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Melt, refreezing and runoff at the surface of the Greenland ice sheet

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Across the accumulation zone of the Greenland ice sheet (GrIS), a spatially-variable (but unknown) fraction of the summer meltwater does not become runoff, but percolates into the surface snowpack and the underlying firn, refreezing there to form ice layers and lenses. This transformation from snow to ice causes densification and therefore surface elevation change without mass change. Better knowledge of the spatial variability of this process is important for both mass balance studies and interpretation of remote sensing datasets.

We present recent developments to a physically-based model which simulates melt, percolation, refreezing and runoff within a high-latitude snow and firn pack. This model runs on a series of one-dimensional vertical grids, on which density and thermal profiles evolve throughout a melt season. A simple energy balance routine calculates surface melt, which percolates downwards, refreezing according to the sub-surface profiles and running off upon contact with an impermeable layer. Near-surface densification and ice layer formation occurring within the model can be compared to field measurements.

This model has been calibrated and validated, and sensitivity testing carried out, using data from the Devon Island ice cap in Arctic Canada. We now apply it to the GrIS to investigate the changing relationship between melt, refreezing and runoff through a range of surface facies. The model is initialised, and output validated, using snowpit and firn core measurements taken during spring and fall field campaigns in 2004 and 2006 along the EGIG line between 1680 m and 2050 m elevation. Automatic weather stations and weather prediction models provide meteorological data for use in the energy balance calculation. End of melt season comparisons between modelled and measured near surface stratigraphies determine the model's accuracy in predicting changing magnitudes of refreezing within the snow and firn, and the effects on the surface elevation and density structure across the study transect.

Changes in the relationship between melt, refreezing and runoff are explored using a range of perturbations to the meteorological dataset. Better knowledge of this relationship reduces the uncertainty in predictions of GrIS mass balance under a changing climate.