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A terrain-based parameterization for the effect of wind-induced snow redistribution in Alpine terrain

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The water balance in Alpine regions is highly affected by the dynamics of the snow cover and the respective water fluxes. High altitudinal gradients and small scale orographic effects cause a large temporal and spatial variability of meteorological variables that force the development of the snow pack. A main driver of the resulting spatial heterogeneity of the snow cover in complex terrain is the redistribution of snow caused by wind. Besides the role of wind-driven snow redistribution for the local and regional hydrology, it is furthermore an important factor for the assessment of danger potential by natural hazards as wind loaded slopes are often avalanche prone locations due to big snow masses paired with instabilities within the snow pack.

Apart from the wind's impact on the energy-balance of the snow pack, there are three main interacting process mechanisms between wind and snow that shape the complex snow cover distribution in mountainous terrain: preferential deposition of snow precipitation, wind-driven transport of previously fallen snow and the effective sublimation of suspended snow into the atmosphere. These processes lead to a highly variable distribution of snow on different spatial scales. For distributed snow process modelling at the catchment scale and long–term simulations of high mountain snow cover dynamics and glacier response to climate change in Alpine regions, the inclusion of wind–induced redistribution and sublimation processes of snow is an indispensible prerequisite for obtaining realistic results in the simulated snow cover development.

In this study we present a simple parameterization to capture all the described wind-driven snow processes and to reproduce the result of their interaction within hydrological land surface models. The basic idea is the extraction of locations that are sheltered from or exposed to wind by a terrain analysis, and a respective correction of snow precipitation. The correction is based on the specification of sectors containing prevailing wind directions. We implement the new approach within the high-alpine specific snow model AMUNDSEN and the distributed hydrological model WaSiM-ETH. The method is validated by the means of airborne laser scanning data, point measurements, and discharge gauging stations. We present first results from the test site Hintereisferner (Ötztal Alps, Austria) where the modelled wind-driven snow redistribution is compared to snow cover extent and thickness derived by airborne laser scanning data. At the Berchtesgaden National Park (Bavarian Alps, Germany) the method is tested within a hydrological model setup. Here, the measured runoff dynamics during snow melt seasons at nine gauges in the catchment provide an indirect validation method. First results show that the implementation of the new approach generates a considerable improvement in modelling the runoff dynamics influenced by melting snow.