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Influence of slope-scale snowmelt on hydrological response in a high-alpine catchment

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Snow is an important source of water for mountainous areas, but also for many low-lying regions of the world. Predicting mountain snowpack dynamics remains difficult, mainly because of the numerous processes affecting its mass and energy balance (e.g. snow transport, avalanching, topographic shading, water retention). In the present study, we focus on the influence of spatial snowmelt and water transport on the hydrological response of a high-alpine headwater catchment, the Dischma river basin in Switzerland. Based on recent advances in the physically-based Alpine3D snow model, we investigate how the snow distribution and liquid water transport in the snowpack impact the runoff dynamics. Simultaneously, we collected multi-scale observations (snow lysimeter, distributed snow depths and streamflow) in the field, which enable an in-depth validation of model results. The more realistic snow distribution brings a clear improvement in model prediction. At the plot scale, the simulation of the snowpack runoff is greatly improved when the mass balance errors at peak accumulation are corrected. At the sub-basin scale, we can notice not only a faster runoff pulse coming from the shallower areas but also an extension of the melting period by more than a month with meltwater coming from deeper snow areas. At the basin scale, the hydrological response is also improved by a more realistic snowpack, although hydrological calibration is able to compensate for correct physics. A more complex liquid water transport scheme improves the results at the site scale but its influence decreases at larger scales. Our study highlights not only the significance but also the difficulty of obtaining a realistic modeled snowpack distribution even in a very well-instrumented region and presents a worthwhile model validation from multi-scale observations.