C13C-1325: Radar-sounding evidence for a subglacial groundwater table in Hiawatha Crater, Greenland

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Abstract

Recent airborne radar-sounding surveys with a new, ultrawideband system by NASAs Operation IceBridge revealed a large impact crater in the Hiawatha glacier region of northwest Greenland. Notably, an unusual flat, specular reflector below the ice-bed interface was identified by visual inspection potentially as a groundwater table. **However, this observation, and characterization of overlying material, has yet to be confirmed by a detailed radiometric analysis.** This work analyzes four flight segments with subglacial groundwater reflectors to constrain the bed geology and thermal regime, and probability that the sub-bed reflector is indeed a groundwater table. First, we exploit variation in the thickness of the subglacial layer between the ice-bed interface and the proposed ground water table to determine dielectric loss values. The bed material estimated is most likely a mixture of ice, dry sand, and air – with minuscule groundwater present in the layer between the ice-bed interface and the reflector. Lastly, we use the subglacial layer loss values to determine the radar reflectivity difference between the ice-bed interface and sub-bed reflector. The analyses are consistent with the presence of a groundwater table and are useful for providing additional geophysical constraints on the groundwater system beneath Hiawatha Crater.
water table.

Background

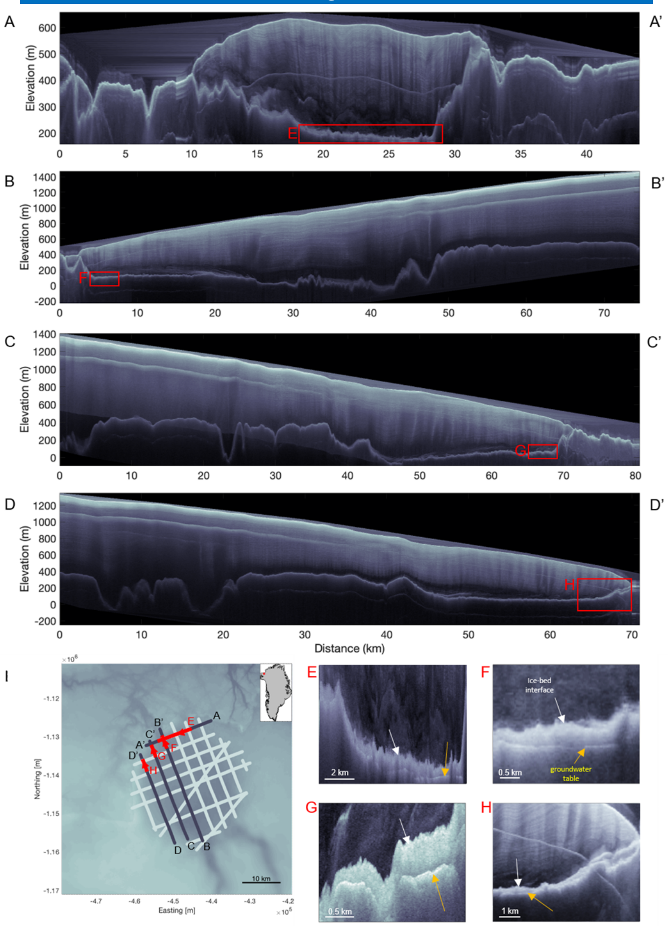

Fig. 1. Radiostratigraphy of (A) 20160517_03_008; (B) 20160512_02_009; (C) 20160516_02_006; (D) 20160512_02_007 [1]. Map (I) of study area shows locations of all transects in light blue, locations of (A), (B), (C), and (D) in dark blue, and the subsurface reflector locations in white. (E to H) show enlarged radargrams of subsurface reflectors.

Methodology

System [1]

- CReSIS 2016 Greenland Polar 6 mission
- Multichannel wideband synthetic aperture radar (SAR) 150-520 MHz, 10kHz PRF
- Range resolution of 0.5 m, azimuthal resolution of 15 m

Dielectric loss tangent properties were estimated from variations in the strength of the radar bed echo and the subsurface reflector anomaly under the assumptions that (1) surface and subsurface roughness are relatively constant, (2) explored layer has constant dielectric loss properties, and (3) dielectric constants at the interfaces are constant. [2]

$$tan\delta = \sqrt{\left\{2\left[\frac{\lambda}{4\pi c\Delta t}ln(L)\right]^2+1\right\}^2-1}$$

Reflectivity constants were extracted considering the radar power equation [3]. The losses due to birefringence, geometric spreading, and radar system parameters are negligible. Subsurface attenuation was taken from the slope in Figure 2.

$$[\Delta R]_i = [\Delta P]_i + [L]_i$$
$$[\Delta R]_i = [R]_{reflector} - [R]_{bed}$$
$$[\Delta P]_i = [P]_{reflector} + [P]_{bed}$$
$$[L]_i = m * d_i$$

Looyenga mixing law [4] was utilized to consider various mixtures of rock, air, water, and ice.

$$\epsilon'^{\frac{1}{\gamma}}_{subsurface} = \phi_1\epsilon'^{\frac{1}{\gamma}}_1 + \phi_2\epsilon'^{\frac{1}{\gamma}}_2 + \phi_3\epsilon'^{\frac{1}{\gamma}}_3$$

Hydraulic head was calculated to determine if the groundwater table existed in a sensible region. Darcy's law calculations were conducted to validate the potential porosity of the bed material and feasibility of a groundwater table existing. The ultrawideband radar's side lobes were evaluated against other system bandwidths, including HiCARS, MCORDS to determine a range of detection.

Results

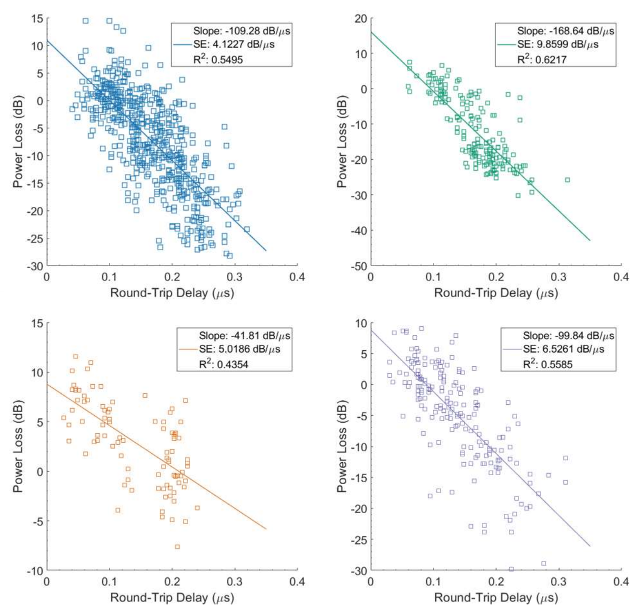

Fig. 2. Subsurface reflector power loss (in dB) versus round-trip time delay

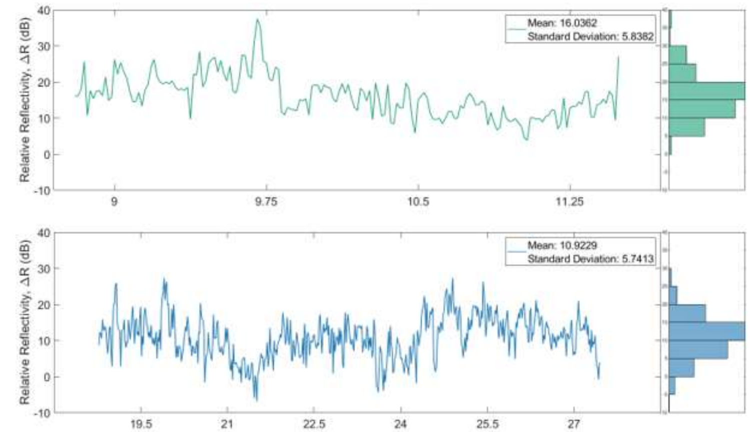

Fig. 3. Reflectivity constants of 20160517_03_008 and 20160512_02_009 along-track

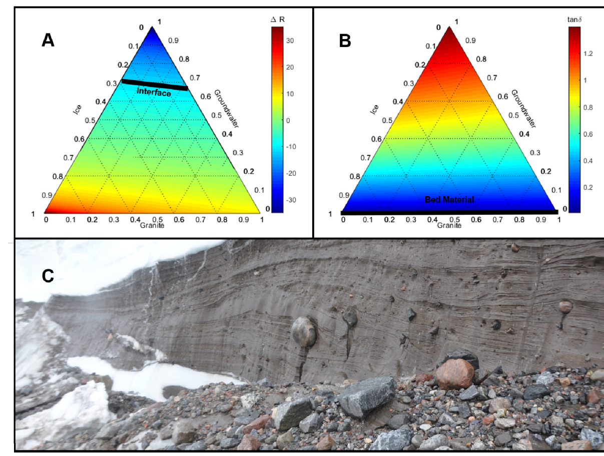

Fig. 4. Ternary Diagrams for ice, groundwater, granite mixtures; (A) Relative reflectivity indicating subsurface reflector composition; (B) loss tangent indicating bed material

Conclusions

1. **This work presents the determination of a groundwater table beneath the ice and bedrock.**
2. **The bed material is likely an ice-granite sand mixture.**
3. **Ultrawideband enables vision, however, other radar systems could theoretically detect this. The detectability thus, is likely attributed to the unique geological context.**
4. **This is important, because groundwater is commonly neglected but is likely an important component of glacier hydrology.**

References

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