EGU22-6414
https://doi.org/10.5194/egusphere-egu22-6414
EGU General Assembly 2022

Ice layer detection, distribution, and thickness in the near-surface firn on Devon Ice Cap: a new dual-frequency radar characterization approach

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Atmospheric warming has led to increased surface melting on glaciers in the Arctic. This meltwater can percolate into firn and refreeze to form ice layers. Depending on their thickness, low-permeability ice layers can act as barriers that inhibit subsequent vertical meltwater infiltration in deeper firn pore space and favor lateral meltwater runoff. Thus, characterizing ice layers in firn is key for understanding the near-surface hydrological conditions that could promote surface meltwater runoff and its contribution to sea level rise.

Airborne ice-penetrating radar (IPR) is a powerful tool for imaging subsurface structure, but only recently have these systems been applied to direct observations of the bulk properties of the near-surface. To evaluate the bulk permeability of the near-surface firn system of Devon Ice Cap (DIC), Canadian Arctic, we use the Radar Statistical Reconnaissance (RSR) technique, originally developed for accumulation studies in West Antarctica. This method utilizes both the coherent and incoherent components of the total surface return, which are predominately sensitive to near-surface permittivity/structure within the system's vertical range resolution and surface roughness, respectively. Here, we apply RSR to IPR data collected over DIC with the High-Capability Airborne Radar Sounder 2 (HiCARS) system (60 MHz center-frequency, 15 MHz bandwidth), operated by the University of Texas Institute for Geophysics (UTIG). Guided by ground-based ice-penetrating radar data and firn core density measurements, we show that the near-surface heterogeneous firn structure, featuring ice layers, mainly affects the observed coherent component.

We further compare the coherent component of HiCARS with that derived from IPR data collected with the University of Kansas Multichannel Coherent Radar Depth Sounder (MCoRDS) 3 system (195 MHz center-frequency; 30 MHz bandwidth), to evaluate the utility of dual-frequency IPR for characterizing near-surface ice layers. We expect that each radar system is sensitive to a different scale of near-surface bulk properties (i.e., depth and thickness of ice layers of different vertical extents), governed by each radar systems' center frequency and bandwidth-limited range resolution. We leverage these differences in range resolution to derive ice layer thickness constraints in the DIC firn zone containing meter-thick ice layers, which are consistent with ground-

based observations. Our results suggest this dual-frequency approach does indeed show that ice layers are vertically resolvable, spatially extensive, and mostly impermeable to surface meltwater. Thus, we hypothesize that lateral flow over high elevation meter-thick ice layers may contribute to the total surface runoff routed through supraglacial rivers down-glacier in the ablation zone.