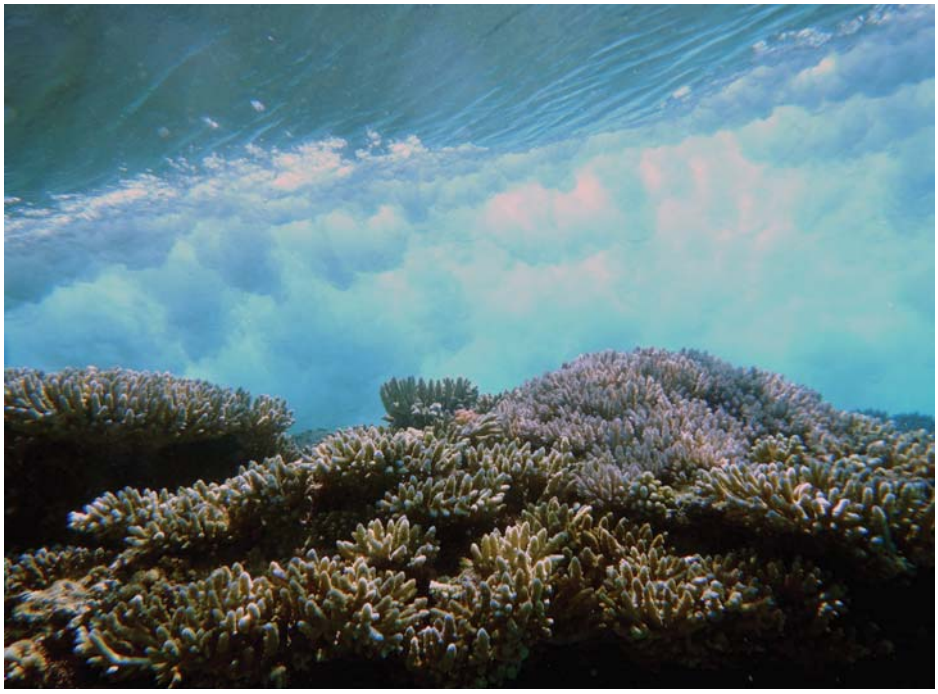
[Reprinted from *NEWSWAVE*, Spring 2014, <**http://www.doi.gov/pmb/ocean/news/Newswave/**>]

Stronger storms, rising seas, and flooding are placing hundreds of millions people at risk around the world, and a big part of the solution to decrease those risks is just offshore. A new study finds that coral reefs provide substantial protection against natural hazards by reducing wave energy that would otherwise impact coastlines by an average of 97 percent.

"Coral reefs are wonderful natural features that, when healthy, can provide wave-reduction benefits comparable to those of many artificial coastal defenses, and they can adapt to sea-level rise," said **Curt Storlazzi**, a coauthor from the U.S. Geological Survey (USGS). "This research shows that coral reef restoration can be a cost-effective way to decrease the hazards coastal communities face due to the combination of storms and sea-level rise."

Published in the journal *Nature Communications*, this study by an international team of researchers from the University of Bologna, The Nature Conservancy, the USGS, Stanford University, and the University of California Santa Cruz provides

(Coral Reefs continued on page 14)



This unique perspective taken from underwater shows a wave crashing over a coral reef protecting the low-lying islands on Kwajalein Atoll in the Republic of the Marshall Islands. It clearly illustrates how healthy coral reefs cause waves to break offshore and dissipate their energy before reaching the shoreline, lessening the probability of coastal erosion and inundation. USGS photograph by ***Curt Storlazzi****.*

(Coral Reefs continued from page 13)

the first global synthesis of the contributions of coral reefs to risk reduction and adaptation across the Atlantic, Pacific, and Indian Oceans.

Lead author **Filippo Ferrario** from the University of Bologna said, "Restoration and conservation of coral reefs is an important and cost-effective solution to reduce risks from coastal hazards and climate change."

The median cost for building artificial breakwaters is $19,791 per meter, compared to $1,290 per meter for coral reef restoration projects.

"Coral reefs serve as an effective first line of defense to incoming waves, storms and rising seas," said **Michael Beck**, lead marine scientist of The Nature Conservancy and a coauthor of the study. "200 million people across more than 80 nations are at risk if coral reefs are not protected and restored."

These are people in villages, towns, and cities who live in low-elevation, risk-prone coastal areas (below 10-meter elevation) and within 50 kilometers of coral reefs. In terms of number of people who receive risk-reduction benefits from coral reefs, the top 15 countries include:

1. Indonesia, 41 million
2. India, 36 million
3. Philippines, 23 million
4. China, 16 million
5. Vietnam, 9 million
6. Brazil, 8 million
7. United States, 7 million
8. Malaysia, 5 million
9. Sri Lanka, 4 million
10. Taiwan, 3 million
11. Singapore, 3 million
12. Cuba, 3 million
13. Hong Kong, 2 million
14. Tanzania, 2 million
15. Saudi Arabia, 2 million

For more information, read the USGS news release at <**http://www.usgs.gov/newsroom/article.asp?ID=3887**>.

See related stories in the Spring 2014 issue of *NEWSWAVE*, <**http://www.doi.gov/pmb/ocean/news/Newswave/**>, including a special feature on the U.S. Department of the Interior's "Diverse Role in Coral Reef Protection" and an article on DOI's involvement with the Coral Triangle Initiative, a multilateral ocean governance initiative to safeguard the marine and coastal resources of the six countries of Southeast Asia's Coral Triangle—Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste.

New Postdoctoral Researchers Enriching USGS Science in Woods Hole, Massachusetts

Several postdoctoral researchers have joined the U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts. Three are studying chemical processes affecting New England salt marshes in projects that grew out of the "Nitrogen and Coastal Blue Carbon Research Project" at the Waquoit Bay National Estuarine Research Reserve on Cape Cod, Massachusetts (<**http://wbnerrwetlandscarbon.net/resources/blue-carbon-demonstration-and-dialogue/**>). The fourth is studying submarine landslide and tsunami hazards.

***Joanna C. Carey** at Nag Marsh on Prudence Island, Rhode Island (part of the Narragansett Bay National Estuarine Research Reserve [NBNERR]), in 2011.*

Joanna C. Carey is working with **Jim Tang** (Marine Biological Laboratory, Woods Hole), **Kevin Kroeger** (USGS Woods Hole Coastal and Marine Science Center), and **Pam Templer** (Boston University) to evaluate how warming affects a range of ecosystem responses. She is conducting warming experiments in New England salt marshes, examining how warming alters greenhouse gas fluxes, soil carbon accretion, and plant phenology (the timing of blooming and other cyclical life events). In addition, Carey is working to synthesize the results of warming experiments across a wide range of biomes (areas with distinctive plant and animal groups, such as grassland or desert). Carey recently completed a postdoctoral fellowship with the U.S. Environmental Protection Agency (EPA) in Narragansett, Rhode Island, studying the impact of oyster-reef restoration and aquaculture on rates of net denitrification (reduction of nitrate back into the largely inert nitrogen gas).

She holds a Ph.D. in Earth sciences from Boston University, where she focused on silicon cycling in temperate salt marsh and river systems. She received a Master of Environmental Science (MESc) degree in environmental science from Yale University in 2007 and a B.S. in environmental policy and planning from Virginia Tech in 2005. Her research focuses on under-

(New Postdocs continued on page 15)

(New Postdocs continued from page 14)

standing the impact of human activities on biogeochemical cycling at the land-sea-atmosphere interface.

Priya Ganguli completed her Ph.D. in Earth sciences in 2013 at the University of California, Santa Cruz, where she studied mercury cycling in aqueous systems. She is now a USGS Postdoctoral Scholar at the Woods Hole Oceanographic Institution (WHOI), where she is characterizing mercury biogeochemical cycling in salt marsh ponds, with an emphasis on the influence of submarine groundwater discharge (the flow of groundwater into the ocean or lakes through submarine springs or by diffuse flow through sediments). **Carl Lamborg** (WHOI) and **Kevin Kroeger** (USGS) are her primary advisors. This mercury study is part of a multidisciplinary project to evaluate carbon sequestration (uptake and storage of atmospheric carbon dioxide) and greenhouse-gas emissions at the Waquoit Bay National Estuarine Research Reserve (<**http://www.waquoitbayreserve.org/the-impact-of-nitrogen-loading-on-salt-marsh-greenhouse-gas-fluxes/**>). Ganguli is also interested in terrestrial-watershed dynamics. She has been involved in remediation projects at several mine sites in the California Coast Ranges, including the abandoned New Idria and Klau/Buena Vista mercury mines, which are EPA Superfund sites. Between her M.S. and Ph.D. degrees, Ganguli was employed as a geologist at the San Francisco Bay Regional Water Quality Control Board, where she worked on large-scale mine-site and wetland remediation projects. Ganguli would like to combine her background in science and policy to continue working on multidisciplinary environmental-restoration projects.

Meagan Gonneea is a National Science Foundation (NSF) Postdoctoral Fellow working with **Kevin Kroeger** at the USGS Woods Hole Coastal and Marine Science Center. Gonneea earned a Ph.D. in chemical oceanography from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (MIT/WHOI) Joint Program (<**http://mit.whoi.edu/**>) in September 2013, completing her thesis on seasonal variability in chemical fluxes from within the subterranean estuary (where groundwater and seawater mix) of a coastal aquifer at Waquoit Bay, Massachusetts (<**http://www.waquoitbayreserve.org/nitrogen-fluxes-to-waquoit-bay-via-groundwater-discharge-identifying-end-member-concentrations/**>). She studied with **Matt Charette,** a senior scientist in marine chemistry and geochemistry at WHOI.

(New Postdocs continued on page 16)

***Priya Ganguli** measuring basic water-quality parameters (temperature, pH, conductivity, dissolved oxygen) at San Gregorio lagoon as part of a study to evaluate seasonal variability in mercury speciation in coastal lagoons along the central California coast.*

***Meagan Gonneea** sampling groundwater through steel piezometers (removable wells) on the coast of the Strait of Magellan, Chile, to determine how subsurface water flow contributes to seawater chemistry.*

(New Postdocs continued from page 15)

Gonneea received an NSF Ocean Sciences Postdoctoral Fellowship to study the impact of sea-level rise and nitrogen enrichment on soil and carbon accretion, and the subsurface cycling of greenhouse gases and carbon in the salt marshes of Cape Cod, Massachusetts.

Nathan Miller came to the USGS through the Mendenhall Research Fellowship Program (<**http://geology.usgs.gov/postdoc/**>). He is working primarily with research geophysicists **Uri ten Brink** and **Daniel Brothers** and research geologist **Jason Chaytor** on seismic characterization of submarine landslide and tsunami hazards. ("Seismic" refers to the use of sound energy to image structures and measure mechanical properties in materials beneath the seafloor.) Miller earned his Ph.D. in geophysics from the MIT/WHOI Joint Program in April 2013. His thesis work focused on early rifting and salt deposition in the Gulf of California, numerical experiments on sediment diapirism (a type of intrusion in which a less dense material, such as sediments, moves upward into denser, overlying rock), and upper-mantle hydration and seismic anisotropy at the Middle America Trench. (Material is considered "anisotropic" if seismic waves move through it faster in some directions than others). Miller is also a Postdoctoral Research Fellow at the Lamont-Doherty Earth Observatory, and he is excited about the opportunity to work on projects related to submarine landslides and oceanic margin evolution with scientists from both institutions.

A warm welcome to these new postdocs and the contributions they are making to USGS science! ❁

Nathan Miller *during recovery of an ocean-bottom seismometer on the research vessel (R/V)* Marcus Langseth *at the Mariana Trench in 2011. These instruments were part of a National Science Foundation (NSF)-funded experiment to measure the amount of water being carried into the mantle as the Pacific plate subducts into the trench.*

Summer Intern Assisting Research at the USGS in Woods Hole, Massachusetts

Kara Vadman is working this summer as an intern at the U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts. She received her internship through the USGS/NAGT Cooperative Field Training Program (<**http://nagt.org/nagt/students/usgs_field.html**>), run jointly by the USGS and the National Association of Geoscience Teachers (NAGT). Working with **Meagan Gonneea**, a National Science Foundation (NSF) Postdoctoral Fellow (see "New Postdoctoral Researchers Enriching USGS Science in Woods Hole, Massachusetts," this issue, <**http://soundwaves.usgs.gov/2014/06/staff.html**>), Vadman is investigating the impact of nitrogen loading and sea-level rise on carbon sequestration in coastal salt marsh ecosystems through evaluation of sediment cores. Vadman completed her undergraduate degree in geology at Colgate University in May 2014. At Colgate, she studied Antarctic marine diatom assemblages and participated in two cruises aboard the research vessel ice breaker (RVIB) *Nathaniel B. Palmer.* In August, Vadman will join the graduate program at University of South Florida College of Marine Science. ❁

Kara Vadman *aboard the research vessel ice breaker (RVIB)* Nathaniel B. Palmer *during a spring 2014 cruise to East Antarctica (Mertz Glacier, Moscow University Ice Shelf, and Totten Glacier).*

New USGS Coastal and Marine Geology Web Pages Open Doors to Diverse Research Topics, Expertise, and Resources

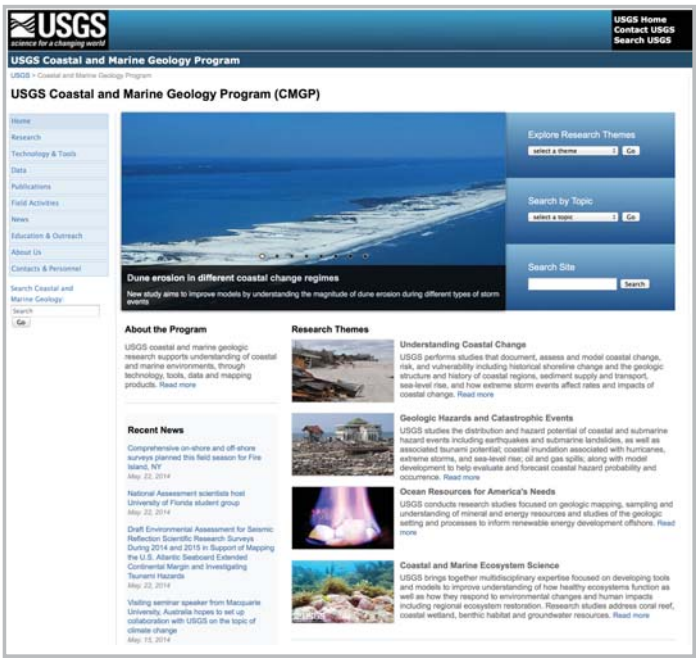
By Jolene Gittens

> We want partners and stakeholders to easily see what we do to support them—to find the tools and products they need. The web is an important resource—our front door. It is important that we share what we are doing and keep it updated so it is current and relevant. These front-end pages are one important piece of our strategy to help the public, agencies at all levels, and a diverse community of researchers find, access, and apply our data and products to their needs and resource management issues.
>
> —USGS Coastal and Marine Geology Program Coordinator, **John Haines**

The U.S. Geological Survey (USGS) Coastal and Marine Geology Program (CMGP) has launched a revised website. Through a thematic and topical organizational structure with technical enhancements that improve navigation and search capabilities, the new CMGP website improves access to both current and historical coastal and marine research information, including research projects, laboratory and technical capabilities, field activities, data, publications, news, outreach activities, and personnel information.

Current scientific research is organized along major themes through which CMGP contributes to the USGS mission:

> ***The U.S. Geological Survey (USGS) Coastal and Marine Geology Program (CMGP) contributes to the greater USGS mission of providing impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we rely on, the impacts of climate and land-use change, and the core science systems that help provide timely, relevant, and usable information.***



*Home page of the new USGS Coastal and Marine Geology Program (CMGP) website, <**http://marine.usgs.gov/**>.*

Understanding Coastal Change—A range of studies and information that document, assess, and model coastal change, risk, and vulnerability, including historical shoreline change and the geologic structure and history of coastal regions, sediment supply and transport, sea-level rise, and how extreme storms affect rates and impacts of coastal change.

Geologic Hazards and Catastrophic Events—Research about the causes, distribution and hazard potential of coastal and submarine hazard events—including earthquakes and submarine landslides, as well as associated tsunamis; coastal inundation caused by hurricanes, extreme storms, and sea-level rise; and oil and gas spills. Included in this theme is the development of models to help evaluate and forecast coastal-hazard probability and occurrence.

Ocean Resources for America's Needs—Research studies focused on geologic mapping, sampling, and understanding of mineral and energy resources, including studies of geologic setting and processes to inform renewable energy development offshore.

Coastal and Marine Ecosystem Science—Multidisciplinary expertise focused on developing tools and models to improve understanding of how healthy ecosystems function, as well as how they respond to environmental changes and human impacts, including regional ecosystem restoration. Research studies address coral reef, coastal wetland, benthic habitat, and groundwater resources.

To learn more about the comprehensive research conducted by the USGS CMGP, there are many ways to get started:

Want to find research projects?

Browse the **Research** section by major research themes, see a list of all current research projects, or search projects using a topical search with a curated result collection and a set of recommended resources. In addition to being able to search by topic, you can find current research by theme organized by national and regional scope and areas of applied science. Each research project includes a project overview, descriptions of research themes and tasks, data products, publications, and contact information.

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Want to learn about research techniques and tools?

The **Technology & Tools** section describes the data-collection tools, analytical techniques, and technologies used in coastal and marine studies. Visitors can learn about laboratory facilities and capabilities, mapping technologies, data modeling and visualization tools, scientific instruments and equipment, and software.

Looking for data?

The **Data** section uses the USGS Coastal and Marine Geoscience Data System (CMGDS; <**http://cmgds.marine.usgs.gov/**>), a web service that provides access to published CMGP data sets. Access to CMGP data is provided via Open Geospatial Consortium (OGC; <**http://www.opengeospatial.org/**) standards services; by serving CMGP data to GeoMapApp (<**http://www.geomapapp.org/**>) and Virtual Ocean (<**http://www.virtualocean.org/**>) 2-D and 3-D earth browsing tools for data integration, visualization, and analysis; and through metadata catalogs for data discovery. The site currently serves up seismic, sidescan-sonar, bathymetry, gravity, magnetic, and lidar data. Data holdings and data-serving capabilities receive frequent updates.

*Many oceanfront homes on Fire Island, New York, were damaged or destroyed during Hurricane Sandy. (From the "Understanding Coastal Change" research theme [<**http://marine.usgs.gov/research/coastal-change.php**>] in revised USGS Coastal and Marine Geology Program website.)*

*Diver uses an underwater drill to take a core sample from a massive brain coral (*Diploria strigosa*) in Dry Tortugas National Park. (From "Reef History and Climate Change" page [<**http://coastal.er.usgs.gov/crest/research-themes/climate.html**>] in the revised website's "Coastal and Marine Ecosystem Science" research theme [<**http://marine.usgs.gov/research/ecosystems.php**>].)*

Looking for maps and other publications?

The **Publications** page features a comprehensive list of publications produced by CMGP; citations include a direct link to the full publication if it is available online.

Interested in field activities?

The **Field Activities** section provides an up-to-date status of all CMGP field activities, including dates, locations, chief scientists, and scientific objectives. Field activities can be viewed in a calendar format as well as in a list view of the current month's activities.

Want to locate educational resources and discover ways CMGP engages with the public?

The **Education and Outreach** section shares a wide range of resources—including multimedia such as podcasts, videos, and images—to help explain and illustrate scientific concepts. Information about community outreach activities, such as center open houses, seminars, and youth programs, is also included.

Want to learn more about the CMGP Program?

The **About Us** section shares CMGP expertise, priorities for research initiatives, and planning documents.

The **News** section is updated weekly and features short articles about newly released publications, upcoming scientific meetings, new research activities, and other events. There is also a link to the Program's bimonthly newsletter *Sound Waves*, which provides in-depth articles about coastal and marine research.

The **Contacts and Personnel** section lists CMGP scientists and staff, along with

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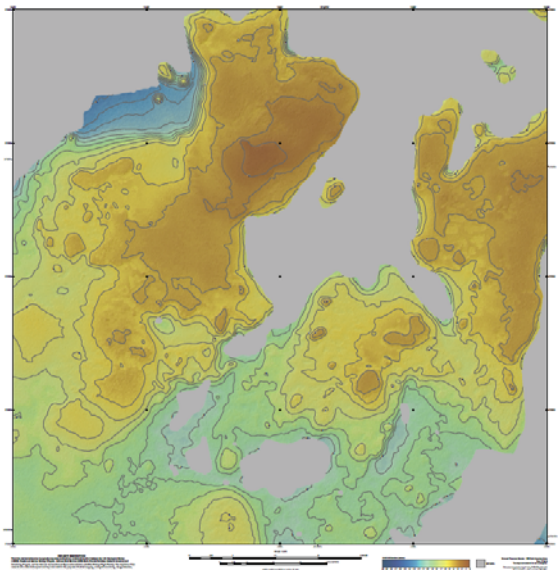

*Example of the many types of data available from the revised website: lidar (light-detection-and-ranging) map of submarine topography in Dry Tortugas National Park. (Sheet 42 of USGS Open-File Report 2006–1244, <**http://pubs.usgs.gov/of/2006/1244/start.htm**>.)*

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their contact information and maps and directions to all CMGP offices.

Launched March 11, 2014, the website is the product of collaboration between the three science centers that make up the USGS Coastal and Marine Geology Program: the St. Petersburg Coastal and Marine Science Center in St. Petersburg, Florida; the Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts; and the Pacific Coastal and Marine Science Center in Santa Cruz and Menlo Park, California.

Please come visit, the "front door" is open: <**http://marine.usgs.gov/**>.

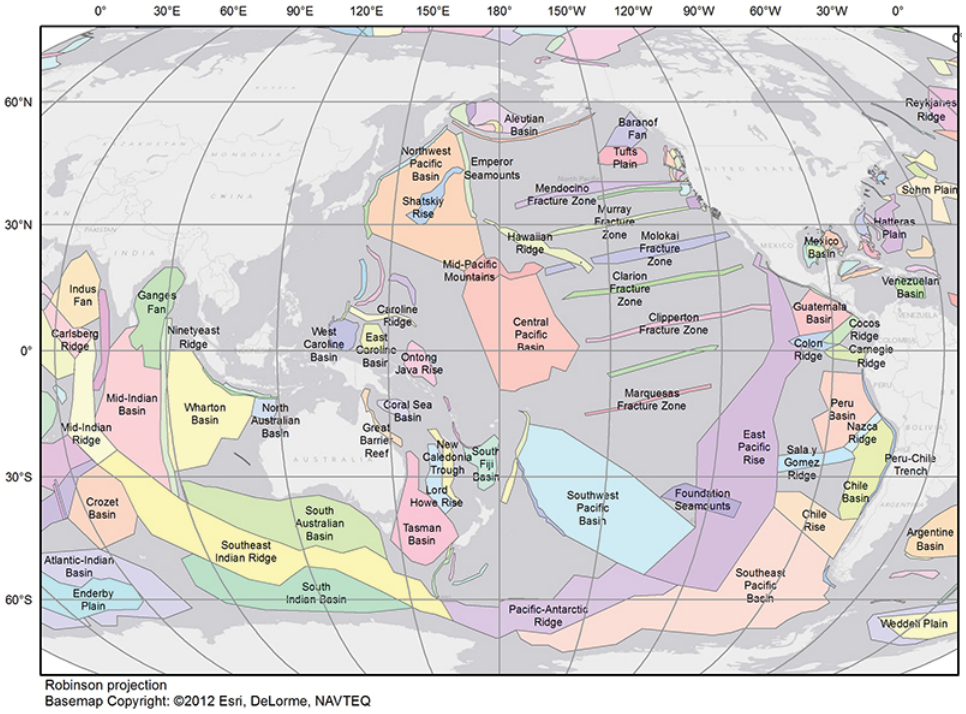
Facilitating Identification of Coastal and Undersea Features—"Footprints" for Marine Gazeteers

By Fran Lightsom and Alan Allwardt

When we look for online information, we are often interested in a particular place where we live, work, or are planning to visit. By typing in the name of the place, we get a map of the area and a list of resources that are keyed to specific places on the map. These online information services make use of gazetteers to look up the geographic footprints of named places. However, gazetteers that list ocean places usually provide the latitude and longitude of a single point—or at most a rectangular bounding box—even for a place as large and irregular as the Pacific Ocean. The USGS Coastal and Marine Geology Program is producing sets of geographic polygons to help people find scientific information about the ocean. These polygons are not authoritative representations of the features in question, but simpler shapes that can be used efficiently by online search interfaces.

The first footprints, published in December 2013 as USGS Open-File Report 2013–1284 (<**http://dx.doi.org/10.3133/ofr20131284**>), represented 492 U.S. coastal counties along with adjacent state waters. A second set of footprints was published in March 2014 as USGS Open-File Report 2014–1040 (<**http://dx.doi.org/10.3133/ofr20141040**>). This report contains 311 footprints for undersea features, including features as large as the Mid-Atlantic Ridge and as small as the banks and basins in the Gulf of Maine. Following these publications, the project will release footprints for coastal features such as capes, islands, and bays. These footprints will be released as an expandable online database, in recognition of the ongoing need to add more coastal features to the list.

The footprints are released in shapefiles compatible with geospatial information systems. Online information systems with the capability to search user-defined, polygonal geographic areas will be able to offer these places in response to user requests. In particular, the spatial extents of oceans and seas will be offered as a search option in the USGS Core Science Metadata Clearinghouse (<**http://mercury-ops2.ornl.gov/clearinghouse/**>). Footprints for high-priority undersea features are being incorporated into the GEBCO (General Bathymetric Chart of the Oceans) Gazetteer of Undersea Feature Names (<**http://www.ngdc.noaa.gov/gazetteer/**>) and will be added to the GEOnet Names Server maintained by the National Geospatial-Intelligence Agency (<**http://earth-info.nga.mil/gns/html/**>).



*This global map shows selected geospatial polygons (footprints) for undersea features such as the Aleutian Basin, the Molokai Fracture Zone, and the East Pacific Rise. These polygons were created after examining historical bathymetric maps, digital data, and scientific literature. (Figure 1 from USGS Open-File Report 2014–1040, <**http://dx.doi.org/10.3133/ofr20141040**>.)*

Complete citations for the two reports are:

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