Seismoelectric exploration of an englacial aquifer on the Greenland Ice Sheet

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Helheim Glacier is a major outlet glacier that drains a large catchment in the southeastern sector of the Greenland Ice Sheet. Over recent years, its ice discharge has increased and it is now the second-largest contributor to global sea level from the Greenland Ice Sheet. Mounting evidence suggests that a complex hydrologic system in the upstream portion of the catchment feeds subglacial water to the main trunk of Helheim Glacier and thus plays a crucial role in ice dynamics. This area contains a large englacial aquifer that drains to the bed through anomalously large crevasses. This system likely gives rise to heterogeneous subglacial water patterns that change ice flow seasonally and over multiple years.

This presentation concerns upcoming fieldwork, to be executed in July 2022. Our work will use seismoelectric (SE) methods to sense the englacial firn aquifer, which lies ∼20 meters beneath the surface of the glacier, and the crevasses that this aquifer water feeds, which we hypothesize penetrate the full ∼500 – 1000 meters to the base of the ice sheet. Application of SE to glaciers is rare to date, with only one study on an alpine glacier published [Kulessa et al., 2006].

We apply a **seismic** source near the surface of the ice, then measure the **electric** response that the seismic waves induce at an interface with any charged or partially charged material – importantly, englacial water. Symmetrically aligned electrode pairs installed at the surface measure the returning electromagnetic wave. The time series of received voltage magnitudes are used to infer the variation of hydraulic conductivity with depth in a typical "layer cake" geophysical inverse problem. Seismoelectric is superior to ground-penetrating radar (GPR) for our application, as GPR is limited to sensing the top surface of the aquifer (the water table), whereas SE can sense both the top and bottom interfaces of the aquifer and can infer its total water content and porosity. Existing airborne GPR data from NASA's recent Operation IceBridge, alongside new data from phase-sensitive ground-based radar (ApRES) deployed by our collaborators, will complement our SE measurements and validate the water table depth.

Kristin Poinar and Erasmus Oware of the University at Buffalo deploying a seismoelectric test at Taku Glacier, Juneau Icefield, Alaska in 2019. The seismic source (akin to a Buffalo gun or a Betsy gun) detonates ∼1.5 meters below the surface of the ice and sounds the englacial environment to hundreds of meters depth.

Our secondary goal is to use SE to resolve vertical features, namely the water-filled crevasses at the downstream end of the aquifer. The geometry makes this a significantly more challenging problem, but the outcome – the depth of propagation of these crevasses – would provide crucial, first-ever field measurements of whether the firn aquifer water connects to the subglacial system, where it can affect ice flow.

The overall goals of the field work are to measure the quantity and fluxes of englacial water inside the Helheim Glacier firn aquifer and constrain its discharge rates to the bed via crevasses. This will contribute toward narrowing uncertainties in seasonal and multi-year ice dynamics of the glacier.

References

B Kulessa, T Murray, and D M Rippin. Active seismoelectric exploration of glaciers. *Geophysical Research Letters*, 33(7), 2006. URL `http://doi.org/10.1029/2006gl025758`.