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The role of subglacial supercooling freeze-on in Greenland Ice Sheet stratigraphy

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Greenland Ice Sheet radio-echo sounding data include large plume-like units of disrupted radiostratigraphy (UDR) originating at the base of the ice and extending up to 1 km within the ice body. The origin of these UDR has been disputed with hypotheses including supercooling freeze-on at the base of the ice, regions of ice stick-slip at the bed, or ice anisotropy. These different dynamic processes have implications for Greenland mass balance and basal flow characteristics, and it is therefore important to establish the relevant basal processes for future analysis of Greenland Ice Sheet stability.

We investigate the role of supercooling freeze-on in the production of UDR by applying a subglacial hydrology model, the Glacier Drainage System model (GlaDS), to the Greenland Ice Sheet. We have adapted the model to allow supercooling freeze-on and frictional melt within the subglacial distributed system, in addition to its more traditional application in the channelized system. We compare the location and rates of supercooling freeze-on produced by the model to location and sizes of UDR mapped from radio-echo sounding data. We also calculate ice particle trajectories over 10ka to determine particle height in the ice given the spatially-variable modeled supercooling freeze-on/melt rates. Finally, to examine temporal changes in freeze-on rates and locations, we apply the model using an estimated paleo ice surface from the LGM. Our findings indicate that there is little relationship between regions of supercooling and locations of UDR and, furthermore, the rates of supercooling freeze-on are too small to account for the UDR that can extend hundreds of meters into the ice. This is particularly the case for the ice divide region that includes many UDR but has modelled freeze-on rates that are much smaller than those calculated closer to the ice margin.