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Refreezing and Runoff at the Surface of the Greenland ice sheet

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Rising air temperatures over high-latitude ice masses are associated with increasing summer melt extent, which correlates with increasing runoff into oceans. However, not all annually-generated meltwater is lost as runoff. Across the accumulation zones of large ice masses, a spatially variable but unknown proportion of this meltwater instead percolates down into the surface snowpack and is retained there. This retention has two important effects. First, the retained meltwater refreezes within the snowpack as near-surface ice inclusions and layers. These ice layers can make identification, by remote sensing methods, of both the snow surface and the glacial ice surface problematic. Second, the fast conversion of snow to ice causes rapid snowpack densification, which causes a surface elevation change without a corresponding mass change. This density change must be considered when making interpretations of mass change based on elevation change. Currently, there is significant uncertainty in both the controls on, and the spatial variation of, snowpack densification and ice layer formation by meltwater retention, as well as how the spatial variation might change under a changing climate. This uncertainty causes projections of sea level rise due to runoff from the Greenland ice sheet over the next century to vary on the scale of centimetres (Pfeffer et al., 1991).

We therefore present recent developments to a physically-based model simulating percolation, refreezing and runoff within a high-latitude snowpack, based on the work of Bell et al. (2008). This model has been applied to a transect covering every snow facies of the Devon Island ice cap in Arctic Canada. Model results closely match in-situ snowpack measurements of surface mass balance, height change and bulk density change over a summer melt season. The model aids investigation of controls on the evolution of both the height and the density stratigraphy over a melt season. The same model will be applied to the Greenland ice sheet to examine the spatial variability of, and controls on, meltwater retention there. In time, the model will be used in a prognostic way, to explore changes in the spatial variation of retention as the spatial extents of snow facies change. Better knowledge of future retention patterns reduces the uncertainty in predictions of the evolution under a changing climate of the mass balance of large ice bodies such as the Greenland ice sheet.

Bell et al. (2008) Spatial and temporal variability in the snowpack of a High Arctic ice cap: implications for mass-change measurements. Annals of Glaciology 48: 159-170

Pfeffer et al. (1991) Retention of Greenland Runoff by Refreezing: Implications for Projected Future Sea Level Change. Journal of Geophysical Research, 96 (C12): 22117-22124