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Research

Coral Reefs, El Niño, and Climate Change: An Interview with Lauren Toth

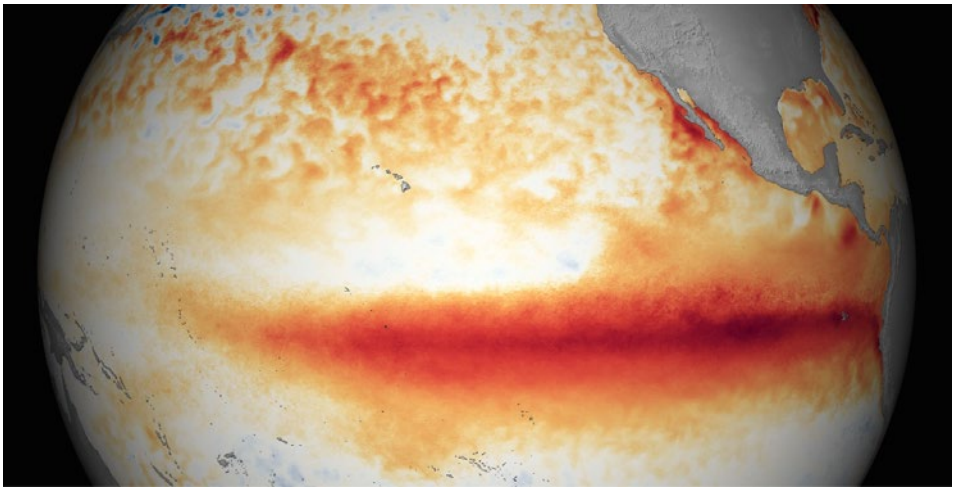
By Rex Sanders

You might have read stories of coral bleaching events, where coral reefs turn stark white after stress from high ocean temperatures. Are they due to climate change, or other factors? Can some reefs recover better than others? What else might affect the recovery and survival of these reefs? Since scientists can't artificially warm up an entire coral reef, they look for natural experiments. One is running this year—an El Niño with record-setting ocean temperatures.

El Niño is the common name for extraordinarily warm seawaters that sometimes appear around Christmas off the west coast of South America. In some other years, La Niña brings colder waters there. Scientists refer to the irregular patterns of El Niño, La Niña, and neutral years as the El Niño–Southern Oscillation, or ENSO. A USGS research scientist plans to take advantage of this year's El Niño to investigate coral reefs in an unusual setting—the Pacific coast of Panama.

Lauren Toth is a physical scientist and Mendenhall Postdoctoral Research Fellow at the St. Petersburg Coastal and Marine Science Center in Florida. Toth's research combines multiple scientific specialties to determine the limits on coral reef growth across broad spans of time and space. She hopes this information will help guide resource management decisions affecting coral reefs.

*USGS physical scientist **Lauren Toth**.*



Pacific Ocean temperature differences during this winter's record-setting El Niño. Dark red areas are much warmer than average. Photo credit: NOAA.

*Map of Panama, with the Pacific coast on the southern (lower) side. Image credit: **http://coastal-map.er.usgs.gov**.*

Toth answered questions by telephone from her office in Florida on February 8th, shortly before departing for three weeks of research offshore Panama. This interview was edited for clarity and length.

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How did you choose Panama?

It's always fascinated me that there even are reefs in Pacific Panama, in an area where you have a 5-meter tidal range and the water is murky all the time. You have, every 10 years or so, a huge El Niño event that knocks back all the corals, and you have upwelling. These are all conditions that should keep reefs from growing. Understanding why and how they grow under those extreme conditions can be really informative.

How is your research related to El Niño?

This project in Panama is an extension of the work that I did during my dissertation. We looked at core records of reefs and found a 2,000 [to] 2,500-year gap. Reefs really weren't growing during that time. Using regional climate records we were able to relate that gap to a period where there was an increase in either the frequency or intensity of the El Niño–Southern Oscillation.

That makes sense, because we know reefs in that area now are really, really strongly affected by both El Niño and La Niña. Stronger or more frequent events could've shut down the development of those reefs in the past.

Collecting a coral core in the Gulf of Chiriquí, Panama, by forcing a 20-foot aluminum tube into the reef. This core retrieved about 6,000 years of reef history. Photo credit: ***Lauren Toth****, USGS.*

Pacific Panama is a really interesting place to do coral reef research because these reefs, in some cases within 50 kilometers of one another, experience very different conditions. What we're interested in with this upcoming El Niño is how some of these very localized differences, whether

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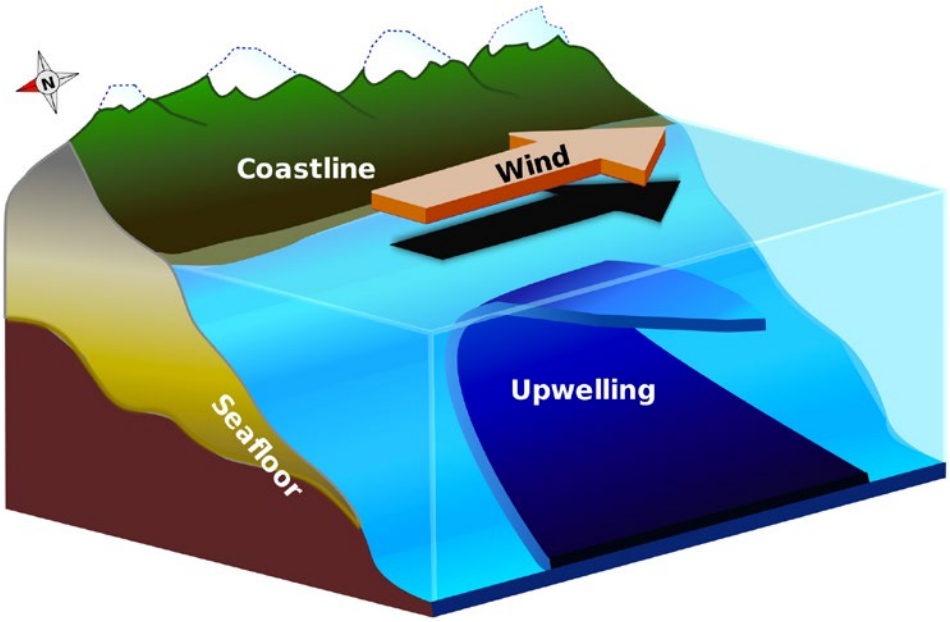

Upwelling happens when sustained winds blow along a coastline, causing cooler, nutrient-rich seawater to rise to the surface. Image credit: Public domain, Wikipedia.

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there is upwelling or not, whether a particular reef is a little more sheltered than another, might impact how the reefs respond.

The overall goal is to use El Niño as kind of a proxy for what's going to happen everywhere as the climate continues to warm. There are studies that have shown that, as a result of those previous El Niños, there are certain corals that may now be genetically predisposed to tolerate warm temperatures. This will be another test to see whether we're selecting for corals that'll handle warmer temperatures.

In California, everyone hopes this year's El Niño brings lots of rain. Is it the same in Panama? How will that affect the reefs?

In Panama, it's actually drier during El Niño events. You also don't have a lot of clouds. This actually might make things a little worse for the corals, because there is no cloud cover to keep the light off the reefs. During the first El Niño that was documented in Panama, that '82–'83 event, the El Niño completely shut down the upwelling, so things got really, really hot, and corals died everywhere.

The intense sunshine warms up the reefs?

Under normal conditions, you want to have a lot of light for corals to grow. But when the water is also really warm, too much light can be a bad thing. You get a bleaching response in corals under high temperature stress: they expel the algae symbionts that live in their tissues. Corals rely on the symbionts for most of the food that they produce.

A coral getting bleached by extreme water temperatures isn't a big deal if those temperatures don't last very long, but if they last through a whole season, that could be a death sentence.

Over thousands of years, they bounce back?

I think that was the really hopeful message that came out of my doctoral research. In the last 2,000 years or so, the reefs in Pacific Panama have actually been doing pretty well. It's just whether enough of the corals are going to be able to survive the current conditions to be able to repopulate these areas.

What are the broader implications of your research?

I think this research can be applied pretty broadly to our understanding of how reefs will respond to climatic changes in the future. If we can find pockets where these reefs in Panama are more resistant, we might be able to learn something about how to protect reefs elsewhere.

Is this a multi-year research project?

The plan is to have all of the monitoring going over a three-year period. This is just the very beginning of that experiment.

What are you measuring?

We're setting up permanent monitoring quadrats on six reefs, half of which are in the upwelling zone, half of which are outside of it. We're choosing random sites on the reef. Each quadrat will be one meter by one meter. We'll hammer in pieces of rebar at four corners, so we'll know how to come back to the exact same spots. We'll photograph those quadrats every six months to look at how coral color changes, how coral mortality changes, and possibly recruitment of new corals.

We're also installing calcification monitoring stations. Our group has blocks that are set out on the reef and a coral that sits on the top of the cinder block. Every six

A cinder block calcification monitoring station offshore Florida, with a live coral on top. Photo credit: USGS.

months, it gets weighed so that we know how much it's calcifying [growing]. We'll get an idea of how calcification varies seasonally and how it might vary in response to [El Niño and La Niña events].

Then we're setting up bioerosion monitoring experiments. We have coral discs [sliced from cores] that have been preweighed and CAT scanned so we know the exact density and skeletal structure of those discs. We're putting those out on the reefs for a couple of years. [Then we'll]

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Brain coral spawning coral larvae. The larvae will settle on other surfaces and grow into new coral in a process called recruitment. Photo credit: NOAA.

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pick them up and run them through the CAT scan again.

What is bioerosion?

Bioerosion is just the breakdown of coral, usually dead coral, by all kinds of different organisms that like to eat down the rock. In Panama, it's things like sea urchins, bivalves, and sponges.

Describe the oceanographic sensors.

Those will be on the same part of the reef that all of our ecological experiments will be on. They look like a metal cylinder that has a whole bunch of sensors on it that measure water temperature, salinity, light, and chlorophyll A, which gives you an idea of the nutrients in the water.

Have you had any scary moments out there?

I did almost hit a humpback whale with a boat once. That was terrifying! We were in a very small dinghy, it was humpback whale migration season, and they just pop up out of nowhere. [On the other hand], it's very cool to be diving and the whole reef is just reverberating with the whale calls.

Your work in Panama is an offshoot of your main project in Florida?

Yes. The main part of my Mendenhall project is to look at trends in reef development over the last 10,000 years or so in Florida.

How is that going?

Great! We collected a whole bunch of new cores last summer and we now have really good coverage of the whole Florida Keys. Reefs throughout the Keys stopped growing about 3,500 years ago. There were still nice looking reefs after that, with high coral cover, but reef accretion really stopped around that time. It had to do with a combination of overall environmental shifts caused by changing sea level.

Why are coral reefs so important?

Corals and coral reefs are primarily important because of the structure that they build. That structure provides habitat to countless marine organisms, the fish that are so important for all the fisheries. In Florida, we're concerned a lot about the impacts that hurricanes have. If we're losing our reefs, we can see an impact on the force of waves that we see during storms.

*USGS scientist **Lauren Toth** operates an underwater coral core drill offshore Florida. Photo credit: USGS.*

Humpback whale breaching. Photo credit: NOAA.

Will coral reefs be able to keep up with sea level rise?

The way in the past that coral reefs have kept up, especially during times of really fast sea level rise, is the corals just recruit to a shallower area. When they reproduce, those juvenile coral settle in a shallower spot, and then reefs start growing there. Corals will be able to keep pace with sea level rise as long as there are not other conditions that are keeping them from living in that area.

For more information:

- USGS Coral Reef Ecosystem Studies: **http://coastal.er.usgs.gov/crest/**
- ENSO Drove 2500-Year Collapse of Eastern Pacific Coral Reefs, Toth, et al, *Science*: **http://dx.doi.org/10.1126/science.1221168**
- USGS El Niño Information: **http://elnino.usgs.gov** ❁

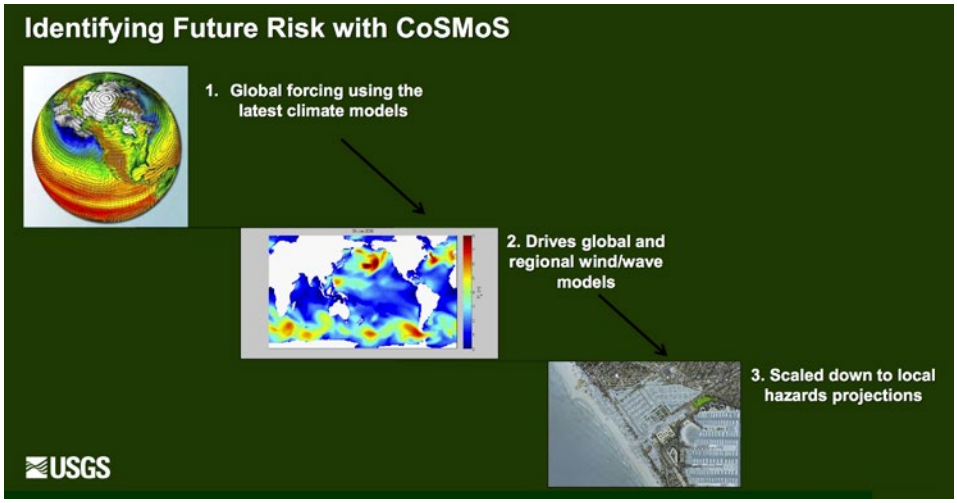
Preparing for El Niño Using Climate Change Forecasts

By Rex Sanders

Most years, USGS research geologist **Patrick Barnard** and his colleagues quietly develop detailed coastal hazard forecasts that include the effects of climate change. This year, coastal managers in southern California are clamoring for early results. Some of those forecasts are a good stand-in for El Niño-enhanced storms.

El Niño is the common name for unusually warm eastern Pacific Ocean surface temperatures along the equator. These changes in ocean heat affect weather around the world. Sea surface temperatures measured during the 2015–2016 El Niño have set new records. Intense El Niño winters typically bring much stronger storms to beaches and cliffs along the west coast of the United States, particularly in California.

"When we have these extreme El Niño events," said Barnard, "we get an increase in wave energy of about 30 percent that results in about a doubling of the typical winter beach erosion in California." People who maintain coastal infrastructure want to know what this means for sewage treatment plants, highways, and harbors.



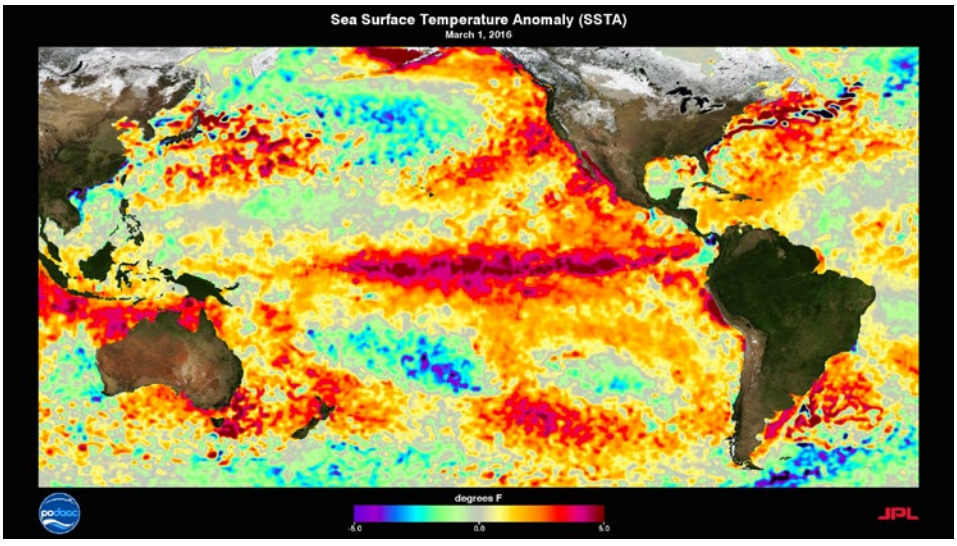
Graphic demonstrating how CoSMoS uses global climate models to forecast local coastal hazards. Image credit: USGS.

Detailed forecasts for a changing world

The USGS Coastal Storm Modeling System (CoSMoS; **http://walrus.wr.usgs.gov/coastal_processes/cosmos/index.html**) makes detailed long-range forecasts of coastal erosion and flooding caused by climate change, sea level rise, and storms. Unlike most coastal hazard forecasts, CoSMoS is dynamic. "The idea is that as the climate is changing, the wave climate will change," said Barnard. "We can't understand that just by looking at the last 20 years of data from a wave buoy." CoSMoS shrinks global climate forecasts to a local level, and uses the physics of tides, waves, and river flooding to make detailed projections of coastal flooding. "You look at the broad scale, be it changes in [air] pressure or any changes in sea level," said USGS oceanographer **Andy O'Neill**. "Then you funnel down to find the regional impacts and then the local scale impacts." CoSMoS flood forecasts go down to 2-meter (6.6 foot) sections of the coast.

Project leader Barnard and a team of USGS scientists developed the first version of CoSMoS for southern California starting in 2011, then improved and applied CoSMoS to the north-central California coast and San Francisco Bay in following years. Now Barnard, O'Neill, and their colleagues are back in southern California, working on CoSMoS 3.0. For this version, they are collaborating with top coastal and climate scientists from the Scripps Institution of Oceanography, Oregon State University, and private companies. The team is adding long-term changes to beaches and cliffs, local seas and storm surge from global climate models, and flooding from rivers. They are distributing initial results quickly, to meet the needs of coastal managers who must respond to El Niño storms.

"There's 40 different scenarios of sea level rise and storms for the whole region," said Barnard. "It's about 500



Sea surface temperature differences on March 1, 2016. Dark red indicates much warmer water. Image credit: NASA Jet Propulsion Laboratory.

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kilometers (300 miles) of shoreline. State agencies, local agencies, and others need this kind information to understand the potential impacts long term, so they can manage their resources appropriately." USGS scientists developed CoSMoS scenarios and forecast products in collaboration with federal, state, and local governments. They included sea level rise scenarios in several steps from 0 to 2 meters (6.6 feet), plus 5 meters (16.4 feet), rather than using specific years such as 2050.

"We've tried to take the timestamp off of it, because sea level rise projections are very uncertain and the science changes," said Barnard. "We try to keep it as flexible as we could so the flooding projections wouldn't become obsolete."

Adding scenarios with zero sea level rise was the key to using CoSMoS forecasts during an El Niño winter. "We purposely developed a number of scenarios that do not include sea level rise at all—just storms," said Barnard. "Those scenarios are a pretty good proxy for El Niño-type storm impacts." The California Office of Emergency Services uses those scenarios now.

Current CoSMoS coastal hazard forecasts cover southern California, from Santa Barbara County in the north to San Diego County in the south. Image credit: ***http://coastalmap.er.usgs.gov****.*

In high demand

"There were close to 100 people," said O'Neill, describing her presentation on "El Niño: What to Expect for southern California." She gave her talk in the fall of 2015 as part of a University of southern California webinar series. "It seemed to be a whole range of people from contractors who will be using our results, to somebody from the Aquarium," she said. "There were people with water districts, city planning and resource councils, and regular public users." O'Neill also gave the presentation to civic groups who wanted to know more about the possible harmful effects of El Niño.

Oceanographer ***Andy O'Neill*** *spent 11 years providing oceanographic and meteorological analyses for the U.S. Navy in Japan before joining the USGS in 2012. Now she fine-tunes CoSMoS coastal hazard forecasts. Photo credit: USGS.*

Research geologist ***Patrick Barnard*** *presents initial results from CoSMoS 3.0 forecasts for southern California. He joined the USGS in 2003 and leads several high-profile coastal research projects. Photo credit:* ***Holly Rindge****, USC Sea Grant.*

At the request of the California Ocean Protection Council, the Governor's Office of Emergency Services, and other agencies, Barnard presented overviews of the CoSMoS forecasting process and initial forecasts along four sections of the California coast: Los Angeles County, Orange County, San Diego County, and Santa Barbara and Ventura counties combined. After each of his presentations, many of the questions focused on cliff erosion and flooding.

Most important forecasts

Two CoSMoS forecasts are most useful during an El Niño winter. The worst El Niño storm could look a lot like a 100-year storm with no sea level rise—one of the 40 CoSMoS scenarios. In southern California, coastal flooding from a storm like that could be a problem in a number of locations. Unfortunately, one of those locations is the Port of Los Angeles. "The economy basically flows through that port," said Barnard, "We're

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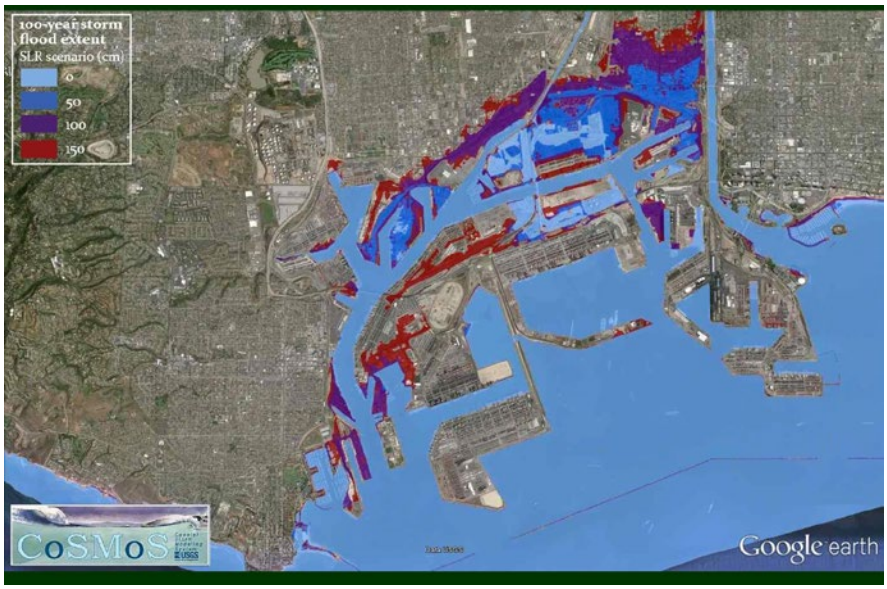

The light blue areas on this map of the Port of Los Angeles could flood during a 100-year storm with no sea level rise, according to CoSMoS forecasts. The port handled about $270 billion of cargo in 2015. Image credit: USGS.

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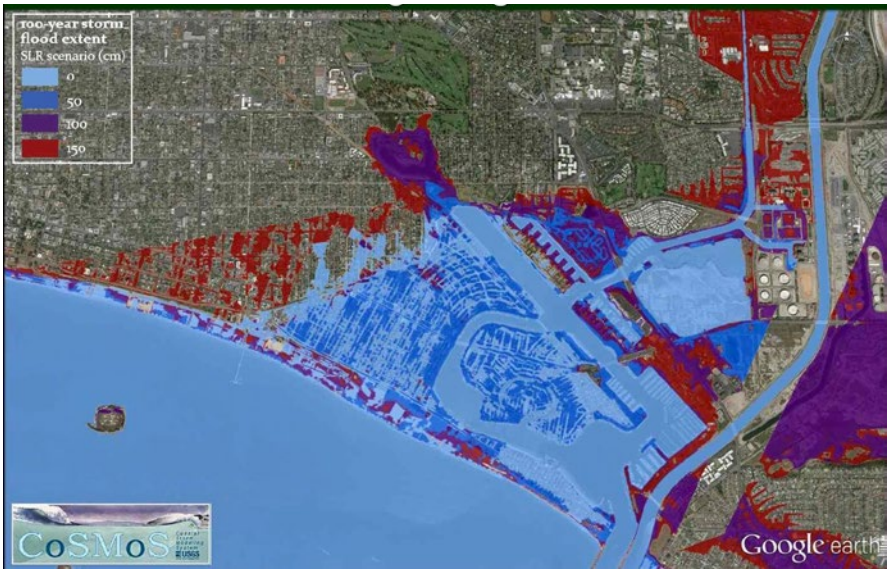
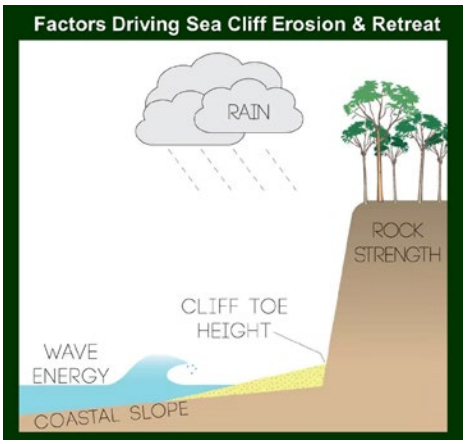


According to CoSMoS forecasts, large parts of Long Beach, California, could flood during an intense El Niño storm (light blue areas). Image credit: USGS.



Several factors affect sea cliff erosion including rain, rock strength, cliff toe height, wave energy, and coastal slope. Image credit: USGS.

trying to give people an understanding of the potential risk through flooding and coastal change."

Other high-value areas in southern California that could be flooded during one of these storms include parts of Goleta, Long Beach, Newport Beach, and San Diego.

The other critical CoSMoS forecast for southern California is cliff erosion. "There's tons of communities that are built right on the cliff edge," said Barnard. "That's going to be a much bigger factor for them, as opposed to coastal flooding." Several of those cliffs are at high risk of collapse during and after intense storms.

The colored bands on this map of La Jolla, California, illustrate how far cliffs could erode in different sea level rise scenarios, according to CoSMoS forecasts. Image credit: USGS.

Many different factors affect cliff erosion. "Surprisingly, there haven't been a lot of cliff models that utilize all the different factors," said Barnard. "It's kind of hard to include them all." USGS geologist **Patrick Limber** is working on cliff erosion forecasts that include waves, rain, and sea level rise, three of the most important factors.

Improving and expanding coastal hazard forecasts

The initial CoSMoS data for southern California is ready to use in Google Earth or ArcGIS mapping software. This summer, USGS and partners plan to add the finished forecasts to Our Coast, Our Future (**http://data.prbo.org/apps/ocof/**). The web site helps anyone zoom into detailed forecasts of coastal flooding, cliff erosion, and related information, without a crash course in computer mapping.

Further developments of CoSMoS are underway. According to Barnard, the next major version should include the harmful effects of coastal flooding and seawater contamination on groundwater. The team also plans to look at the potential impact of hurricanes. Even though only two hurricanes have hit southern California in the past century, the number and strength of these storms could change as the climate changes. USGS geographer **Nathan Wood** plans to add forecasts of coastal hazard effects on the local economy and population. In addition, the team wants to provide CoSMoS forecasts for other areas.

After completing work in southern California this year, Barnard and his colleagues plan to work on central California in 2017, then in 2018 study the California coast north of Bodega Bay. "We're currently developing plans in Puget Sound," said Barnard. "Then there are also preliminary talks about moving it to Hawai'i and the north slope of Alaska." CoSMoS forecasts for these areas could help coastal resource managers prepare for long-term climate change—and the next El Niño winter. ❁

What a Drag: The Global Impact of Bottom Trawling

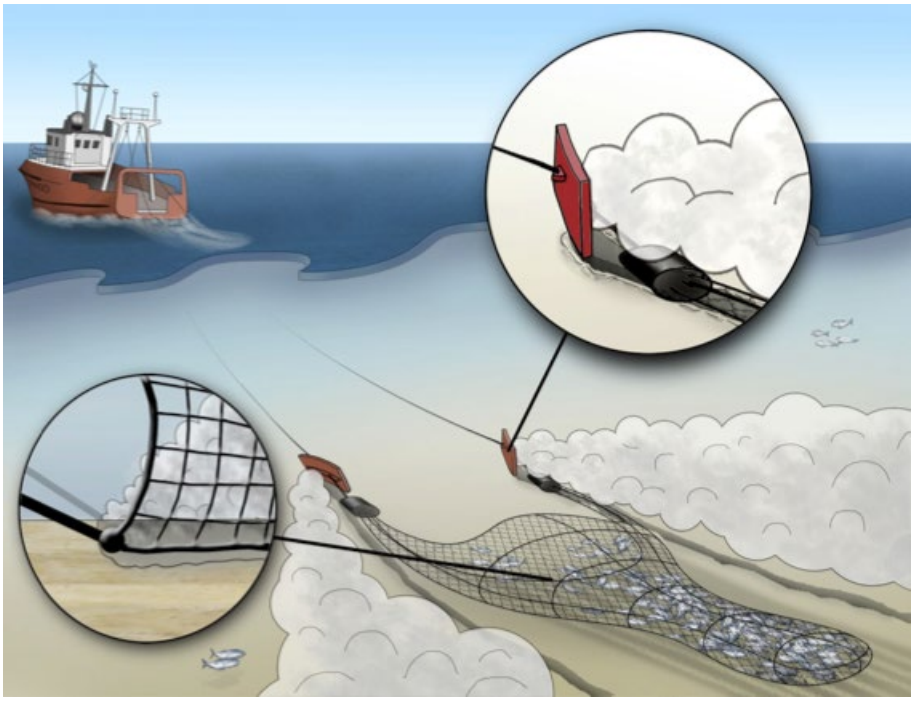
By Ferdinand Oberle, Leslie Gordon, and Curt Storlazzi

Recent research outlines the severe consequences that bottom trawling has on loose sediment on the ocean floor. Bottom trawling is a widespread industrial fishing practice that involves dragging heavy nets, large metal doors, and chains over the seafloor to catch fish. Although previous studies have documented the direct impacts of bottom trawling on corals, sponges, fishes, and other animals, an understanding of the global impact of this practice on the seabed remained unclear until now. The first calculation of how much of the seabed is resuspended (or stirred up) by bottom-trawling shows that the sediment mass is approximately the same as the amount of all sediment being deposited on the world's continental shelves by rivers each year (almost 22 gigatons).

Oceanographic research vessel (R/V) Meteor. *Photo credit:* ***Ferdinand Oberle****.*

Understanding regional and global magnitudes of resuspended sediment is essential for analyzing the environmental consequences of trawling for continental shelf habitats and their associated seafloor and open-ocean ecosystems. The scientists compared natural causes of resuspension (waves and currents) with bottom trawling-induced resuspension and found new ways to look at and into the seabed to document the effects of bottom trawling.

Bottom trawling can produce vastly different effects on different types of seabed sediment (such as sand, silt, or mud), each with different ecological consequences. Trawling destroys the natural seafloor habitat by essentially rototilling the seabed. All of the bottom-dwelling plants and animals are affected, if not outright destroyed, by tearing up root systems or animal burrows. Resuspending bottom sediment changes the entire chemistry of the water, including nutrient levels. Resuspended sediment can lower light levels in the water and reduce photosynthesis in ocean-dwelling plants, the foundation of the food web. The resuspended sediment is carried away by currents and often lost from the local ecosystem. It may be deposited elsewhere along the continental shelf, or in many cases, permanently lost from the shelf to deeper waters. Changing parts of the seafloor from soft mud to bare rock can eliminate those creatures that live in the sediment. Species diversity and habitat complexity are directly affected when trawling changes the physical environment of sand, mud, or rock.



Conceptual drawing of bottom trawling from a fishing boat, showing a net and metal plate being dragged along the seafloor behind a boat on the surface. Image credit: ***Ferdinand Oberle****, 2014.*

"This study raises serious concerns about the future stability of continental shelves—the very source of the vast majority of the fish we consume," said

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One of the many passing bottom trawlers on the northwest Iberian shelf as seen from the R/V Meteor. *Photo credit:* ***Ferdinand Oberle****.*

Scientific equipment mounted on a tripod being deployed from the R/V Meteor. *Photo credit:* ***Ferdinand Oberle****.*

geological oceanographer and lead author **Ferdinand Oberle**, now a visiting scientist at the USGS and previously with the Woods Hole Oceanographic Institution. He was at MARUM, the Center for Marine Environmental Sciences, University of Bremen (Germany), when the study was done. "A farmer would never plow his land again and again during a rainstorm, watching all his topsoil be washed away, but that is exactly what we are doing on continental shelves on a global scale."

As part of the study, scientists developed a new, universal approach to calculate bottom-trawling-induced sediment resuspension that gives marine management a new and important tool to assess the impact from bottom trawling. Previous studies characterized the seabed as either "trawled" or "untrawled," but with these novel methodologies it was possible to show systematically a range of bottom-trawling-induced changes to the seabed and classify them in accordance with how often the seabed was disturbed by bottom trawlers.

"The global calculations were a big surprise, and we calculated them at least 10 times to make sure we were not making a mistake. I am still in awe of these results and their environmental implications," said USGS oceanographer **Curt Storlazzi**, a coauthor of the paper who helped develop the computational models for the study.

These new understandings about the effects of bottom trawling come out of scientific cruises on the research vessel (R/V) *Meteor* from Germany to the offshore area northwest of the Iberian Peninsula with a team of international scientists. During the cruises, scientists conducted sidescan-sonar surveys and collected bottom current data. Laser sediment-particle samplers and a remotely operated submersible vessel were used as well. After the cruises, scientists conducted laboratory work involving lead-isotope dating and sediment grain-size analysis and developed a sediment-mobilization model, all of which contributed to the conclusions of the study.

Two new research papers from this study were published in Elsevier's *Journal of Marine Systems* and are available online. The full citations are:

- Oberle, F.K.J., Storlazzi, C.D., and Hanebuth, T.J.J., What a drag—Quantifying the global impact of chronic bottom trawling on continental shelf sediment: Journal of Marine Systems, published online 30 December 2015, **http://dx.doi.org/10.1016/j.jmarsys.2015.12.007**.

- Oberle, F.K.J., Swarzenski, P.W., Reddy, C.M., Nelson, R.K., Baasch, B., and Hanebuth, T.J.J., Deciphering the lithological consequences of bottom trawling to sedimentary habitats on the shelf: Journal of Marine Systems, published online 31 December 2015, **http://dx.doi.org/10.1016/j.jmarsys.2015.12.008**. ❁

USGS Data from 1981–1982 Still Serving the Nation

By Fran Lightsom

For coastal residents, the constant movement of sand along the shore is fascinating, until it becomes frightening. After watching winter storm waves spend their energy carrying away a coastal dune, we find the dune is gone, the beach is long gone, and the waves are undercutting homes and roads. When summer comes, the waves bring sand back to rebuild the beaches and dunes, but sometimes not completely. Often coastal communities choose to bring in extra sand to protect properties along the shore—and not just any sand will do for these "beach nourishment" projects.

In 2014, the Bureau of Ocean Energy Management funded **Larry Ward** of the Center for Coastal and Ocean Mapping at the University of New Hampshire to locate offshore sand and gravel resources in the western Gulf of Maine for beach nourishment and other purposes. The goal of the project is to characterize the seafloor off of New Hampshire and map the distribution and thickness of sand and gravel deposits by using existing data; no funds are available to collect new data. Because not enough seafloor samples and cores have been collected to identify the sediment deposits directly, Ward's group is primarily using data collected with seismic profiling systems (see <**http://woodshole.er.usgs.gov/operations/sfmapping/seismic.htm**>). The seismic data are then verified by the available samples and cores, a process called "ground-truthing." This requires access to original seismic records and physical samples from research cruises in the Gulf of Maine, which led the Center for Coastal and Ocean Mapping group to the USGS Woods Hole Coastal and Marine Science Center.

Thirty-five years after the data were originally collected as part of a study of glacial geology of the western Gulf of Maine, USGS seismic and sampling data are being used to assist coastal communities in locating offshore sand resources for mitigating coastal erosion. Photo credit: ***Linda McCarthy****, USGS.*

In August 2015, USGS data librarian **Linda McCarthy** received an email from **Zach McAvoy** (Center for Coastal and Ocean Mapping) requesting access to seismic records and samples from research cruises conducted on the USGS research vessel R/V *Neecho* in 1981 and 1982. McCarthy identified the original cruise records that are still available through the Science Center's data library, along with physical samples (vibracores) collected during other cruises that are available at the Center's Samples Repository (<**http://woodshole.er.usgs.gov/operations/ia/samprepo/**>). USGS data specialist **VeeAnn Cross** arranged for Ward to bring a group of University of New Hampshire students and technicians to visit Woods Hole in November 2015 and January 2016. At the data library, McCarthy and Cross assisted the University of New Hampshire team in evaluating and digitizing seismic profiling data from the cruises while Cross created metadata records to accompany the new digital datasets. At the samples repository, **Brian Buczkowski** located the physical cores from the cruises and assisted the visitors in photographing and sampling. In addition to collecting the data, the visitors also enjoyed an opportunity to talk science with USGS geologists **Laura Brothers** and **Elizabeth Pendleton**. As Ward said later, "Access to the seismic records and vibracores was important for our work. The USGS staff in Woods Hole were extremely helpful in obtaining the records, scanning, and sampling. We appreciate their efforts and the extra time they put in for us." ❁

Shorebird Science? iPlover is the App for That

By Rob Thieler and Hannah Hamilton

The latest tool designed to help manage the threatened piping plover is only a download away; iPlover is the first smartphone data collection application developed by the USGS and will help those managing plover populations.

iPlover supports a long-established network of partners working to address ongoing impacts on plover populations, such as habitat gain or loss due to storms and sea level rise.

More importantly, data from the app is used to develop models that address long-term management concerns for habitat availability. It also improves the overall quality of coastal geologic information available to effectively manage this species.

The piping plover is a small shorebird that depends on open coastal beaches to breed and raise its young. Listed as threatened along the Atlantic coast in 1986, the piping plover's conservation has been mandated by the Endangered Species Act. Although Atlantic Coast piping plover numbers have more than doubled since their listing nearly 30 years ago, they are still at risk. Recent estimates place the population at fewer than 2000 pairs, and climate change has introduced new threats to their coastal habitat.

Coastal beaches are dynamic systems and managing them for beach-dependent species like the piping plover requires collecting data on physical and biological characteristics that will be affected by sea level rise. Given the extensive Atlantic breeding range of the piping plover—spanning from North Carolina to Newfoundland—biologists have a lot of ground to cover.

The iPlover app supports the need for coordinated, synchronized data collection. It is a powerful new tool to help scientists and coastal resource managers consistently measure and assess the birds' response to changes to their habitat. Rather than compiling data from multiple sources and formats, the app gives trained resource managers an easy-to-use platform with which they can collect and instantly share data across a diverse community of field technicians, scientists, and managers. iPlover improves scientists' data gathering and analysis capabilities by simplifying and facilitating consistent data collection and input into models of shoreline change and beach geomorphology.

An adult piping plover. The piping plover is a small migratory shorebird listed as endangered in Canada and the U.S. Great Lakes, and threatened throughout the remainder of its U.S. breeding and winter range. Recent surveys indicate that there are only about 8,000 adults in existence. Photo credit: ***Susan Haig****, USGS.*

"The data come in from all of our study sites basically in real-time," said **Rob Thieler**, USGS scientist and lead developer of the app. "It's already formatted, so data can be quickly plugged into our research models. This should really shorten the time between collecting the data, doing the science, and turning it into actionable information for management."

"The USGS worked with diverse project partners to incorporate specific data collection needs and enable important stakeholders and partners to contribute data from hundreds of field observations within the plover's U.S. Atlantic coastal breeding range," said **Andrew Milliken**, coordinator of the North Atlantic Landscape Conservation Cooperative. "This included getting inputs from the U.S. Fish and Wildlife Service, National Park Service, state agencies and non-governmental organizations."

"The app highlights the synergies and benefits of interagency and interdisciplinary science that advances conservation," Milliken added. "The information collected will not only greatly improve our understanding of impacts from sea level rise, storms and beach management on piping plovers but also how managing for plovers can benefit other beach-dependent species, such as the American oystercatcher."

Funding for iPlover was provided through the Department of Interior North Atlantic Landscape Conservation Cooperative as part of its Hurricane Sandy response. The app was developed by the USGS Woods Hole Coastal and Marine Science Center and the Center for Integrated Data Analytics.

"iPlover is a great example of the USGS' ability to build and deliver a variety of science applications that use modern technology," said **Nate Booth**, USGS Chief of Office of Water Information and former Lead Architect for the USGS Center for Integrated Data Analytics. "It offers research teams great gains in data collection efficiency so that more time can be spent on analyzing the data rather than managing it." ❁

Examining the Chemistry of Seawater and Coral to Promote the Health of West Maui's Coral Reefs

By Nancy Prouty and Helen Gibbons

Coral reefs are among the most diverse and biologically complex ecosystems on Earth. They provide nursery grounds for fish and shellfish; they protect harbors, beaches, and coastal communities from storm-wave damage and erosion; and they serve millions of people as areas of natural beauty and recreation. These important ecosystems are facing multiple threats worldwide, including climate change, disease, destructive fishing practices, coral collecting, and pollution and sediment from adjacent lands.

During fieldwork in March 2016, USGS scientists focused on understanding the link between land-based pollutants and coral reef health along the coast of west Maui in the Hawaiian Islands. Many reefs in this area are being overgrown by invasive seaweeds, a concern since the late 1980s. The algal growth has been linked to pollutants from the land, including elevated levels of nutrients—such as nitrogen and phosphorus—in water from wastewater injection wells. This nutrient-rich water enters the groundwater system and then discharges into the ocean near the reefs. In 2014, the federal district court in Honolulu ruled that Maui County's use of injection wells at the Lahaina Wastewater Reclamation Facility violates the federal Clean Water Act and imposed civil penalties for the county's violations.

Sampling seawater every 4 hours for a period of 72 hours required the team to work during the early hours of the day. Left to right: ***Chris Gallagher*** *(Pacific Coastal and Marine Science Center),* ***Kim Yates*** *(St. Petersburg Coastal and Marine Science Center [SPCMSC]), and* ***Nate Smiley*** *(SPCMSC). Photo credit:* ***Nancy Prouty****, USGS.*

Aerial view (taken by a drone) of the USGS team sampling seawater for carbonate chemistry along the reef of Kā'anapali, west Maui. Clockwise from left: ***Nate Smiley*** *(St. Petersburg Coastal and Marine Science Center [SPCMSC]),* ***Chris Gallagher*** *(Pacific Coastal and Marine Science Center [PCMSC]),* ***Nancy Prouty*** *(PCMSC), and* ***Kim Yates*** *(SPCMSC). Photo courtesy of a passerby.*

Problems with nutrients and contaminants are not unique to the reefs of west Maui. Around the world, heightened nutrient loads have been attributed to recent land-use changes—such as residential subdivisions, golf courses, agriculture, suburban and commercial developments that rely on septic systems—as well as the establishment of wastewater treatment facilities that discharge water with elevated nutrient levels.

Corals are already being threatened by the effects of climate change, including warmer water and ocean acidification.

(Examining Chemistry continued on page 13)

(Examining Chemistry continued from page 12)

USGS researchers pose with some of the 30 community members who gathered at Kahekili Beach Park on Friday, March 25, for a "talk story" with the team—an informal chat about their fieldwork and findings. Can you spot the researchers? (Hint: look for the matching t-shirts.) Photo credit: ***Liz Foote****, Project S.E.A.-Link (****http://www.projectsealink.org****).*

Excessively warm water causes coral bleaching: the loss of single-celled organisms that live in the tissues of many corals, giving them color and providing them with vital energy. Ocean acidification —the lowering of seawater pH that results from increasing amounts of carbon dioxide (CO_2) entering the atmosphere and dissolving into the ocean—makes it difficult for marine organisms such as shellfish and corals to build their calcium carbonate shells and skeletons.

Land-based sources of pollution that increase nutrients and change pH levels in coastal waters can magnify the global stressors to corals. One result is accelerated bioerosion—the breakdown of coral by other organisms. Bioerosion is a natural process that removes old dead coral and makes room for new coral, but if it proceeds more quickly than calcification (the process by which new coral is built), the reef will decline. With global warming and ocean acidification projected to compromise calcification, managing the compounding effects from local stressors is a top priority in coral reef management.

For two weeks in March 2016, research oceanographers **Nancy Prouty** of the USGS Pacific Coastal and Marine Science Center in Santa Cruz, California, and **Kim Yates** of the USGS St. Petersburg Coastal and Marine Science Center in St. Petersburg, Florida, joined forces in an intensive field sampling program along the reefs offshore of Kāʻanapali, west Maui. Their goal was to quantify the key variables controlling the delicate balance between reef erosion and calcification. Together with geologist **Nathan Smiley** from the St. Petersburg center and lab assistant **Chris Gallagher** from the Santa Cruz center, they sampled seawater for a suite of chemical parameters (pH, alkalinity, nutrients, and isotopes) every four hours for six days in order to quantify how the carbonate chemistry along the reef varied over time and from place to place. This effort builds on previous studies of seawater flow and sediment movement in the area (for example, see **http://pubs.usgs.gov/of/2008/1215/**) and underwater discharge of groundwater into the ocean near the reef (**http://dx.doi.org/10.1016/j.ejrh.2015.12.056**).

By applying a rigorous, high-resolution sampling protocol that Yates and Smiley have successfully used at reef sites in the Atlantic, Pacific, Gulf of Mexico, and Caribbean (for example, see **http://dx.doi.org/10.5194/bg-11-4321-2014**), the team is producing an unprecedented data set to quantify the exposure of reefs to high nutrient/low pH waters. Preliminary results from Yate's real-time pH measurements suggest that the pH of freshwater discharging from underwater vents in the study area can range from 7.3 to 8.0. (Average seawater has a pH of 8.2.)

Yates' measurements will complement research by Prouty and her team, who are analyzing coral cores collected along the reef to quantify bioerosion rates and inputs of nutrients over the past several decades. CT scans (a series of X-ray images) of the coral cores reveal skeletal density and the history of bioerosion. Chemical analyses reveal the amount of nutrients and other seawater constituents that have been incorporated into the coral over time. The team's results, to be presented at the 13th International Coral Reef Symposium in June 2016, suggest that nutrient input from human activity is driving a disproportionate escalation of bioerosion rates under ocean acidification conditions. Reducing such stressors as nutrients and pollutants from nearby land is imperative for future coral reef resiliency.

In addition to doing their fieldwork, the team met with local residents at Kahekili Beach Park for a "talk story," or informal chat, about their work and preliminary findings. (Read an article in the *Lahaina News* announcing the gathering and the fieldwork: **http://www.lahainanews.com/page/content.detail/id/532496/USGS-studying--impacts-of--groundwater-quality-upon-coral-reef-health.html**.) The group included members of the West Maui Kumuwai, a movement to protect the area's ocean and way of life (**http://westmauikumuwai.org**), and members of the State of Hawaiʻi Makai Watch Program, a collaborative, statewide program in which citizens and nongovernmental organizations assist Hawaiʻi's Department of Land and Natural Resources in the management of marine resources through promoting compliance to rules, education, and monitoring (**http://dlnr.hawaii.gov/makaiwatch/**).

The scientists expect that their results will help resource managers make informed decisions to improve the health of coral reef ecosystems and associated watersheds. ❁

Future Fieldwork, June–July 2016

Rex Sanders, May 25, 2016

Summer is usually a busy time of year for USGS fieldwork, and 2016 is no exception. Just in June and July, scientists plan to visit more than 16 locations, studying tsunamis, coral reefs, eelgrass beds, and much more. Read on for a preview of some coastal and offshore fieldwork planned by USGS researchers in June and July 2016. Plans could change at any time.

- **Cape Cod, Massachusetts:** Examine the environmental geochemistry and health of 11 estuaries, April 11–November 30, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-016-FA**
- **Southeastern Alaska:** Assess earthquake and tsunami hazards along the Queen Charlotte-Fairweather fault system, May 17–June 12, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-625-FA**
- **Barter Island, Alaska:** Measure permafrost temperature, collect time lapse images of coastal change, and measure subsurface geology, May 20–September 30, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-645-FA**
- **Icy Bay, Alaska:** Map tsunami deposits created by a landslide-generated tsunami, May 26–July 1, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-648-FA**
- **Monterey Bay, California:** Study changes in ripple scour depressions offshore Santa Cruz during an El Niño season, May 31–June 3, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-647-FA**
- **Aitutaki, Cook Islands:** Document sea level history on motus (atoll islets), June 1–June 30, 2016. Details at: **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-635-FA**
- **Puget Sound, Washington:** Annual vegetation surveys for eelgrass, and other plant measurements, June 3–6, 2016. Details at: **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-633-FA**
- **Sacramento-San Joaquin Delta, California:** Time series measurements of suspended sediment concentration, tidal stage, and wave attributes for habitat restoration, June 7–August 19, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-646-FA**

Approximate locations of some planned USGS coastal and offshore fieldwork in June and July 2016. Image from ***http://coastalmap.marine.usgs.gov/****.*

- **Gulf of Maine:** High-resolution multichannel seismic survey of the continental slope, to characterize and tie together shelf, slope, and rise stratigraphy, June 9–13, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-018-FA**
- **Chandeleur Islands, Louisiana:** Measure bathymetric change and borrow site deposition, and provide elevation control for a lidar survey, June 10–19, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-335-FA**
- **Fire Island, New York:** Ongoing beach recovery assessment, post-Hurricane Sandy, June 14–17, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-336-FA**
- **Offshore Delaware and Virginia:** Measure the acoustic characteristics of high-resolution geophysical sources, June 26–July 17, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-002-FA**
- **Shetland Islands, U.K.:** Examine and sample tsunami deposits from the Storegga landslide to validate future tsunami modeling efforts, June 24–July 3, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-642-FA**
- **Key Largo, Florida:** Conduct reef imaging and personal watercraft surveys to ground truth lidar data, June 22–July 1, 2016. Details at: **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-333-FA**
- **Kaua‘i, Hawai'i:** Collect oceanographic, geologic, hydrologic, and biologic data to evaluate links between circulation, submarine groundwater discharge, and coral disease, June 29–August 5, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-631-FA**
- **Kaua‘i, Hawai'i:** Collect sediment samples from seven watersheds, July 29–August 3, 2016. Details at **http://cmgds.marine.usgs.gov/fan_info.php?fan=2016-630-FA**. ❁

Outreach

New Video on USGS Investigation of Coral Disease in Hawai'i

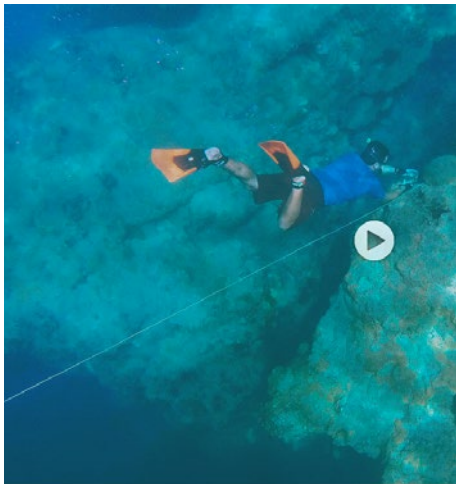
By Helen Gibbons

A new video, "Exploring Causes of Coral Disease," follows USGS researchers as they investigate potential causes of black band disease affecting corals on the Hawaiian island of Kaua'i.

In spring 2015, scientists from the Pacific Coastal and Marine Science Center (Santa Cruz, California) and the St. Petersburg Coastal and Marine Science Center (St. Petersburg, Florida) ran initial surveys to check water temperature, salinity, and whether water running off the land may be affecting coral health. An expanded team will return this summer for more in-depth work. Healthy reefs protect the shore from wave damage, provide shelter for important fish species, and are vital to tourism.

View the 3:46-minute video at **http://coralreefs.wr.usgs.gov/CoralDiseaseVideo.html**.

For more information, visit the USGS Pacific Coral Reefs Web Site (**http://coralreefs.wr.usgs.gov/**) and the Coral Reef Ecosystem Studies (CREST) website (**http://coastal.er.usgs.gov/crest/**). ❁



*View the 3:46-minute video at **http://coralreefs.wr.usgs.gov/CoralDiseaseVideo.html***

Awards

Shoemaker Awards for "From Icefield to Ocean" and the Coastal and Marine Geology Program Web Site

By Ann Tihansky and Jolene Gittens

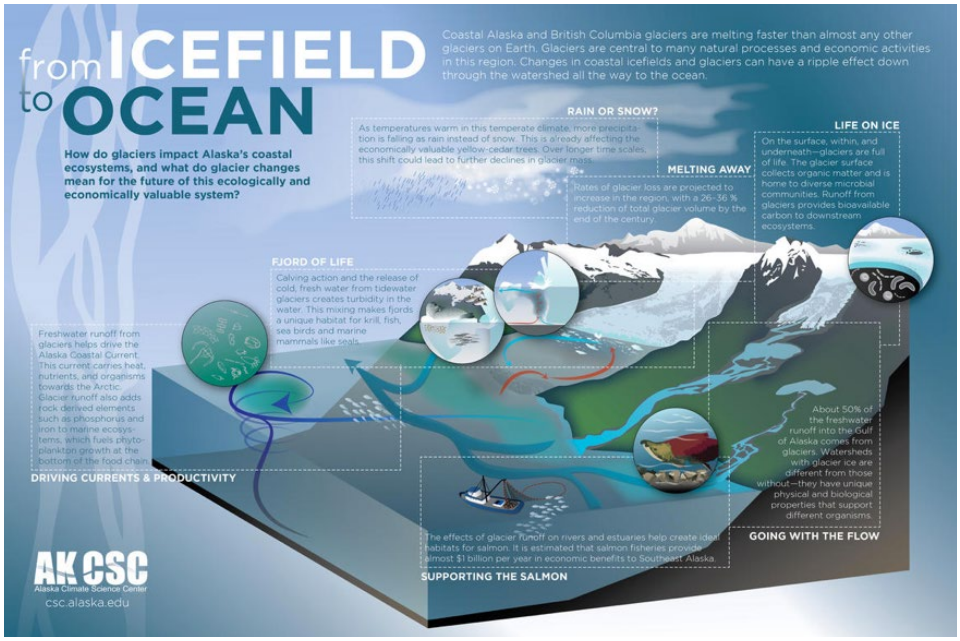
The Eugene M. Shoemaker Award for Communications Excellence recognizes USGS products that demonstrate extraordinary effectiveness in communicating and translating complex scientific concepts and discoveries into words and pictures that capture the interest and imagination of the American public.

Print Product Category

"From Icefield to Ocean" by **Shad O'Neel** (USGS Alaska Science Center), **Kristin Timm** (University of Alaska Fairbanks), and **Eran Hood** (University of Alaska Southeast) won the Shoemaker Award for Communication Excellence in the print product category.

The poster depicts the important linkages between glaciers and ocean and coastal ecosystems. Glaciers cover 16 percent of the northern Pacific coastal temperate rainforest (PCTR). They are experiencing the some of the highest rates of glacier loss

(Shoemaker Awards continued on page 16)



The "From Icefield to Ocean Poster" depicts the important linkages between glaciers and the ocean. The product is a result of Alaska Climate Science Center research projects and workshops. The team felt that it was particularly important to find a compelling way to communicate these research findings to Alaskans, because Alaska's coastal glaciers are among the most rapidly changing areas on the planet, and glacier runoff can influence marine habitats, ocean currents, and economic activities.

(Shoemaker Awards continued from page 15)

on Earth. Melting from these glaciers can produce downstream changes all the way to the ocean, including changes to currents and important resources such as fish species. Many of these changes are poorly understood, and the linkages between glaciers and coastal and ocean ecosystems have not been studied holistically.

The Pacific coastal temperate rainforest runs for 4,000 kilometers from Northern California to Kodiak Island, Alaska, and includes glaciers and old growth forests. Residents of the area depend upon tourism and healthy natural resources such as fisheries for their livelihoods. Evidence shows global-scale warming is increasingly affecting the coastal rainforest with projections of warmer, wetter weather, though with less precipitation falling as snow.

Because of the complex interactions within the coastal rainforest, the authors call for interdisciplinary research that connects ecosystems from the icefields all the way to the oceans. Improving the long-term scientific records through a holistic scientific approach and coordinated research will also help improve decision-making for resource use and tourism.

View the poster online: **https://www.usgs.gov/media/images/icefield-ocean-poster**.

Read "Icefield-to-Ocean Linkages across the Northern Pacific Coastal Temperate Rainforest Ecosystem" article from *BioScience*: **http://bioscience.oxfordjournals.org/content/early/2015/03/12/biosci.biv027.full**.

*Coastal and Marine Geology Program web team members receive their awards at the USGS Awards Ceremony on May 3, 2016. From left to right: USGS Director **Suzette Kimball**, who presented the awards; **Jolene Gittens**; **Greg Miller**; **Kerry Rae**, Chief of Staff for **Jennifer Gimbel**, Deputy Assistant Secretary for Water and Science, U.S. Dept. of Interior, who also helped present the awards; **Andrea Toran**; **Laura Torresan**; and **Ann Tihansky**.*

Internet Product Category

The USGS Coastal and Marine Geology Program (CMGP) website developed by **Jolene Gittens** (USGS St. Petersburg Coastal and Marine Science Center), **Greg Miller** (USGS Woods Hole Science Center), **Andrea Toran** (USGS Woods Hole Science Center), **Laura Torresan** (USGS Pacific Coastal and Marine Science Center), and **Ann Tihansky** (USGS Coastal and Marine Geology Program) won the Shoemaker Award for Communication Excellence in the internet product category.

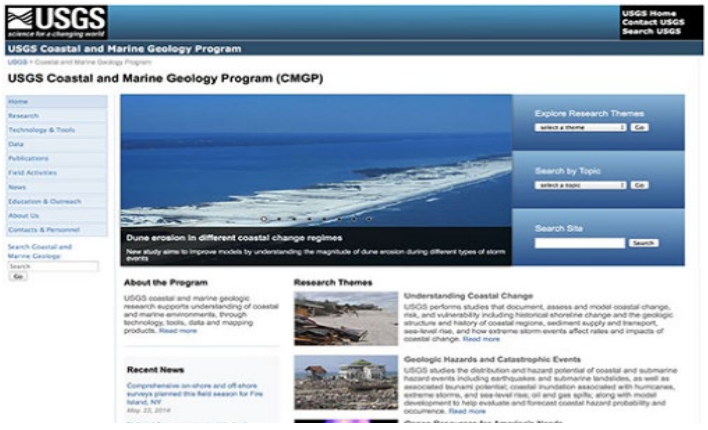
Launched in 2014, the website was designed in response to a request from CMGP Coordinator **John Haines** and the CMG Program Council:

"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 help our web visitors find the content they need."

The website content is designed to reach diverse internal and external audiences, who are curious about changes to the ocean and coasts. The site improves access to both current and historical coastal and ocean research information, including research projects, laboratory and technical capabilities, field activities, data, publications, news, outreach activities, and personnel information. The site allows users to browse research by theme or topic, as well as search by key words.

The website is a holistic presentation of USGS coastal and ocean science, and represents a successful collaborative effort among the three science centers within CMGP. CMGP offices are located in Santa Cruz, California; St. Petersburg, Florida; and Woods Hole, Massachusetts.

Visit the site at **http://marine.usgs.gov**. ☸



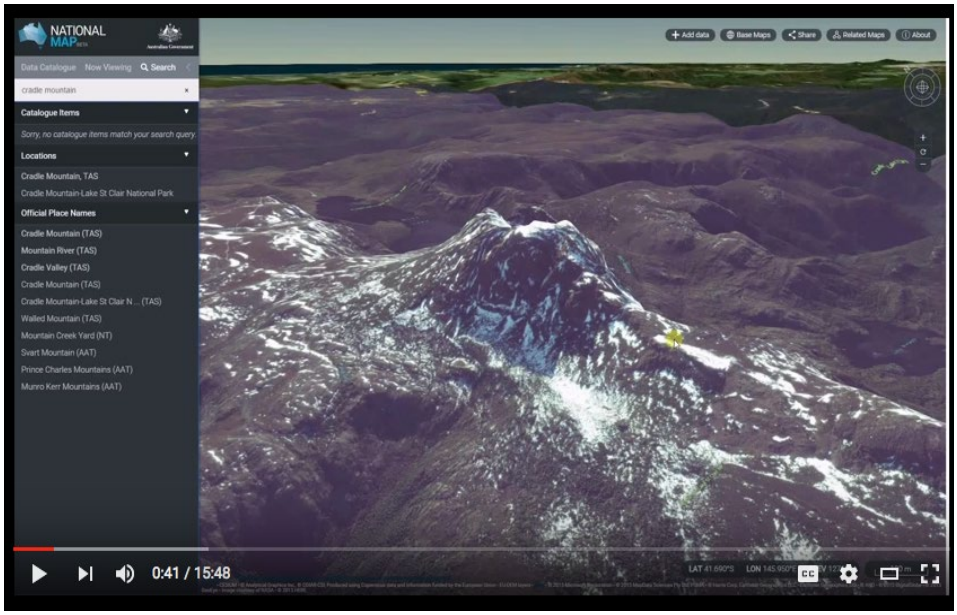
*The home page of the Coastal and Marine Geology Program website (**http://marine.usgs.gov**).*

Community for Data Integration Awards Projects to Woods Hole Science Center Scientists

By Susan Verner

In March, the USGS Community for Data Integration announced their FY16 awarded projects (**https://my.usgs.gov/confluence/display/cdi/2016+Proposals**). More than 30 statements of interest were submitted, of which only 13 were funded after review of full proposals. Two of the 13 awarded projects are led by USGS Woods Hole Science Center scientists:

"**Evaluating a new open-source, standards-based framework for web portal development in the geosciences**" is led by **Rich Signell** (USGS Woods Hole Science Center) with a team including **Soupy Dalyander** (USGS St. Petersburg Coastal and Marine Science Center), **Jordan Walker** (USGS Center for Integrated Data Analytics), and collaborators from NOAA, Florida Fish and Wildlife, Metanomy.org, and the Australian Government (CSIRO). The team will assess a new open-source framework for developing geospatial web portals. Although there are numerous portals with geospatial content throughout the USGS and the geoscience community, most of these are developed at relatively high effort and cost, with web developers working with highly skilled data specialists on custom solutions to meet user needs. In 2015, the Australian National Government funded the development of an open-source framework for building web portals called TerriaJS, which consumes web map services from both ESRI and the Open Geospatial Consortium and is easily configured for custom applications. This means that basic portals based on web map services can be created by non-developers such as scientists, environmental managers, and emergency response support personnel. It also means they can be constructed rapidly, in hours or days instead of weeks or months. This project will assess the capabilities of the framework by building several portals, and assess the accessibility of the code base by attempting to enhance the framework to better handle web map services produced by oceanographic models, using a combination of USGS and TerriaJS developer resources.



Screenshot of demo of the Austrailan National Map from Youtube. View it at ***https://www.youtube.com/watch?v=QMDICNIl0As****.*

See a video demo of the Australian National Map, created with TerriaJS, here: **https://www.youtube.com/watch?v=QMDICNIl0As**.

"**Integration of National Soil and Wetland Datasets: A Toolkit for Reproducible Calculation and Quality Assessment of Imputed Wetland Soil Properties**" is led by **Eric Sundquist** (USGS Woods Hole Coastal and Marine Science Center) with a team including scientists from the U.S. Department of Agriculture Natural Resources Conservation Service and the U.S. Fish and Wildlife Service National Wetlands Inventory. The team will develop a national geospatial dataset of imputed wetland soil properties, including carbon storage, and a toolkit to enable other investigators to reproduce and modify the dataset and the imputation methods. Wetland soils are vital to the Nation because of their role in sustaining water resources, supporting critical ecosystems, and sequestering significant concentrations of biologically produced carbon. The U.S. has the world's most detailed continent-scale maps of soils and wetlands, yet scientists and land managers have long struggled with the challenge of combining the information from these maps in ways that can be used for research and resource management. The difficulties include differences in the types of features depicted in the different maps, and uncertainties in the locations of wetlands and the soil types that are associated with wetlands. This project is developing methods to estimate and map the characteristics of wetland soils by combining information from maps distributed by the U.S. Department of the Interior and the U.S. Department of Agriculture. The derived maps will be available to the public with a set of tools that can be used independently to check the results and to develop methods to map other important properties of wetland soils.

For more information about these projects and all the awarded projects, visit **https://my.usgs.gov/confluence/display/cdi/2016+Proposals**. ❁

Recent Publications

Ben-Horin, T., Lafferty, K.D., Bidegain, G., and Lenihan, H.S., 2016, Fishing diseased abalone to promote yield and conservation: Philosophical Transactions of the Royal Society B: Biological Sciences, v. 371. [**http://dx.doi.org/10.1098/rstb.2015.0211**]

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