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Improved modelling of the present-day Greenland firn layer

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Recent studies indicate that a declining surface mass balance will dominate the Greenland Ice Sheet's (GrIS) contribution to 21st century sea level rise. It is therefore crucial to understand the liquid water balance of the ice sheet and its response to increasing temperatures and surface melt if we want to accurately predict future sea level rise. The ice sheet firn layer covers ~90% of the GrIS and provides pore space for storage and refreezing of meltwater. Because of this, the firn layer can retain up to ~45% of the surface meltwater and thus act as an efficient buffer to ice sheet mass loss. However, in a warming climate this buffer capacity of the firn layer is expected to decrease, amplifying meltwater runoff and sea-level rise. Dedicated firn models are used to understand how firn layers evolve and affect runoff. Additionally, firn models are used to estimate the changing thickness of the firn layer, which is necessary in altimetry to convert surface height change into ice sheet mass loss.

Here, we present the latest version of our firn model IMAU-FDM. With respect to the previous version, changes have been made to the handling of the freshly fallen snow, the densification rate of the firn and the conduction of heat. These changes lead to an improved representation of firn density and temperature. The results have been thoroughly validated using an extensive dataset of density and temperature measurements that we have compiled covering 126 different locations on the GrIS. Meltwater behaviour in the model is validated with upward-looking GPR measurements at Dye-2. Lastly, we present an in-depth look at the evolution firn characteristics at some typical locations in Greenland.

Dedicated, stand-alone firn models offer various benefits to using a regional climate model with an embedded firn model. Firstly, the vertical resolution for buried snow and ice layers can be larger, improving accuracy. Secondly, a stand-alone firn model allows for spinning up the model to a more accurate equilibrium state. And thirdly, a stand-alone model is more cost- and time-effective to use. Firn models are increasingly capable of simulating the firn layer, but areas with large amounts of melt still pose the greatest challenge.