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Investigating the scale-adaptivity of a shallow cumulus parameterization scheme with LES

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In this study we investigate the scale-adaptivity of a new parameterization scheme for shallow cumulus clouds in the gray zone. The Eddy-Diffusivity Multiple Mass-Flux (or ED(MF)^n) scheme is a bin-macrophysics scheme, in which subgrid transport is formulated in terms of discretized size densities. While scale-adaptivity in the ED-component is achieved using a pragmatic blending approach, the MF-component is filtered such that only the transport by plumes smaller than the grid size is maintained. For testing, ED(MF)^n is implemented in a large-eddy simulation (LES) model, replacing the original subgrid-scheme for turbulent transport. LES thus plays the role of a non-hydrostatic testing ground, which can be run at different resolutions to study the behavior of the parameterization scheme in the boundary-layer gray zone. In this range convective cumulus clouds are partially resolved. We find that at high resolutions the clouds and the turbulent transport are predominantly resolved by the LES, and the transport represented by ED(MF)^n is small. This partitioning changes towards coarser resolutions, with the representation of shallow cumulus clouds becoming exclusively carried by the ED(MF)^n. The way the partitioning changes with grid-spacing matches the results of previous LES studies, suggesting some scale-adaptivity is captured. Sensitivity studies show that a scale-inadaptive ED component stays too active at high resolutions, and that the results are fairly insensitive to the number of transporting updrafts in the ED(MF)^n scheme. Other assumptions in the scheme, such as the distribution of updrafts across sizes and the value of the area fraction covered by updrafts, are found to affect the location of the gray zone.