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Boundary Layer Characteristics over Homogeneous and Heterogeneous Surfaces simulated by MM5 and DALES

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The Multiple-Single-Column (MSC) approach is proposed as a new concept to study and evaluate the performance of the boundary-layer parameterisation scheme in a mesoscale model. Normally, the parameterisation schemes are examined by comparing a) the mesoscale model results with case studies data, or b) single-column model (SCM) against a large-eddy simulation model (LES). The first has a shortcoming that due to the complexity of a real situation, it is very difficult to discriminate the effects of land-atmosphere couplings in and between the parameterisation schemes. The latter is a more transparent method but due to the one-dimensionality restricted to the large scale external forcing and surface heterogeneity can not be investigated. In the MSC approach, a mesoscale model is initialised and updated with idealised surface and upper air conditions in every grid box over the entire domain, instead of employing the forcing provided by large scale atmospheric models as normally used. Each thermodynamic variable within the grid box are interacting with the other grids like a normal three-dimensional mesoscale numerical experiment. Therefore, the MSC has as an advantage that by performing control academic simulations in a mesoscale model, instead of evaluating against case studies, the method retains the benefits of a SCM. Further, the MSC technique can be used to investigate the influence of horizontal surface variability on atmospheric phenomena, because we are able to design experiments with a domain consisting of multiple grid cells interacting to each other. In this study we compare the Medium Range Forecast boundary layer-scheme (MRF) from the non-hydrostatic fifth-generation PSU/NCAR mesoscale model version 3.6.1 (MM5) with the Dutch Atmospheric LES model (DALES). In order to determine the role of homogeneous and heterogeneous surface forcing in boundary-layer development, we have performed homogeneous and heterogeneous idealised control experiments with the same surface forcing as in DALES using the MSC technique applied to MM5. From the homogeneous experiment, MM5 shows a slightly shallower, colder and moister boundary layer than DALES. This is an effect of an underestimation of turbulent mixing near the surface and less vigorous entrainment of heat and dry air in the MRF scheme. In the heterogeneous surface experiment, the domain is divided into dry and wet patches. As a result, both models reproduced a mesoscale circulation. However, we found differences in the circulation characteristics of the two models. In DALES surface heterogeneity influenced the turbulent pattern, whereas in MM5 this cannot occur due to the imposed parameterisation of turbulence. MRF underestimated the circulation ($w_{\max}$ is six times smaller) and above the cold patch MM5 showed still a relatively well-mixed boundary layer for θ and q. Consequently, the boundary layer dynamics between the two models differ more over a heterogeneous surface than over a homogeneous area. Therefore, we conclude that it is important to further compare mesoscale experiments with detailed large-eddy simulations to understand the role of land heterogeneity on the boundary layer dynamics.