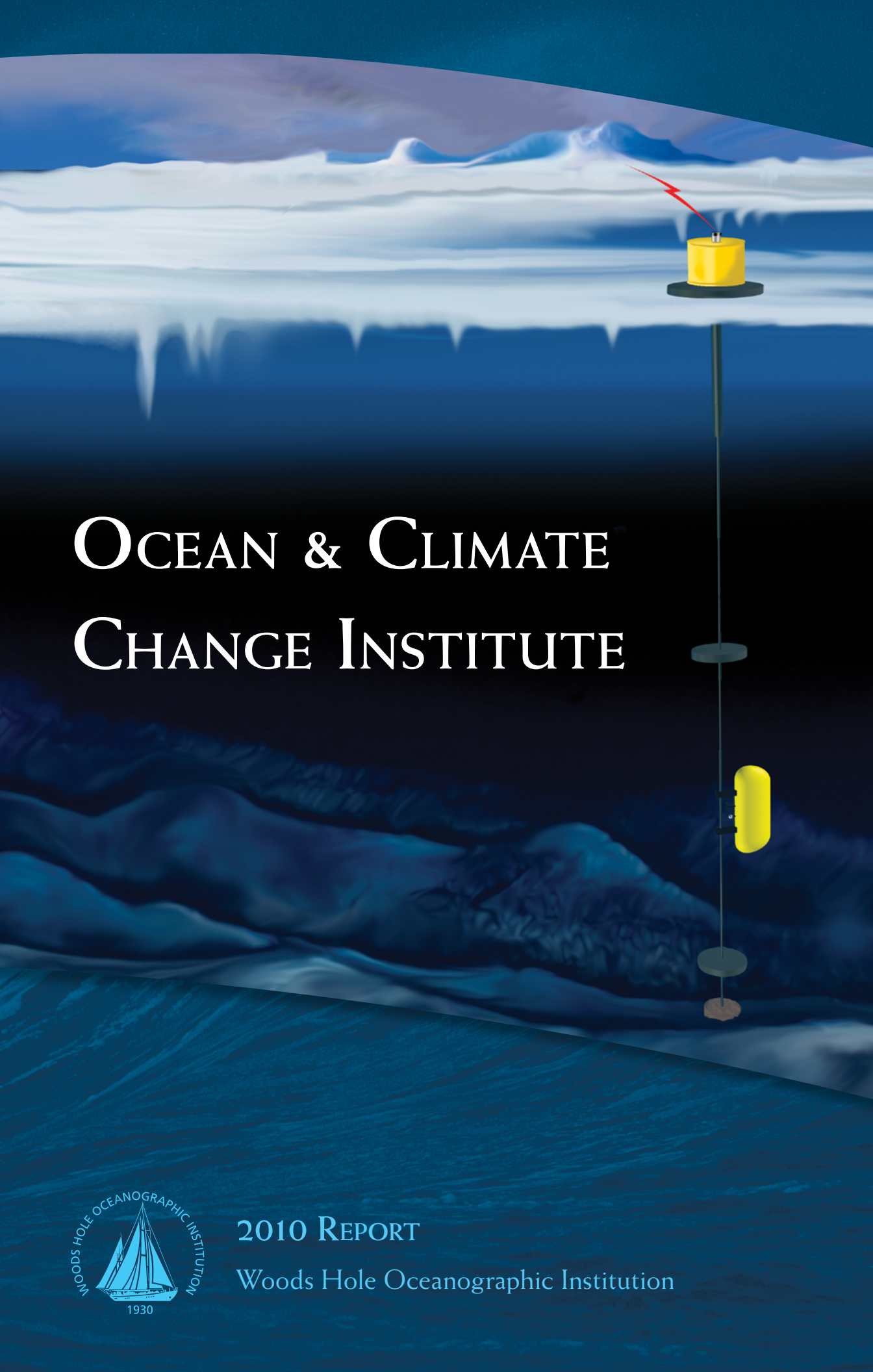


Ocean & Climate Change Institute

2010 Report

Woods Hole Oceanographic Institution

Director's Message

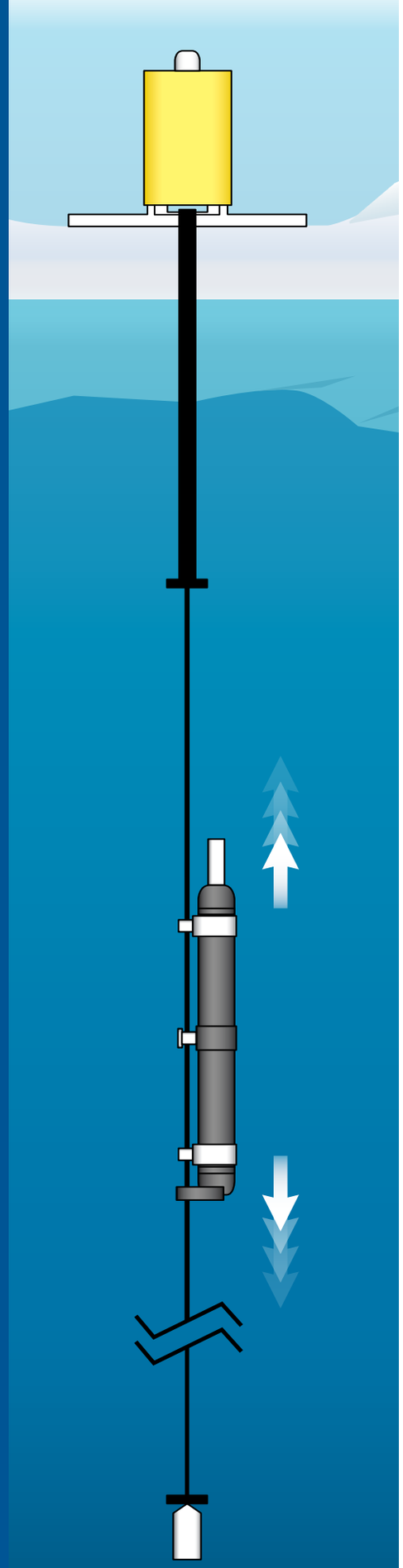
Photo of Bill Curry by Tom Kleindinst, WHOI

The Ocean and Climate Change Institute supports a wide range of activities—seeding basic research, supporting research with implications for federal policy, and nurturing high risk projects to meet the long-term goals of the institute. In this report we highlight several projects that demonstrate the wide range of research activities supported by the OCCI.

Fiamma Straneo (Physical Oceanography, PO) has been studying the interactions of the oceans and glaciers in several fjords of Greenland where warm ocean waters are causing significant melting where the ice and the ocean meet. OCCI, through its Clark Arctic Research Initiative (ARI), provided initial funding for her surveys of the fjords, helped her demonstrate the feasibility of the project and gain support from the National Science Foundation for a large, multi-year study of this critical coupled climate system.

The ARI supported Hal Caswell (Biology) to perform a population study of polar bears that contributed to their recent designation by the Department of the Interior as a threatened species. Andrey Proshutinsky (PO) and John Toole (PO) received support to deploy the sophisticated Ice Tethered Profiling system as part of an international program to monitor sea ice conditions in the Arctic Ocean. Al Plueddemann (PO) leads the fourth project, the development and testing of under-ice navigation systems for autonomous underwater vehicles. During this multi-year development effort, Al has been supported by OCCI with funds from the Comer Science and Education Foundation and the Clark Arctic Research Initiative. Al and his colleagues have a proposal pending with NSF to continue this research and development.

The Arctic is the leading edge of the warming climate and the receding summer sea ice extent is its most visible expression. WHOI is committed to supporting the best possible research to understand, document and project these changes in the Arctic. We hope you enjoy reading about how philanthropic contributions to WHOI and the OCCI have turned these great ideas into important successful research programs.



Breakthrough technology breaks through ice cover

The Arctic is particularly sensitive to Earth's changing climate. And changes in the Arctic, in turn, will likely catalyze further ocean and climate shifts that will have significant repercussions on polar habitats and wildlife, regional and global climate, international shipping, as well as other societal impacts.

Understanding the evolution of the Arctic's interconnected atmosphere-ice-ocean system has been hindered by a lack of observations. The ice blanketing the Arctic Ocean and extreme weather have historically deterred researchers from bringing instruments to the environment, leaving them there, or getting them back.

To surmount these obstacles, WHOI scientists and engineers led by physical oceanographer John Toole, Arctic research specialist Rick Krishfield and senior scientist Andrey Proshutinsky have devised innovative technology called the Ice-Tethered Profiler, or ITP (see illustration, left). Anchored to ice floes, ITPs slowly drift with the natural movement of the Arctic ice pack, measuring seawater properties below and transmitting data back to shore-based labs. Data are available within hours at www.whoi.edu/itp. ITPs are designed to last three years, about the same lifespan as the floes that support them.

Krishfield and colleagues deployed the first experimental ITP in the western Arctic Ocean north of Alaska in late summer 2004, then two more in 2005 and three more in 2006. The ITPs demonstrated their capabilities.

WHOI researchers have collaborated with North American, European, and Asian scientists to deploy 37 ITPs to date, creating a network of ITPs and other similar instruments throughout the ice-covered Arctic. In May 2010, six ITPs remained dispersed throughout the Arctic Ocean, collecting essential observations that will help scientists understand what is happening now and provide better predictions of what could happen over the next century.

OCCI provided $261,028 in 2007 and $151,746 in 2008 to supplement federal funding for Proshutinsky and Toole and their participation in the International Polar Year deployments of Arctic observing systems. To date, a total of 37 Ice Tethered Profilers have been deployed into the Arctic Ocean relaying information on ice drift and ocean hydrography.

Greenland glacier retreat

Over the past decade, glaciers in Greenland unexpectedly have begun to flow faster into the ocean, turning ice into water and raising sea levels. The glaciers terminate in deep fjords, where ice extends into the ocean several hundreds of meters below sea level. At roughly the same time as the glaciers started accelerating, waters circulating around Greenland also started to warm. Could changes in the ocean be triggering the rapid loss of glacier ice?

This new hypothesis, with potentially profound implications for our planet, was largely unverified because the remote, ice-choked fjords are difficult to get to and work in, and so scientists lacked any measurements of what is going on at the boundaries where ice meets ocean.

In 2009 WHOI physical oceanographers Fiamma Straneo, Ruth Curry, and Dave Sutherland and mooring engineer Jim Ryder ventured into three glacial fjords in eastern Greenland: Sermilik Fjord and Kangerdlugssuaq Fjord, whose glaciers have shrunk significantly in recent years, and a fjord called "79 North" at the far northeast corner of Greenland, which so far has remained fairly stable. They took advantage of a "ship of opportunity"—an icebreaker operated by Greenpeace International. They also made good use of the ship's helicopter to gain access to the ice-clogged fjords.

Surprising evidence links ocean changes to changes in the glaciers

The research team measured temperature, salinity, and currents at various depths in the fjords. They were surprised to find warm, subsurface water in all three. Near the surface of each fjord was a layer of cold, relatively fresh water of Arctic origin. But from a depth of about 150 meters all the way to the bottom (up to 900 meters deep) the water was saltier, denser, and warmer—warm enough to melt glacier ice.

Straneo's team found that prevailing winds and large storms drive a very active exchange of water between the fjords and the continental shelf just outside the fjords, where warm water from the subtropics is carried north by the Gulf Stream and other large currents and flows past Greenland.

The seawater outside the fjords has become warmer in recent years, likely due to climate change. The team's findings, while not conclusive, provide evidence that oceanic changes may be contributing to the accelerating loss of ice from the front of the glaciers.

Straneo received $481,942 in 2009 to deploy instruments in the Greenland fjords. With support from OCCI and NSF, she will return to the fjords in August to recover and redeploy several mooring systems.

A study links sea ice loss with declines in polar bear populations

Melting Arctic sea ice threatens polar bears' survival

If current trends of Arctic sea ice melting continue, polar bears are likely to become extinct in the southern Beaufort Sea region of Alaska and adjacent Canada, according to a demographic analysis led by Hal Caswell of Woods Hole Oceanographic Institution and Christine Hunter of the University of Alaska. The study concluded that climate change, and in particular the melting Arctic ice, is a critical threat to the bears' survival and reproductive rates.

Polar bears need ice as a platform to hunt for their main food source: seals. If the Arctic Ocean has more ice-free days in the summer, polar bear survival and breeding will decline below the point needed to maintain a viable population, the researchers concluded. The findings contributed to the polar bears' designation in 2008 as a federally protected threatened species.

From 2001 to 2006, scientists from the U.S. Geological Survey conducted an extensive survey of the Southern Beaufort Sea polar bear population. The USGS enlisted Caswell and Hunter, mathematical ecologists who specialize in population dynamics models, to advise the team.

Caswell and Hunter used novel analytical methods to develop new models that incorporated USGS-collected information about polar bears' mortality rates, birth rates, life cycles, and habitats. They coupled these models to projections of Arctic climate changes, especially forecasts of sea ice conditions. They calculated the interplay of all these factors—"some 10,000 simulations," Caswell said—to estimate the probabilities of future polar bear population growth or decline.

"One of our challenges in this analysis was the incorporation of uncertainty," Caswell said. "Each parameter in the model is an estimate, with associated statistical uncertainty. But in spite of the uncertainty, the conclusions about population decline and the critical effects of sea ice changes on that decline are robust."

The population models suggested that 130 "ice-free" days is a threshold, constituting a "bad-ice" year that has negative impacts on the polar bear population. The frequency of "bad-ice" years is critical: If they occur too often (more often than once every six years or so), the bear population shrinks, the scientists said.

Climate models predict that bad-ice years will occur more often in the future, as the Arctic warms. That projects a dire future for polar bears, though some small populations might hang on in isolated regions where ice remains, Caswell said.

In 2008, Caswell received a two-year award for $225,674 to support his analysis of polar bear populations.

For more information, see the 2010 paper "Climate change threatens polar bear populations: a stochastic demographic analysis" in Ecology: *www.esajournals.org/doi/abs/10.1890/09-1641.1*

Sending an untethered vehicle under the ice isn't easy

Getting it back again poses daunting challenges.

Offshore of northern Alaska lies a key region for understanding Earth's climate. Large amounts of sea ice are formed off the coast each winter, and in the process ocean water is transformed—made colder and saltier. This cold, salty water flows from coastal regions to the Arctic Ocean where it contributes to a layer called the halocline which acts to shield sea ice above from warmer water below that could melt the ice.

Scientists want to learn exactly how the halocline forms and how it could change in the future, potentially causing momentous ocean and climate changes well beyond the Arctic. "The problem is that these critical transformations occur in water beneath the sea ice, so they are difficult to observe," said Woods Hole Oceanographic Institution physical oceanographer Al Plueddemann. In polar coastal regions, mammoth ice floes break up, collide, and override each other, creating an unpredictable and rapidly shifting jumble of ice that even icebreakers can't work in; instruments left in it would be lost or destroyed.

A fast-moving research team dodges fast-changing ice conditions

Plueddemann and colleagues in the WHOI Ocean Systems Laboratory posed an alternative strategy: send in mobile teams via snowmobiles, cut holes in the ice, and deploy an autonomous underwater vehicle, or AUV, to make critical measurements of the unknown halocline-forming processes going on in the ocean beneath the ice. But the plan posed several challenges.

Could people and equipment get out to the ice and work? Could AUVs navigate adequately using acoustic signals in an "echo chamber" bounded on four sides by ice above, the seafloor below, and keels of ice floes jutting downward? Could AUVs find their way back to holes in the ice? Could they be rescued if they missed the hole or got trapped under the ice?

To test these questions, a team of intrepid WHOI researchers set off to Barrow, Alaska, in March 2010, equipped with one of WHOI's Remote Environmental Monitoring Units (REMUS)—a portable, 100-pound, 5-foot-long, battery-powered AUV. They outfitted it with custom low-frequency long-range acoustics that improved its navigation capabilities, but not enough to hit a 1-meter target (an ice hole) reliably. For that, they installed a short-range directional acoustic homing system.

They custom-designed a hull module to house equipment needed for under-ice operations: an uplooking altimeter to detect ice; beacons to locate the AUV below the ice or on the bottom; a strobe light to help find it at night; and a harpoon to snare a net they designed to stick into the ice hole and grab an oncoming AUV.

We'll save the long and highly adventurous story for another time, but the bottom line is: "The concept works," Plueddemann said. "We can deploy, navigate and recover a person-portable AUV in coastal sea ice. The scientific goals are within reach."

During the past decade, Plueddemann has received awards from OCCI, the Arctic Research Initiative and the Comer Science and Education Foundation to help nurture this challenging and high risk program for AUV operations under the ice.

What's coming

In 2009 OCCI awarded approximately $200,000 to five new research projects. The Clark Arctic Research Initiative awarded an additional $1.8 million to support eleven new research programs. Here are some of the projects and the individuals making them happen.

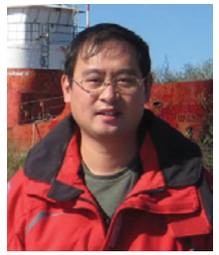
Rachel Stanley Brown, a new Assistant Scientist in Marine Chemistry and Geochemistry, was awarded $52,491 to study the carbon cycle on the Atlantic continental margin. Rachel brings a novel approach to this study—by measuring dissolved oxygen gas in sea water she is able to quantify the rate of biological production and the uptake of CO_2 by biological activity in the high productivity regions along continental margins.

A new hire in Geology and Geophysics, Assistant Scientist **Kris Karnauskus**, received $56,843 to study the connections between the tropical Pacific and tropical Atlantic climates caused by the winds. Mountain gaps in Central America direct the flow of winds from the Atlantic to the Pacific. In this manner, North Atlantic climate variability can have a great influence on tropical Pacific variability. Kris is part of a hiring initiative to expand WHOI's climate research.

Matt Charette, Associate Scientist, and his graduate student **Meagan Gonneea** in Marine Chemistry and Geochemistry are using chemical measurements on tropical shallow water corals to monitor the past history of ground water flow into the lagoon of the Pacific atoll Guam. Matt received $28,720 to test whether coral chemistry records are faithful recorders of the changes in groundwater discharge. Understanding past changes will help us better predict future changes in ground water discharge as the earth's climate warms.

Delia Oppo, Senior Scientist and **Pat Lohmann**, Emeritus Scientist in Geology and Geophysics , have teamed up to sample several long-lived corals from the Bahamas. Their goal is to produce a 440-year-long record of sea surface temperatures. Extending the records back in time provides researchers with an important view of the natural variability in the climate system and helps researchers to quantify the relative importance of natural variability and human impacts on climate today.

In the past, large discharges of freshwater from melting ice sheets played a role in changing Atlantic Ocean circulation. An interdisciplinary collaboration of **Olivier Marchal**, Associate Scientist in Geology and Geophysics, with **Jack Whitehead**, Emeritus Scientist in Physical Oceanography, will use lab-based experiments to determine the processes involved when large amounts of freshwater are discharged into a salty ocean. This understanding is crucial to predict the effects of future melting on ocean circulation.



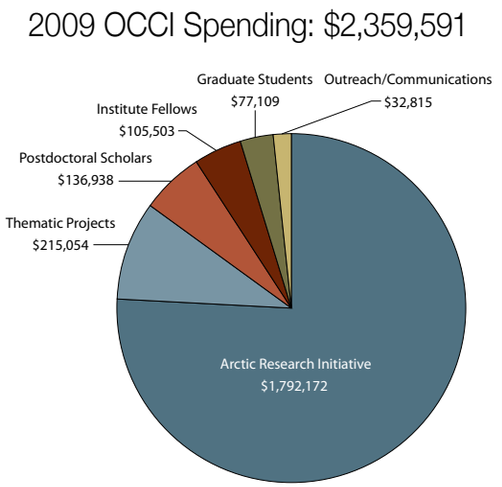
New Assistant Scientist **Aleck Wang** in Marine Chemistry and Geochemistry received support totaling $229,813 from ARI to develop and test a CO_2 monitoring system for long-term deployment in Arctic river systems. As the Arctic warms and soil permafrost melts, there is likely to be a significant release of organic carbon back into the rivers and oceans. The fate of this carbon is of concern since it represents a large potential source of CO_2 to the atmosphere.

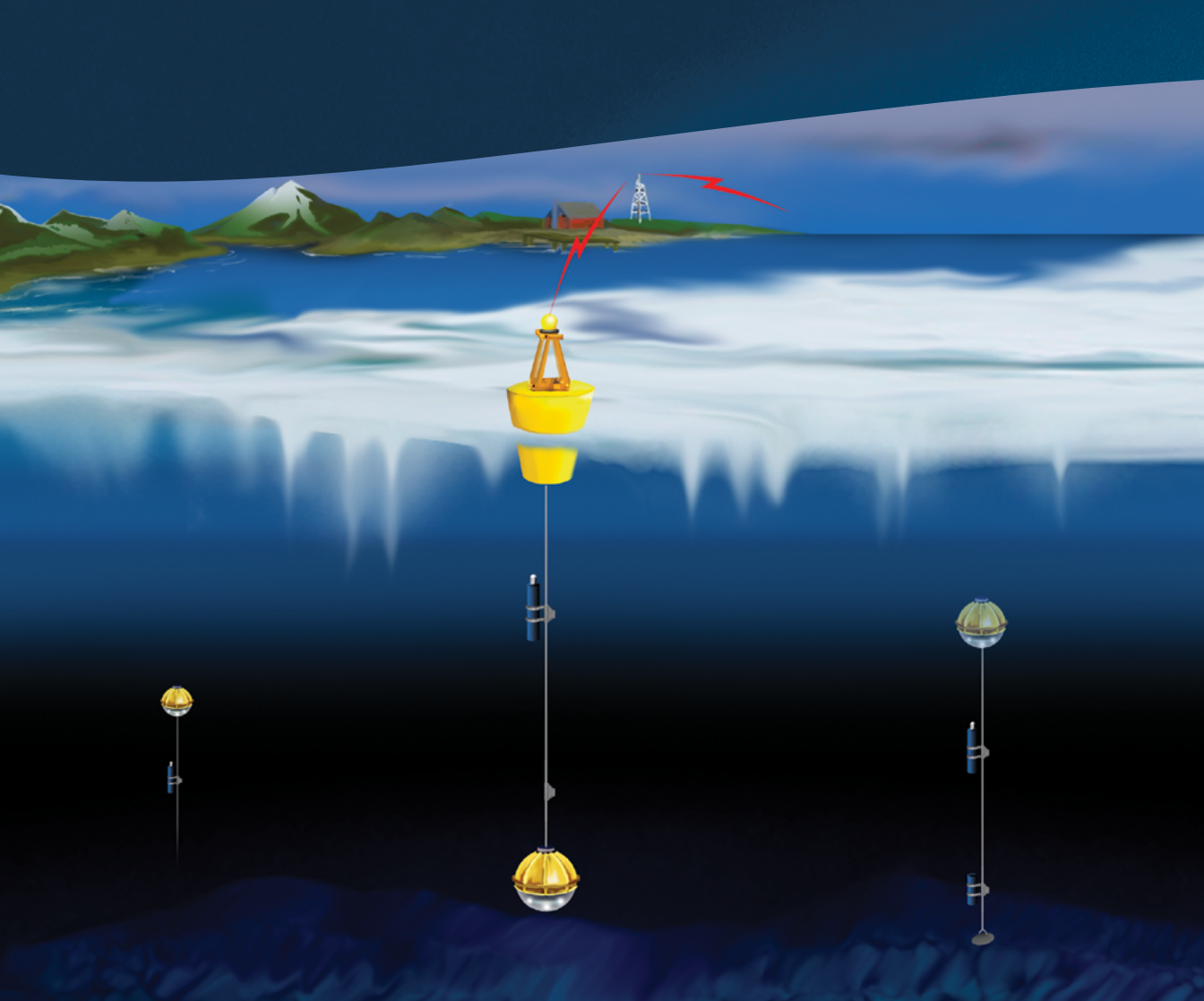
Senior Research Specialist **Ann McNichol** and Research Specialist **Li Xu** in Geology and Geophysics will be using measurements of radioisotope carbon-14 to quantify the rate of carbon input into the Canadian Basin of the Arctic Ocean. The carbon released by melting permafrost has been frozen for many millennia and so it has a distinct, low carbon-14 signature. They will make the measurements using the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) at WHOI.

Senior Engineer **Lee Freitag** and his colleague **Andrey Morozov**, Research Associate III in Applied Ocean Physics and Engineering, are working on acoustic techniques for autonomous navigation beneath sea ice when GPS and other navigation techniques are unavailable (See page 8). One of OCCI's goals is to help establish a large scale Arctic observing system with seafloor and ice tethered moorings that serve as docking locations for autonomous vehicles deployed to measure sea ice and hydrographic conditions.

Funding highlights

Although OCCI devotes most of its resources to research projects, a significant percentage supports fellowships, graduate education, and outreach activites. In 2009, OCCI supported two Institute Fellows, (Sarah Das of Geology and Geophysics and Young Oh Kwon of Physical Oceanography, PO), two WHOI Postdoctoral Scholars (Magdalena Andres and Emily Shroyer of PO) and one MIT/WHOI Joint Program graduate student (Katie Silverthorne, PO). For the first time in 2009 OCCI sponsored summer research internships for local high school students in a partnership with Falmouth Academy science teacher Joanne Muller. Based on the success of this pilot program, we plan to make this program a regular feature of the OCCI outreach program.





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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