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Typical errors when calculating snow ablation in mountains

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The mountain snow-cover gets patchy in the course of the melting season. The patchiness of a snow cover is caused by the spatially variable snow-depth distribution at the time of peak accumulation and by the spatially variable energy balance. The local energy balance is driven by net radiation and turbulent exchange of sensible and latent heat. As turbulent heat fluxes are linearly dependent on the local wind speed, the topographically induced air flow is crucial for modelling turbulent heat fluxes. Once the snow cover is patchy, thermal boundary layers develop and advection of warm air from adjacent bare ground to the snow surface provides an additional source of energy possibly contributing to snow melt.

The objective of this study is to demonstrate the capability and the limits of a state of the art physically-based energy-balance model to capture the diverse small-scale processes driving melt of a patchy snow cover. We investigate snow melt in an Alpine catchment by combining a three-dimensional meteorological model with a fully distributed energy balance model. To account for the spatial variability of turbulent fluxes as a function of the local flow conditions, we drive the energy balance model of Alpine3D with high-resolution atmospheric flow-fields, calculated with the non-hydrostatic and atmospheric prediction model Advanced Regional Prediction model (ARPS). We also consider the snow-depth distribution at the start of the ablation period by initializing the Alpine3D model with snow depths measured by an airborne laser scan at the time of peak accumulation. Modelled ablation patterns are compared to measured ablation rates obtained from six terrestrial Laser scanning campaigns covering the complete ablation season 2009.

Measured and modelled results demonstrate that areas of high wind velocities are characterized by high ablation rates mainly driven by increased turbulent fluxes. Areas affected by wind-induced snow erosion and deposition become patchy first. The measured ablation rates indicate that the advection of sensible heat causes locally increased ablation rates at the upwind edges of the snow patches. Nevertheless, the effect of local-scale advection appears to be dominant only over rather short distances. Neglecting the local advection in the energy balance calculations, we are able to model the mean ablation rates for the early ablation periods with a fractional snow cover above 0.6. Once the fractional snow cover is below 0.6 the model starts to strongly overestimate melting. Although the model considers stable conditions suppressing turbulence over snow patches, the air temperature appears to be strongly overestimated by the model. Similar to most energy balance models, the air temperature driving the Alpine3D model is obtained from single weather stations in the surrounding area, with sensors located several meters above ground. The measured air temperatures seem to overestimate the local air temperature above snow patches, where stable internal boundaries layers have started to develop.

Modelled and measured results suggest that the over-prediction of melt energy results from overestimations of the local air temperature causing very high turbulent fluxes of sensible heat towards the snow surface when the fractional snow-cover is below a critical value. We conclude that for snow-melt calculations the development of stable internal boundary-layers above snow patches and its influence on melt energy fluxes needs to be investigated in detail.