EARTHSCIENCES

Tidewater glacier mass-loss mechanisms in Northwest Greenland

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Key words:	Ice-ocean interactions, tidewater glaciers, subglacial hydrology, Greenland Ice Sheet
Research theme(s):	• Geophysics and Geodynamics • Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP) • Intelligent Earth (UKRI CDT)

This project is well suited for a researcher interested in glaciology, ice-ocean interactions, data analysis, and numerical modelling, who has a background in earth science, physics, computer science, or related fields. Prior fieldwork experience and/or prior research in glaciology is not expected, nor is such experience required as a prerequisite for successfully completing this project!

Overview

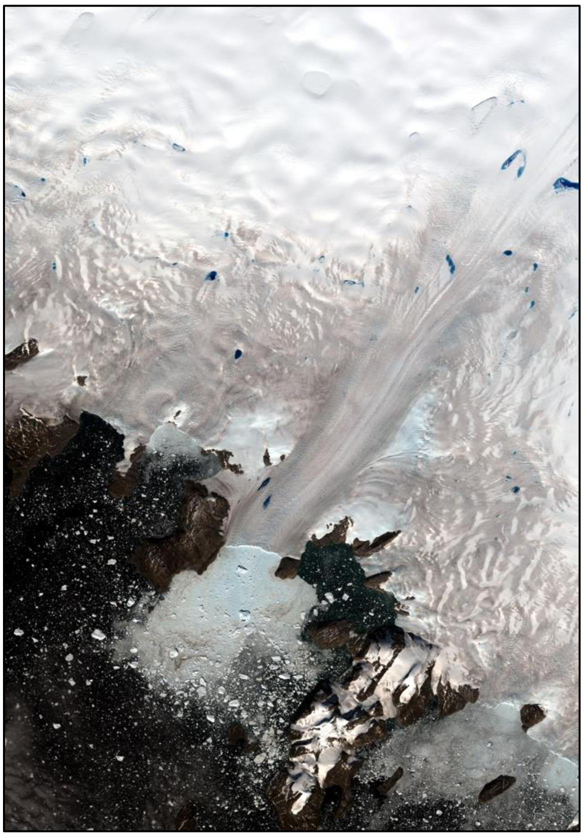
The Greenland Ice Sheet is currently the leading ice-sheet contributor to sea-level rise. Focused research, starting in the mid 2000's, has concluded that the two main driving forces of this mass loss are (1) increased surface melting in the ice sheet's land-terminating southwestern region [*Enderlin et al.,* 2014], and (2) warm, ocean currents in the south-eastern and western regions driving iceberg calving at tidewater-glacier termini [*Straneo & Heimbach,* 2013].

The Northwest Greenland Ice Sheet (NWGIS) experiences little surface melt and terminates in among the coldest ocean water in all of Greenland. Thus, we would expect some of the lowest rates of mass loss in NWGIS relative to other sectors. What we observe is that NWGIS has contributed the most to sea-level rise of any sector from 1972–2018 [*Mouginot et al.,* 2019]! The magnitude and acceleration of NWGIS mass loss indicates that there are rapid mechanisms for mass loss that we do not yet understand. Targeted research on the NWGIS is required to fill in knowledge gaps on the mechanisms at work in Northwest Greenland, and the mechanisms that lead to ice-sheet mass loss globally.

Most NWGIS mass loss occurs dynamically through calving, but we lack a solid explanation for whether ocean-driven or atmospheric-driven processes cause this mass loss [*Slater & Straneo,* 2022]. To tackle this knowledge gap, this research project will bring together observations of glacier calving events, modelled estimates of ice-sheet surface runoff, and numerical modelling of the subglacial drainage system to test the hypothesis that NWGIS tidewater glaciers *can* retreat rapidly under low oceanic thermal forcing, if the basal drainage system releases water in a way that facilitates calving. The hypothesis that we will test contrasts with earlier tidewater-glacier retreat hypotheses that rely on warm ocean currents driving high rates of calving and submarine melting [*Straneo & Heimbach,* 2013].

Finally, a fundamental challenge in our ability to predict tidewater glaciers' dynamic, future response to increased atmospheric and oceanic warming is quantifying and understanding mass-loss mechanisms at work today. The work of this research project will fill in our knowledge gap on mass-loss mechanisms at work today, which, in turn, will enhance our ability to predict mass loss for the full Greenland Ice Sheet in future decades.

European Space Agency Sentinel-2 image of Kong Oscar Glacier, Northwest Greenland:



Methodology

The student will use numerical modelling and remotely sensed observations to understand processes controlling mass loss at tidewater glacier calving fronts, and, specifically how the movement of water through the subglacial drainage system of fast-flowing outlet glaciers may promote calving. This project will involve analysing timeseries of iceberg calving events (via satellite imagery and glacial-earthquake records) [*Olsen et al.,* 2021] and remotely sensed glacier velocities for two Northwest Greenland outlet glaciers: Kong Oscar Glacier and Upernavik Isstrøm–North. By project's end, the student will fully integrate the data-analysis and modelling project components to directly quantify and link atmospheric and oceanographic forcing to mass-loss mechanisms occurring at these two tidewater glaciers.

Timeline

Year 1: NERC DTP Core Training Programme; literature survey; initial data analysis of terminus positions, glacial earthquake records, and satellite remote sensing of supraglacial-lake-drainage timing; presentation of research at a national conference (e.g., International Glaciological Society–British Branch).

Years 2 and 3: Integration of data analysis with subglacial hydrology modelling and further analysis of remotely sensed outlet velocities; presentation of research at international conferences (e.g., EGU, International Glaciological Society Symposium).

Year 4: Final integration of data-analysis and modelling project components; thesis completion; write papers for international journals; presentation of research at an international conference (e.g., AGU).

Training & Skills

The supervisory team are leaders in observational and numerical investigations within the fields of ice-glaciology (L. Stevens) and physical oceanography (H. Johnson). As part of this project, you will learn how to analyse multiple different types of glaciological data, including satellite imagery, glacial earthquake records, and observations of glacier flow. The data analysis and interpretation will involve collaborations with faculty, postdoctoral scientists, and graduate students in the UK, Denmark, and US. You will also be trained in the use of sophisticated computational modelling techniques that enhance our understanding of subglacial-hydrology processes and glacier calving. You will receive training and guidance on how to interpret and synthesize observational data alongside model output, how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

Enderlin et al. (2014), An improved mass budget for the Greenland Ice Sheet. *Geophys. Res. Letts.,* 41, 866–872.

Mouginot et al. (2019), Forty-six years of Greenland Ice Sheet mass balance from 1972 to 2018, *Proc. Nat. Acad. Sciences,* 116, 9239–9244.

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Stevens et al. (2021), Helheim Glacier diurnal velocity fluctuations driven by surface melt forcing. *J. Glaciology,* 1–13.

Stevens et al. (2022), Tidewater-glacier response to supraglacial lake drainage, *Nature Comms*. 13:6065.

Straneo & Heimbach (2013), North Atlantic warming and the retreat of Greenland's outlet glaciers, *Nature,* 504, 36–43.

Further Information

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