Geophysical Research Abstracts
Vol. 18, EGU2016-15241, 2016
EGU General Assembly 2016

Refreezing on the Greenland ice sheet: a model comparison

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Mass loss of the Greenland ice sheet (GrIS) is an important contributor to global sea level rise. Besides calving, surface melt is the dominant source of mass loss. However, only part of the surface melt leaves the ice sheet as runoff whereas the other part percolates into the snow cover and refreezes. Due to this process, part of the meltwater is (intermediately) stored. Refreezing thus impacts the surface mass balance of the ice sheet but it also affects the vertical structure of the snow cover due to transport of mass and energy. Due to the sparse availability of in situ data and the demand of future projections, it is inevitable to use numerical models to simulate refreezing and related processes. Currently, the magnitude of refrozen mass is neither well constrained nor well validated.

In this study, we model the snow and firn layer, and compare refreezing on the GrIS as modelled with two different numerical models. Both models are forced with meteorological data from the regional climate model RACMO 2 that has been shown to simulate realistic conditions for Greenland. One model is the UU/IMAU firn densification model (FDM) that can be used both in an on- and offline mode with RACMO 2. The other model is SNOWPACK; a model originally designed to simulate seasonal snow cover in alpine conditions. In contrast to FDM, SNOWPACK accounts for snow metamorphism and microstructure and contains a more physically based snow densification scheme.

A first comparison of the models indicates that both seem to be able to capture the general spatial and temporal pattern of refreezing. Spatially, refreezing occurs mostly in the ablation zone and decreases in the accumulation zone towards the interior of the ice sheet. Below the equilibrium line altitude (ELA) where refreezing occurs in seasonal snow cover on bare ice, the storage effect is only intermediate. Temporal patterns on a seasonal range indicate two peaks in refreezing; one at the beginning of the melt season where water infiltrates the cold snow pack and one in early winter where the penetration of the cold surface temperature refreezes the retained liquid water.

However, the model comparison reveals differences especially close to the equilibrium line where refreezing and runoff seem to be highly sensitive to the exact model formulation and fresh snow density initialization. Furthermore, SNOWPACK's densification scheme generally underestimates densification rates in case of high overburden pressure.