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Large-eddy simulation of the daytime boundary layer and heat transfer processes over an idealized valley

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The mechanisms governing the evolution of the daytime boundary layer and the heat transfer over an idealized, infinitely-long valley are investigated by means of large-eddy simulations. To allow for the response of the surface fluxes to the evolving slope flows, the atmosphere is coupled to an interactive land surface and the surface fluxes are computed based on Monin-Obukhov similarity theory. To simplify the process study, the valley system is forced by a prescribed, time-invariant incoming solar radiation flux, resulting in near-steady turbulence after about 1 hour.

The structure of the boundary layer is documented in terms of first- and second-moment statistics and the spatial variation of the PBL height. To analyze the heat transfer processes during the daytime heating of the valley atmosphere, the flow field is decomposed into its mean and turbulent component. As documented in previous studies, the mean component consists of the upslope flows, quasi-steady thermals over the mountain ridges, and two compensating circulations, one below and one above the capping inversion over the valley. The flow decomposition allows to clearly distinguish between the different heating processes, those associated with the mean flow, such as advection-induced cooling by the upslope flows and the warming induced by the compensating subsidence, and those associated with the turbulent motions. The latter include the warming of the mixed layer due to the divergence of the turbulent heat flux and cooling in the capping inversion due to overshooting thermals. These different processes are quantified and this local point of view is complemented by the analysis of the bulk valley heat budget and the associated heat fluxes.