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Modelling ice layer formation using a preferential flow formulation in the physics based multi-layer SNOWPACK model

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For physics based snow cover models, simulating the formation of dense ice layers inside the snowpack has been a long time challenge. In spite of their small vertical extend, the presence of ice lenses inside the snowpack can have a profound impact on vapor, heat and liquid water flow. These effects may ultimately influence processes on larger scales when, for example, looking at hydrological processes or wet snow avalanche formation. Also microwave emission signals from the snowpack are strongly influenced by the presence of ice layers. Recent laboratory experiments and modelling techniques of liquid water flow in snow have advanced the understanding of liquid water flow in snow, in particular the formation of preferential flow paths. We present a modelling approach in the one-dimensional, multi-layer snow cover model SNOWPACK for preferential flow that is based on a dual-domain approach (i.e., separation into a matrix flow and a preferential flow domain) and solving Richards equation for both. In recently published laboratory experiments, water ponding inside the snowpack has been identified to initiate preferential flow. Those studies also quantified the part of the snowpack involved in preferential flow as a function of grain size. By combining these concepts with an empirical function to determine refreezing of preferential flow water inside the snowpack, we are able to simulate preferential water flow in the model. We found that preferential flow paths arriving at a layer transition in the snowpack may lead to ponding conditions. Subsequent refreezing then may form dense ice layers (>700 kg/m^3). We compare the simulations to 14 years of biweekly snow profiles made at the Weissfluhjoch study plot at 2540m altitude in the Eastern Swiss Alps. We show that we are able to reproduce several ice lenses that were observed in the field, whereas some profiles remain challenging to simulate.