Geophysical Research Abstracts
Vol. 20, EGU2018-8557, 2018
EGU General Assembly 2018

Subglacial Sediment Characterisation using Analysis of Seismic Surface Waves

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Subglacial hydrology exerts a substantial control on the flow dynamics of glaciers and ice masses. Subglacial water influences ice flow by modulating basal friction, the strength of subglacial sediments and their potential then to deform. Geophysicists have developed a range of glacio-geophysical methods for investigating the character of subglacial drainage systems: seismic reflection, refraction and ground penetrating radar (GPR). However these conventional techniques can often experience problems for measuring material properties beyond the immediate vicinity ($\sim$2 m) of the glacier bed.

This paper applies the seismic technique 'Multichannel Analysis of Surface Waves' (MASW) to the exploration of the subglacial sediment, to a greater depth than is often practical with conventional methods. MASW is sensitive to changes in the velocity, Vs, of seismic shear waves; a small amount of unfrozen water in sediment pores can lead to large decreases in Vs. Therefore the Vs profile provides useful information on water content and degree of freezing in sediment pores.

Active source seismic and GPR lines were acquired around the frontal margin of the glacier Midtdalsbreen, an outlet of the Hardangerjøkulen ice cap, in spring 2017. A 200 MHz GPR survey was used to constrain ice thickness of the glacier (to a maximum of $\sim$70 m) to support the MASW analysis and Vs inversion. A Vs profile of the glacier and its subglacial sediments, extending to $\sim$40 m depth, was obtained from this analysis. The profile showed low Vs zones (600-800 m/s) directly underlying the glacier bed, suggesting unfrozen and unconsolidated till within the sediment package. These data match well synthetic MASW responses for ice overlying unfrozen/wet subglacial sediments. Results from this test survey show promising use of surface wave analysis for improving the understanding of liquid water content within the subglacial sediments. A return to Midtdalsbreen in 2018 will complement MASW acquisitions with electromagnetic data, to constraint the electrical conductivity of sediment.