Retreating glaciers and carbon-cycle feedbacks

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Key words:	Glacier and cryosphere hydrology; weathering; carbon cycle
Research theme(s):	Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP) • Intelligent Earth (UKRI CDT)

Overview

Ongoing climate change is causing profound change to the cryosphere. In particular, rising temperatures and changing ice-melt and precipitation patterns drive glacier retreat, exposing new land surfaces to the atmosphere and changing the pathways and residence times of water beneath glacial systems (Moon et al., 2018). One consequence of these large-scale, glacier-margin reconfigurations is that recently exposed rocks can be subject to rapid chemical weathering. The resulting cascade of reactions can release CO_2 and trace elements into the atmosphere and hydrosphere. In addition to ongoing and future change, these processes are likely to act over Earth's history, when deglaciation may have influenced the carbon cycle and metal export to the oceans as continental scale ice sheets waxed and waned.

Despite this recognition, the impacts of deglaciation on changing weathering fluxes remain largely obscured. Of particular relevance are the oxidation of sulfide minerals, which can produce acidity, trace metals and act to release CO_2 to the atmosphere. In addition, sedimentary rocks exposed by deglaciation may release CO_2 to the atmosphere they are exposed. These rocks are also subject to physical weathering processes and biogeochemical reactions which can lead increased oxidative weathering and CO_2 release as temperatures warm (Walsh et al., 2024). Moreover, in terms glacial hydrological drivers of carbon-cycle feedbacks, while sophisticated computational models of subglacial water flow along the beds of glaciers and ice sheets exist (e.g., Stevens et al., 2022), these models require further development to track geochemically relevant quantities.

This project will provide much needed insight by fusing the geochemical and glaciological drivers of carbon-cycle feedbacks and accelerated CO_2 release in deglaciating environments. The research will focus on how deglaciation impacts fluid residence time and water-rock interactions beneath glaciers. The work will also consider the glacial foreland and how time-dependant weathering reactions influence the production and delivery of weathering products. Finally, this project will consider direct carbon cycle impacts, in addition to the delivery of co-hosted metals which can act as nutrients and pollutants in downstream ecosystems.

Figure showing (left) deglaciating landscape in New Zealand, and (right) example of how physical weathering processes produce large amounts of rock debris that can be full of pyrite and rock organic matter.

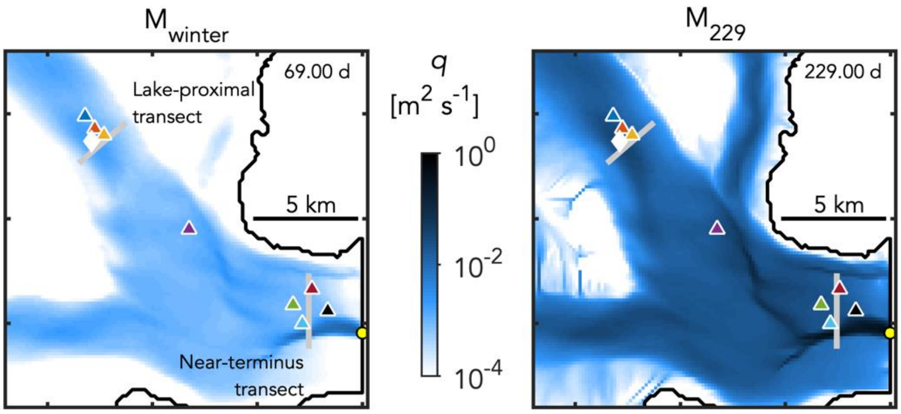

Figure showing modelled subglacial drainage system beneath Helheim Glacier, East Greenland, in (left) wintertime and (right) the late melt season (Stevens et al., 2022). Colormap shows subglacial discharge (q) flowing along the bed of the glacier. Provided as an example of hydrological-modelling approaches that could be expanded to track and assess geochemical processes in the subglacial environment.

Methodology

The project will use a combination of methods to achieve its objectives, which can be tailored to fit the exact interests of the applicant. These methods will include computational methods to quantify glacial hydrology and water residence times in glacial systems; geospatial techniques to quantify glacier change; geochemical datasets and model-data validation; fieldwork and sample network design; geochemical analysis of waters and gases.

Timeline

Year 1: Training in key numerical, geochemical, and computational modelling techniques. Project design, literature review and data collation and collection.

Years 2 and 3: Continued advanced training in core methods and computational modelling development and validation; initial writing of papers for international journals; presentation of research at a national conference.

Year 4: Data integration, thesis completion, writing papers for international journals; presentation of research at an international conference.

Training & Skills

The supervisory team are leaders in observational geochemical (B. Hilton) and observational and numerical glaciology (L. Stevens). As part of this project, you will learn numerical methods; data processing; geochemical analyses; research project design; and computational modelling of subglacial-hydrology processes. You will receive training and guidance on core academic skills of how to analyse, interpret, and synthesize observational data and model output, how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

Moon et al. (2020), Rapid reconfiguration of the Greenland Ice Sheet coastal margin, *Journal of Geophysical Research: Earth Surface.* 125(11). e2020JF005585.

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

Walsh, Hilton, Tank, & Amos (2024), Temperature sensitivity of the mineral permafrost feedback at the continental scale, *Science Advances*. 41, DOI:10.1126/sciadv.adq4893

Further Information

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