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Investigating seismic properties of the NEGIS onset region using ice-drilling noise as a seismic source

Charlotte Schoonman[1], Olaf Eisen[1], Coen Hofstede[1], Nicolas Stoll[1], Steven Franke[1], and Emma C. Smith[2]
[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany (charlotte.schoonman@awi.de)
[2]School of Earth and Environment, University of Leeds, Leeds, United Kingdom

Investigating the physical conditions underlying and enabling fast glacier flow is crucial to understanding the future stability of ice sheets, as well as their impact on future sea-level rise. Seismic surveys have been widely used to measure material properties of the ice and substrate, including seismic velocity structure, anisotropy, and bed properties. While traditional seismic surveys rely on natural seismicity or man-made sources such as explosives, anthropogenic noise generated through ice-core drilling can also be used as a seismic source. Placing geophones around an ice-core drilling site therefore presents an exciting opportunity to complement and extend measurements from ice cores to the surrounding area.

Here, we present preliminary results from a seismic investigation conducted using noise generated by ice-core drilling activities at the East Greenland Ice Core Project (EGRIP) site. The EGRIP site is located near the onset region of the Northeast Greenland Ice Stream (NEGIS), which drains over 10% of the Greenland Ice Sheet. The ice-core drilling process creates a variety of semi-continuous (e.g., generator-induced) and impulsive (e.g., core break) seismic source signals. As drilling progresses through the ice column, the corresponding variation in seismic signals can be used to generate a vertical profile of seismic properties. In the summer of 2019, nine 3-component surface geophones were deployed at 0, 300, 750, 1500 and 3000 m distance from the drill site along two lines corresponding to the along- and cross-flow directions of the ice stream. The network recorded at a sampling frequency of 400 Hz for 28 days, during which drilling progressed between 1920 and 2110 m depth below the surface. Both continuous and impulsive sources related to the drilling process were recorded at all stations. Impulsive arrivals were identified using STA/LTA phase-picking across multiple components and stations. Because the depth of the drill head at any given time is known, the move-out of each event could then be used to determine the integrated seismic velocity structure along the source-receiver ray path.

Additionally, sporadic passive microseismic signals resulting from ice stream motion over the bed were observed at all stations. Both individually distinguishable icequakes and 3-5 minute-long “gliding” tremors were recorded, indicative of stick-slip motion at the bed of NEGIS. Further work will concentrate on modelling these tremors to resolve the shear modulus of the substrate, and on incorporating continuous drill-generated noise into our overall analysis. Our approach

demonstrates the added value of opportunistic seismic networks as a complement to ice drilling operations.