Investigating tidewater glacier and iceberg submarine melt rates in Greenland's fjords

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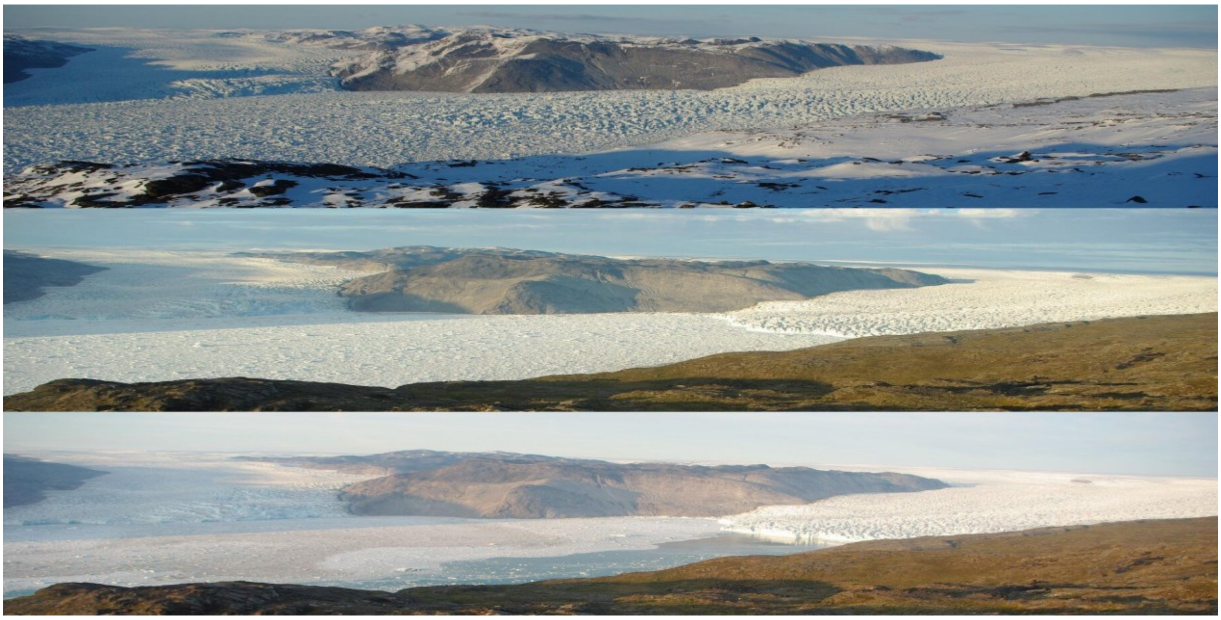

Project background

An improved understanding of the processes controlling the dynamics of the Greenland Ice Sheet (GrIS) is needed if the response of the ice sheet to predicted climate change is to be more accurately determined. Recent observations indicate that the GrIS is losing mass at ~375 Gt yr^{-1} and that the rate of loss is accelerating (van den Broeke et al, 2009; Rignot et al, 2011; Helm et al, 2014). This increase in mass imbalance is attributed to marginal thinning resulting from increased rates in both surface melting and ice motion. Mass loss through the acceleration and dynamic thinning of tidewater glaciers has risen dramatically over the last two decades (e.g. Howat et al, 2005; Rignot and Kanagaratnam, 2006; Rignot et al, 2011) with implications for the long-term stability of the GrIS. However, the precise mechanism(s) responsible for the observed dynamic thinning remain equivocal including the extent to which the forcing is driven by atmospheric and ocean processes.

Proposed marine mechanisms for dynamic thinning include the effects of a reduction in the resistance to ice flow presented by the thinning or collapse of a floating ice-shelf, or glacier retreat and ungrounding (Straneo and Heimbach, 2013). There is increasing evidence pointing to the significance of submarine melting of tidewater glaciers in inducing frontal instability (Holland et al, 2008; Rignot et al, 2010). Critical to the rate of submarine melting is both the temperature of the fjord waters at the ice front and the speed at which these waters flow along the ice front. An increase in flow rate and/or water temperature will enhance submarine melting with implications for ice motion and dynamic thinning. However, obtaining estimates of submarine melt rates is extremely difficult due to the inaccessibility and instability of tidewater glacier margins. As a result, estimates of melt rates are typically derived from either modelling studies using fjord water circulation models (e.g. Xu et al, 2013) or from hydrographic surveys that estimate energy fluxes to the tidewater glacier front (e.g. Inall et al, 2014). Both methods have their limitations which include model parameterisations and the fact that hydrographic surveys are often conducted at a considerable distance from the front of the tidewater glacier ensuring that measurements may be poorly related to the energy exchange actually occurring at the ice front.

This proposal aims to use an alternative methodology to estimate the potential rates of tidewater glacier submarine melting. The winter melange that builds up in front of many tidewater glaciers and the large icebergs calved by glaciers provide an opportunity to measure submarine melt rates. If the rate of surface lowering of the melange and/or of large bergs can be measured through time, then average rates of submarine melting can be derived. Such estimates should be more accurate in the winter months, when lowering by surface melt can be neglected, but can also be estimated if submarine melt rates are an order of magnitude greater than surface melt rates, which numerous studies suggest they are. A recent proof of concept of this methodology (Enderlin and Hamilton, 2014) suggested that monitoring of large bergs using remotely sensed data generated estimated melt-rates of ~0.39 m d^{-1} in Sermilik Fjord. This project seeks to extend this work by determining how melt-rates vary both along fjord during different periods of the annual melt-regime and between different fjords along a transect extending up the east coast of Greenland where there is evidence that offshore shelf waters have experienced considerable temperature change in recent years. The estimates of along fjord melt-rates will be compared with melt-rates derived from fjord circulation models associated with an ongoing NERC grant.

Aims and Methodology

The aim of this project is to investigate the variations in iceberg melt rate in Greenland fjords in order to derive estimates of submarine melt-rates at tidewater glacier margins. More specifically the research will determine how iceberg melt-rates vary i) along fjords during different periods of the annual melt-regime; and ii) between fjords along a transect extending up the east Greenland coast. The melt-rates will be compared with modelled estimates of melt derived from an MITgcm fjord circulation model, which incorporates the effect of how changes in glacial runoff impact fjord circulation rates, water temperatures and thus iceberg melt rates. Surface elevation change of icebergs and ice melange will be derived, through the differencing of DEMs derived from satellite imagery, both along fjords and between different time-periods in order to obtain a spatial and temporal record of iceberg melt-rates. These data will be analysed to determine the extent to which melt-rates vary seasonally and between fjords, and in conjunction with modelling, will be used to determine the factors controlling iceberg and tidewater glacier melt-rates.

Research training and student requirements

We seek an enthusiastic student with a suitable undergraduate and/or Masters Degree equipped with quantitative skills in earth sciences, remote-sensing, physical geography, engineering, physics or mathematics. The student will be a key component of a research team involved in an ongoing project investigating the dynamic behaviour of Greenland's outlet glaciers and the role of meltwater runoff in controlling tidewater glacier dynamics through its effect on fjord circulation and submarine melt rates. A comprehensive training programme will comprise both specialist scientific training and generic transferable and professional skills linked to Edinburgh's E^3 NERC funded DTP. They will receive training and develop expertise in analysing a variety of remotely sensed imagery (e.g. TanDEM-X, CryoSat, IceSat, ASTER, Pleiades, SPOT5). There is the expectation that the student will visit Greenland to set up time-lapse imagery of a tidewater glacier melange to calibrate the satellite results. The student will be expected to present their findings at conferences, publish their results in high impact journals and will be encouraged to participate in international summer schools in glaciology.

Project Summary

This project will investigate temporal and spatial variations in iceberg melt rates in Greenland fjords in order to derive estimates of submarine melt-rates at tidewater glacier margins.

Key references

Enderlin, E. and Hamilton, G. 2014, Estimates of iceberg submarine melting from high resolution digital elevation models: application to Sermilik Fjord, East Greenland. *J. Glac.*, **60**(224), doi: 10.3189/2014JoG14J085

Straneo, F. and Heimbach, P. 2013, North Atlantic warming and the retreat of Greenland's outlet glaciers, *Nature.*, 504, pp36-43, doi:10.1038/nature12854.