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Extreme heterogeneity of land surface in spring inducing highly complex micrometeorological flow features and heat exchange processes over partly snow covered areas

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The melting mountain snow cover in spring typically changes from a continuous snow cover to a mosaic of patches of snow and bare ground inducing an extreme heterogeneity of the land surface. Energy balance models typically assume a continuous snow cover, neglecting the complex interaction between the atmospheric boundary layer and the strongly variable surface.
We experimentally investigated the small-scale boundary layer dynamics over snow patches and their effect on the energy balance at the snow surface. A comprehensive measurement campaign, the Dischma Experiment, was conducted during three entire ablation periods in spring 2014, 2015 and 2016. The aim of this project is to investigate the boundary layer development and the energy exchange over a melting snow cover with a gradually decreasing snow cover fraction. For this purpose, two measurement towers equipped with five to six ultrasonic anemometers were installed over a long-lasting snow patch. Furthermore, temporally and spatially high resolution ablation rates and snow surface temperatures were determined with a terrestrial laser scanner and an Infrared camera. This data set allows us to relate the spatial patterns of ablation rates and snow surface temperatures to boundary layer dynamics and the changing snow cover fraction.

Experimental data reveal that wind conditions, snow cover distribution, local wind fetch distance and topographical curvature control the near-surface boundary layer characteristics and heat exchange processes over snow. The strong heterogeneity of land surface induced by the patchy snow cover caused a high spatial and temporal variability of snow surface temperature and snow melt patterns. Small scale flow features, such as katabatic flows or wind sheltering can be shown to strongly affect the temporal evolution of snow surface patterns. Furthermore, turbulence data reveal a strong correlation of turbulent heat exchange over melting snow with the occurrence of internal thermal boundary layers during daytime. Measured daytime turbulent heat fluxes appear to be strongly suppressed when shallow stable internal boundary layers are observed. Data show that the occurrence of shallow internal boundary layers was especially favoured by short upwind fetch distance and wind conditions (i.e. low friction velocities) causing persistent footprint patterns near the surface at the same time. For these situations, in particular, all tested energy balance models (using different stability corrections) strongly overestimated the turbulent sensible heat flux directed towards the snow cover.

These measurements confirm previous wind tunnel experiments that evidenced a suppression or even shut-down of near-surface turbulence, especially within topographical depressions and when ambient wind velocities are low. The dependence of the suppression of heat exchange over snow on stable internal boundary layer formation controlled by snow cover fraction, synoptic wind forcing and the local topography will allow the parametrization and consideration of those small-scale effects in high-resolution energy balance models.