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Analysing the interactions of coupled soil-atmosphere simulations on turbulent scales

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Until now, land-surface models (LSM) have mostly been used in numerical weather prediction models from the global to the regional scale. In the near future, convection-resolving models will replace traditional numerical weather prediction (NWP) models on the regional scale. Currently, the turbulence-resolving model ICON-LEM (Icosahedral non-hydrostatic Large-Eddy Model) is being developed for regional weather prediction over Germany. These models have time steps of the order of a second to resolve the turbulent motions which is an order of magnitude lower than current NWP models. In nature, atmospheric state variables are modified by horizontal variability at all scales. In this study, we investigate how small-scale variations of surface fluxes which result from turbulent motions impact boundary-layer turbulence. If this turbulent land-atmosphere feedback is relevant, the uppermost layer of LSMs should be very thin, i.e. of the order of a millimetre, to allow for adjustments on the relevant high-frequent scale. This would be much finer compared to present-day LSMs, which have a soil layer thickness of the uppermost soil layer of a few centimetres. Consequently, the question is whether LSMs coupled to turbulence-resolving models require a finer soil-model configuration.

We conduct several idealised case studies using the LES model PALM with an implemented LSM. The LSM is set up with dry bare soil and configurations of the layer depths are varied from millimetre to decimetre scale. The LES is configured with grid sizes from one to ten metres in a domain of ten square kilometres in order to cover the large eddies of the size of the boundary layer height as well as the small eddies with an extent of tens of metres. The analysis of simulations with LSM as well as comparative runs with prescribed homogeneous forcing show minor effects of different soil layer configurations. We conclude that the small-scale and high-frequent soil-atmosphere feedback caused by turbulence is not significant for the state of the atmospheric boundary layer.