Exploring the interactions between Greenland’s glaciers and fjords

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Introduction

The connection between oceans and ice sheets is a key coupling in the climate system, with major implications for ice loss, sea level rise, and ocean circulation. Oceanic heat drives submarine melting at Greenland’s ~280 marine-terminating glaciers, with ocean warming associated with a rapid acceleration of glacier retreat in since the early 2000s (Straneo & Heimbach, 2013). The increased freshwater discharged from the ice sheet may in turn be capable of modifying ocean with global climatic implications (Golledge et al., 2019). There remain however significant limitations in our understanding of this interaction, hindering our ability to study and simulate these systems and their evolution in the face of ongoing climate change.

One of the biggest challenges is created by the long, deep and narrow fjords that link the Greenland Ice Sheet to the wider ocean. By modulating the exchange of heat and freshwater between the ocean and ice sheet, fjord processes play a key yet poorly understood role in governing the interaction between these systems. If the impact of increasing ocean temperatures on Greenland’s glaciers is to be understood, then we need to understand how and why water temperature in glacial fjords differs from that on the adjacent continental shelf. Similarly, the impact of the ice sheet on the ocean is dependent on how freshwater entering fjords is transformed as it is transported to the shelf.

One of the key processes driving the modification of waters in Greenland’s fjords is the input of freshwater from marine-terminating glaciers. Surface meltwater runoff cools and freshens the upper layers of fjords, whilst submarine melting of glaciers and icebergs injects freshwater at depth (Davison et al., 2020). Most spectacularly, subglacial runoff draining along the bed of marine-terminating glaciers drives powerful buoyant plumes at glacier termini, upwelling warm, deep waters (Jackson et al., 2017; Slater et al., 2022). Constraining the individual and combined effects of these processes on fjord water properties is a key step towards achieving a better understanding of ice sheet / ocean interaction in Greenland.

Research questions

- How do water properties vary within and between Greenland’s fjords, and between the fjords and the continental shelf?
- To what extent can these differences be explained as a function of plume mixing, ice melt and surface runoff?
- How does this modification affect ice sheet / ocean interaction?

Icebergs and meltwater plumes visible at Kangiata Nunata Sermia, a marine-terminating outlet glacier in southwest Greenland (Photo: Pete Nienow)
Methods

The project will utilise a broad suite of methods, including extraction and processing of oceanic, climatic and glacial data from existing databases, numerical modelling of plume processes, analysis of hydrographic observations, and the use of remote sensing to collect bespoke observations (e.g. of iceberg concentration) as required.

Firstly, the study will utilise the widely available conductivity-temperature-depth (CTD) observations from NASA’s Ocean’s Melting Greenland (OMG) project to explore the spatial variation of water properties within and between Greenland’s fjords, and between the fjords and the continental shelf. These differences will be evaluated against variables such as fjord geometry, glacial meltwater inputs and iceberg density to provide an assessment of the key controls on this modification.

Following this, the project will seek to identify the extent to which this modification can be explained as a result of subglacial runoff, surface runoff and ice melt, each of which has a distinct impact on temperature and salinity properties. This will provide an improved understanding of the nature and drivers of fjord water modification, and a pathway to incorporating these impacts in studies of ice sheet / ocean interaction. The final phase of the project is then to evaluate the implications of these findings for ice sheet / ocean interaction. There is flexibility as to what direction this could take: one possibility would be to examine which of Greenland’s glaciers might be expected to be more/less sensitive to ocean-driven melting once fjord water modification has been taken into account, combining the outcomes of the first two phases with Greenland-wide databases on fjord and glacier properties.

Training

The student will develop the skills necessary to undertake the data analysis outlined in the project description, supported by an annual Research Training and Support Grant of £750. This will be delivered primarily through in-house expertise, with the opportunity of attending external training courses as required. The project will run alongside a larger NERC funded project on a related theme, and the student will benefit from the experience of working as part of a larger team spanning several institutions. Further training in transferable skills, including project management, oral and written presentation and media and outreach engagement is available through the Centre for Educational Enhancement and Development (CEED) at the University of St Andrews. The student will be expected to present their work at appropriate national and international conferences throughout their PhD research.

References


