OCEAN AND CLIMATE CHANGE INSTITUTE

2011 Annual Report

Woods Hole Oceanographic Institution

Director's Message

Photo of Bill Curry by Tom Kleindinst, WHOI

Since its founding in 2000, the Ocean and Climate Change Institute has been working to gain a comprehensive understanding of the ocean's effects on the climate. During many of the past 12 years, I've had the great privilege of serving as OCCI's director and am proud to have encouraged my colleagues in their pursuit of challenging new projects in climate science.

In July, I accepted an exciting new project of my own: President and Director of the Bermuda Institute of Ocean Sciences (BIOS), effective in September. BIOS is an independent marine science organization, a US-based non-profit corporation, and it has a long standing relationship with WHOI researchers. I'm thrilled to have the opportunity to lead BIOS into new areas of ocean science research and education while reinforcing over a century of scientific exploration and innovation.

I'm pleased to tell you that I leave OCCI in the best of hands. My friend and colleague Scott Doney—a graduate of the MIT/WHOI Joint Program, an American Association for the Advancement of Science Fellow, a recipient of the James E. and Barbara V. Moltz Institute Research Fellowship and a recognized expert on ocean acidification— recently accepted an offer to lead the Institute. I am sure that you will enjoy working with him as much as I have.

Woods Hole Oceanographic Institution's leadership has enabled OCCI to focus on the value-added science and engineering that WHOI does best. Still, as you can see from the pages that follow, we have substantial progress to make. From the Greenland Ice Sheet to tropical corals, we still have much to learn about how the ocean, atmosphere and ice sheets will respond to today's exceptional climate perturbation. I am proud of the work we have accomplished together, and look forward to the collaborations that will advance it.

—Bill Curry

Diving into the PAST

Bermuda's submarine caves offer insight into historical climate records

Image courtesy of Tamara Thomsen, Bermuda Deep Water Caves 2011 Exploration, NOAA-OER.

Bermuda's Walsingham Cave System is a divers' paradise.

The blue-green waters of its submarine and subterranean caves and grottos are home to unique ocean life, and its limestone composition forms new, other-worldly walls, columns and curtains with every drop of rainwater.

As it turns out, the Walsingham Cave System is also a climate scientists' paradise, which is situated on the northeast coast of the island. Preliminary evidence suggests that the temperature of the groundwater flooding this underwater cave may be linked to the vigor of the Gulf Stream in the North Atlantic. This potentially makes the cave system an ideal location to study how the Atlantic Meridional Overturning Circulation, or AMOC (a deep ocean current), responded to, or forced, intervals of abrupt climate change over the past 12,000 years.

With funding from the Ocean and Climate Change Institute, Peter van Hengstum and Jeff Donnelly of the Geology and Geophysics Department have teamed up to continuously measure temperature and salinity in Walsingham Cave. These measurements will provide a cave-wide perspective of how oceanography in coastal lagoons and the western Sargasso Sea influences the hydrography in the underwater cave.

"Studies of submarine caves are an innovative solution to the problem of having so few high-resolution ocean climate records," van Hengstum said. "This is because underwater caves contain carbonate organisms suitable for traditional geochemical analysis and they can have high sedimentation rates."

Using advanced cave-SCUBA diving techniques, the researchers installed four hydrographic stations into Walsingham Cave in December 2011. The four hydrographic stations are strategically positioned to observe passages increasingly isolated from the ocean. These stations have been sampling temperature, salinity and depth every five minutes ever since.

"This research will be the first complete hydrographic analysis in a submarine cave using a continuous observation network," van Hengstum said. "It will provide essential preliminary data and infrastructure to leverage into a National Science Foundation-funded program completing a cave-wide calibration program of carbonate geochemistry in submarine caves."

Peter J. van Hengstum and Jeffrey P. Donnelly were awarded $12,165 for the study, "Does the Gulf Stream regulate hydrography in Walsingham Cave, Bermuda? Implications for developing high-resolution records of Holocene Gulf Stream variability."

EPIC

ICE MELT

IN GREENLAND

Courtesy of Ben Linhoff, WHOI

Scientific field work is often challenging, but MIT/WHOI Joint Program student Ben Linhoff raises the bar for difficulty on the southwestern edge of the Greenland Ice Sheet.

“The river coming out from beneath Leverett Glacier is running somewhere around 800 cubic meters per second, over twice what anyone has measured in previous seasons. …The river we cross has grown appreciably and occasionally it is choked with small icebergs. …we are cautiously optimistic that we won’t become stranded.”

Working in Senior Scientist Matt Charette’s lab with funding from the Ocean and Climate Change Institute’s Clark Arctic Research Initiative, Linhoff spent two consecutive summers (2011-12) camping on the Greenland Ice Sheet’s edge to study glaciers and the profound impact glacial meltwater has on their movement to the sea. In 2012, he captured more than data; he witnessed history.

Linhoff and his colleagues measured unprecedented ice melt and recorded the largest accelerations of ice this summer. Like so many Woods Hole Oceanographic Institution (WHOI) scientists and engineers before him, he’s playing a part in the discoveries that form modern understanding of the ocean and how it interacts with other parts of the planet.

“The Greenland Ice Sheet is the Northern Hemisphere’s largest terrestrial permanent ice mass; melting the entire ice sheet would raise the ocean’s surface more than seven meters,” Charette said. “However, surprisingly little is known about how surface warming controls ice sheet loss or if the composition of meltwater-derived chemical fluxes has changed.”

Forced downhill by gravity, glaciers compress, deform, and slide while moving and crushing the rocks beneath them. Lakes of meltwater form on the ice surface and when the weight of the water becomes too great, the ice splits open, and can drain them in a matter of hours. On the ice sheet, Linhoff tested a new way to measure the rate and fate of glacial meltwater as it traveled, using a radiotracer based mixing model. He also took water samples and deployed “a hefty arsenal of detectors, probes, and instruments into the river to monitor things like pH and electrical conductivity 24 hours a day.”

During last year’s melt season, Leverett Glacier’s catchment area probably lost about one-third as much ice as what melted this summer. Yet, despite the relatively cold melt season in West Greenland in 2011, more ice was lost than gained over the course of the year. This year, Linhoff believes that much more ice will melt from the ice sheet than will form.

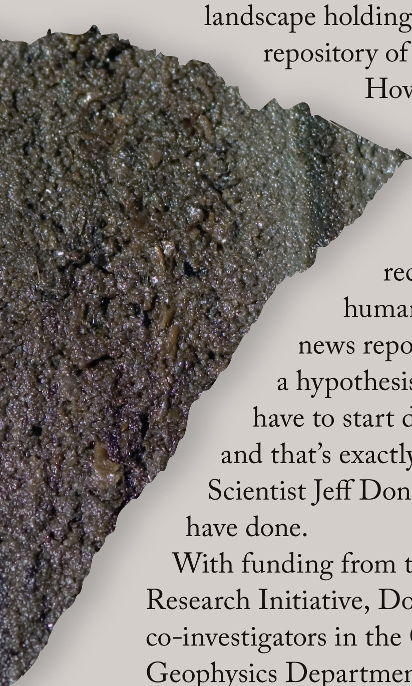
“According to ice core records, epic melting years like 2012 seem to occur in Greenland about every 150 years or so,” he said. “I’m sure there will be much debate about whether this year’s high melt was part of a natural cycle or if it is yet another symptom of climate change. The answer to that question doesn’t actually matter. The fact remains that during this year, like every other year in the past decade, more ice will be lost than created. It’s the trend that matters and this year’s melting will accentuate the ice-loss trend. I think it’s safe to say that at this point, it would take decades of cold, snowy weather to reverse course in Greenland.”

Senior Scientist Matt Charette received a grant of $49,392 from the Arctic Research Initiative for his study, “Seasonal Evolution of Greenland Ice Sheet Hydrology.” OCCI is also funding Ben Linhoff’s graduate student support.

Robin Littlefield, WHOI

Digging In

A team of WHOI researchers collects Arctic sediment samples to chart climate variability



The remoteness of Alaska's Aleutian Islands is a double-edged sword for climate scientists. As a data collection site, it's a clean slate—a largely undisturbed landscape holding fast to a vast repository of geological records. However, the lack of human habitation also means there are almost no traditional climate records, such as human observations or news reports, that can inform a hypothesis. Scientists just have to start digging in, literally, and that's exactly what Associate Scientist Jeff Donnelly and his team have done.

With funding from the Arctic Research Initiative, Donnelly and his co-investigators in the Geology and Geophysics Department—Joan Bernhard, Liviu Giosan, Andrew Ashton, Kris Karnauskas and Andrea Hawkes—collected and examined sediment records from the bottom of Skan Bay in the Aleutian Islands in order to answer a fundamental question about climate variability: How will Arctic coastal landforms and estuaries change as a result of potentially dramatic reductions in sea ice and permafrost?

The current loss of sea ice and permafrost, which began in the late 19th century, has now accelerated over the last three decades and may lead to a nearly ice-free Arctic by the mid-21st century. The team believes that the presence of sea ice might reduce the transport of sediments during storms, and longer periods of open ocean associated with decreased seasonal ice cover will likely cause accelerated coastal erosion in some areas while increase sediment transport to other areas.

"Unfortunately, we lack a fundamental understanding of how sea ice and permafrost variability influences coastal landforms like protecting barrier and bayhead deltas that play an essential role in controlling estuary processes," Donnelly explained. "Our approach couples analysis with observations and numerical modeling to examine past and current change as well as project future scenarios."

Donnelly, Hawkes and lab technician Richard Sullivan started their journey in September 2010 in Goodnews Bay, Alaska, because existing records indicated it was deep and close to significant sea ice in the


Jeff Donnelly, WHOI

recent geological past. When they began to collect data, they quickly discovered that the location was anything but good news.

"The bathymetry records were incorrect; Goodnews Bay was closer to three feet deep rather than 180 feet," Donnelly said. "We needed a deeper bay."

Fortunately, the team was able to move their operation to Skan Bay in the Aleutians. Aboard the *Miss Alyssa*, a 43-foot charter vessel out of Dutch Harbor in May of 2011, Donnelly and crew deployed sonar and water-profiling technology in addition to collecting core samples. The 10 meter continuous cores document the geologic record of the past 1,000 years and helped the team begin to model how Arctic systems may change in the future.

"Understanding the role of sediment delivery is critically important if we are to assess the nature and scale of future change," Donnelly explained. "These cores give us a good story of storminess in the region and the resulting sedimentation rates."

The team—which spans much of the breadth of the Geology and Geophysics Department as well as junior to mid-level scientists—is now writing up their results for publication and considering next steps, including federal funding. This multifaceted project has the potential to stimulate numerous WHOI-led initiatives in the Arctic targeted by the National Science Foundation, NOAA, the Departments of Energy and Defense and the Office of Naval Research, particularly as the strategic importance of a more ice-free Arctic continues to become more apparent.

Donnelly would just like to get back out into the field to dig a little deeper.

"Thirty feet of sediment told us a 1,000-year story; a longer core can brings us back thousands of years," he said. "Of course, we'll need a bigger boat."

Principal Investigator Jeff Donnelly was granted $393,438 by the Arctic Research Initiative in 2010 to conduct the study, "Examining the Effects of Arctic Warming on Coastal Landforms and Estuarine Ecosystems."

A RARE EXPEDITION

Biologist Carin Ashjian and her team seek to unlock the mysteries of the Arctic ocean in winter

"Covered in sea ice, enveloped in darkness, buffeted by howling winds, beset by frigid temperatures. Cold, dark, icy, and stormy…what motivates us to leave our cozy lives at home and embark on a 40-day cruise into this inhospitable place?"

Biologist Carin Ashjian and her team explore the Arctic Ocean in winter because, in many ways, it remains a mystery. The Arctic system is undergoing significant changes related to a warming climate, most notably decreased sea ice cover, which may have significant impacts on Arctic ecosystems. Understanding of seasonality, and of winter conditions and biological and physical processes during that time, in the Arctic is severely limited because it has been so difficult to access these winter seas.

With funding from the Ocean and Climate Change Institute's Arctic Research Initiative and the National Science Foundation, Ashjian and her team, including Sam Laney from the Biology Department, Krista Longnecker from the Chemistry Department, and colleagues from the University of Rhode Island and the University of Alaska Fairbanks, set out in November 2011 on the USCGC *Healy* on a rare expedition to explore the early winter ocean conditions—biological, physical and chemical—in the Bering and Chukchi Seas. Scientists' lack of knowledge about winter conditions there has compromised their ability to model and to predict future states of Arctic ecosystems, efforts that are central to understanding the potential impacts of ongoing climate change.

Overall, Ashjian reported that the challenging expedition was highly successful.

"More than 100 percent of the planned sampling stations in the Chukchi Sea, the Bering Strait and regions of the Bering Sea to the north and east of Saint Lawrence Island were achieved," she said. "Weather severely limited our sampling in the Bering Sea proper, to the south of the region of sea ice, but the success rate at the stations where we were able to sample was very high."

At each station they collected a variety of data and samples, including plankton, and lots of it.

In particular, they wanted to gain a better understanding of the overwintering, strategies of one of the dominant copepod genera, *Calanus* spp., an important component of the oceanic food web. They also wanted to understand phytoplankton distribution and overwintering and bacterial activity and utilization of organic material.

"Each tow brought a sense of anticipation and a great curiosity," Ashjian explained. "We found many krill that are important

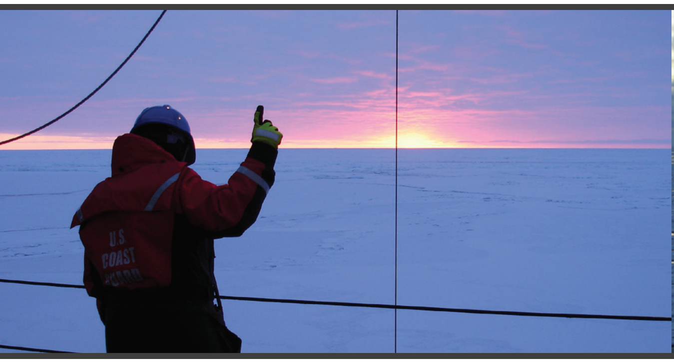
Gong, Donglai, WHOI

prey for bowhead whales in the Beaufort and Chukchi Seas, particularly near Barrow. We also found *Calanus* copepods, including a very large abundance of males. Male *Calanus* are rarely seen so it was quite strange to see so many!"

At each sampling station, many of the copepods and krill were picked out, photographed, and saved for later analysis of their carbon and nitrogen content to see how much fat they had stored for the winter. Additional analyses would also offer clues into their metabolic activity (how active are they are?) and their genetics to identify if the animals originated in the Bering Sea or in the Arctic Ocean.

With samples collected, the team is now analyzing data so they can put together a fuller story of the Bering and Chukchi Seas in winter—under conditions where no one has been able to work before.

Carin Ashjian was granted $56,487 by the Ocean and Climate Change Institute in 2011 to conduct the study, "A Winter Expedition to Explore the Biological and Physical Conditions of the Bering, Chukchi and Southern Beaufort Seas."



Left: This is what the middle of the day looked like for scientists and crew who voyaged to the Chukchi Sea last winter. Right: Pancake ice covers the sea on one of the last sunrises that scientists and crew aboard the U.S. Coast Guard icebreaker Healy *saw in the northern Chukchi Sea, where the sun doesn't come up in winter.*

Carin Ashjian, WHOI

Other 2011 Funded Projects

Northeast US Rainfall: Variability versus Long-Term Change
Caroline Ummenhofer, Ray Schmitt and Terry Joyce, Physical Oceanography

Sensitivity of Climate Policy to Uncertainty about the Carbon Cycle
Hauke Kite-Powell and Andy Solow, Marine Policy Center

An Exploration of Centennial-scale Climate Variability in the Tropics Using a Coupled Climate Model and Coral Geochemistry
Kris Karnauskas, Geology & Geophysics Department; Konrad Hughen, Marine Chemistry and Geochemistry

Modeling Interactions between the Gulf Stream and Deep Western Boundary Current by the Tail of the Grand Banks
Magdalena Andres and Mike McCartney, Physical Oceanography

Laboratory Experiments Investigating the Influence of Sea Ice Extent on the Distribution of Pacific-origin Water in the Arctic Ocean
Claudia Cenedese, Physical Oceanography

CSI Microscale: Calcification Scene Investigation of Calcareous Microbenthos-Method Development and Test Case
Joan Bernhard, Geology & Geophysics

79NEXT: Is Ice Loss Triggered by Ocean Warming Extending to north Greenland?
Fiamma Straneo and Richard Limeburner, Physical Oceanography

Arctic Phytoplankton: Surviving the Winter and Preparing for Spring
Sam Laney, Biology

Seasonal Fluxes Across Submarine Ice Sheet Margins: A Pilot Study in West Greenland
Sarah Das, Geology & Geophysics; Hanu Singh and Lee Freitag, Applied Ocean Physics & Engineering; Al Plueddemann and Fiamma Straneo, Physical Oceanography

The Water-mass Signature and Pathways of Greenland Ice Sheet Meltwater in the Arctic and North Atlantic as Inferred by an Inverse Method
Jake Gebbie, Physical Oceanography

Dynamical Analysis of Surface Wind Responses to Sea Ice and Surface Temperature Variations in the Arctic Ocean: Synthesis of Data and Model Simulation
Hyodae Seo and Jiayan Yang, Physical Oceanography

Freshwater Discharge and Sediment Dispersal on the Alaskan Beaufort Shelf
David Ralston and Rocky Geyer, Applied Ocean Physics & Engineering

Bioavailability of Ancient Terrestrial Organic Carbon in the Mackenzie River System
Amanda Spivak and Marco Coolen, Marine Chemistry & Geochemistry

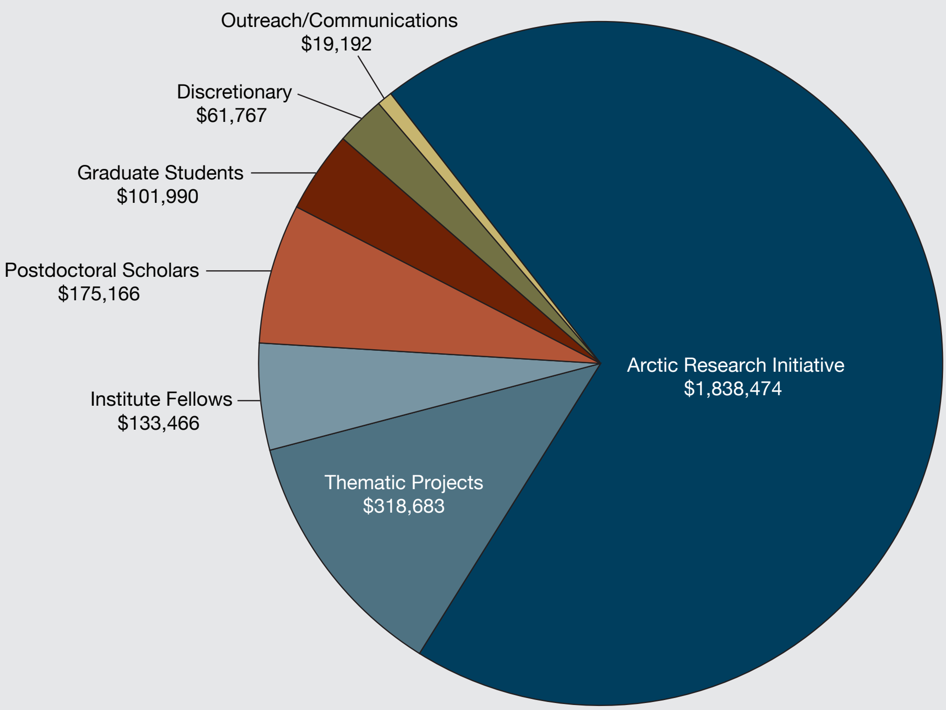
Bacterial Utilization of Organic Carbon Produced by Arctic Copepods
Krista Longnecker, Marine Chemistry & Geochemistry; and Carin Ashjian, Biology

The Transport Pathways of the Dense Water Formed in the Western Arctic Polynyas and Their Transformation under Predicted Future Regional Climate
Weifeng Zhang, Applied Ocean Physics & Engineering

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 2011, OCCI supported two Institute Fellows (Sarah Das and Young-Oh Kwon), postdoctoral scholars Magdalena Andres, Sean Bryan, Donglai Gong, Emily Shroyer and David Thornalley, and two MIT/WHOI Joint Program students. Funds also provided support for educational activities, and Discretionary and Communication funding was used to support conferences and publications.

2011 OCCI Spending: $2,648,738



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: A team of researchers that includes MIT/WHOI Joint Program graduate student Ben Linhoff, approached Leverett Glacier on the southwestern edge of the Greenland Ice Sheet. Linhoff and his colleagues are studying changes to the glacier as it undergoes seasonal melting. Photo courtesy of Ben Linhoff, WHOI.