Mapping thermal and hydrological conditions beneath a polythermal glacier with radioecho sounding

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ABSTRACT
Spatially contiguous patterns in residual bed reflection power (BRPₜ) are used to map the thermal and hydrological conditions at the base of a high Arctic polythermal glacier. Residual bed reflection power represents the difference between measured and predicted bed reflection powers, once the influence of dielectric loss with ice depth has been accounted for. Areas with crevassing and other englacial features were removed from analysis since large internal reflections may reduce the power that reaches the glacier bed. Most surveys were made in the spring, while the snowpack was dry, to minimize the influence of variable coupling between the antenna and glacier surface. Correlation plots show that bed slope does not have a significant effect on BRPₜ.

Based on our findings, several conclusions can be made about the thermal structure of the glacier. Positive BRPₜ and the presence of an internal reflecting horizon over the glacier terminus suggest a warm basal layer in this region. In comparison, positive BRPₜ and the absence of an internal reflector in overdeepened and valley bottom areas in the upper ablation zone suggest that the pressure melting point is only reached at the glacier bed. Finally, negative BRPₜ and the absence of an internal reflector in all other regions are indicative of cold ice. Within the positive BRPₜ regions, variability in BRPₜ shows patterns similar to subglacial hydrological reconstructions and observations. Maximum BRPₜ values occur in areas where drainage is predicted, and an elongated area of high BRPₜ occurs directly upglacier from an artesian fountain which brought large volumes of turbid meltwater to the glacier surface. These observations imply that water at the glacier bed is a major control on BRPₜ. This is probably because water has a higher dielectric contrast with ice than any other subglacial material.

1. INTRODUCTION
Polythermal glaciers are widespread in the high latitudes, and contain ice that is both at and below the pressure melting point (‘warm’ and ‘cold’ ice, respectively). Liquid water exists where the ice is warm, and surface melt may gain access through cold surface layers to warm areas of the glacier bed via moulins and crevasses (Skidmore and Sharp, 1999). Borehole temperature measurements suggest that polythermal glaciers in the Canadian high Arctic consist predominantly of cold ice with a thin layer of warm basal ice beneath the centre of the ablation area (Blatter, 1987). This differs greatly from the polythermal glaciers found in locations such as Spitsbergen and northern Scandinavia, where latent heat release from melting and refreezing in the accumulation area results in warm ice throughout most of the accumulation and lower ablation areas. In these glaciers cold ice is generally present only in a relatively thin layer close to the surface (Holmlund and Eriksson, 1989).

In the Canadian high Arctic, the glacier margins and terminus remain generally cold and frozen to the bed due to the steep englacial temperature gradient that conducts away geothermal heat where the ice is thin. Hydrological observations suggest that the cold margins create a thermal dam to subglacial water outflow. This allows the formation of a subglacial reservoir, in