

OCEAN^{AND} CLIMATE CHANGE INSTITUTE

2011 Annual Report



Woods Hole Oceanographic INSTITUTE

Director's Message



Photo of Bill Curry by Tom Kleindinst, WHOI

The Ocean and Climate Change Institute is steadily gaining a comprehensive understanding of the ocean's effect on the climate. Continuing in that pursuit during 2010, the OCCI and its Arctic Research Initiative (ARI) initiated support for 13 research projects, new postdoctoral scholars, and WHOI/MIT students. Highlighted in this report are a few projects that illustrate the wide range of research and fieldwork that we support.

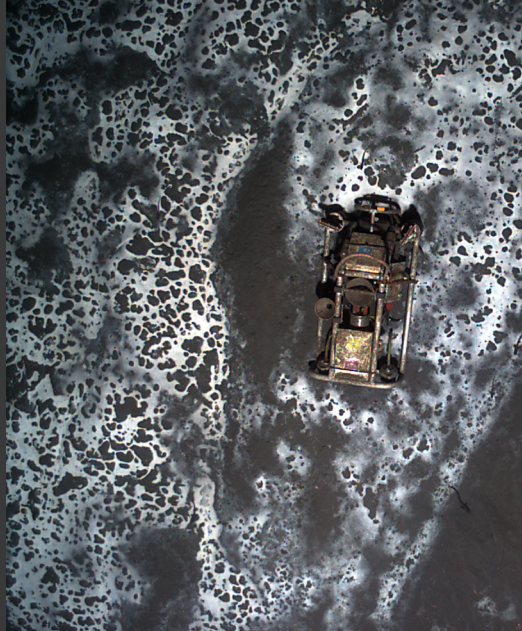
Recent field testing by Chris German (G&G), Rich Camilli and Dana Yoerger (both in AOP&E) of a newly developed mass spectrometer was used to detect and measure minute amounts of natural gas leaking from the sea floor off the coast of Norway at the Haakon Mosby mud volcano. Prepared to test the instrument on the vehicle Sentry, their plans were superseded by the Deepwater Horizon oil spill disaster.

In an important new study, physical oceanographers Terry Joyce, Xujing Jia Davis and Young-Oh Kwon tracked the migratory patterns of silver hake as they move north and south along the U.S. East Coast in response to fluctuations in the position of the Gulf Stream. This joint OCCI and OLI study has economic implications for the fishery industry if future changes in the position of the Gulf Stream become more predictable.

Looking to the past to gain perspective, Delia Oppo, Ann McNichol and Mark Roberts are using radiocarbon dating of corals to understand ocean circulation and climate change over the past 400+ years. The chemistry of coral skeletons tells us about ocean conditions at the time of their growth, and the data generated can be used to better understand past interactions of climate and the oceans and perhaps improve forecasts climate changes in the future.

With ARI funding, chemists Rachel Stanley and Brice Loose set off on a northern expedition to study the transport of CO₂ from the atmosphere to the sea in actively melting ice zones. What transpired was a near calamity, but yielded new leads for future success.

This was the fifth and final year of the Arctic Research Initiative. We are grateful to Ruth and Jim Clark and all involved in supporting Woods Hole Oceanographic Institution and the OCCI.



As Sentry flew over the study site, it was able to image a time-lapse camera working above a microbial mat (top) and a lander that can sample seafloor processes (bottom).



A Happy Marriage

The Haakon Mosby mud volcano (HMMV) is a curious phenomenon. Located off the coast of Norway on the continental shelf of the Barents Sea, HMMV emits mud and methane—not lava—from the Arctic deep. The release of methane from the seabed is particularly troubling in the Arctic. This potent greenhouse gas is estimated to contribute approximately 15 percent to current global warming. Recent studies have suggested

*New
vehicles and
instruments
open doors to
deep-ocean
exploration*

that warming of the ocean by as little as 1°C could pose a threat to regional or even global ecology.

To Chris German of the Geology and Geophysics Department, and Richard Camilli and Dana Yoerger of the Applied Ocean Physics and Engineering Department, Haakon Mosby represented the perfect natural laboratory to test Camilli's then-new mass spectrometer, TETHYS, a backpack-sized instrument capable of detecting and measuring tiny amounts of specific chemicals in the water. With Arctic Research Initiative funding and an invitation from collaborators in Europe, they mapped a plan to take *Sentry* and TETHYS to the Arctic to measure methane release at HMMV.

Unfortunately, one big crisis stood in the way: The Deepwater Horizon oil spill. In June 2010, Camilli deployed to the Gulf of Mexico, where *Sentry* and TETHYS were able to detect and characterize a plume of hydrocarbons in deep Gulf waters. Haakon Mosby would have to wait.

"We knew that HMMV was a place where we could exploit *Sentry*'s range and new instrumentation," German explained. "There's a great deal of concern about methane in the Arctic, and this was a chance for us to demonstrate the Deep

Submergence Lab's latest assets and capabilities, a happy marriage between vehicles and instruments."

Three months later, that's exactly what they did. In September 2010, the team made a series of six *Sentry* dives at HMMV, where they used on-board sonar to image methane bubbles coming up through the water column; employed a new sub-bottom profiler—some six years in the making—to map the mud structures; and deployed TETHYS to conduct *in situ* measurements of HMMV emissions in order to determine if they were carbon dioxide or methane. The results, German said, are very encouraging.

"The sub-bottom profiler has great potential as a system that can be used in the systematic exploration for further cold seep sites along previously uninvestigated ocean margins," he explained. "The *Sentry*-mounted TETHYS mass spectrometer performed without fault on all three dives at the HMMV site, recording over 4,100 discrete sample measurements. *In situ* data recorded during dive operations indicate highly localized methane emission sites."

Another important result of the project was the establishment of stronger collaborations between WHOI researchers and European colleagues investigating the Arctic Ocean through two related programs: ESONET, which is dedicated to establishing a series of ocean observatories encircling the European Margin (of which the HMMV site is just one); and HERMIONE: Hotspot Ecosystem Research and Man's Impact on the Ocean.

Overall, the expedition established that the latest WHOI technologies offer researchers new, cost-effective methods for investigating gas hydrates and associated methane release that can be used not just throughout the Arctic, but along all the world's ocean margins.

OCCI and ARI awarded Chris R. German, Richard Camilli and Dana Yoerger \$382,891 for their project, 'Arctic Warming and Destabilization of Gas Hydrates.'



Braving the Elements

When
scientists
battle ice
and wind,
sometimes
Mother
Nature
wins

In the spring, regions of polar ice melt are where the action is, chemically-speaking. That's why chemists Rachel Stanley and Brice Loose nearly risked life and limb to study one of them in 2011.

Polar ice zones are important regions for the transport of carbon dioxide (CO₂) from the atmosphere to the sea. The advance and retreat of polar ice modulates this exchange. During the winter, sea ice acts as a barrier to air-sea gas exchange.

In the spring, when the ice melts, biological production thrives as light and nutrients become plentiful. As the ice melt season lengthens, scientists like Stanley and Loose are eager to measure the impact of ice on CO₂ cycles, but it isn't easy.

With funding from the Arctic Research Initiative, Stanley and Loose set out to develop a new methodology for simultaneously quantifying biological production and air-sea gas exchange in melting ice zones. They proposed a pilot study in the Bras D'Or Lakes, Nova Scotia—an analog to the Arctic environment that they hoped would provide an ideal natural laboratory for studying ice melting processes in an accessible field environment.

"The boat is the biggest challenge," Stanley explained, adding that the craft has to be agile enough to navigate tight channels in ice-choked waters. "We're also using a mass spectrometer and a



gas chromatograph, which are generally launched from larger ships, so those instruments had to be modified for this deployment.”

The Bras d’Or expedition proved to be a perfect illustration of just how challenging it can be to work in extreme environments.

After waiting weeks for the first signs of thawing, Stanley and Brice received the call from Dr. Bruce Hatcher of Cape Breton University to tell them that the ice was starting to melt. The pair rushed to Nova Scotia, only to be met by a cold snap. It persisted for eight days. They tried a few reconnaissance missions in the dive boat they had hired, but found that the ice was too thick for them to take good measurements. When the ice finally started to melt, the wind kicked up.

“Ice is manageable,” Loose said. “Ice and wind is not manageable.”

Day One of ice and wind wasn’t ideal, but the team was able to take some measurements. Day Two was a different story. Just as they located a “sweet spot” for taking measurements, the wind shifted, and ice started to blow back against the ship, causing it to drift onto a sandbar. The boat stopped drifting, but the ice did not. With the boat in frigid waters and listing at more than 45 degrees, Stanley and Loose had to retrieve and secure their instruments, back up their data onto laptops, evacuate to a dinghy, and row to shore amid the ice floes—quickly.

In three days, the storm had passed and the team was able to retrieve their

equipment from the damaged boat. By then, the ice—and the opportunity for taking good measurements—had melted away.

The team has been thinking about what they could have done differently. “When we do this work in the Arctic, we’re supported by a logistics team,” Loose said. “We never have to think about things like our own safety.

“We’ve both asked for immersion suits for Christmas,” Stanley added.

One thing they will do differently next time—OCCI granted the team an additional \$48,500 to attempt the fieldwork in spring 2012—is use a smaller boat, one that quickly can be hauled out of the water and onto a trailer. Perhaps the most interesting lesson learned was that although Stanley and Loose sought out Bras d’Or, Nova Scotia, as a proxy environment for the Arctic, they found fascinating climate issues right where they were.

“The fisheries in this area have experienced dramatic changes as the rate and timing of ice melt changes each year,” Loose said. “Huge climate impacts have changed people’s lives, and we rarely hear about it. Research like ours, we hope, will help us better understand both the Arctic and places like Bras d’Or.”

Rachel Stanley and Brice Loose were awarded \$192,056 in Arctic Research Initiative funds for “Controls on CO₂ Fluxes in the Marginal Ice Zone: Biological Productivity and Air-Sea Gas Exchange.”

Climate Change and Fisheries

Silver hake offer a glimpse into how shifting currents impact Atlantic fish stocks



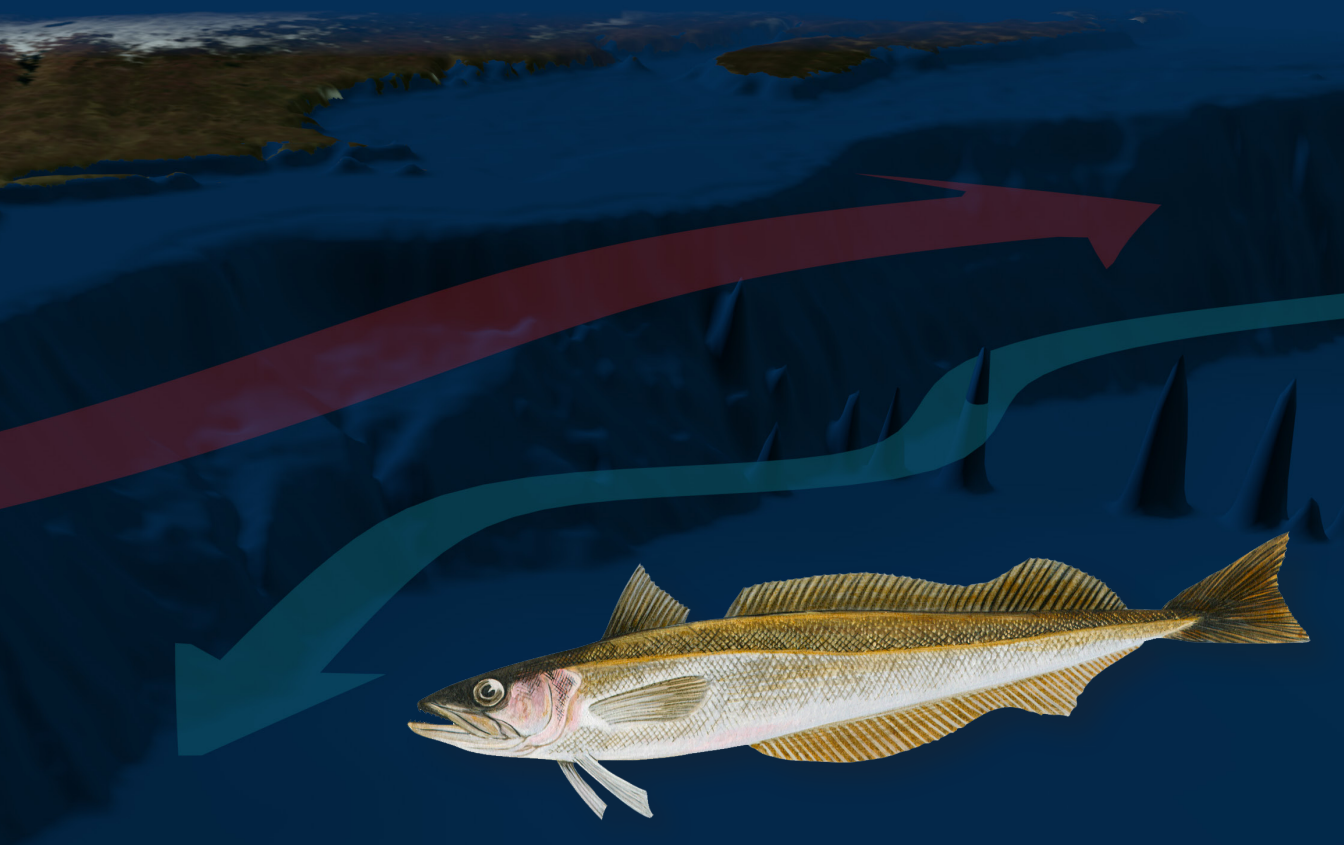
Researchers Young-Oh Kwon, Terry Joyce and Xujing Jia Davis.

The North Atlantic's most powerful currents, the warmer Gulf Stream (depicted in red) and the colder Atlantic Meridional Overturning Circulation (depicted in blue) may play critical roles in determining and predicting the behavior of fish stocks in the region.

Scientist Emeritus Terrence Joyce likes a nice silver hake, not so much for eating as for studying.

Hake make good study subjects because they are predictable; they prefer to hang out on the slope of the East Coast's Continental Shelf, where the water is a comfortable (for them) 46 degrees F. Hake also are popular with landings in 2007 exceeded 6,000 metric tons, at a value of more than \$7 million. This commercially important fish has been monitored by the National Marine Fisheries Service for more than 40 years.

Because of the silver hake's predictability and popularity, Joyce and his team found the fish to be an excellent proxy for better understanding how fauna react to changes in the North Atlantic's most powerful currents: the Atlantic Meridional Overturning Circulation (AMOC) and the Gulf Stream (GS). With funding from OCCI and the Ocean Life Institute, Joyce and fellow physical oceanographers Xujing Jia Davis and Young-Oh Kwon found that silver hake move north and south along the U.S. East Coast in response to fluctuations in the path of the Gulf Stream. These findings provide needed scientific data to explain the significant amount of observed



changes in both the location and biomass (density in a given area) of the fish.

“We’ve used the GS path as a leading indicator of conditions at the shelf break,” Joyce explained, “but in reality the silver hake and the Gulf Stream are responding to processes ‘upstream’ from our study area arising in the Labrador Sea and reflecting large-scale circulation changes associated with the AMOC.”

When flow into the region from the Labrador Sea decreases, the northeast U.S. shelf is warmer, the GS is closer to the shelf, and the preferred habitat of the silver hake is shifted northward. Conversely, when the flow from the Labrador Sea increases, the shelf is cooler and the GS moves away from it, and the silver hake shift south. There is a clear suggestion, Joyce, Kwon and their co-authors wrote in a paper published in *Nature Communications*, “that climatic signals influence the bottom waters over the shelf and that silver hake are responding to this remote forcing.”

Of equal interest to Joyce and his team are two other findings with far-reaching implications. First, their data shows that the GS path changes appear to lead changes in hake distribution by about a

year, which could allow fisheries managers to use the GS to predict where hake fishing might be most productive. Second, they believe that silver hake—traditionally classified as two separate stocks (northern and southern)—might not be as independent as previously thought.

“We’re not doing the fish any favors,” Kwon explained, “because we’re explaining where they are, what they are and where they will likely migrate. However, this is important data for managing fisheries.”

Joyce believes that as the silver hake continue to shift north, they may largely disappear from their largest fishery, the southern part of the mid-Atlantic. The economic implications are obvious; less evident but equally important is how this shift might impact ecosystems. The fish is an important prey and predator in the ocean food chain, so shifts in distribution may be reflected in other Atlantic fish stocks.

As the team continues to analyze its data, Joyce envisions extending this study to other commercially important fish found in New England waters.

OCCI and the Ocean Life Institute granted \$74,978 to Joyce and his team for the project, “Can Changes in Silver Hake Be Related to and Forecast by Changes in the Gulf Stream Path?”

Tracking the Little Ice Age

What subtropical corals
tell us about historical
climate change



Mark Roberts, Delia Oppo & Ann McNichol

Some of the most striking images of the climatic event known as the Little Ice Age—a period of large scale, possibly global, cooling between the 16th and the mid-19th centuries—are paintings by Pieter Brueghel the Elder. His iconic works featuring frozen Netherlands canals and other unusually harsh winter scenes are often cited as anecdotal evidence of a cooler planet during this period. At Woods Hole Oceanographic Institution, researchers are looking for evidence of the Little Ice Age in a far more tropical scene: corals.

Delia Oppo, Ann McNichol and Mark Roberts, all of the Geology and Geophysics Department, are evaluating the link between ocean circulation and the sea surface temperature in the low-latitude western Atlantic using radiocarbon measurements in corals from the Bahamas, Yucatan and U.S. Virgin Islands. We know that even small changes in sea surface temperature gradients can influence climate at low latitudes, and these gradients vary on decadal and multi-decadal time scales. To learn more about variation on centennial time scales, researchers need an archive that has lived over hundreds of years.

Coral colonies are the ideal archive for measuring climate over time. They can live for hundreds of years and the annual growth bands in their skeletons—similar to those on trees—can be counted to create a precise timescale. The chemistry of their skeletons also tell us something about ocean conditions at the time of their growth, as measured in properties such as carbon-14, a naturally occurring radioactive isotope of carbon that forms in the atmosphere and enters ocean surface waters. Carbon-14 also appears in coral skeletal bands and when in low amounts might reflect times when deep mixing brought low-radiocarbon from colder deeper waters nearer to the surface where the corals live, whereas skeletal bands with more carbon-14 might reflect times of less intense vertical mixing. Thus, radiocarbon variations recorded in a coral has the potential to tell us about changes

in oceanography and circulation, and helps us test ideas about why tropical sea surface temperatures might have been colder in the past.

“When we compare data from the Bahamas versus data from the Florida Keys, we see some interesting differences. Oppo said. “The Bahamas dataset — going back to about 1550 A.D.—more closely reflects the mean carbon-14 in the atmosphere whereas the Florida record shows more evidence of mixing with deeper low-radiocarbon waters. The WHOI NOSAMS laboratory produces data with very small errors, allowing us to resolve very small changes in surface radiocarbon, that might be significant oceanographically. In the future, we’ll collaborate with WHOI modelers to understand what these small variations may mean.”

The team’s goal is not only to take measurements, but also to utilize high precision radiocarbon to understand climate change over the last 400+ years. This multidisciplinary approach has created new opportunities for these researchers.

“Our work capitalizes on our different capabilities,” explained Roberts, a physicist who specializes in making high precision measurements. “Delia couldn’t do the

“Our work capitalizes on our different capabilities.

—Mark Roberts

climate work she does without our carbon dating technologies, and I couldn’t do the work I do if she wasn’t asking these questions. The data we generate can also be used to test numerical models. If the models do a good job reproducing our data, I have confidence that they can be used to tell us something about the future changes in climate and oceanography.”

OCCI awarded \$56,723 to Delia Oppo, Ann McNichol and Mark Roberts (co-PIs) for the study, “Using Coral Radiocarbon as a Tracer of Atlantic Circulation during the Last 400 Years.”

OCCI 2011 Grantees



OCCI awarded physical oceanographers **Caroline Ummenhofer**, **Ray Schmitt** and **Terry Joyce** \$74,986 to identify recurrent northeast US rainfall and circulation patterns, develop a physical understanding of these patterns within the region's ocean-atmosphere system, determine their variation across different timescales, and assess recent northeast US rainfall trends in light of a better understanding of long-term variability. Such improved understanding becomes crucial for water resource managers in light of significant changes to the region's climate projected for the 21st century.



The oceans play an important role in the global carbon cycle, and have absorbed about a third of carbon dioxide from fossil fuel combustion to date. Future climate change depends in part on how the rate at which the oceans absorb CO₂ change as the planet warms; there is at present considerable uncertainty about this. OCCI awarded **Hauke Kite-Powell** and **Andy Solow** of the Marine Policy Center \$56,827 to study the economic value of scientific research that reduces uncertainty about the future role of the oceans in the global carbon cycle.



Quantifying and understanding natural climate variability at the centennial time scale is critical for detecting and attributing externally forced changes. With \$74,935 in funding from OCCI, **Kris Karnauskas** (Geology & Geophysics) and **Konrad Hughen** (Marine Chemistry and Geochemistry) aim to construct a much-needed tropical sea surface temperature record on multi-century time scales, and use that new proxy record to guide and ground-truth the detailed analysis of a set of four global coupled general circulation model simulations. The study will contribute substantially to the growing interest in low-frequency tropical climate variability, and place the researchers in position to help lead the charge into this emerging topic.



In some defined geographic regions, local changes in ocean currents have consequences for basin-wide or global-scale climate. The area southeast of the Tail of the Grand Banks of Newfoundland in the North Atlantic is likely one such "big impact" site that has not been well-studied. Here the swift Gulf Stream converges with the equatorward-flowing Labrador Current and Deep Western Boundary Current as each navigates the abrupt topography of a submarine ridge that juts into their paths. The North Atlantic Current emerges from these interactions and transports warm waters poleward. Physical Oceanographers **Magdalena Andres** and **Mike McCartney** were awarded \$49,874 to carry out a set of numerical modeling experiments aimed at investigating the dynamics that control how the Gulf Stream and Deep Western Boundary Current interact with each other and with the Southeast Newfoundland Rise by the Tail of the Grand Banks.



Claudia Cenedese of the Physical Oceanography Department was awarded \$49,896 to investigate the possibility that sea ice extent plays a significant role in Pacific-origin water distribution in the Arctic Ocean through a series of laboratory experiments. This study is complementary to the observational and numerical work that Al Plueddemann, Robert Pickart and Michael Spall are conducting in the Beaufort Sea, and could have a great societal impact since changes in the sea ice extent can have significant consequences on the global climate system.

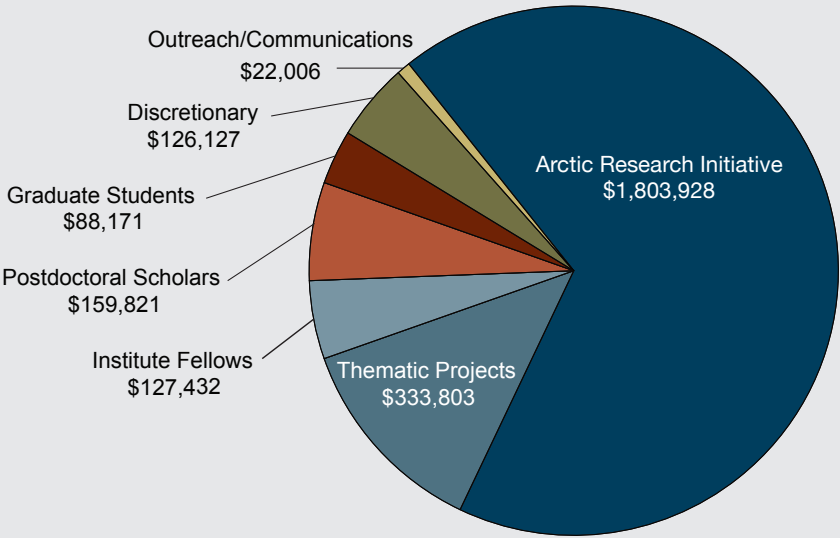


Not knowing where and when microfauna live and produce their shells introduces significant uncertainty in paleoceanographic and paleoclimate data. **Joan Bernhard** of the Geology & Geophysics Department was awarded \$20,000 to develop a new method that will unequivocally identify where and when important calcareous microfauna such as benthic foraminifera calcify *in situ*. The project is jointly funded by OCCI and the Ocean Life Institute.

Funding highlights

Although OCCI focused the majority of its funding on research grants, significant support also went to fellows, graduate education and outreach activities. In 2010, OCCI supported two Institute Fellows (Sarah Das and Young-Oh Kwon), postdoctoral scholars Magdalena Andres, Sean Bryan, Elizabeth Douglass, Donglai Gong and Emily Shroyer, and three MIT/WHOI Joint Program student. Funds also provided support for educational activities, and Discretionary and Communication funding was used to support conferences and publications.

2010 OCCI Spending: \$2,661,228





About the Ocean & Climate Change Institute

We are an institute without walls or permanent staff. We are dedicated to understanding the ocean's role in climate by devoting resources to interdisciplinary research teams, educating the next generation of ocean and climate researchers, and communicating the importance of ocean research to a variety of climate stakeholders including the government, corporations and the public at large.

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Cover: WHOI geologist and OCCI Fellow Sarah Das in Greenland looking for the perfect location for an experiment to trace how lake water drains through the ice sheet, over the bedrock below, and out to the ocean. Photo by Chris Linder, WHOI.