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Structure of the atmospheric boundary layer in the vicinity of a developing upslope flow system: A numerical model study

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The development of a morning upslope flow is studied by means of idealized numerical simulations. In particular, two cases are examined: a plane slope connecting a lower plain and an elevated plateau, and a symmetric mountain in the middle of a uniform plain. The analysis examines various steepness cases and aims at understanding the processes occurring in the area of transition between the upslope flow region and the convective boundary layers (CBLs) growing nearby. A characteristic sequence of events is recognized in the simulations, and their relationship with the along-slope variability of the thermal energy and turbulent kinetic energy budgets is studied. Features occurring after the onset of the upslope wind include a transient depression in the boundary layer depth at the base of the slope and the formation of elevated turbulent layers above the CBL, caused by the divergence of turbulent flow from a thermal plume at the slope top. Numerical evidence agrees well with the results of previous experiments, including both field campaigns and water tank models. It is observed that the development of streamwise inhomogeneities in the upslope flow field favours the occurrence of a multi-layered vertical structure of the CBL near heated slopes. Multiple layering appears to be a transient feature, only persisting until sufficient heating causes the merging of the CBL with the overlying elevated turbulent layers. The analysis suggests that the slope steepness is an important factor in determining the speed at which the boundary layer structure near a slope evolves in time: in particular, the development of the wind system appears to occur faster in the vicinity of a steeper slope.