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# Time-Domain Reflectometry Observations of Meltwater Percolation and Retention in the Firn Layer of the Greenland Ice Sheet

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Mass loss from the Greenland Ice Sheet has increased in recent decades due to significant increases in surface melt and runoff. The fraction of summer melt retains as a liquid water or refreezes as it percolates into the underlying cold firn, acting as a buffer to the summer runoff. There are challenges to quantifying both infiltration and refreezing of meltwater in this complex heterogeneous cold firn and to understand the spatial variability of these processes. In this study we present continuous in situ measurements of near-surface temperature and dielectric permittivity, a proxy for volumetric water content, using TDR (Time Domain Reflectometry) methods in the percolation zone of the southern Greenland Ice Sheet. We established two observation sites near Dye 2 in April, 2016, excavating firn pits to depths of 2.2 and 5.3 m. The two sites are 650 m apart to quantify the percolation and refreezing of meltwater and to observe the spatial variability of these processes through summer 2016. Thermistor arrays were used to track the thermal signature of meltwater penetration in firn, through the effects of latent heat release when meltwater refreezes. Through the addition of TDR probes, we attempt to directly quantify meltwater volume as well as hydraulic conductivity of the near-surface snow and firn. An automatic weather station (AWS) configured for surface energy balance monitoring was also installed. AWS data were used to calculate the surface energy balance and model meltwater production. The melting front, characterized by 0°C conditions and direct evidence of liquid water, penetrated to a depth of between 1.8 and 2.1 m in summer 2016; at depths of 2.1 m and greater, temperatures remained below 0°C, there was no evidence of abrupt warming (i.e. latent heat release), and dielectric permittivities remained at their background levels. Meltwater penetrated several thick ice layers, but not until temperatures reached the melting point at these depths, implying that ice layers may transition to a permeable 'slush' layer, given enough conductive and latent heating, permitting progressive penetration of meltwater to depth. Firn temperatures (sub-zero conditions below ~2 m) appear to have been the main barrier to deep penetration of meltwater during summer 2016.