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Formation of Surface Hoar in Alpine Terrain

M. Lehning (1), F. Stössel (1), C. Manes (2), M. Guala (3), C. Fierz (1), and M. Parlange (4)

(1) WSL Institute for Snow and Avalanch Research (SLF), Davos Dorf, Switzerland (lehning@slf.ch), (2) University of Torino, Italy, (3) CALTECH, USA, (4) EPF Lausanne, Switzerland

The formation of surface hoar, which takes predominantly place during cold and clear nights over snow covered surfaces, is particularly important for avalanche formation since a buried surface hoar layer forms very often a significant weak layer. We present measurements and simulations of surface hoar formation at an Alpine study plot in the Swiss Alps.

We model the complete surface energy and mass balance with SNOWPACK, which uses a bulk formulation based on Monin-Obukhov similarity for the turbulent fluxes and allows shortwave radiation to penetrate into the surface snow layers. Using the measured eddy fluxes and the measured surface temperature as validation data, we show that fluxes are well reproduced if the surface temperature is imposed (as Dirichlet BC to SNOWPACK) but that the complete energy balance (with the surface temperature predicted together with the fluxes by SNOWPACK) leads to more uncertainty in the modelled fluxes. Discussing sensitivity model runs based on measured results on atmospheric stability and roughness lengths, we conclude that often the simple assumption of neutral stability is to be preferred for bulk models over stability corrections in such complex terrain. We explain this finding by the generation of turbulence by the terrain even in the absence of strong synoptic forcing.

Based on the fact that surface hoar formation is quantitatively explained by measured latent heat fluxes we then show that larger wind speeds typically stop surface hoar formation because of increased sensible heat flux to the surface, which prevents significant latent heat flux to the surface. This corresponds to observations and offers an explanation different from the often cited mechanical destruction of surface hoar at higher winds. It is thus hypothesised that hoar formation over complex snow covered surfaces is often a result of local energy and moisture budgets. This explains the observed discontinuity of surface hoar layers.