

Using In-situ Firn Temperatures to Track Melt Water Retention and Firn Densification in Greenland's Accumulation Area

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ABSTRACT Poorly understood processes controlling retention of melt water in snow and firn have strong implications for the Greenland Ice Sheet's mass balance and flow dynamics. Here we present results from a three-year field campaign focused on an 85 km transect of the percolation zone of West Greenland. We installed one-to-two thermistor strings at 14 study sites, with each string having 32 sensors spaced between 0-10 m depth. Data from our network of over 500 sensors were collected at 15-60 minute intervals for 1-2 yr, thereby recording the thermal signature of melt water infiltration and refreezing across the percolation zone over one-to-two annual melt cycles. We document three types of heating of firn related to different mechanisms of melt water motion and freezing, including heterogeneous breakthrough events, wetting front advance, and year-round heating from freezing of residual deep pore water. Vertically infiltrating melt water commonly penetrates through cold firn accumulated over decades, even where ice layers are present at the previous summer surface and where ice layer thickness exceeds several decimeters. The offset between the mean annual air temperature and the 10 m firn temperature reveals the elevation dependency of melt water retention along our transect. The firn is $>10^{\circ}\text{C}$ warmer than the mean annual air temperature at the region where meltwater runoff initiates. During 2007-2009, runoff was limited to elevations lower than ~ 1500 m with no sharp runoff limit; rather, the ratio of retention-to-runoff transitioned from all retention to all runoff across a ~ 20 km wide zone. The techniques developed should be applicable to both firn densification and studies of climatic variation and climate change on WAIS.