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Microphysical impacts of entrainment and mixing in large-eddy simulation of boundary-layer clouds

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This paper will discuss applications of the approach to predict homogeneity of the subgrid-scale turbulent mixing to large-eddy simulation of warm shallow boundary-layer clouds, such as tropical shallow cumulus or subtropical stratocumulus. The homogeneity of subgrid-scale mixing refers to the partitioning of the cloud water evaporation due to parameterized entrainment between changes of the mean droplet radius and changes of the mean droplet concentration. Homogeneous and extremely inhomogeneous mixing represent two limits of possible scenarios, where either the droplet concentration or the mean droplet radius remains unchanged during the microphysical adjustment, respectively. To predict the subgrid-scale mixing scenario, we merge the double-moment microphysics scheme with the approach to delay droplet evaporation resulting from entrainment.

First, results from simulation of the tropical oceanic shallow convection based on the BOMEX case (cf. Siebesma et al., J. Atmos. Sci. 2003) will be discussed. The simulated homogeneity of mixing varies significantly inside shallow convective clouds, from close to homogeneous to close to extremely inhomogeneous, because of the variability of local conditions, such as the droplet size and the level of cloud turbulence. The mean mixing characteristics become more homogeneous with height, reflecting increase of the mean droplet size and the mean turbulence intensity, both favoring homogeneous mixing. Model results appear consistent with microphysical effects of entrainment and mixing deduced from field observations. Mixing close to homogeneous is simulated in volumes with the highest LWC and strongest updraft at a given height, whereas mixing in more diluted volumes is typically close to the extremely inhomogenous. Second, aircraft observations and large-eddy simulations of the May 15, 2008, North-Sea boundary-layer clouds from the EUCAARI-IMPACT field campaign will be discussed. The observed boundary layer featured stratocumulus-over-cumulus cloud formations, with almost-solid stratocumulus deck in the upper part of the relatively deep weakly decoupled marine boundary layer overlaying a field of small cumuli with a cloud fraction of about 10%. The two cloud formations featured distinct microphysical characteristics that were reproduced well by the large-eddy simulation.