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A new long wavelength airborne sounding radar for temperate glacier thickness measurement with a case study on the Hubbard Glacier, Alaska, USA

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Radar sounding of temperate glaciers to determine ice thickness is a persistently difficult problem. Strong attenuation and scattering of radio frequency signals caused by warm ice necessitates transmitting high power, long wavelength signals to achieve the necessary depth penetration. Additionally, many temperate glaciers inhabit relatively narrow valleys, which can cause extreme ambiguity when interpreting radar products. Reflections from valley walls or other off-nadir features can very often appear to be the base of a glacier, leading to incorrect interpretation if this issue is not acknowledged and dealt with. A final issue common to all fast flowing glaciers are zones of heavy crevassing making ground based radar infeasible. In this scenario airborne radar becomes necessary to quickly and safely acquire thickness measurements over the crevassed areas. Airborne radar presents a unique set of benefits and challenges when compared to ground based radar.

We present a newly developed sounding radar system suitable for airborne use. The radar transmits a two kilowatt peak power linear chirp with a center frequency of either 2.5 or 5 MHz, enabling detection of a basal reflection at depths of 900 meters or more. In conjunction with the radar hardware we have developed a surface clutter simulator, software that can predict the locations of off-nadir returns that frequently occur when radar sounding in narrow valleys. This allows for significantly increased confidence when interpreting radar products.

As a part of NASA's operation IceBridge, radar data was acquired over the Hubbard Glacier with the new sounder in May 2018. Hubbard descends from the St. Elias Mountains into Disenchantment Bay, which opens into the Gulf of Alaska. We chose Hubbard as a case study site for this radar because there are few reliable thickness measurements, even though Hubbard is the largest tidewater glacier in North America. The radar successfully penetrated to the base of the glacier, measuring thicknesses greater than 600 meters. This new data is combined with previously acquired thickness measurements and historical bathymetric data to create a raster map of the bed below Hubbard. This bed map shows a large trough underneath the convergence of Hubbard and the Valerie Glacier that reaches depths of over 400 meters below sea level. There is a finger from the main trough extending up Hubbard. These bed troughs are conduits for subglacial water and sediment movement, and therefore are an important control on the evolution of the morainal bank which in turn is a major player in tidewater glacier terminus dynamics. Increasing knowledge of bed topography through radar sounding will enable more accurate modeling of the Hubbard Glacier and systems like it.