Ocean and Climate Change Institute
Final Report

Observing Ice Sheet/Ocean Interactions in a Greenland Glacial Fjord

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What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)

In the late 1990s glaciers in southern Greenland suddenly accelerated, thinned and retreated releasing large volumes of ice into the ocean and contributing to sea level rise. The widespread change was unexpected and unpredicted by ice sheet models. A decade later, the leading hypothesis is that the acceleration was triggered by increased submarine melting at the glaciers' edge driven by warming ocean waters. Definitive conclusions are difficult to reach, however, since we have no measurements from the glacial fjords from the period prior to the glaciers' acceleration and because our understanding of the submarine melting process is very limited. In this project we proposed to survey and deploy moored instrumentation in several of Greenland's largest glacier/fjord systems. The goal was to document, for the first time, how warm the waters in the fjords were, how quickly these waters were renewed and what mechanisms regulate the inflow of (warm) water towards the glaciers.

What have you discovered or learned that you didn't know before you started this work?

Our work showed that warmer than expected waters of Atlantic origin, carried by the Gulf Stream, penetrate deep into Greenland's glacial fjords and drive melting of the underside of the glaciers. Using moored data we were also able to show that these waters are continuously flushed through the fjords and that their properties influence the extent and distribution of melting at the ice edge.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?

The fact that warm ocean waters circulate rapidly through these fjords means that they can potentially drive a large amount of melting and, thus, supports the notion that ocean changes may have driven the acceleration and retreat of Greenland's glaciers. Our work also shows that ocean conditions near the edge of the glaciers influence how much melting and where it occurs. This, in turn, indicates that the ocean in part controls the shape of these glaciers and thus their stability.

What is the significance of this research for society?

The ice sheet/ocean connection is presently absent from climate and ice sheet models because of how little we know of how it works. This, in turn, means that we cannot accurately predict the ice sheets' contribution to sea level rise – something of great societal important. By identifying the relevant processes and mechanisms, our work is strongly contributing to model improvement and through this to our ability to interpret past and predict future sea level change.

What were the most unusual or unexpected results and opportunities in this investigation?

The OCCI grant allowed us to make use of an icebreaker of opportunity to collect some of the best available data from the vicinity of the glaciers. Here, we were surprised to find waters whose temperatures at times exceeded 41 °F – which is very warm for a glacier.

What were the greatest challenges and difficulties?

Greenland's glacial fjords are packed with mile-long icebergs that are many hundreds of feet deep. Not only is access difficult but also the icebergs pose a major threat to any instrumentation which is deployed within iceberg reach. Indeed, we have lost several of the moorings we deployed and several others were hit and dragged by icebergs to deeper waters. Also, getting measurements near the glaciers is practically impossible with a ship – since the ice pack becomes so dense that even icebreakers cannot penetrate. Thus, we developed a technique of using a hovering helicopter as a platform from which to deploy instruments near the ice edge.

When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)

We spent a month, in summer 2009, working in three major glacial fjords in East Greenland. Moorings deployed that summer were recovered using a smaller local vessel in the summer of 2010.

What were the key tools or instruments you used to conduct this research?

Because of the challenges of working near 'big ice' we used a variety of tools. These included standard hydrographic surveys (lowering an instrument from a ship) as well as moorings, to be recovered a year later, and several different kinds of probes deployed from a helicopter. Additional velocity measurements were made by lowering a velocity measuring profiler to the sea floor at every station.

Is this research part of a larger project or program?

This research contributed to an NSF funded project with which we have been able to continue our measurements (and especially mooring deployment) in on the glacial fjords we surveyed in 2009.

What are your next steps?

I have a large field proposal pending with NSF to return to the most northern one of the glaciers surveyed in 2009 which, we think, may be the next large glacier to undergo major changes. Also, we are planning to submit continued monitoring of one southeast fjord with NSF's Arctic Observing System.

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

Straneo, F., D. Sutherland, D. Holland, C. Gladish, G. Hamilton and H. Johnson, 2011: Submarine melting of Greenland's glaciers by Atlantic Waters, *Annals of Glaciology*, under revision.

Sutherland, D. and F. Straneo, 2011: Estimating ocean heat transports and submarine melt rates in Sermilik Fjord, Greenland, using lowered ADCP velocity profiles. *Annals of Glaciology*, under revision.

Andresen, C., F. Straneo, M.H. Ribergaard, A. Bjork, T. Andersen, A. Kuijpers. N. Norgaard-Pedersen, K.H. Kjaer, F. Schjoth, K. Weckstrom, A. Ahlstrom, 2011: Rapid response of Helheim Glacier, Greenland to climate variability over the last century. *Nature Geoscience*, in press.

Straneo, F., R. Curry, D.A. Sutherland, G. Hamilton, C. Cenedese, K. Väge, L.A. Stearns, 2011: Impact of fjord dynamics and subglacial discharge on the circulation near Helheim Glacier in Greenland. *Nature Geoscience*, doi:1038.ngeo1109, 4, pp 332-327.

http://www.whoi.edu/oceanus/viewArticle.do?id=73766
http://www.whoi.edu/oceanus/viewArticle.do?id=98469

Please provide photographs, illustrations, tables/charts, and web links that can help illustrate your research.

New York Times November 2010 Article
http://www.nytimes.com/2010/11/14/science/earth/14ice.html?pagewanted=all