The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

Stress transmission between neighbouring Greenland supraglacial lakes from geodetic observations

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Key Words	**Glaciology, Geophysics, Geodesy**

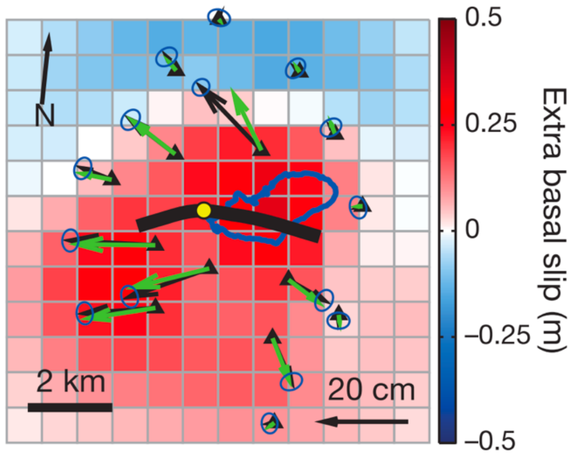
Overview

Mass loss from the Greenland Ice Sheet is accelerating, partly due to increases in the rate at which ice flows out to the ocean [*King et al.*, 2020]. Ongoing increases in the magnitude and spatial extent of surface melting play a complex role in this process: meltwater flows down through hundreds of meters of ice to the ice-sheet bed, lubricates the ice-bed interface, and modulates ice flow speeds on hourly to decadal timescales. As the area of the ice surface that endures melting continues to expand inland as the climate warms [*MacFerrin et al.*, 2019], a leading question is: *Will a larger area of the ice sheet receive injections of meltwater, and, if so, will this lead to faster flow?*

Although it is possible for water to hydro-fracture to the bed through thick, cold ice [*Das et al.,* 2008], whether it happens in any particular location is controlled by the stress state of the ice [*Stevens et al.,* 2015]. For example, it is currently unclear how vulnerable the thicker, inland regions of the ice sheet are to hydro-fracture. While it has been hypothesized that surface-to-bed meltwater injection in the ice-sheet interior could destabilize significant regions of the ice sheet [*Alley et al.*, 2005], this has not been tested by targeted observations. Answering the question of whether, and when, the Greenland Ice Sheet interior will *dynamically* respond to surface melt is vital for predicting future sea-level rise [*Meredith and Sommerkorn*, 2019].

To tackle this question, a deeper understanding of the processes involved in getting surface meltwater to the bed is required. Rapid drainage of supraglacial lakes generates new surface-to-bed meltwater pathways [*Das et al.*, 2008]. The expanding range of supraglacial lakes has been tracked in satellite imagery over recent decades [*Howat et al.*, 2013]. However, the locations of emerging inland lakes may not correlate well with where the meltwater stored in the lakes reaches the bed [*Stevens et al.*, 2015]. Currently, rather than rapidly draining to the bed, inland lakes mostly drain supraglacially for 10s of kilometres, before entering lower-elevation, pre-existing surface-to-bed pathways [*Poinar et al.*, 2015].

A fundamental challenge in predicting the ice sheet's dynamic response to the formation of upper-elevation supraglacial lakes is quantifying ice stresses in basins of nascent lake formation. Are stresses in these basins large enough to promote crevasse formation and trigger drainage of lakes to the bed? And, are these stresses influenced by drainage of neighbouring lakes?



GPS displacements (green arrows from black triangles) and Network Inversion Filter-calculated extra basal slip (colorbar) during the rapid drainage of a single supraglacial lake [Stevens et al., 2015]. Moulin location, last known lake shoreline, and hydro-fracture surface trace are shown as a yellow circle, blue line, and black line, respectively. A project goal is to determine how stress is transmitted between neighbouring lake basins during the drainage of one or more lakes.

Methodology

The student will use field observations and numerical modelling to understand processes controlling the penetration of water to the ice-sheet bed in regions of emerging supraglacial lakes. This project will involve field work on the Greenland Ice Sheet with US collaborators to collect timeseries of ice-sheet surface displacements from an array of on-ice GPS receivers in the vicinity of a set of lakes and moulins in West Greenland. GPS-derived measurements of ice-sheet surface strain will be used to investigate stress transients in neighbouring supraglacial lake basins in the mid- to upper-ablation zone of the ice sheet. The student will use high temporal resolution (seconds) GPS data to determine the drainage characteristics of populations of neighbouring lakes. Finally, the student will ideally incorporate inverse and/or forward modelling techniques [*Stevens et al.,* 2015; 2018] to test interpretations of field data.

Timeline

Year 1: NERC DTP Core Training Programme, initial data analysis of preliminary GPS data, field work training and preparation, Greenland field work campaign.

Years 2 and 3: GPS data processing, GPS data analysis, GPS inverse modelling and/or subglacial hydrology modelling, presentation of research at international conferences (EGU, IGS).

Year 4: Integration of GPS and modelling project components, thesis completion, papers for international journals, presentation of research at an international conference (AGU).

Training & Skills

The supervisory team are leaders in observational glaciology (L. Stevens) and mathematical models applied to glaciers and ice sheets (I. Hewitt).

As part of this project you will learn how to collect, process, and analyse GPS data from an ongoing ice-sheet field work campaign. The field campaign, data analysis, and data interpretation will involve collaborations with researchers and graduate students in the US. You will also be trained in the use of inverse and forward modelling techniques that enhance our understanding of ice-sheet fracture and subglacial hydrology processes. You will receive training and guidance on how to analyse and interpret data and model output, how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

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Further Information

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This project is well suited for a student interested in glaciology, data analysis, numerical modelling, and/or field work with a background in geosciences, physics, or computer science. Prior field work experience is not required, nor is participation in the Greenland field work campaign.