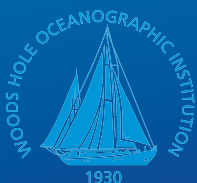




OCEAN & CLIMATE CHANGE INSTITUTE



JANUARY 2008 REPORT

Woods Hole Oceanographic Institution

Message from the OCCI Director

This past year proved to be very interesting for Earth's climate system, for climate scientists and for the Ocean and Climate Change Institute (OCCI). In September 2007, Arctic sea ice reached record low levels and appeared to be melting at a rate greater than projected by climate models. The area of summer sea ice was about 1 million square miles smaller than the average and broke the previous minimum area by 460,000 square miles (roughly the size of Texas and California) according to the National Snow and Ice Data Center in Boulder, Colorado.

This past year was also the beginning of the International Polar Year – IPY, a multi-national effort to study the changes occurring in the Arctic and Antarctic. This is the fourth IPY and the first in fifty years (others occurred in 1882-1883, 1932-1933, and 1957-1958). The most recent IPY in 1957-58 was also called the International Geophysical Year and is notable for beginning the first accurate measurements of atmospheric CO₂ at the peak of Mauna Loa in Hawaii.

A change occurred in the Ocean and Climate Change Institute as well. I returned as Director after a two and a half year hiatus. During that period, I coordinated WHOI's new Arctic Research Initiative, a \$10 million, five year program funded by a gift from the Sealark Foundation. These funds will enable the study of changes in the Arctic Ocean and surrounding land area that result from a warming planet. Since OCCI and the Arctic Research Initiative share many of the same research goals, WHOI Acting Director Jim Luyten combined ARI activities with the OCCI and named me as the Director.

With all of this activity in the Arctic, it will come as no surprise that this year's annual report highlights several



Photo of Bill Curry by Tom Kleindinst, WHOI

Arctic research projects. The first is led by Sarah Das and Mark Behn, Assistant Scientists in the Geology and Geophysics Department. Sarah and Mark are studying the Greenland Ice Sheet – in particular, the seasonal melting of the surface, the development of surface glacial lakes, and the rapid, often overnight, demise of these lakes through cracks in the ice sheet. Their research is of great importance because the melting of the ice plays a role in lubricating the base of the ice sheet, which may lead to its more rapid disintegration. The most recent IPCC report makes it clear that understanding this phenomenon is critical for accurate projections of future sea-level rise.

Our second science feature is from Bob Pickart, a Senior Scientist in the Physical Oceanography Department. Bob is studying the exchange of water between the east Greenland Current and the saltier waters of the North Atlantic. This is one likely pathway for fresh water from the Arctic Ocean and the melting Greenland ice sheet to enter and possibly disrupt the oceans overturning circulation.

Our third science feature is by Laura Robinson, an Assistant Scientist in the Marine Chemistry and Geochemistry Department. Laura is using ancient deep sea corals to reconstruct the history of deep water circulation in the North Atlantic using a variety of naturally occurring radioactive tracers. These tracers provide us with information about the past patterns and rates of ocean circulation, which ultimately affect Earth's climate.

Each of these studies will provide important information about the nature of climate change in the North Atlantic and Arctic regions as well as a better understanding of the ocean's role in the changes. Many donations to the Ocean and Climate Change Institute have significantly benefited climate change research and provided seed support to leverage further funding from the federal government. We are grateful to all involved in supporting Woods Hole Oceanographic Institution and the OCCI.

— Bill Curry

Greenland Ice Sheet

Surface melting and a slippery bottom

Should the polar ice sheets melt in response to rising global temperatures, dramatic effects are predicted in the form of higher sea-level and the alteration of ocean circulation patterns. The Greenland Ice Sheet is more than a kilometer thick in most places, and until recently, many believed that it would take over a thousand years for temperature variations at the surface to reach the bed of the ice sheet.

Recent observations from Greenland, however, suggest that ice sheets have the potential to respond much more rapidly to climate change than was previously believed. New data show that ice-flow acceleration can occur within hours or days following the onset of melting at the surface. This surprising finding suggests that meltwater might be draining through the ice sheet rather than running off the surface, thereby rapidly lubricating and warming the bed. This would result in a quicker movement of the ice sheet toward the coast and ultimately into the ocean. If we are to fully grasp the effects of increased ice melting on ice sheet flow and its effects on sea-level change, we need to understand where and how the meltwater gets to the ice sheet bed.

One mechanism that has been proposed to quickly transport meltwater from the surface to the bed of an ice sheet is the propagation of water-filled fractures beneath lakes that form annually on the surface of the ice sheet. While theoretical models suggest that the draining of supraglacial lakes through fractures in the ice is a plausible transport mechanism, water-filled cracks that reached the bed had never been observed in the thick, subfreezing ice sheets. New results in 2006 & 2007 from our National Science Foundation-funded project to study the behavior of supraglacial lakes (see *Oceanus* article: [Tracking an Ocean of Ice Atop Greenland](#)) have revealed that large lakes do in fact drain

rapidly—some in a matter of hours—through an apparent fracture-driven process (see front cover). This study represents the first glimpse into the pathways and time scales of surface-to-bed water flow.

Sarah Das and Mark Behn drilling to install a seismometer on the Greenland Ice Sheet.

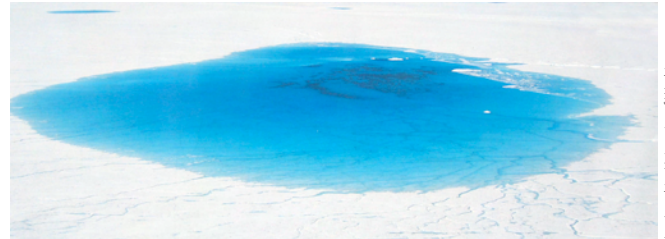


Our next step, supported by the Ocean and Climate Change Institute, will be to monitor the fracture process with field-based measurements to determine the location and timing of fracture events and test our numerical model results. To accomplish this, we have designed an observational network to measure seismicity around seasonally draining supraglacial lakes. Our experiment is designed to determine the rate and extent of water-filled crack propagation. We expect that crack propagation will be accompanied by enhanced seismicity near the crack tip.

During our field expedition in July 2007, we deployed a network of seismometers around two lakes on the Greenland Ice Sheet. We will retrieve the instruments and data in July 2008. With this seismic network we should be able to determine the strength of the “icequakes” associated with lake drainage and establish: 1) whether crack propagation coincides with drainage and 2) the location and maximum depth extent of crack penetration.

These measurements will provide some of the first direct observations of the mechanisms behind rapid meltwater transport from supraglacial lakes to the bed of the Greenland Ice Sheet. ■

—Sarah Das and Mark Behn



Ian Joughin, University of Washington

Large lakes form as ice melts and pools on the surface of the Greenland Ice Sheet. The lake shown above is 1 kilometer wide by 1.5 kilometers long. These “supraglacial” lakes drain seasonally through cracks in the ice.

Ocean Circulation

How Changes in the Arctic Affect the World's Oceans



Photo of Bob Pickart courtesy of WHOI

At the end of last summer’s melt season the Arctic ice cover was at its lowest extent since satellite observations began nearly 30 years ago. Shockingly, this is roughly 40% lower than the previous minimum, measured just two years ago. While there has been a steady decline in ice cover over the satellite record, some scientists believe that the shrinkage will continue to accelerate, leaving an ice-free summertime Arctic Ocean in a matter of decades. Although the vanishing of the ice has

garnered headlines, other high-latitude manifestations of global warming have also been observed and/or predicted, including more storms (hence more precipitation), more river run-off, increased glacier melt, and fresher input into the Arctic from the Pacific Ocean. All of these changes, in addition to the vanishing pack-ice, consistently point to an increasing discharge of freshwater from the Arctic to the Atlantic Ocean.

Consequently, there is widespread concern about the impact of this increased freshwater on the meridional overturning circulation (MOC) of the Atlantic. The MOC helps regulate our climate by bringing warm, shallow water poleward (primarily via the Gulf Stream system), which then cools and sinks at high latitudes – ultimately returning to the equator as a deep flow. The worry is that, if the open North Atlantic gets flooded with freshwater, this will inhibit the sinking (freshwater will freeze before becoming dense enough to sink) and dampen or shut down the MOC. Such an alteration of the MOC would have global consequences on our climate.

However, roughly half of the freshwater that exits the Arctic Ocean does so in a narrow boundary current known as the East Greenland Current (the other half exits through the Canadian Arctic Archipelago). Hence, in order for the freshwater to spread into the interior basin and impact the MOC, it must first be transferred off the Greenland shelf. Presently, we don't know how this will happen, how quickly it will occur, or what quantity of water will be moved seaward.

In an effort to investigate this, we deployed an array of instrumentation in Fall 2007 across the edge of the East Greenland shelf, at the spot where the outflowing Arctic water first meets the open Atlantic (see Figure 1). Here a sharp front forms between the cold, fresh Arctic water and the warm, salty Gulf Stream water. While it has been known for decades that this front is leaky, the mechanisms responsible for the exchange of water remain unknown. This is largely because these processes happen at very small spatial scales. Hence, our array was designed as a “picket fence” bracketing the East Greenland Current, with closely spaced moorings extending through the water column (Figure 2). We believe that the transfer of water happens primarily for two reasons: from inherent instability of the front (i.e., the front regularly contorts and sheds swirls of water), and because wind forces the water offshore during the winter storm season. This portion of the East Greenland Current lies along the North Atlantic storm track and is thus subject to fierce winds.

Not surprisingly, such a venture to measure the East Greenland current is not without risk. The flow of the current can reach extreme speeds that can knock down moorings. Icebergs frequent the area in spring and summer, and deep-sea trawling occurs in this region. As we set the moorings in September 2007 among a multitude of icebergs, we tried to remain optimistic about the prospect of seeing all of our gear again. However, understanding how an increased Arctic hydrological cycle will impact the North Atlantic requires that such risks be taken. Mother Nature willing, a successful outcome will provide us with some important clues for sorting out the climate change puzzle. ■

—Robert Pickart

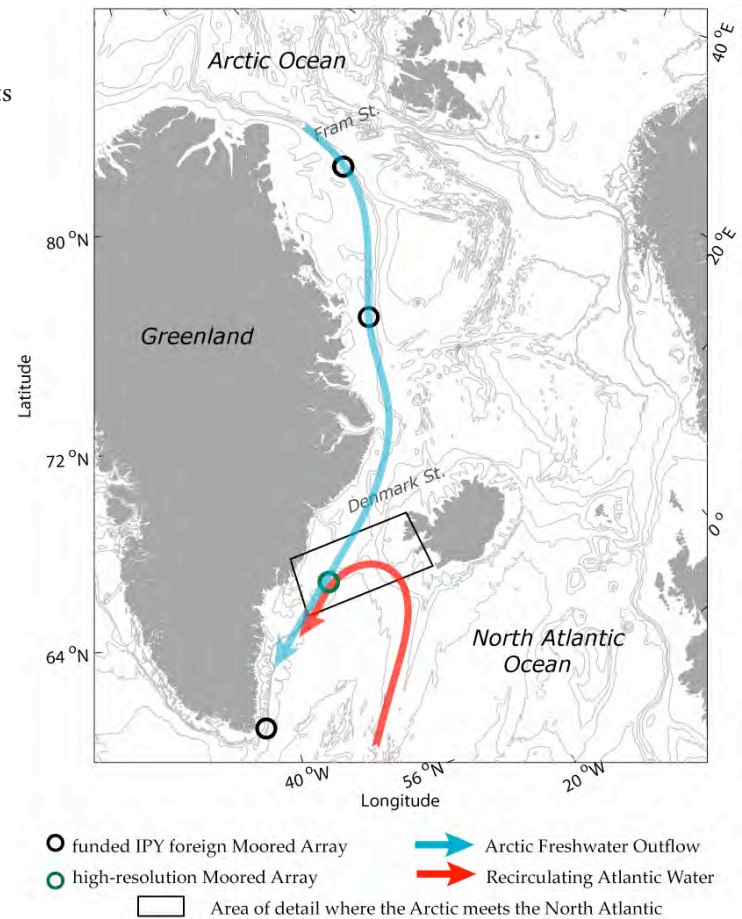


Figure 1: Schematic showing the path of the Arctic outflow in the East Greenland Current and where it meets the Gulf Stream-origin water of the Atlantic. The green circle denotes the location of the mooring array deployed in September 2007. The boxed region is the area of detail shown in Figure 2.

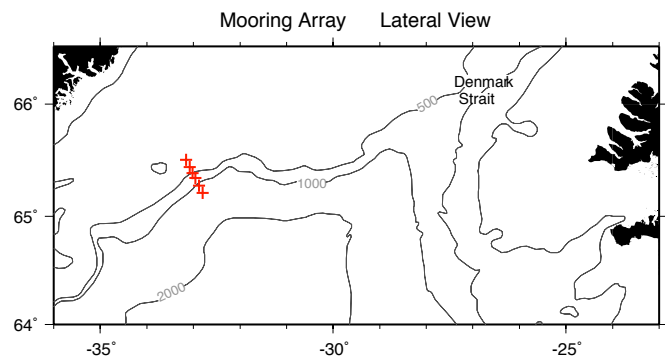


Figure 2: Configuration of the mooring array. Lateral view of the array within the detailed region of Figure 1.

Climate Records

What Corals Tell Us About the Past



Photo of Laura Robinson courtesy of WHOI

There are many species of deep-sea (also known as cold-water) corals and they live in a wide diversity of environments. For example, the solitary coral *Desmophyllum dianthus*, which has a life expectancy of about a hundred years,

can live close to the surface in high-latitude fjords and also at thousands of meters water depth in the North Atlantic. Although very little is known about the biology and ecology of these organisms, we do know enough to be able to predict the most likely locations of both living and fossil corals on the seafloor. We study the chemical make-up of fossil samples of these organisms to infer changes in deep-ocean circulation rates over tens of thousands of years, which in turn aids our understanding of how and why Earth's climate changes.

Chemicals derived from seawater are incorporated into corals, allowing their skeletons to form some of the best records of climate variability in the ocean. There have been numerous climate studies using tropical corals; however their symbiotic relationship with photosynthetic algae limits them to the warm shallow waters of the low latitudes. Luckily, some corals do not use algal symbionts and are able to live in cold or dark waters, extending their range to a global distribution. Measurements of the chemistry of these corals are important because we are interested in tracing water as it spreads through the deep ocean.

With support from the Ocean and Climate Change Institute, I am working to develop new chemical tracers of past ocean circulation. The rare earth element neodymium (Nd) proves useful for this purpose, as different water masses display distinctive Nd isotopic signatures. In collaboration with Tina van de Flierdt at Columbia University's Lamont Doherty Earth Observatory (LDEO) and using coral samples loaned to us by Stephen Cairns at

the Smithsonian Institution, we have found that Nd isotopes are not altered when incorporated into coral skeletons. We have also shown that this signature is well preserved, even in corals that are over two hundred thousand years old. Coupled with radiocarbon analyses, this new chemical tracer can now be used to improve our understanding of past ocean circulation rates in the deep ocean.

In the spring of 2008, coral biologist Rhian Waller (University of Hawaii) and I will head to the Southern Ocean on the R/V *Nathaniel Palmer* to map, image and collect deep-sea corals from the Drake Passage and the Scotia Sea. These samples will be used to determine how deep water that forms in the Southern Ocean has changed over time, and how these changes influenced deep waters in the rest of the ocean. Support from the OCCI was instrumental in securing funding from the National Science Foundation for this upcoming cruise and for my ongoing collaboration with Tina van de Flierdt. ■

—Laura Robinson



Laura Robinson, WHOI, RV Atlantis cruise AT735



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Above, deep-sea or cold-water corals such as *Desmophyllum dianthus* (pink pleated coral in the right center) provide a record of how ocean circulation has changed over time. This photo shows live coral on the New England Seamounts. Opposite page: A 40,000-year-old fossil of the same deep-water coral species. Analyzing fossil skeletons such as these enables researchers to construct climate records spanning tens of thousands of years.

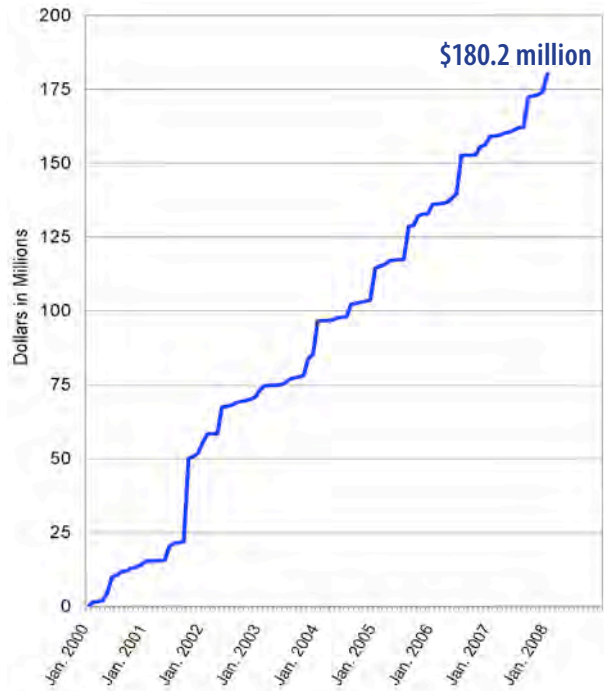
Financial update

WHOI's campaign to support the Ocean Institutes raised \$21.2 million in 2007, bringing our total to \$180.2 million. In this final year of the campaign, we are closing in on our \$200 million goal. Many thanks to all who support the Institution and its mission!

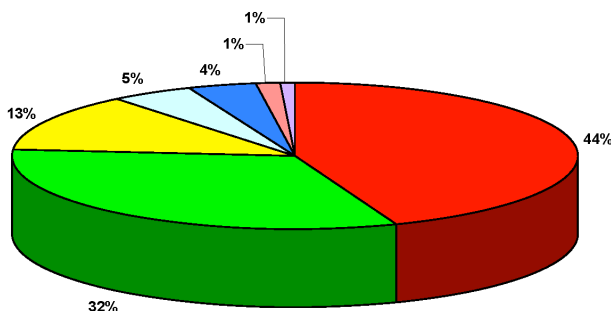
Between 2001 and 2007, the OCCI has funded numerous research projects involving 52 Scientific Staff and 15 Engineering and Technical Staff members as Principal Investigators. In addition, OCCI has supported the work of ten Institute Fellows, seven Postdocs, and three Graduate Students. A variety of workshops, conferences, seminars, and outreach activities have also been supported.

Campaign Funds Raised to Date: \$180,206,818

As of December 31, 2007



Allocation of OCCI Funds



OCCI Spending 2001-2007: \$8,732,921

- **Focused Research Initiatives**
■ \$3,856,997
- **Thematic Research**
■ \$2,817,302
- **Insitute Fellows**
■ \$1,115,879
- **Postdocs**
■ \$409,858
- **Graduate Students**
■ \$347,853
- **Other**
■ \$65,676
- **Conf., Wkshop Outreach**
■ \$119,356



About the Ocean and 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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Front cover: WHOI Assistant Scientist Sarah Das and graduate student Maya Bhatia looking down a giant crevasse in the center of a recently drained lake basin on the Greenland Ice Sheet. Photo by Ian Joughin, University of Washington. Back cover: The sun shines over the Arctic Ocean in the summer of 2007. Scientists predict there will be no ice cover during the Arctic summer by the middle of this century. Photo by Chris Linder, WHOI. Brochure design: Katherine Joyce, WHOI Graphic Services.