Geophysical Research Abstracts
Vol. 16, EGU2014-10220, 2014
EGU General Assembly 2014

Boundary layer development and energy exchange over a patchy mountain snow cover

Rebecca Mott (1), Megan Daniels (2), Stefan Horender (1,3), Philip Crivelli (1), Michael Lehning (1,4)

(1) WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland (mott@slf.ch), (2) School of Architecture, Civil and Environmental Engeneering, Ecole Polytechnique de Lausanne, (3) Leibniz Institute for Tropospheric Research, Leipzig, (4) School of Architecture, Civil and Environmental Engeneering, Laboratory of Cryopsheric Sciences (CRYOS), Ecole Polytechnique de Lausanne

Once the snow cover gets patchy in spring, small-scale thermal internal boundary layers develop, involving strong vertical and horizontal flux divergences. Furthermore, the advection of warm air from bare ground towards snow-covered areas can promote strong atmospheric stabilities and boundary layer decoupling above snow, that suppress the net turbulent heat flux close to the snow surface, thus, changing the heat budget there.
We experimentally and numerically investigated the small-scale boundary layer dynamics over snow patches and their effect on the energy balance at the snow surface. Local eddy flux measurements at an alpine test site revealed that wind velocity, wind fetch distance and topographical curvature control the boundary layer growth, boundary layer decoupling and the efficiency of advective heat transport to contribute to snow ablation. These results were verified in a wind tunnel experiment on the boundary layer development over a single snow patch. The experiments showed that heat advection was very efficient at short fetch distances and high wind velocities forming strong thermal gradients close to the snow surface. The heat potentially available from the advective heat transport was, however, not efficiently transferred towards the snow surface. The turbulent heat exchange was strongly suppressed at the lowest centimetres above the snow surface, where the Richardson number exceeded the critical value. Thus, boundary layer decoupling caused by very shallow layers of increased thermal stability could be shown to be very efficient, even for higher wind velocities. In addition to experiments, we numerically analysed the effect of heat advection, boundary layer decoupling and changing patterns of secondary flows on the energy balance of patchy snow cover characterized by different snow-cover fractions. The atmospheric boundary layer flows over patchy snow-covers were calculated with an atmospheric model (Advanced Regional Prediction System) on a very high resolution of 5 m. The numerical results revealed that the relative importance of boundary layer processes and the development of local flow patterns depend on the snow patch size distribution and the synoptic wind forcing. Calculations for quiescent wind situations demonstrated that well-developed katabatic winds exerted a major control on the energy balance at the patchy snow cover leading to a maximum in the mean downward heat flux over snow for high snow-cover fractions. Although, katabatic wind systems result in a decoupling of the local atmosphere from its warmer surrounding, the strong suppression of turbulence close to the snow cover was not captured. In contrast, strong synoptic winds promote the effect of heat advection and mitigate the impact of boundary layer decoupling on the catchments melt behaviour. The strong heat advection resulted in a maximum in the heat flux directed towards the snow cover for low snow-cover fractions if the flow field was forced by a synoptic wind. A sensitivity analysis to grid resolution suggests that the grid resolution is a critical factor for energy balance calculations over patchy snow covers. The comparison of simulations results from coarse (50 m) and fine (5 m) grid resolutions show a difference in the mean turbulent heat flux of 40% for high snow-cover fractions and of 70% for low snow-cover fractions. The lower mean values of the turbulent heat flux over snow for coarser grid resolutions can be explained by the inadequate representation of thermal internal boundary layers and the mitigation of local advection of sensible heat. A resolution smaller than 5 m would be, however, necessary to calculate the very shallow stable layers close to the surface, where efficient boundary layer decoupling occurs.