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Bulk convergence of cloud-resolving simulations of diurnal moist convection over complex terrain

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The diurnal evolution of summertime moist convection is a common phenomena over complex terrain. It has a large influence on regional climate and strongly impacts the large-scale flow. While cloud-resolving models with kilometer-scale resolution show a much improved representation of the diurnal cycle than models using parameterized convection, it is known that the accurate representation of the fine-scale structure and evolution of moist convective phenomena requires considerably higher resolution. But what about climatologically relevant bulk quantities? Here the convergence of the diurnal cycle of bulk properties, such as net heating and moistening in a large control volume and the associated vertical fluxes, is investigated. The COSMO model is utilized to simulate a 9-day period of diurnal summer convection over the European Alps, using a large computational domain with grid spacings of 4.4, 2.2, 1.1, and 0.55 km and grid-independent topography. Besides numerical convergence, "physical convergence" (Reynolds number increases with resolution) is addressed for two conceptually different subgrid-mixing approaches (1D mesoscale and 3D LES).

Results show that the simulated bulk properties and vertical fluxes converge numerically toward the 0.55-km solution. In terms of bulk effects, differences between the simulations are surprisingly small, even within the physical convergence framework that exhibits a sensitivity of the small-scale dynamics and ensuing convective structures to the horizontal resolution. Despite some sensitivities related to the applied turbulence closure, the results support the feasibility of kilometer-scale models to appropriately represent the bulk feedbacks between moist convection and the large-scale flow.