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How Well Does Grain Boundary Sliding Represent Densification Rates in the Upper Firn?

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The simulation of firn densification, although first models were already developed in the 1960s, is still a work in progress. Various models and variants of earlier models developed throughout the decades testify for this (e.g. Lundin et al. 2017, Stevens et al, 2020). Here we focus on the first stage of firn densification up to the density of 550 kg m^{-3}, hence the first few meters of the firn column. Describing the early stage of the process well is crucial as it proceeds fastest and influences further densification. Alley first applied the process of grain boundary sliding to firn in 1987 and thereby provided a physics based material model for the densification of firn at low densities. Despite being used in many firn densification models, it is sometimes debated if grain boundary sliding is governing the densification at low densities as there are very few observations of intra-crystalline deformation in firn.

We aim to test to which extent grain boundary sliding can be used to reproduce measured firn density profiles and to constrain the parameter range in the constitutive relation. To this end, we conduct a high number of simulations for various locations, stepping through the parameter space and select the best match with corresponding measured density profiles. By doing so, we are following Alley's original approach, but we make use of a much larger firn density dataset provided by the SUMup working group (Koenig & Montgomery, 2020).

Forcing data provided by the regional climate model RACMO (van Wessem et al., 2014, Noël et al., 2015) allows not only to simulate steady state solutions but transient simulations. Our model implementation provides a very fast, complete and flexible simulation environment, allowing to test wide parameter ranges in short time and hence enables us to cover a great amount of firn properties. The broad testing approach allows to evaluate if and in which ways grain boundary sliding might play a role in firn densification at low densities.