Submarine Melting and Freshwater Export in Greenland's Glacial Fjords: The Role of Subglacial Discharge, Fjord Topography and Shelf Properties

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Increased submarine melting of Greenland's glaciers has emerged as a plausible trigger for their recent acceleration and for quadrupling Greenland's contribution to sea level rise from 1992-2000 to 2001-2011. Notwithstanding its importance, our understanding of submarine melting is limited and it is presently absent or crudely parameterized in glacier, ice sheet, and climate models. Ocean models are beginning to include freshwater discharge from Greenland, but where and when this freshwater enters the continental shelves is largely unknown. Understanding the dynamics that govern both submarine melt and freshwater fluxes, including their magnitude and spatial distribution, is a key step in projecting sea level rise and the consequences of the Greenland-induced ocean freshening.

Intellectual merit

The exchange of heat and freshwater between the ocean and Greenland's outlet glaciers, typically grounded hundreds of meters below sea level, occurs at the head of long, deep fjords that connect the ice sheet margins to the continental shelves and the large-scale North Atlantic circulation. Recent work by the PIs, and others, has shown, for several idealized or specific cases, that the fjord's temperature and stratification, as well as the summer discharge of surface melt at the base of the glacier (subglacial discharge) have a first order impact on the magnitude, distribution, and timing of submarine melting. We propose to generalize these results by formulating parameterizations, suitable for large-scale ice sheet and climate models, of submarine melting and associated freshwater export distributions as a function of large-scale controls. Specific tasks are:

- Establishing dynamical links between submarine melting, and the associated freshwater export from the glacier, and its dominant controls, which include: the magnitude and spatial distribution of subglacial discharge; hydrographic properties and stratification on the continental shelf; and fjord size and topography, in particular the presence and height of a sill.
- Formulating two complementary parameterizations: one for the magnitude and spatial distribution of submarine melting as a function of the fjord's topography and size, the shelf stratification and the subglacial discharge, to be used in glacier and ice sheet models; and one for the magnitude and vertical distribution of the freshwater export from the fjords to be used in large-scale ocean and climate models which do not resolve the fjords.

This project involves the analysis of existing data, laboratory experiments, and high-resolution numerical simulations. It will be carried out in collaboration with two international experts: a glacial hydrologist (I. Hewitt, U. of Oxford) and a fjord oceanographer (L. Arneborg, U. of Goteborg). The work is aimed at understanding a newly discovered 'wiring' of our climate system and is timely because of the large and unanticipated changes that are occurring at Greenland's margins. It is complementary to the study of ice sheet/ocean interactions around Antarctica (the more studied of the two) since both the large-scale ocean circulation and the presence of narrow, long fjords in Greenland contribute a unique set of relevant dynamical mechanisms.